ORIGINAL

NUCLEAR REGULATORY COMMISSION

ATOMIC SAFETY AND LICENSING BOARD

In the Matter of: :
:
UNION ELECTRIC COMPANY : DOCKET NO. STN 50-483 OL
:
(Callaway Unit No. 1) :
:

RECEIVED DEC 7 1981

DATE: December 5, 1981 PAGES: 2084 - 2171

AT: St. Louis, Missouri

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UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

ATOMIC SAFETY AND LICENSING BOARD

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Tiara Room
Chase Park Plaza Hotel
St. Louis, Missouri

Saturday, December 5, 1981

The hearing in the above-entitled matter was reconvened, pursuant to recess, at 9:03 a.m.

BEFORE:

JAMES GLEASON, Chairman
Atomic Safety and Licensing Board

GLENN O. BRIGHT, Member
Atomic Safety and Licensing Board

JERRY R. KLINE, Member
Atomic Safety and Licensing Board

APPEARANCES:

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1300 M Street, N.W.
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and

JOSEPH E. BIRK, Esq.
General Counsel's Office
Union Electric Company
1901 Gratiot Street
St. Louis, Missouri

Appearing on behalf of Applicant.

KENNETH M. CHACKES, Esq. and KAY DREY
Chackes and Hoare
314 North Broadway
St. Louis, Missouri

Appearing on behalf of the Joint Intervenors Coalition for the Environment, Missourians for Safe Energy, Crawdad Alliance.

ROY LESSY, Esq.
Office of the Executive Legal Director
Nuclear Regulatory Commission
Washington, D. C. 20555

Appearing on behalf of the Staff.

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LIMITED APPEARANCES

P R O C E E D I N G S

(9:03 a.m.)

JUDGE GLEASON: Could we get started, please?

For those of you who have not had an opportunity, there is a sheet of paper on the table to the side of the room for those who want to make a limited appearance statement. You can put your name down.

This is an opportunity set aside by the Licensing Board under the rules of the Regulatory Commission for those who desire to make a limited appearance statement regarding the application of the Union Electric Company to operate a nuclear facility in Callaway County.

I might say there are no constraints on what you might say. It doesn't even have to be relevant.

(Laughter.)

We like to keep it what I classify as genteel. As you know, we are all -- I hope you know we are all trying to carry out our responsibilities, but we do have a kind of requirement that your remarks be limited to a five-minute period. If you have a lengthy statement and you have it written out, why we can include it in the record, if you desire -- you know, if it goes beyond five minutes.

I should also say that your remarks that you make are considered by the Board. They are considered not in terms of something that Board can base its decision on but in terms of areas the Board might be looking at that perhaps it may have overlook in the process and in the hearings of this application.

I would like to say one further thing before we start, that this Board is composed of three members and you see only two of us here today. Dr. Kline has been with us up until the end of yesterday's proceedings and had to return to Washington because he is embarking on another training course, starting, I think, tomorrow. But he will be reading your remarks in the record and all of the remarks are taken down by the reporter and they are reviewed again as the Board goes about making its decision.

So with that brief preliminary statement, calling them in the way they have signed up, the first person is Eldora Spiegelberg. Would you please come forward?

XXXX

This is the table here. You can just sit right down and if you'll just give your name and your location -- you don't have to give your address for the reporter.

LIMITED APPEARANCE STATEMENT OF ELDORA SPIEGELBERG

MS. SPIEGELBERG: I am Eldora Spiegelberg and I live in University City. I am President of the Women's International League for Peace and Freedom, the St. Louis Branch.

The Women's International League for Peace and Freedom opposes the construction of the Callaway nuclear plant for many reasons. We know that the price of uranium fuel has skyrocketed, as has the price of construction and maintenance of the Callaway plant, so that the cost to us, the consumers of electricity, will be extremely high.

But fear of exhorbitant prices is minor compared to our fear for our health and safety. Our study of these factors for previous testimony at public hearings has convinced us that: one, the nuclear waste from this plant will be with us for generations to come; two, the risk of nuclear accidents which are potentially catastrophic is always high; three, the construction of each additional plant adds to the need for maximum security since it produces the raw materials for nuclear bombs with the risk of terrorism, thus threatening our civil liberties.

Four, radiation from the plant itself contaminates the atmosphere and the water, enters the food chain and ultimately affects the health of all those living in its proximity. It always seems when we weigh the benefits and risks of nuclear power that we get all the risks and the utility gets all the benefits.

Our insurance policies exclude nuclear accidents, yet the Price-Anderson Act absolves the utility from most of its financial responsibility. We are unalterably opposed to the construction of the Callaway plant for the above reasons and would like to cite the Wall Street Journal statement that

"Unreliability is becoming one of their -- i.e., the nuclear plant's -- most dependable features." When a nuclear plant like Consolidated Edison Indian Point 2 plant in New York was shut down for repairs it took seven months and $1 million to complete a series of repairs which the utility's president admitted would have taken two weeks at a fossil fuel plant and over and above unreliability we have seen studies which indicate that the need for -- the future need for electricity does not warrant the construction of the Callaway plant in the first place.

JUDGE GLEASON: Thank you, Ms. Spiegelberg.

Pearlie Evans? Just give your name and your location.

XX LIMITED APPEARANCE STATEMENT OF PEARLIE EVANS

MS. EVANS: My name is Pearlie Evans and I am from the office of Congressman William L. Clay. I serve as his district assistant here in the St. Louis area.

I am here because there are a couple of things that I want to express on behalf of Representative Clay, who has had many concerns about the building of the Callaway nuclear power plant and has expressed his opposition to it for many of the reasons that have already been cited.

But I would like to enter into the record the fact that Congressman Clay was the sole representative who contacted Dr. Ernest Votenau, who at that time was Director of the Nuclear Regulatory Commission Office of Inspection and Enforcement, asking for an investigation of the Bill Smart firing incident.

Now on Monday, December 12, 1977, Bill Smart was demoted from an ironworker foreman to a general foreman with a big pay cut. I am told that this was one of the first cases that was investigated by the NRC, but on Monday, I believe this was Tuesday, of '78, he was fired.

Now the concern here is that the power plant and the three organizations that have filed their joint petition have asked for -- asked that Union Electric be denied a licensing permit. Mr. Clay supports that effort. These groups are Coalition for the Environment, the Crawdad Alliance and the Missourians for Safe Energy.

I would like to enter into the record Bill Clay -- Congressman Clay's rationale for his opposition and this is a publication from the Wednesday, December 2, edition of the Post-Dispatch, citing comments from Nunzio J. Palladino, who is the new NRC Chairman. This is what he says, and he was speaking, I might add, at the annual conference of the Atomic Industrial Forum in San Francisco.

What he said was this to the industry people represented there: "There have been lapses of many kinds in design analysis resulting in built-in design errors, in poor construction practices, in falsified documents, in harassment of quality control personnel and in inadequate training of reactor operators," he said. Quality cannot be inspected into a plant. It must be built into the plant.

And all of you, that is this group, I would say I'm sure you know this, but the practices at some plants do not confirm that the importance of this principle is always understood.

The Bechtel company is one of the largest nuclear power plant builders, I am told, in the world. That company has asked to be connected or hooked into the Union Electric Callaway County plant. We also oppose that on behalf of that group and from his office, that the application should be denied.

Thank you.

JUDGE GLEASON: Thank you.

Marjorie Reilly?

LIMITED APPEARANCE STATEMENT OF MARJORIE REILLY

MS. REILLY: My name is Marjorie Reilly and I live in University City, Missouri. I want to thank you for making this time available for limited appearance statements from the public.

I realize that the Board is required to rule only on matters in controversy among parties to this hearing, that is, the single contention that the failure of the quality assurance program for the construction of the Callaway nuclear plant raises the possibility that the operation of the plant will endanger the health and safety of the public. However, I hope that the Board will also consider, on its own initiative, other matters affecting public health and safety that have been beyond the resources of intervenor groups to raise.

For example, I hope that the Board will review, with the Missouri Public Service Commission, the Applicant's technical and financial qualifications to operate the Callaway plant in accordance with 10 CFR Chapter 1.

The Missouri Public Service Commission is conducting an audit of the projected and actual costs incurred by Union Electric in building the Callaway plant, including the recently-cancelled second unit. Last year, the Missouri Public Service Commission refused to allow Kansas City Power and Light Company to place in its rate base the newly-constructed and operating Iatan coal-fired plant.

The Missouri Public Service Commission determined that Kansas City Power and Light Company had de-rated existing plants in order to justify the need for the new plant.

Should Union Electric attempt to justify the need for the Callaway plant in a similar manner, or should the Missouri Public Service Commission determine from its audit that Union Electric cannot charge customers for certain costs of the Callaway plant, it is possible that Union Electric would be unable to meet its revenue requirements for the

Callaway plant.

This, in turn, raises serious questions about the Company's ability to fulfill the financial protection requirements for liability insurance, indemnity agreements, additional safety requirements stemming from the accident at Three Mile Island and other costs associated with the safe operation, shutdown and decommissioning of the Callaway plant, particularly if these costs cannot be recovered from customers and are assessed to the Company for its management decision to build this nuclear plant.

Thank you.

JUDGE GLEASON: Thank you, Ms. Reilly.

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Gwen Giles?

LIMITED APPEARANCE STATEMENT OF GWEN GILES

MS. GILES: Thank you very much. My name is Gwen Giles. Until July of this year I was State Senator, representing roughly one-fourth of the city of St. Louis, the fourth that is in this general area in which we are presently sitting.

My purpose here today is simply to relate to you experience I've had since 1977 in the Missouri Senate in responding to concerns of ordinary citizens regarding the Callaway plant. Very briefly, that response to me in the forms of letters, personal telephone calls, telegrams, questions at public hearings was in almost total opposition to the operation of that plant, not just for reasons of physical integrity in terms of what those citizens felt would result as increased cost to the, but more and overriding as reasons for opposition the ordinary citizens' fear -- great fear -- of personal health and safety, not just for themselves but for future generations of Missourians.

In all honestly, I would say to you that I received two statements of support for that plant. They were both from women who were about to enter a training program -- who had entered training programs and came to me with complaints of sex discrimination at that plant. So those are the concerns I came to express to you.

I hope that there will be a denial of the license for the benefit of plain ordinary citizens who really don't have a chance or the capacity to appear before such a group of citizens.

Thank you very much.

JUDGE GLEASON: Thank you, Ms. Giles.

William Vaughn?

XXX LIMITED APPEARANCE STATEMENT OF WILLIAM VAUGHN

MR. VAUGHN: My name is William Vaughn. I have a Ph.D. in biophysics. I reside in University City, Missouri. I am a Union Electric stockholder and I am Vice President of a consulting firm entitled "Environmental Measurements, Inc."

I wish to address to you a few remarks on Union Electric's application for an operating license for Callaway Unit 1. The perspective on my comments is that I was Chairman of the St. Louis Coalition for the Environment's Energy Committee in 1974 and 1975 when the construction permit was first filed for.

Our group intervened in opposition to that application. As I reflected back on our preparation for that -- those hearings -- and our presentation for those hearings I am somewhat surprised at how well our group of volunteers actually prepared our research and presented our issues. While we had more than thirty initial contentions, in the prehearing negotiations a lot of these contentions were restricted and very few actually survived into the hearing.

Many of those contentions were ruled out as being generic, which by no means indicates that they were spurious or unresponsible. They were just too general for the Callaway plant, as viewed at that time. Other issues were ruled out because we could not financially afford the expert witnesses required to formally present our case, again no reason to dismiss these contentions as frivolous.

Among those contentions that did survive, perhaps the strongest was the issue of Union Electric's forecast of demand and their financial capability to safely operate the Callaway facilities. As I reviewed these Contentions I thought it would be worthwhile to share some of them with you today and to demonstrate the continued strength of our arguments from 1974 and 1975 against the Callaway facility and show that troublesome generic issues still have not been resolved.

First, in 1974, we raised the point that electrical demand would not grow as Union Electric was predicting it, and that their financial position was not strong enough to allow them to safely build and operate the facility. Now, in 1981, Union Electric sites many of the same arguments which we raised in 1974 for the reasons they were cancelling Unit 2 back in October of 19[illegible]

I[illegible] ci[illegible]s could see the validity of these issues, why couldn't Union Electric see the validity of these issues back in '74 and '75? As a matter of fact, Union Electric cancelled 1200 megawatts of capacity which would be less expensive for them to build, less financially burdensome for them to build, in favor of continuing with the more financially risky Callaway nuclear facility.

Second, we raised the issue that Union Electric would bear enormous burden from a temporary or long-term shutdown due to safety considerations at other plants. Since that time there have been several instances of reduced power operating conditions throughout the industry and imposed by the Nuclear Regulatory Commission which have imposed financial burdens on other utilities.

The problems following Three Mile Island are an example. We do no feel that Union Electric could stand the financial ripple of an impact of reduced power considering how delicate their financial situation is now.

Third, we raised the point that the pressure fatigue -- the pressure vessel fatigue cracks were a significant issue, even thought it was not resolved at the time. Because it was generic, we could not raise it for the Callaway facility. Yet in 1981 the issue of pressure vessel fatigue and safety considerations has surfaced publicly as thermal shock issues were discussed and Oak Ridge National Laboratory was asked to look into this issue which we raised in 1974.

If Union Electric cannot benefit from the results of those findings that Oak Ridge National Lab may come up with, may not implement them in the plant, we feel that the pressure veseel integrity is still in question for the Callaway facility.

Fourth, we raised the issue of quality assurance, whether or not Union Electric would be able to implement adequately a quality assurance program that would assure safety for the public. I believe in your hearings recently you have had several questions raised about that point, which we also raised in 1974 and 1975. There has been inadequate implementation of that concern.

We question the ability of Union Electric to design and implement an adequate emergency evacuation plan. Such emergency evacuation plans depend heavily on dispersion models of air pollutants. Union Electric's models, in turn, depend heavily on the calcine assumption that there will be long-term statistical behavior of the plume of pollutants, of radiation. That is well known. That is not going to be the case in the event of an accident that requires an emergency evacuation.

There need to be different modeling considerations. For an adequate protection of the public, models must be able to take into account reasonably well the short-term dispersion conditions from such facilities. Union Electric's models, as far as we can determine, still do not take into account the latest research on any diffusion from such low structures.

There are many other issues which were raised in 1974 and 1975 which we feel are still very germane to the Callaway plant. We still question very strongly the safety and the wisdom of having the plant operating with so many unresolved questions and I ask you to think in terms of the public safety rather than the enormous number of dollars that have been poured into the holes out at Callaway building that facility.

Think of the public safety rather than dollars at the moment as you come up with your decision. We think that they have not adequately addressed all of these long-standing issues.

Thank you.

JUDGE GLEASON: Thank you, Mr. Vaughn.

Louis Green, please?

LIMITED APPEARANCE STATEMENT OF LOUIS GREEN

MR. GREEN: My name is Louis Green. I'm a lawyer practicing here in St. Louis. I have been, all of my adult life, as were my father and grandfather before me, my family and I have roots in this community and we are concerned about the potential impact on this community of the decision that you will make.

We are concerned about many aspects of it, of course, but the one I want to address here is the one of construction defects. I know you've heard a lot about construction defects. I assume that substantial construction defects may or do give rise to potential safety hazards. I'm not an engineer. I don't know enough about the consequences of construction defects, as you do, and I am not here to talk about the consequences of them.

The one thing that I do know about construction defects that you don't know is what I want to tell you. That relates to the complaints that have been made, if you want to call them complaints, the statements and allegations that have been made about deficiencies in construction by Bill Smart.

Unlike you, I have known Bill Smart personally for a number of years. I have known him pretty well, and I want you to understand that in my opinion he is an extraordinarily truthful person. I think there can be no serious question about his competence to judge whether a plant is being built, at least the things he has pointed out, whether they are being done correctly or not.

His performance demonstrates that he is perfectly capable of knowing whether something is being done right or not within the range of his experience. What I am here to tell you is that he is a very credible, truthful person. He will tell the truth, in my experience, even when the truth is very, very harmful to him. He will come forward and volunteer it.

So I urge that you give very great consideration to the allegations he has made about construction defects. They are not to be dismissed lightly. Whatever he has complained about that has not been investigated in the field should be checked out. If necessary to tear something down to get at the construction and find out what is in there, that should be done because I am confident that you will find that most of what he has said will turn out to be accurate.

Thank you.

JUDGE GLEASON: Thank you, Mr. Green.

Thomas -- I really can't make that name out -- Perril? Your writing is as bad as mine.

LIMITED APPEARANCE STATEMENT OF THOMAS THIRLKAL

MR. THIRLKAL: My name is Tom Thirlkal and I am a resident of University City. I am here today as a representative of Missouri Energy Action and the Missourians for Safe Energy, which is an intervenor in this hearing.

end 2

Intervenors have clearly shown that construction defects are a great hazard to the citizens of Missouri. These defects only increase the likelihood of a temporary shutdown of the Callaway plant. There are serious questions as to how the costs of such a shutdown would be handled.

This issue was addressed at the last shareholders' meeting of Union Electric, where a group of shareholders introduced a resolution requiring the Board of Directors to include in their annual report the projected cost of a shutdown of the Callaway plant for a period of six months or more. Regrettably, the Board of Directors refused to be responsible on this issue and recommended that it be rejected.

This is not an idle question. Three Mile Island was the grossest example of how ratepayers have been made to bear the brunt of a shutdown of a nuclear plant. The Wall Street Journal noted that so far ratepayers of Pennsylvania, through an 18 percent rate hike, and state and federal subsidies have paid $1 billion for the cost incurred by the plant's closing.

The consideration of economic issues is of particular importance in the time of this recession. According to the Electric Power Monthly and Industry Journal, when the Callaway plant goes on line Missouri Electric rates will be increased by thirty percent. When this happens, Missourians' electrical rates will be the sixth highest in the nation.

The irony of this is that Missouri is one of the most economically depressed states in the nation. Our unemployment rate is almost twice the national average of 8.4 percent. We believe that these extreme increases in rates are not justified because of the huge cost overruns that have occurred since the plant's inception.

The estimated price of Callaway is now $2.1 billion. This is up from $550 million in 1971. In short, the ratepayers are now being punished for Union Electric's inability to effectively plan for the Callaway plant. We think it is unfortunate that the NRC does not consider the economic impact of a nuclear power plant when it issues an operating license.

A study by the Commission on Environmental Quality shows that the implementation of solar power would create twice as many local jobs as would nuclear power. Clearly, in the long run, solar would be more beneficial. The above arguments are clearly demonstrating the need to deny Callaway its operating license on all levels -- health, safety and economics. The operation of the Callaway plant is a mistake.

Simply put, to allow the Callaway plant to operate turns both the physical and economic concerns, both the safety and health of Missourians.

Thank you.

JUDGE GLEASON: Thank you, Mr. Thirlkal.

Mr. Rudolph Kaufman?

LIMITED APPEARANCE STATEMENT OF RUDOLPH KAUFMAN

MR. KAUFMAN: Good morning. My name is Rudolph Kaufman. I live in University City. I am not here as a representative of any organization that has been involved in these proceedings. I come here as a concerned and interested citizen.

I was able to attend parts of the four hearings and I read part of the transcripts. What I have heard and seen during these days has been enough to give me great concern about the safety of the Callaway plant and, therefore, of the safety of all of us in this area. I was astonished to find out that Union Electric and its contractors are almost entirely responsible for the monitoring of construction and the reporting of safety violations.

We seem to be operating on some kind of honor system called self-regulation where we, the citizens of this area, are utterly dependent on the reliability, efficiency and honesty of the representatives of companies which have a vested interest in producing a plant as fast as possible at the lowest cost possible.

Even so, enough has come out of the testimony presented here by these company representative to cause serious doubts about the safety of Callaway. We have heard about defects in concrete, defects in welds and embeds, defects in pipes, but we have been assured that all is well, even though many areas have so far progressed in construction that they are not accessible and can no longer be inspected.

One of the most shocking things, to me, was that a defect in pipes was discovered not by the quality assurance inspectors on the site but by a report from Wolf Creek, where a worker had discovered similar defects in similar pipes and had reported it to his superiors.

Can we count on the workers at Callaway to help monitor the safety of construction work? I don't think so. The name of Bill Smart has been mentioned a number of times here and I think after the Bill Smart incident the word must have gone out to the workers at Callaway to hear no evil, see no evil, speak no evil. Don't rock the boat or you will lose your job.

So I don't think we can rely on the work force at Callaway to contribute to the safety and quality assurance people and if contractors and Union Electric don't do their jobs they have to get word from some other plant about something that's already being installed in theirs, then I think we're all in trouble.

I was going to quote Mr. Nunzio Palladino's speech that's already been quoted. So I don't want to repeat it, but I do want to repeat this one sentence, when he said, "Quality cannot be inspected into a plant; it must be built into the plants."

Mr. Chairman, you and your committee of experts will have to make a judgment as to whether quality has been and is being built into this plant. I have heard and read enough testimony to think that it isn't, even though I am not an expert. You will have to weigh the financial fate of Union Electric against the potential for disaster of the population of a vast area.

You are asked to put on the line an enormous time bomb which even its own builders have found to be full of flaws. Can the NRC gamble with our lives to license such a plant which even industry sources recognize we probably don't even need because of the diminished quote and demands for power.

Shutting down construction now will be cheaper for Union Electric than another Three Mile Island and a lot better for our health and welfare.

Interestingly enough, there was an article in the paper yesterday about the operators of Three Mile Island who are now suing the NRC for billions of dollars. The suit says negligence and omissions by the Nuclear Regulatory Commission in the performance of its duties and responsibilities were causes of the TMI accident and the resultant damages to GPU. So now the NRC is being blames for the failures that occurred on the Three Mile Island.

And on the principle that if we don't learn from the mistakes of the past, we are bound to repeat it, I would like you to accept into your record a two-part article from the New Yorker that relates to what happened at Three Mile Island that may not directly pertain to these hearings but certainly directly pertains to the problems of nuclear power.

I have a set of these documents here, if you will accept them.

JUDGE GLEASON: We'll have it appended to the record, so it would be there, but we would like to see it ourselves.

MR. KAUFMAN: I have about six or eight copies here.

JUDGE GLEASON: All right, if you could just give them to the reporter.

(The documents referred to follow:)


April 6, 1981
THE NEW YORKER
Price $1.25

A REPORTER AT LARGE

THREE MILE ISLAND

I—CLASS NINE ACCIDENT

A CARDINAL rule for the designers of commercial nuclear power plants is that all systems essential to safety must be installed in duplicate, at least, so that even if some of the apparatus fails there will always be enough extra equipment to keep the plant under control. Federal regulations governing the industry mandate strict conformity to this prudent design philosophy. Still, there is a type of accident that can jeopardize the safety of a nuclear plant despite the fact that it may be equipped with several levels of carefully engineered safety devices. This type of accident involves what is known as a common-mode failure—a single event or condition that can cause simultaneous multiple malfunctions and create a widespread failure in the plant's safety system. Dr. Stephen H. Hanauer, who is an engineer with the Nuclear Regulatory Commission and has been one of the federal government's chief nuclear-safety experts for the last fifteen years, has written an extended series of official reports on the "disastrous effect" that common-mode failures could have on the reliability of key safety systems in nuclear plants. On July 17, 1969, while Dr. Hanauer was the head of the Atomic Energy Commission's Advisory Committee on Reactor Safeguards, he sent a memo on behalf of the committee to Dr. Glenn T. Seaborg, the chairman of the commission. Hanauer said that he and his colleagues, in reviewing the design of a proposed nuclear power plant, had observed that it would incorporate certain devices "vital to the public health and safety" which could be disabled by common-mode failures. Hanauer's memo urged that the problem be corrected while the plant was under construction, but the recommendation was never carried out. On March 28, 1979—barely three months after the plant started commercial operation—it was struck by common-mode failures that contributed to what is now regarded as the worst accident in the history of commercial nuclear power. Hanauer's memorandum, which was just one of the unheeded warnings pertaining to the plant that federal safety authorities had received over the previous decade, was entitled "Report on Three Mile Island Nuclear Station Unit 2."

Dedication ceremonies for Three Mile Island Unit 2, some ten miles southeast of Harrisburg, Pennsylvania, were held on September 19, 1978. Deputy Secretary of Energy John F. O'Leary, a leading spokesman for the Carter Administration's nuclear-power policies, described the new plant on that occasion as an "aggregation of capital and patience and skill and technology" that was "sort of a miracle in many ways." According to Dr. O'Leary, who served as the director of licensing at the Atomic Energy Commission from 1972 to 1974, the plant was "a scintillating success," and he added that from this achievement "it is fair to conclude . . . that nuclear [power] is a bright and shining option for this country." Dr. O'Leary returned to Washington, D.C., after the ceremony, taking back with him a souvenir Three Mile Island Unit 2 paperweight, and for months afterward he kept on his desk a photograph of himself taken during that speech—in which, it must be noted, he did not discuss Dr. Hanauer's report of July, 1969, or any of the other documents in the government's internal files which pertained to potential safety problems affecting Three Mile Island Unit 2. Nor did he make any mention of a candid and much more general private memo, dated November 1, 1976, that he himself had prepared at the request of the policy-planning staff for the incoming Carter Administration. In that memo, which focussed on some of the weaknesses in the federal government's handling of what he referred to as "the massive safety issues associated with the commercialization of nuclear power," O'Leary said that "the frequency of serious and potentially catastrophic nuclear incidents supports the conclusion that sooner or later a major disaster will occur at a nuclear generating facility," and that "the N.R.C., as was the case with its predecessor, the Atomic Energy Commission, has been unwilling to face up to the policy consequences of assigning high probability to a serious nuclear

"I thought they responded to these college applications by letter."

moreover, had also received only superficial training on how to respond to complicated plant malfunctions. Craig Faust and Edward Frederick, both of whom were high-school graduates who had formerly operated submarine reactors for the Navy and were licensed by the N.R.C. to operate the new reactor at Three Mile Island, were on duty in the Unit 2 control room. The shift supervisor, William Zewe, another high-school graduate who had been through the Navy's nuclear program and was a licensed senior reactor operator, was doing paperwork in his office, next to the control room. Zewe was in charge of the plant during that night's graveyard shift—11 P.M. to 7 A.M. Two technicians on Zewe's sixteen-person overnight crew were in the basement carrying out routine maintenance on part of the main feedwater system, which provided the reactor with one of two vital supplies of cooling water. The plumbing arrangements in a nuclear plant—unlike the pipes in, say, a house—are built to exacting standards and require exceedingly careful maintenance. In addition, the water carried by these pipes must be continuously purified to prevent foreign matter from circulating through the system and damaging any of the equipment.

The maintenance workers, who were not required to have federal licenses or to go through any federally approved training programs, were trying to cope with a problem common to any type of plumbing system—a clogged pipe. The pipe in question was a small one coming from one of eight tanks, known as polishers, that removed impurities from the main feedwater system. The polishers themselves had to be cleaned out periodically, so that the sludge accumulating inside them could be disposed of and fresh filters—tiny resin beads that had the consistency of coarse sand—could be installed. The work had been going

accident." The day after the accident, an aide noted that Dr. O'Leary's memorabilia from the Three Mile Island dedication ceremonies had been removed from his desk

Given the regulatory lapses leading up to the accident, and the extensive warnings about the plant's safety weaknesses which had long been available to federal officials, there is some question whether the event at Three Mile Island should, in a strict sense, be called an "accident" at all. Indeed, government records indicate that in most respects what happened was a predictable outcome of known deficiencies in the type of nuclear equipment installed there. This regulatory failure raises unsettling questions about the safety of the tens of millions of people living near the other commercial nuclear power stations—seventy-one in all—that are now operating in this country under the auspices of the Nuclear Regulatory Commission, which in 1975, by act of Congress, replaced the A.E.C. The questions about nuclear risks are not new ones: they have figured prominently in the continuing public controversy over nuclear power, and they have been the focus of research that, as a member of the Union of Concerned Scientists, I have carried out for the last ten years. Results of this research had, in fact, prompted the U.C.S., in a report published on January 26, 1979, to recommend that sixteen plants, including Three Mile Island Unit 2, be shut down for repairs.

IN the early-morning hours of Wednesday, March 28, 1979, Three Mile Island Unit 2 was functioning normally, under full automatic control. (The adjacent Three Mile Island Unit 1, its sister nuclear plant, had been shut down six weeks earlier for refuelling and was undergoing tests before it was to resume operation, later that day.) No one on duty at the plant was a qualified nuclear engineer, or even a college graduate, nor had anyone there ever received adequate technical training on how to handle complex reactor emergencies. Such training was not required by the N.R.C. and was not customarily given in the standard one-year operator-training programs conducted by the utility companies and designed primarily to instruct the operators on how to go about their routine duties. Plant supervisory personnel, on for about eleven hours, and the small transfer pipe, which was supposed to allow sludge from Polisher No. 7 to be flushed into a receiving tank, had become blocked. Donald Miller, one of the technicians on duty, had been trying to clear the line for about an hour by shooting in water and bursts of compressed air.

Shortly before 4 A.M., Frederick Scheimann, the Unit 2 shift foreman, went to the basement to see how work on the pipe was progressing. He discussed the problem with Miller and with Harold Farst, the other technician on duty. Scheimann climbed up on top of a larger pipe so that he could look into the polisher through a glass window. "All of a sudden, I started hearing loud, thunderous noises, like a couple of freight trains," he said later. He jumped down from the pipe, heard the words "Turbine trip, reactor trip" over a loudspeaker, and rushed to the control room. The maintenance crew working on the polisher had accidentally choked off the flow in the main feedwater system, forcing Unit 2's generating equipment—its turbine and reactor, which had been operating at ninety-seven per cent of full power—to shut down. The equipment suddenly tripped at thirty-seven seconds past 4 A.M.

Routine emergency procedures were initiated automatically. Unit 2 had been equipped with multiple automatic devices, supposedly fail-safe, that were designed to respond immediately in the event of a serious plant malfunction. These devices were linked to an electronic alert system that constantly monitored all major aspects of plant performance and triggered remedial action if it detected an abnormal condition or any signs of impending trouble—including, certainly, the failure of the plant's main feedwater system. To deal with this particular problem, the plant had been equipped with three emergency feedwater pumps that were designed to operate automatically if the main feedwater system malfunctioned. Within seconds after the equipment was shut down, the three emergency feedwater pumps went into operation, just as the reactor's designers had planned. The incident should have ended there. A few seconds into the shutdown, however, all the careful plans for insuring the safety of Unit 2 were upset. The crisis had two immediate causes. First, the nuclear reactor—the steel tank that holds the plant's uranium fuel—had responded violently to the shutdown of the main feedwater system. The pressure of the cooling water in the reactor had increased rapidly, since it was still being heated by the hot uranium fuel, and the pressure surge had popped open a relief valve. All this activity was predictable, but what happened then had not been predicted or allowed for: the relief valve, which should have reclosed after a few seconds, jammed open. Cooling water started to drain out of the reactor at a rate of up to a hundred and ten thousand pounds an hour, or about two hundred and twenty gallons a minute—a hemorrhaging that seriously threatened the safety of the plant. Second, the crisis was compounded by one of those instances of carelessness that easily escape detection in a complicated machine like a nuclear power plant. Somebody, most likely during routine tests two days before, had shut two valves in the system that piped water from the emergency feedwater pumps into the parts of the cooling system where cooling water was urgently needed. The three pumps that were expected to cool the reactor—a single steam-driven emergency feedwater pump and two emergency feedwater pumps powered by electric motors—were rendered completely ineffective. In other words, a testing procedure had created a common-mode failure—a multiple safety-system failure—of the sort that, because of its supposedly remote probability, had been officially regarded as an "incredible" event.

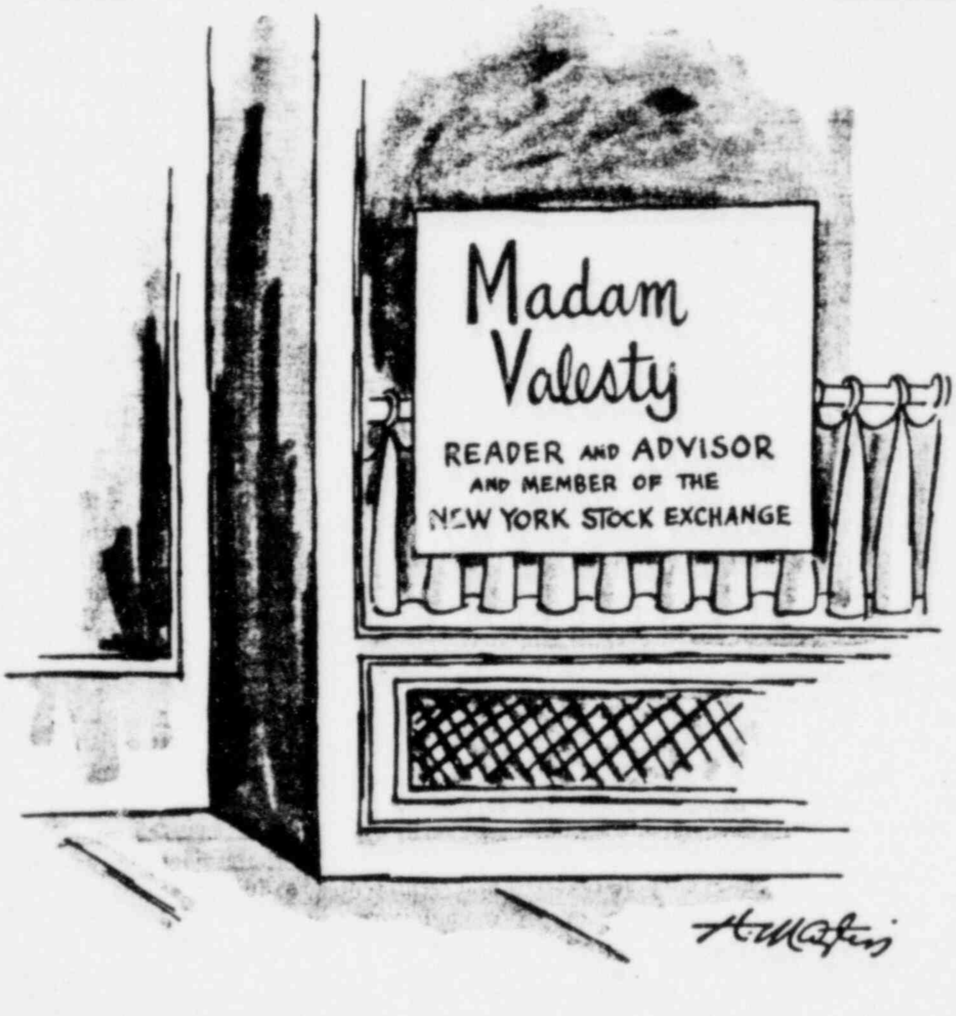
"And now it is my pleasure to introduce His Honor the State Bird."

During the first few minutes of the accident, conditions at the plant were grave but not desperate, since there was a remaining set of safety devices available to help cool the reactor. This equipment consisted of three additional pumps—part of the high-pressure injection system, which was connected to a special reservoir of emergency cooling water—that were capable of resupplying the reactor with a thousand gallons of water a minute, or more than enough to compensate for what was being lost through the stuck relief valve. Two minutes after the accident began, two of these emergency pumps automatically went on, but to no avail, for the reactor operators monitoring the accident on instruments in the control room decided to shut them off. They throttled the pumps so that practically no emergency water could be delivered to the reactor. This shutoff occurred some four minutes after the accident began, and represented a further common-mode failure—in this case, a deliberate maneuver by the operators to override the plant's automated safety equipment. The operators then inadvertently worsened the accident still further. They opened a drain line to remove even more water from the reactor—an action that effectively doubled the severity of the coolant loss. Faust, Frederick, Zewe, and Scheimann, who were trying to cope with the accident as best they could and were performing in accordance with their limited training, had interpreted control-room instrument readings to mean that the reactor had too much water in it rather than too little. They were unaware of the open relief valve.

The control room at Unit 2 had no indicator that directly reported whether or not the relief valve was open, and so it remained open, unknown to the operators, for some two hours and twenty minutes. (Brian Mehler, the supervisor of the incoming shift, arrived early that morning and discovered the open relief valve during his review of plant conditions.) Nor—odd as it may seem—was the control room equipped with any instrument that directly told the operators how much cooling water was inside the reactor. Instead, the operators had been trained to monitor the water level in another tank—a separate one, called the pressurizer—which was connected to the reactor's primary cooling system. The pressurizer, which was partly filled with hot water, helped control the pressure of the reactor's primary cooling water. The operators had been instructed, in the absence of a reactor-water-level indicator, to infer the amount of water in the reactor from the amount in this auxiliary tank. Accordingly, since the pressurizer instruments indicated that the pressurizer was full, the operators assumed that the reactor was full, too. This particular way of interpreting their instruments, Frederick later explained, was "what everybody punches into you" during the operator-training program.

Within five minutes after Unit 2's main feedwater system failed, the reactor, deprived of both normal and emergency sources of cooling water, and no longer able to use its enormous energy to generate electricity, gradually started to tear itself apart. The pressure of the water inside, which had increased suddenly in the few seconds after the accident began, now kept decreasing, uncontrollably and at times precipitately. The water remaining inside the reactor began to flash into steam, which in the next few hours expanded and blanketed much of the reactor's uranium fuel, preventing effective cooling. A series of further instrument problems, equipment malfunctions, computer-system breakdowns, and numerous other difficulties beset the Unit 2 operators and a growing number of plant officials who were coming to their aid. "It seemed to go on and on, surprise after surprise," Thomas Mulleavy, a radiation-protection supervisor at the plant, has recalled. "The equipment that we had to use did indeed malfunction, as most equipment will do on occasion, and always seems to when you need it most." At 7:24 A.M., shortly after Gary Miller, the station manager, arrived in the Unit 2 control room, a "general emergency" was declared—the first ever to arise at a commercial nuclear power plant in the United States. Plant personnel tried to telephone this news to the N.R.C.'s regional office, outside Philadelphia, but they were unable to reach anyone there at that hour and had to leave a message with the N.R.C.'s answering service.

The net result of a long chain of human and mechanical failures was that for some sixteen hours the hot, uranium-fuelled core in the Unit 2 reactor was not adequately cooled. All the uranium fuel rods overheated, swelled, and ruptured, according to post-accident N.R.C. estimates, with about a third of the core reduced to rubble. The severely damaged fuel rods released large amounts of radioactive material into the rest of the reactor, and, because of the open relief valve, much of this material escaped into the containment building housing the reactor. The atmosphere there became "murderously radioactive," as one N.R.C. official later described it, and thousands of gallons of radioactive water from the reactor were accidentally pumped from the containment building into a less secure auxiliary building. Plant officials, however, say that they were unaware of the extensive fuel damage—believing, because of the readings from the pressurizer tank, that the fuel in the reactor was adequately covered with cooling water—and they assured the public throughout the day that there was no threat of a radiation release. (Some congressional investigators have concluded that the managers of the plant knew about, but did not disclose to the N.R.C., certain data that would have indicated the true peril the plant faced that Wednesday.) Like the plant officials, the N.R.C. concluded from the data it received from the plant that



"Of course, Barnaby Tadpole is just my pen name."

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the reactor had been kept in a stable condition, and in very carefully worded public statements agency officials went to great lengths to play down the seriousness of the accident. (According to tape recordings that were made of some of the conversations that day at the N.R.C.'s emergency headquarters, senior N.R.C. public-relations coördinators said that "we ought to be real cagey" in reporting what the N.R.C. knew about conditions at the plant.) Joseph Hendrie, chairman of the N.R.C., briefing members of Congress the next day—March 29th—said that there might have been some minor "cracks" in "perhaps about one per cent" of the reactor's uranium fuel rods, but he emphatically assured them that there was no serious "ongoing problem" at the plant. Instrument readings from the plant by then showed extremely high radiation levels in the containment building, but Hendrie dismissed these readings as an "oddball" instrument error.

Not until early on the morning of Friday, March 30th—two days after the start of the accident—did the magnitude of the problem begin to be understood by plant and N.R.C. officials. A three-and-a-third-ounce sample of cooling water taken from the reactor late Thursday afternoon was found to contain so much radioactive material that it became clear an appreciable fraction of the reactor's fuel had been grossly damaged. N.R.C. analysts admitted to being dumbfounded by "failure modes" that had "never been studied," and they concluded that the fuel damage might make it extremely difficult to keep the reactor safely under control. As the officials pondered the difficulties, they received word from the plant that unexpected bursts of radioactive gases had been released from Unit 2 and were being blown by the wind toward some of the neighboring towns. Furthermore, N.R.C. officials, relying on hasty consultations with expert advisers, concluded that a large, growing, and potentially explosive "hydrogen bubble" might have formed inside the reactor—a development that conjured up the spectre of a possible large-scale release of radioactive material from the plant. Federal and state officials began preparing contingency plans for an evacuation of the region, and announced to the public that evacuation might be necessary. An estimated hundred and forty thousand people fled the area during that weekend—some in response to advice issued by Pennsylvania's Governor Richard Thornburgh to pregnant women and to families with preschool children, but most through their own good sense.

By the evening of Sunday, April 1st, the atmosphere of crisis had begun to abate, for the N.R.C. had found that its fears of a hydrogen explosion were based on spurious technical analysis. There was never any possibility at all of a hydrogen explosion, the agency learned, to its embarrassment, because the amount of oxygen needed to combine with the hydrogen to make an explosive mixture was simply not present in the reactor. Moreover, what hydrogen there was could be removed by relatively straightforward techniques. This encouraging news still left N.R.C. and Unit 2 officials facing several pressing problems, however, the most important of which was trying to keep the fuel in the reactor adequately cooled. To aid in this effort, industry experts from around the country converged on Three Mile Island and formed advisory groups, which developed plans for providing long-term cooling of the reactor and for preventing further leakage of radioactive materials from the containment and auxiliary buildings. On April 27th, after weeks of delicate maneuvering, the plant was finally stabilized and put into controlled shutdown. No appreciable quantity of radioactive materials had escaped from the plant during the accident, according to the subsequent official investigations; they did find, however, that it had been a very close call. *not so.

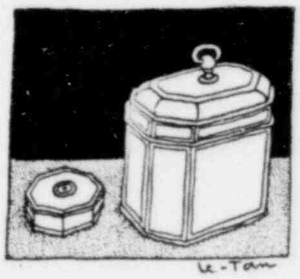
Two years after the accident, Unit 2 remains shut down. Its uranium fuel has by now been much cooled off, but its containment building and auxiliary tanks are flooded with more than a million gallons of radioactive water, and its status as a showpiece for the country's "bright and shining" nuclear-powered future is greatly diminished. Unit 1 also remains idle, pending an N.R.C. decision on whether it may safely resume operation. The only work in progress at the plant is a cleanup effort aimed at disposing of the radioactive debris left from the accident. Metropolitan Edison, the company that operates the plant, has been trying to recruit a work force for this grim chore, which is expected to go on for years and to cost at least a billion dollars—an expense that the owners of the plant would like to see covered by some type of federal bailout. The company's employment advertisements, such as one placed in the *Times* in late 1979, have promised prospective recruits for the cleanup work "unprecedented opportunities for new scientific experience" and "immediate ground floor opportunities for dedicated scientists and engineering personnel who want to be in the forefront of emerging technologies."

UNIT 2, before its operation was interrupted on March 28, 1979, was performing a routine task that has been of growing importance to society since the early eighteenth century: it was boiling water to produce steam. Since 1712, when an ironmonger named Thomas Newcomen introduced into the coal mines of the English Midlands a steam engine he had devised, steam power has been a decisive factor in the world's economic progress. Newcomen's primitive device was one of the most significant technical innovations in history, for it allowed water to be pumped out of the coal mines more efficiently, and so made more readily available the major fuel supply that helped bring about the Industrial Revolution. Several improvements on Newcomen's simple pumping equipment which were made later in the eighteenth century by James Watt, an instrument-maker from Glasgow, led to the eventual introduction of a rotative engine powered by the expansion of steam. Watt's steam engine became the source of power for new techniques of spinning and weaving cotton which were introduced in the late eighteenth century. These separate technical innovations combined to produce the textile factories that transformed agrarian England into an industrialized nation. Steam subsequently became the motive power for railroads and shipping, and by the end of the nineteenth century it had begun to spin turbines invented for the generation of electricity.

In this century, steam boilers of increasing size and sophistication—fired, successively, by wood, coal, oil, natural gas, and nuclear energy—have been developed. Today, a single large generating station can supply all the electricity needed by hundreds of thousands of consumers. A concerted effort over the last century by private corporations and, more recently, the federal government has carried forward the development of technology for central generating stations. Among the important innovators in boiler technology was a Rhode Island engineer named Stephen Wilcox, who in 1856 proposed a new type of water-tube boiler, capable of producing steam more efficiently than existing boilers and with less risk of a boiler explosion. Joining forces a decade later with a New York inventor named George Herman Babcock, Wilcox founded a company, which patented its first boiler in 1867 and continued to develop boilers of advanced design. The Babcock & Wilcox Company, which is now a subsidiary of McDermott, Inc., has become a major multinational enterprise, and is one of the four principal American manufacturers of nuclear reactors. (The others are the Westinghouse Electric Corporation, Combustion Engineering, and General Electric.) Two of the nine Babcock & Wilcox reactors currently licensed for commercial operation in the United States are on Three Mile Island, and Babcock & Wilcox reactors are on order for ten more nuclear plants, in the United States and abroad.

In contrast to the brewer's copper kettle that was used as a boiler in Thomas Newcomen's revolutionary steam engine, a nuclear steam-supply system, comparable though it is in basic purpose, is a machine of great complexity. At the center of the system is a reactor vessel that is connected to one of the most elaborate plumbing systems ever devised. The typical Babcock & Wilcox reactor, to use a specific example, is a steel bottle that stands some forty feet high, measures fifteen feet across, and weighs more than four hundred tons. Inside the reactor's walls—eight and a half to twelve inches of steel—is the uranium core, itself weighing a hundred tons or more, where controlled chain reactions provide the heat that, as in a conventional electric plant, is used to turn water into steam to drive a turbine. The reactor's core is impressively compact: it is only twelve feet wide and twelve feet high.

In a controlled nuclear reaction, uranium nuclei fission—split apart—with a consequent release of therm[al] energy, which can be used to convert water into steam to power a turbine. It was not until the end of 1938, when Otto Hahn, Fritz Strassmann, Lise Meitner, and Otto Frisch discovered how the uranium nucleus could be fissioned, that any method for tapping the energy inside the atomic nucleus was even theoretically available. The successful theoretical and experimental work carried out during the Second World War under the Manhattan Project led to the development of methods for fissioning a relatively rare form of uranium—U-235. The knowledge gained about how to split the nucleus of U-235 was used—as all the world is aware—to develop weapons of unprecedented destructive ability. After the war, atomic-bomb scientists advocated the commercial production of electric power by a domesticated version of the process that had devastated Hiroshima and Nagasaki. For some thirty-five years, the United States government, several major private companies, and cadres of technical specialists have worked to exploit nuclear energy as a means of powering electric-generating stations. Over most of this period, the promoters of the program, the American scientific establishment, and many members of the general public have looked upon uranium as the basic fuel that the nation will depend on for its future material prosperity.



In most modern power reactors, the uranium fuel is in the form of millions of ceramic uranium-dioxide pellets, each about the size of the tip of one's little finger, which are stacked inside slim tubes made of an alloy called Zircaloy. These fuel rods—there are about forty thousand of them in a typical Babcock & Wilcox reactor—stand upright inside the reactor, as if someone had created a forest of precisely spaced metal trees. Putting the uranium fuel in large numbers of metal tubes rather than in one clump increases the surface area, so that the water flowing through the reactor can more effectively carry off the heat generated by fission. This is important for both safety and economic reasons: the arrangement helps prevent the reactor fuel from overheating, and allows the most efficient use of a given quantity of fuel.

There are several types of commercial power reactors. Some use ordinary water to cool their fuel, some are cooled by a gas, such as carbon dioxide, and some use liquid metal as a coolant. A Babcock & Wilcox reactor is generically identified as a pressurized-water reactor—a type of reactor that was developed to power nuclear submarines for the Navy and has become the world's most widely used commercial power reactor. There are now forty-three pressurized-water reactors licensed to operate in the United States, and sixty-four more are operating around the world. In a pressurized-water reactor, the water is kept under extremely high pressure—approximately twenty-two hundred pounds per square inch—so that it can absorb the heat from the nuclear reaction and yet not turn to steam. The water must be kept moving through the reactor—or else it would soon overheat—and large, nine-thousand-horsepower pumps are provided to keep it flowing upward through the hot uranium-fuelled core. After it emerges from the core, the heated water flows through pipes three feet in diameter into steel tanks—the steam generators—that are partly filled with water supplied by the plant's main feedwater pumps. The water that goes through the reactor is known as the primary cooling water, and the water supplied by the main feedwater pumps is designated the secondary cooling water. The heated water from the reactor does not mix with the water supplied to the steam generators by the feedwater pumps; instead, the water from the reactor flows through thousands of small tubes inside each steam generator. These tubes are surrounded by the water—the secondary cooling water—that is supplied by the feedwater pumps. Much as a conventional radiator for home heating passes hot water through its coils to warm the surrounding air, heated water from the reactor, moving through the tiny steam-generator tubes, heats the colder secondary cooling water surrounding the tubes. Like a relay race, in which one runner passes a baton to another, the reactor-cooling system is designed so that the heat added to the primary cooling water as it passes through the core is subsequently transferred—inside the steam generators—to the secondary cooling water.

The water in the secondary cooling system, which is kept at much lower pressure than the primary cooling water, boils and turns into steam, and this steam, as in a conventional power plant, is piped into a turbine, where it expands and, in so doing, spins the large turbine blades, the way wind turns a windmill. The shaft of the turbine is connected to a giant electric generator, and the turning of the shaft spins the generator. The net result of all this motion is an electric current that can be sent through transmission lines to the power station's customers.

If all goes well, the reactor and the steam generators in a nuclear power plant of the pressurized-water variety maintain a stable, businesslike relationship such as might obtain between two complementary monopolies. The reactor can be thought of as selling heat to the steam generators. The various water-circulating systems in the plant provide the transportation for this commodity: the primary cooling water delivers heat from the reactor to the steam generators, and the secondary-cooling-water system delivers the heat—in the form of high-pressure steam—from the steam generators to the turbine. In terms of the conventional-power-plant goal of using steam to rotate a turbine generator, the power-producing achievement of the primary and secondary cooling systems in a typical Babcock & Wilcox nuclear plant would surely astonish James Watt. Every hour, the steady working relationship between the reactor and the steam generators in one of these plants creates more than eleven million pounds of high-pressure steam. This steam, which causes a giant turbine-generator to make eighteen hundred revolutions a minute, produces about nine hundred thousand kilowatt-hours of electric power.

For a nuclear plant incorporating a pressurized-water reactor to function satisfactorily, its internal energy supply and demand must neatly balance: the output of heat by the reactor has to match the uptake of heat by the steam generators. If this delicate equilibrium is upset, the temperatures and pressures inside the reactor can increase or decrease suddenly and create an accident in which the uranium fuel can overheat, perhaps uncontrollably. One obvious direct threat to normal cooling is the rupture of any of the pipes that deliver primary cooling water to the reactor. A more indirect but no less threatening interference with the reactor-cooling process can arise from malfunctions in the secondary cooling system, such as a failure in the main feedwater pumps that supply the steam generators. In that circumstance, with the steam generators no longer functional, there would be no method for removing the heat generated by the uranium fuel, and the fuel would overheat. Furthermore, the relationship between the primary and secondary cooling systems is so complex that there are circumstances in which too much cooling water from the main feedwater pumps would be as much of a threat as too little. An excessive supply of secondary cooling water to the steam generators could drain so much heat out of the reactor that the pressure of the primary cooling water might suddenly decrease. If that occurred, some of the primary cooling water could flash into steam, and the resulting steam pockets in the reactor could prevent needed cooling water from reaching the uranium fuel and keeping it adequately cooled. Increases and decreases—large ones, especially—in the temperature and the pressure of reactor-cooling water must be carefully avoided in order to maintain steady power production as well as safe and stable cooling of the reactor's fuel. This requirement must be given priority attention by both plant designers and plant operators.

To keep a nuclear reactor operating smoothly and under control, a number of systems, subsystems, components, structures, and people have to work together in a coördinated and reliable way. The task is customarily accomplished by an operating crew of a few dozen people with the aid of—at current prices—up to a billion dollars' worth of hardware. The focus of the plant operators, and the purpose of much of the elaborate machinery they work with, is the absolutely essential task of keeping the power levels, pressures, and temperatures inside the nuclear reactor completely under control. To this end, the plant is equipped with intricate systems linked by miles of electrical cables—the central nervous system of the plant. Data from electronic monitors are fed into computers and ranks of automated protection systems that, in theory, will respond swiftly and appropriately to any contingency that might compromise the reactor's steady operation. Federal safety regulations, rules, and standards set forth—sometimes precisely but sometimes only in a general fashion—the precautions required of each commercial nuclear generating plant. (These official safety requirements were initially promulgated by the Atomic Energy Commission, which in 1954 was empowered by Congress to oversee the development of commercial nuclear power. Congress abolished the A.E.C. twenty years later, as a result of the A.E.C.'s overzealous promotion of nuclear power, and replaced it in 1975 with the Nuclear Regulatory Commission. The N.R.C., as its first order of business, adopted all the safety rules and policies that had been established by its predecessor.) All components, systems, and structures important to safety and all operator actions and procedures that could affect the health and safety of the public are supposed to be covered by the web of federal regulations. The plants must be outfitted with vast arrays of safety equipment. This apparatus must be highly reliable—conservatively designed, routinely tested, carefully maintained, and almost always installed at least in duplicate, so that redundant equipment will compensate for the failure of a single system or component. Controlling the power level of the reactor, for example, is a critically important safety priority, and dependable methods for rapidly inserting control rods to shut off the nuclear reaction are mandated. Sixty-nine control rods are installed in the typical Babcock & Wilcox reactor for this purpose. The control rods act as blotters that absorb neutrons—the subatomic particles that are given off when U-235 nuclei fission and that then hit the nuclei of other U-235 atoms and cause subsequent fissions. By capturing neutrons, and so curtailing the fission chain reactions, these rods control the reactor's power output. Cooling the reactor is another major focus of the regulatory framework. Plants are required to have several networks of devices that can propel copious supplies of cooling water through the reactor during all the different types of cooling difficulties that can arise.

To generate power and comply with the safety guidelines, a nuclear power station typically requires some fifty miles of piping, held together by twenty-five thousand welds; eight hundred and fifty miles of electrical cables; eleven thousand five hundred tons of structural steel; and a hundred and seventy thousand cubic yards of concrete. Countless electric motors, con-

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duits, batteries, relays, switches, switchboards, condensers, transformers, and fuses are needed. Plumbing requirements in the various cooling systems call for innumerable valves, seals, drains, vents, gauges, fittings, pipe hangers, hydraulic snubbers, nuts, and bolts. Structural supports, radiation shields, ductwork, fire walls, equipment hatches, cable penetrations, emergency diesel generators, bulkheads, walls, and floors must be installed. Instruments must be provided to monitor temperatures, pressures, chain-reaction power levels, radiation levels, flow rates, cooling-water chemistry, equipment vibration, and the performance of all key plant components. Written procedures must be provided to cover normal operations, equipment installation, periodic maintenance, component and system testing, plant security, and appropriate operator actions during reactor start-up, reactor shutdown, and all anticipated emergencies.

All nuclear-power-plant systems, structures, components, procedures, and personnel are potential sources of failures and malfunctions. Problems can arise from defects in design, manufacturing, installation, and construction; from testing, operational, and maintenance errors; from explosions and fires; from excessive corrosion, vibration, stress, heating, cooling, radiation damage, and other physical phenomena; from deterioration due to component aging; and from external events such as floods, earthquakes, tornadoes, and sabotage. The possibilities of such failures and their consequences are supposed to be studied carefully before nuclear plants are licensed to operate, and appropriate steps are supposed to be taken to prevent any failures that would lead to major nuclear-radiation accidents. Over the years, government safety analysts have looked into a large number of possible accidents that could arise at nuclear plants, and they have made judgments about which types of possible accidents have a high enough probability of occurring to pose a "credible" threat to plant safety. To streamline the safety-review process, accidents presumed to be "credible" have been divided into eight categories, ranging from trivial mishaps, known as Class One accidents, all the way up to major disruptions of the plant—Class Eight accidents, which would require the emergency operation of plant safety systems. A.E.C. and N.R.C. safety reviewers have concluded that even in the worst Class Eight accidents, plant safety systems would satisfactorily prevent any serious damage to the reactor's core and any serious release of radioactive materials into the environment. It is possible, they admit, that there are "hypothetical" circumstances in which the safety apparatus could fail, thereby setting the stage for a huge release of radioactive debris into the neighboring region. Still, these potentially catastrophic accidents have been assumed to be so unlikely that they pose no "credible" safety problem. All such possible but "incredible" accidents—accidents that supposedly could never happen—are lumped together, for bureaucratic convenience, in one catch-all category. In the official shorthand, they are simply referred to as Class Nine accidents.

Experience with accidents in complex systems shows that major mishaps often have humble beginnings, easily overlooked even by diligent safety reviewers: a moment of inattention or carelessness by an operator; the failure of some small, seemingly inconsequential component; an elementary design deficiency that was not detected. Simple malfunctions in a system as subtle and intricate as that of a nuclear reactor can combine with unsuspected flaws or induce other malfunctions in some vulnerable piece of equipment. As the chain of malfunctions proceeds, circumstances may require the emergency operation of one or more of the nuclear plant's safety systems. Such a scenario presupposes, of course, that the contingency is one for which plant designers have provided appropriate safety apparatus. If not—if the accident unfolds in a way against which no protection has been provided—the accident may cause the plant to go out of control. Safety systems, even if they are incorporated into the plant design, may or may not perform as intended. The accident may be terminated safely or it may develop in ways that can set the stage for a terrible nuclear-radiation calamity.

The most widely feared type of reactor accident is one that involves the overheating and melting of the reactor's uranium fuel. As a reactor operates, the fissioning of the uranium nuclei results in the accumulation of radioactive waste—nuclear ashes, so to speak—inside the reactor core. These wastes, principally the fragments of the split uranium nuclei, give off an amount of radiation that itself constitutes a significant source of heat. In normal operation, this so-called decay heat is equivalent to six or seven per cent of the full power of the reactor. The radioactive processes responsible for the persistent decay heating cannot be controlled, as the chain reaction can. Thus, even when the fissioning of the uranium fuel is halted—which occurs when the control rods are inserted in the reactor's core—the reactor continues to generate heat. The heat produced by the radioactive decay does diminish with time—rapidly at first, then more slowly—but for months after a reactor is shut down it remains at levels that require continuous cooling-water circulation.

Inadequate core cooling can give rise to what is termed a meltdown accident. If, for example, the reactor suddenly lost its primary cooling water through a large pipe rupture and was not quickly supplied with emergency cooling water, the temperature of the fuel rods would rise within a minute, or perhaps even sooner, from the normal six hundred degrees to more than thirty-three hundred degrees, at which point the Zircaloy tubes that hold the uranium would begin to melt. The reactor core, with its hundred tons of uranium fuel, would start to slump, and lose its precisely arranged geometry. The uranium itself, heated by the radioactive waste materials that had been generated during reactor operation, would in turn begin to melt when the temperature climbed above about five thousand degrees—and in the absence of cooling the temperature would do just that. In short order, the core would turn into a white-hot blob of molten radioactive metal. Pouring to the bottom of the reactor, the fuel could melt its way through the steel reactor vessel in half an hour, and would then drop onto the thick concrete floor of the containment building. The containment building is not designed to withstand a meltdown; it has no special features to stop the molten fuel from penetrating the concrete and continuing downward into the ground. (The assumption in designing containment buildings has been that meltdown accidents have a negligible probability.) The sequence of events in a meltdown accident has been called, as long as anyone in the business can remember, the China Syndrome—a facetious reference to the general direction in which the molten core would be travelling. If a meltdown accident took place, the containment building could undergo several forms of collateral damage. The buildup of pressure, the formation of hydrogen and carbon-dioxide gases, explosive reactions between molten metal and residual water in the building, and other phenomena could damage the containment building and allow radioactive contaminants to escape into the surrounding area.

The radioactive material in a typical commercial reactor represents an almost unimaginably large quantity of biologically hazardous material. Using the unit of measurement named after Marie Curie, a leading pioneer in nuclear physics, scientists describe the typical nuclear plant's normal accumulation of radioactive materials as about fifteen billion curies; a single curie is thirty-seven billion radioactive disintegrations per second. In terms that may better illustrate the potential hazard, it can be said that the long-lived radioactive material in a modern commercial reactor would be about equal to the long-lived radioactive fallout produced by the detonation of more than a thousand Hiroshima-sized nuclear weapons. Though there is no possibility of a nuclear explosion at any of today's commercial reactors, a simple leak of any appreciable portion of a plant's radioactive materials is all that is necessary to set the stage for a peacetime catastrophe that could exceed anything the nation has ever experienced. Some of the accumulated radioactive material is gaseous or volatile in form; this material, which is normally locked inside the uranium-fuel pellets, would be released in a meltdown. Various paths out of a damaged nuclear plant could allow an invisible, lethal cloud of radioactive gases to be blown across the neighboring countryside.

Several estimates have been made concerning the consequences of meltdown accidents. These consequences depend on population density near the plant, prevailing weather conditions, and the effectiveness of any evacuation that can be arranged, as well as on the circumstances of the accident itself. In "fortunate" cases—a seaside reactor and just the right wind direction—the neighboring population might be spared immediate injury, though the molten fuel, embedded in the ground under the plant, could leach large quantities of radioactive contaminants into the groundwater and neighboring bodies of water for decades. In less fortunate cases—for instance, a large release of radioactive gases upwind of a populated area under adverse weather conditions, such as a temperature inversion, which would keep the radioactive cloud trapped close to the ground—widespread injuries could result. These would include both short-term, life-threatening injuries from acute radiation exposure and long-term increases in cancer and genetic defects induced in the exposed population by the punishing radiation that would emanate from the passing radioactive cloud. Ingestion and inhalation of radioactive materials would also contribute to the exposed population's radiation dose. According to the estimates published in an official government study of reactor safety completed in 1975, a major nuclear accident could result in thirty-three hundred immediate fatalities, forty-five thousand cases of acute radiation injury, and fourteen billion dollars in property damage. Longer-term health effects from the same hypothetical accident were estimated to include forty-five thousand latent-cancer fatalities, two hundred and forty thousand cases of thyroid tumors (caused by exposure to radioactive iodine, which would be released from the damaged reactor and concentrated in the thyroid after it was inhaled or ingested by the exposed population), and five thousand genetic defects in the first generation after the accident. Another government study, which was completed in 1965 by the Atomic Energy Commission but never published, concluded that a major reactor meltdown accident could create an "area of . . . disaster" that "might be equal to that of the State of Pennsylvania." The hypothetical reactor that could produce such an accident was a pressurized-water reactor only slightly larger than the one at Three Mile Island Unit 2. On March 28, 1979, during the critical early phase of the Three Mile Island accident, Unit 2—according to engineering estimates prepared by a special N.R.C. study group—came within thirty to sixty minutes of a meltdown.

The near-meltdown of Unit 2 represented a Class Nine accident—a supposedly "incredible" event that prompted Dr. Hanauer, a few days later, to issue a memo to top N.R.C. officials in which he announced certain "changes in my thinking." He wrote, "Core damage is credible." This new outlook on Class Nine accidents was also noted a few months later in a speech by Harold Collins, the N.R.C.'s assistant director for emergency preparedness. He remarked that as a result of the accident the "cherished" official notion that "the chances of a serious accident occurring were extremely remote . . . has, in my view and the view of others, been essentially 'knocked into a cocked hat.' "

THREE MILE ISLAND is a flat area of some four hundred acres, with rich, sandy silt underlaid by Gettysburg shale. It lies about nine hundred feet from the east bank of the Susquehanna River and ten miles southeast of Harrisburg, Pennsylvania's capital. The west bank of the river is just over a mile away, and about a mile and a half south of the island is the York Haven Dam. Some fifty miles below the island, the Susquehanna feeds into the head of Chesapeake Bay. Three Mile Island is in Dauphin County, in the middle of the heavily industrialized region of south-central Pennsylvania. The county has a population density of four hundred and thirty-one per square mile—seven times the national average—with the highest concentrations northwest of the island along the east bank of the river, including Harrisburg and such smaller municipalities as Steelton, Highspire, Middletown, and Royalton. There has always been vague official recognition of the fact that prudence requires the siting of nuclear plants at reasonable distances from populated areas, to minimize the number of people who might be injured by potential accidents, yet numerical criteria specifying the maximum allowable population density in the vicinity of a proposed plant site have never been issued by federal nuclear-safety authorities. In the late sixties, when the Atomic Energy Commission approved the construction of the Three Mile Island plant, there were six hundred and twenty-one thousand people living within twenty miles of the site.

Until recent years, Three Mile Island was actively farmed, like much of the land in Dauphin County and in neighboring York and Lancaster Counties. Some land in those counties is still used for dairy farming and poultry farming and for growing tobacco, vegetables, fruit, alfalfa, corn, and wheat. A farmer who leased two hundred and seventy acres of Three Mile Island in the nineteen-fifties and sixties used the land primarily to grow corn and tomatoes, and since there was no bridge to the island he transported his equipment and produce by barge. Seventy vacation cabins were built on the island, nestled in among its woodlands. As in many a near-paradise, there was luxuriant poison ivy and no electricity. Most game animals of interest to hunters could be found on Three Mile Island. The Susquehanna River southwest of the island and just above York Haven Dam was a popular spot for sportfishing.

Since early in this century, Three Mile Island has been owned by utility companies—the General Public Utilities Corporation and its predecessors—which leased portions of it for farming and recreational use. G.P.U., the nation's seventeenth-largest investor-owned electric utility, is a holding company based in Parsippany, New Jersey. Three G.P.U. operating subsidiaries—Metropolitan Edison, the Pennsylvania Electric Company, and the Jersey Central Power & Light Company—serve a total of more than one and a half million customers in Pennsylvania and New Jersey. In 1966, G.P.U. announced that it wanted to use Three Mile Island to further a regional power-development plan by making it the site of a commercial nuclear power station. The application to construct Three Mile Island Unit 1 was filed with the Atomic Energy Commission on May 1, 1967. The proposed plant was to be operated by Metropolitan Edison. The company also decided that it would add a second unit to its Oyster Creek Nuclear Generating Station, in Toms River, New Jersey, which would be operated by the Jersey Central Power & Light Company. A construction-permit application for this plant was filed on April 29, 1968. In January of 1969, however, because of labor problems affecting the New Jersey site, G.P.U. announced that the additional plant intended for Oyster Creek would instead be built as Three Mile Island Unit 2. It would be owned jointly by the three G.P.U. subsidiaries and operated by Metropolitan Edison. The A.E.C. processed the applications for the two Three Mile Island nuclear plants expeditiously, held brief public hearings, and issued the appropriate construction permits. The permit for Unit 1 was issued on May 18, 1968, and the one for Unit 2 on November 4, 1969. The A.E.C.'s regulatory staff wrote an official "Safety-Evaluation Report" for each plant, stating that there was "reasonable assurance" that the proposed plant could operate "without undue risk to the health and safety of the public."

There was nothing about the design of either Unit 1 or Unit 2 that specially prompted a broad and reassuring official conclusion about the plant's prospective safety. In truth, the A.E.C. regulatory staff, according to its standard practice, never reviewed—or even saw—the detailed designs for these or other proposed nuclear plants before issuing the official safety-evaluation reports that approved their construction. Under established A.E.C. licensing procedures, utility companies seeking federal approval to build a nuclear power plant faced minimal requirements; they were merely asked to submit a generalized "summary" description of the proposed facility (which instead of detailed drawings of safety-system design included what some A.E.C. safety experts referred to as "cartoons") and to make a commitment (which A.E.C. officials privately called a "bunch of promises") that the plant would be built according to federal safety standards. On this basis, the A.E.C., relying on the good sense and good faith of what it regarded as "self-regulating" companies rather than on thorough independent checking and detailed federal safety instructions, had issued dozens of nuclear-plant-construction permits before those for Three Mile Island. When these two plants were proposed, the A.E.C., without much pause for reflection, followed its usual procedure and awarded its official safety imprimatur almost automatically. After all, the A.E.C. had set up such coöperative licensing arrangements with the emerging nuclear industry because, under the terms of the Atomic Energy Act of 1954, the agency's function was to promote as well as to regulate nuclear energy. This dual and conflicting mandate, if adhered to scrupulously, might have created a continuing struggle between the A.E.C.'s ambitions and its prudence. Things hardly came to that, however, because from its earliest days the promotional role dominated all other A.E.C. interests and obligations. The A.E.C. became so steadfastly devoted to an enlarged nuclear-power program that nuclear-plant-construction permits flowed from the agency to the industry with almost no close individual scrutiny or extensive deliberation. It was easy to approve the Three Mile Island Nuclear Station, because this facility could be treated as just one of a batch of Babcock & Wilcox nuclear plants, whose construction, approved by the A.E.C., had already begun.

When Unit 1 was completed, in

1974, the A.E.C. issued a federal operating license for the facility. Then, in 1978, when work on Unit 2 was finished, the Nuclear Regulatory Commission, having replaced the A.E.C. as the federal nuclear-licensing authority, issued the formal certificates permitting Unit 2 to go into commercial service. N.R.C. officials were aware of still unresolved questions—noted in private A.E.C. files, which contained such documents as Dr. Hanauer's memorandum of July 17, 1969, on the problem of potential common-mode failures—that materially affected the safety of this plant and others authorized for construction by its predecessor agency. (The N.R.C. couldn't help knowing of these matters, because practically every A.E.C. regulatory official, including Dr. Hanauer himself, had gone to work for the N.R.C. when the new agency was formed.) Before licensing Unit 2, N.R.C. experts had flagged some fourteen "open safety items"—problems needing further technical evaluation—including one that dealt with the ability of the plant's safety apparatus to control small loss-of-coolant accidents (such as can be created by stuck-open relief valves). But the N.R.C., carried forward by the A.E.C.'s momentum and by the commitment of successive Administrations to nuclear expansion, licensed Three Mile Island Unit 2 anyway. According to Governor Bruce Babbitt, of Arizona, who heads a new Presidential Nuclear Safety Oversight Committee, which reviews the N.R.C.'s performance, Unit 2 was licensed on the basis of the "unquestioned assumption by the N.R.C. . . . that any utility that wanted to produce nuclear power could do so—a policy that no matter how small or unsophisticated the utility, it was eventually entitled to wrap its arms around a nuclear reactor."

There had been little local opposition to the proposal to convert Three Mile Island into a nuclear generating complex. The Metropolitan Edison Company had adopted a course that has become customary for American utility companies entering the nuclear-power business: it had pursued a low-key but aggressive public-relations strategy. Local officials were taken on tours of the site and provided with data emphasizing the economic advantages that would accrue to the region as a result of the project. Local newspapers were provided with the same information, and it was approvingly passed on to their readers. One strong selling point was the boost that the plant-construction activities would give local business, the housing market, and even the school system; the construction, it was said, would help the area recover from the closing, in 1964, of the nearby Olmsted Air Force Base, which had been one of the largest employers in the region. And, indeed, in 1972, at the peak of construction on Three Mile Island, the project employed a work force of thirty-one hundred and twenty. The local Chamber of Commerce was persuaded without difficulty of the merits of the nuclear plant, and local unions provided further support for the project, which was entirely a union job. Met Ed obligingly relocated the existing Three Mile Island summer cottages on other islands in the river, and proposed an extensive recreation complex on Three Mile Island itself as a further spur to local acceptance. People in the communities abutting Three Mile Island expressed little concern about their safety, and over the years they received mostly comforting news on the subject from the local newspapers, whose reporters had benefitted from information supplied by Metropolitan Edison. (A feature article that appeared in the Harrisburg *Evening News* on January 14, 1969, for example, had the headline "ON THREE MILE ISLAND: NUCLEAR REACTOR IS NOTHING TO GET 'STEAMED UP' OVER." Such articles were highly effective in reassuring the local population; this one, by Alec Green, pointed out that one of the main materials used in the plant was boric acid, which, it said, was nothing more than "just plain eyewash.") The few citizens who worried about the plant—about, for example, possible aircraft accidents caused by the proximity of the plant's large cooling towers to Harrisburg International Airport (formerly Olmsted Air Force Base), about the effects of low-level radiation from the plant, and about the lack of adequate evacuation plans in the event of an accident—were unable to muster the financial resources or the political clout needed to mount an effective challenge to the company. Efforts by these citizens to press their concerns through legal action did not succeed in preventing the construction and operation of the facilities, nor was community sentiment in favor of the plant greatly altered by the efforts of the local activists.

The only major difficulties slowing construction of the plant arose from brief strikes; from Hurricane Agnes and consequent flooding, in 1972; and from financing problems that the company experienced as it tried to meet the increasing costs of the project. Unit 1, which had been expected to cost a hundred and ten million dollars, was completed at a cost of nearly four hundred million. Unit 2, whose completion was delayed several times by lack of funds, was supposed to cost a hundred and thirty million dollars, but by the time it went into commercial operation, on December 30, 1978, its total cost was estimated to be more than seven hundred million. The combined bill for the project was thus one billion one hundred million dollars. Cost escalation of this magnitude has been a recurring problem for the commercial nuclear-power industry in the United States.

THE high cost of building large nuclear power stations such as Three Mile Island Unit 2 has had a subtle but pervasive impact on the safety of these facilities, and it played an influential background role in bringing about the events of March 28, 1979. With their high fixed costs, the only way nuclear plants can produce power economically is by operating as close to a hundred per cent of their capacity as they can for as much of the year as possible. On-again, off-again operation that left a billion-dollar nuclear plant idle much of the time would vastly increase the cost of the electricity it generated: the fixed costs would have to be spread over a smaller output of electricity. Accordingly, utility companies want to have their nuclear plants operating at high capacity to provide continuous "base load" electric production for their customers; the companies rely on less expensive conventional power plants to meet daily and seasonal periods of peak demand.

In the effort to keep their nuclear units at full power day in and day out, except for an annual refuelling shutdown of a few weeks, utility companies frequently find themselves under intense pressure to compromise on safety. To acknowledge safety problems might be to expose themselves to mandatory equipment changes or repairs that could mean extensive plant shutdowns; their tendency, therefore, is to discount evidence of possible safety problems and to keep their nuclear units on line. Even when equipment defects or safety difficulties are acknowledged, there is a strong financial incentive for the companies to try to delay necessary repairs that would require the plant to cease operation, even temporarily. The established practice is to seek to put off major repairs until the next scheduled refuelling shutdown, which might be several months away—or, if federal officials permit, to postpone the repairs still longer. The solutions to newly discovered safety problems are not always immediately obvious, and the companies are naturally unwilling to keep their expensive nuclear plants out of service for an indefinite period—it might stretch into years—while research and testing are undertaken to find answers to intricate safety questions. When such research is completed, moreover, the nuclear utility companies strongly resist proposals to improve the plants with new safety equipment, however useful or necessary. Although the state of the art of nuclear safety has changed very rapidly in the last decade, there has been an underlying financial obstacle to the introduction of improved safety technology: not only the direct costs of new devices but also the costs that would arise from what might be a prolonged shutdown while the new equipment was installed or some part of the plant rebuilt. Utility companies have thus steadfastly opposed any general policy that would require them to upgrade their nuclear plants on a regular basis to keep them supplied with the best available safety technology. The Atomic Energy Commission, in the interests of protecting the economic viability of nuclear electric-power production, routinely exempted nuclear plants already built from meeting subsequently developed federal safety standards, and the Nuclear Regulatory Commission retained this forgiving attitude toward the safety problems of nuclear plants already operating. As a result, new federal regulations almost always contain a grandfather clause that allows existing plants to continue in operation without the safety design changes or improvements mandated for new plants. This policy, in the view of some of the government's senior safety analysts, has led to the accumulation of increasing numbers of operating nuclear plants with pronounced safety defects.

The safety compromises made by the Metropolitan Edison Company and permitted by federal safety policies formulated to encourage the expansion of the commercial nuclear industry were very much in evidence on the morning of March 28, 1979. One standard cost-minimizing shortcut that the company had adopted was a program for carrying out much of the required routine testing and maintenance on the plant while it was in operation rather than when the reactor was safely shut down. No one would think of performing major equipment checks or maintenance on an airplane in flight—disassembling and cleaning its landing gear, for example—but utility companies commonly do something very much like that to avoid frequent, costly shutdowns of their nuclear units. This effort to keep plants running during testing and maintenance has at least two manifest risks. First, such work might inadvertently interfere with the equipment that is keeping the plant in steady operation, and so cause a serious accident. Second, standby safety equipment that is deliberately taken out of service for tests or maintenance would not be available (or its operation might be delayed) if an accident that necessitated the use of this equipment occurred while the work was under way. (There are some requirements aimed at insuring that only a limited amount of a plant's basic safety apparatus will be intentionally disabled at any one time, but these requirements have been neither comprehensively set out nor diligently followed.) There is a third risk posed by maintenance and testing, regardless of whether it is performed while the plant is operating or while it is shut down, and that is the possible failure to return equipment to service or to restore the plant to its normal condition after these tasks are completed—for example, a failure to reopen valves that were closed or to restore electrical power that was shut off. The first of these risks materialized as the immediate cause of the Three Mile Island accident (the maintenance being performed on the polishers, which led to the failure of the main feedwater system), and the third category of maintenance-related safety risks was evidenced in the two closed valves (apparently shut during emergency-feedwater-pump tests two days before the accident, and not reopened) that disabled the entire emergency feedwater system.

THE maintenance that had to be performed on the polishers at Unit 2 was a necessary, unglamorous chore—one of the numberless small tasks connected with the day-to-day operation of the plant. Each of the eight polishers held a twenty-eight-day supply of the resin beads used to filter out impurities from the cooling water. The system had been designed so that only seven polishers would be needed while the plant was operating, and one could be out of service for maintenance. But even though it was intended that maintenance on the polishers would take place when the reactor was running at full power, the safety problems that might arise from this practice were not carefully investigated when the plant was designed. What now appears to be a serious oversight was officially permitted under N.R.C. regulations, because the polishers, like much of the other equipment in Unit 2—including such items as the main feedwater system, the relief valve, and the pressurizer-level instruments, all of which figured so prominently in the March 28th accident—were classified as "non-safety-related" components. (The N.R.C. permitted this classification in order to spare utility companies the extra costs of complying with the elaborate requirements imposed on "safety-related" equipment.) Consequently, there were no detailed federal safety requirements governing the design of the polishers, there were no routine federal safety reviews of them during plant licensing, and their performance was not examined during the N.R.C.'s standard plant inspections. By classifying the polishers as non-safety-related, the N.R.C. had effectively waived all regulatory requirements over them. Since the polishers were exempted from federal safety rules, they were bought from an outside manufacturer, L.A. Water Treatment, and were installed in Unit 2 without the standard scrutiny that Metropolitan Edison's designers gave to safety-related equipment. Indeed, when investigators went to Unit 2 after the accident they found that the plant officials did not even have accurate engineering drawings and schematics for the Unit 2 polisher system; the drawings that were available showed valves in the wrong places, identified components improperly, and had air-line positions and interconnections incorrectly displayed. Also missing were other types of useful drawings—showing, for example, how the polishers related to other plant systems and equipment.

The periodic removal of spent resins from the polishers had been a chronic problem at Unit 2. The detritus inside the polishers had to be flushed into a receiving tank through a small

transfer line that frequently clogged up. Maintenance logs indicate that there was a problem with about one of every twelve transfers. The recurrent difficulties had been reported to the plant's management, but satisfactory corrective action—such as installing alternative filtration processes or modifying the transfer pipe—had not been undertaken. Maintenance workers were simply instructed to try to overcome the blockage by injecting water and compressed air into the transfer line—a seemingly straightforward procedure that actually had serious potential complications, because of leaky valves in the compressed-air system, which sometimes allowed water to seep into it. Since other equipment in the plant—such as instruments that controlled valves directing the flow of water to the main feedwater system—depended on this compressed-air supply, water in the air lines could precipitate a series of malfunctions in the plant. This tie-in meant that a clogged transfer line in the polisher could create more than a localized inconvenience that delayed routine maintenance; it could escalate into real trouble—a fact that had been known for at least seventeen months before the accident at Unit 2.

On October 19, 1977, a maintenance worker removing spent resins from Polisher No. 2 noticed that some of the air-operated equipment on the polisher's control panel had water running out of it. The technician had been using the standard water-plus-compressed-air method of flushing out the polisher's transfer line. Then, suddenly, a set of valves on the polisher system unexpectedly closed, cutting off the flow of cooling water through the polishers and causing the main feedwater system to fail completely. Fortunately, the Unit 2 reactor was not running, since Unit 2 was still in its pre-operational testing phase. But the serious implications of this maintenance-related failure were clear. As the event was summarized in an internal memorandum by John Brummer and Michael Ross, two senior members of the plant's technical staff, which was dated November 14, 1977, the maintenance work had inadvertently created "a total loss of feedwater," so that if the reactor had been operating "the unit would have been placed in a severe transient"—abnormal—"condition." The memo recommended nine corrective actions, but they were rejected in a cryptic memo, dated November 17, 1977, from R. J. Toole, the director of G.P.U.'s start-up operations; he wrote, "No further action required."

The problem did not go away, however. On May 12, 1978, while spent resins were being transferred out of Polisher No. 7, key valves on the polisher once again unexpectedly slammed shut, disabling the entire feedwater system. Since the reactor was not running at the time, the problem was once again passed over by plant management—this time despite a sharply worded memorandum from the shift supervisor, William Zewe, dated May 15, 1978. Zewe's memo, concerning water in the air and instrument lines, said, "It's time to really do something on this problem before a very serious accident occurs. If the polishers take themselves offline at any high level of power, resultant damage could be very significant." Zewe recommended, as Brummer and Ross had after the earlier loss-of-feedwater incident, that a "bypass" system be installed. If the cooling-water flow *through* the polishers was accidentally cut off by the maintenance crew, a fast-acting, automatic bypass that kept the water flowing *around* the polishers could prevent an abrupt disruption of the normal reactor-cooling process, all three plant officials said. This recommendation was never acted upon.

Unit 2, in sum, had been operating with a documented history of maintenance-caused failures in its main feedwater system—a situation that had been reported to, but tolerated by, plant management. The accident that occurred on March 28, 1979, initiated by routine work on the polisher system, was in essential respects a replay of the episodes of October 19, 1977, and May 12, 1978—with, of course, the major difference that the Unit 2 reactor, instead of being safely shut down, was operating at ninety-seven per cent of full power.

THE types of human error that caused and then exacerbated the Three Mile Island accident were not freak occurrences that can be dismissed as the bad luck of a particular maintenance crew at one individual power plant on a randomly selected day. Government records show that maintenance-caused accidents—and safety-system failures attributable to improper maintenance procedures—are among the dominant, widespread, and recurring safety problems in the American commercial nuclear-power industry. These and other forms of human error were listed as the cause of eighteen per cent of all the serious nuclear-plant malfunctions reported to the N.R.C. in 1978, according to the agency's statistics. To see the Three Mile Island accident as part of this persistent pattern of nuclear-plant safety deficiencies is to understand more fully not only how the accident came about but also what the accident implies about the general state of safety in the other nuclear plants now operating in the United States.

To find documentation of how human error can cause plant accidents, one need dig no further in the government records than the accident that up until the events at Three Mile Island had been regarded as the most serious in the nuclear program's history. This accident, which occurred at the Browns Ferry Nuclear Plant, near Decatur, Alabama, on March 22, 1975, involved a fire in the plant's electrical system which was started by a workman's candle. The plant, which, like Three Mile Island, had been in commercial operation for only a few months, was undergoing a post-construction modification, and this work required technicians to check for air leaks in a section of the electrical system where some cables passed through the reactor-building wall. The plant had three nuclear reactors, two of which were operating at full power. An electrician's aide, twenty years old and untrained, who had been on the job only two days, was holding a lighted candle and watching its flame flicker as an indication of possible air leaks. He found a leak, and in the process accidentally set a fire that burned uncontrolled in Unit 1 for seven and a half hours and badly damaged sixteen hundred electrical cables, including six hundred and eighteen cables that were connected to plant safety systems. The fire burned through the cables and swiftly crippled the plant—and especially its emergency cooling apparatus. The error resulted in a common-mode failure that simultaneously incapacitated multiple safety systems. The plant's superintendent, Harry J. Green, has commented, "We had lost redundant components that we didn't think you could lose." Six years later, the debate about how narrowly the Browns Ferry plant escaped a meltdown accident is still going on.

Another accident related to improper testing and maintenance occurred at the Zion Nuclear Power Station, in Zion, Illinois, on July 12,

1977. Because of what Dr. Hanauer referred to in an N.R.C. internal memorandum, dated August 18, 1977, as an "obvious gross management deficiency" that was worsened by an "unsafe" Westinghouse design for the plant's pressurized-water reactor, the plant experienced a serious accident. What happened, quite simply, was that technicians, in the process of checking some of the safety-system circuitry while preparations were being made for re-starting the plant after a brief shutdown, fed thirty-one "dummy" instrument signals to the control room which made it appear that the reactor had an adequate cooling-water supply when in fact it was losing water through a drain line. The plant safety systems, which would have automatically supplied the reactor with more water under normal circumstances, failed, because they, too, received the false instrument signals. In other words, the safety equipment that had been provided to control this accident was simultaneously paralyzed—as a result, once again, of a common-mode failure. Forty minutes later, after several thousand gallons of cooling water had been drained out of the reactor, the operators finally recognized the problem—fortunately, in time to correct it before the water supply had declined to critically low levels. Dr. Hanauer's memorandum warned that "next time, some different and not now foreseen sequence of events may start the ball rolling," and urged a broad review of all plants, "Westinghouse and non-Westinghouse," to prevent the recurrence of such an incident. The review was never carried out.

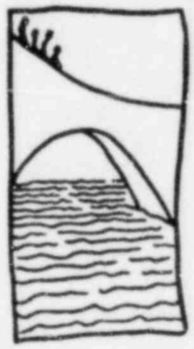
Despite these examples and others, and despite the estimates from the N.R.C.'s own eight-volume "Reactor Safety Study" that testing and maintenance were among the leading expected causes of safety-system "unavailability" during reactor accidents—thirty-five per cent of the failures in reactor-protection systems would be caused by testing or maintenance, according to this study, which was done in 1975—no satisfactory remedial action has been taken by the N.R.C. Unlicensed technicians are still allowed to carry out work on sensitive plant components. No regulations have been issued which require plants to be modified systematically so that their equipment can be tested or maintained in ways that would reduce the likelihood of accidents. No over-all ban has been imposed on testing and maintenance while plants are in operation.

Thus, while great care is supposed to be taken in designing the essential equipment of nuclear plants, testing and maintaining this equipment have been left a largely unregulated aspect of plant operation. Moreover, despite federal requirements that each plant be provided with a broad assortment of sophisticated safety devices, federal nuclear-safety authorities sanction industry practices allowing this equipment to be intentionally disabled for tests and maintenance during plant operation. The official listing of each plant's safety systems is, therefore, something like a menu that might be offered by a gifted but erratic chef: it has impressive entries, but what is available on any given day—such as March 28, 1979—may be just potluck.

A NUMBER of measures, of varying degrees of cost and effectiveness, can be taken to prevent workers from meddling with equipment, disabling safety systems, and otherwise interfering with the safe operation of a nuclear power plant. The preferable approach to the problem of human error is for plant designers to provide positive physical safeguards aimed at protecting all critical equipment in the plant from inadvertent or inappropriate human tampering. Such measures could be compared to some of the steps that many parents take in an effort to childproof a house—capping electrical outlets, installing special locks on windows, putting gates on staircases. Instead of providing safety features of this type in a nuclear plant, one can, of course, simply tell the nuclear-plant technician, like the child, not to do certain hazardous things. While specific, safety-related instructions, careful training, and repeated exhortations would be of considerable value, there is little doubt about the superiority of physical safeguards.

Comprehensive automation is obviously the most far-reaching countermeasure that can be taken at a nuclear power plant to reduce the opportunity for human error. The specific safety procedures stipulated by the designers can be locked into the electronic memories of the plant's control devices, which will then issue the commands that direct all critical operations. Automated control systems can be exhaustively tested in an effort to insure that they unfailingly adhere to the designers' orders. Though no system would be flawless, the technology for automated control equipment has progressed to the point where the machine is vastly more reliable than human beings—who are sometimes capricious, forgetful, distracted, tired, confused, error-prone, or negligent. Unfortunately, the automated systems required to carry out all the complex tasks associated with nuclear-plant operation are expensive, so American nuclear-utility companies are reluctant to use them except for a limited set of plant functions. The companies prefer to rely on relatively low-salaried and often unskilled technicians to perform what they regard as mundane chores. Even under emergency conditions, the automated equipment that is in general use has a narrow function: it is relied upon merely to turn on safety equipment. Once this is done, human operators rather than carefully programmed machines are responsible for all remaining aspects of crisis management. The current division of labor between man and machine during nuclear-power-plant accidents was illustrated quite precisely during the accident at Three Mile Island: two minutes after the accident began, automated command signals turned the plant's emergency core-cooling system on; the control-room operators then took command and, some two minutes later, decided to turn this system off.

There are steps short of full automation which can be taken to mitigate potential human errors. For example, valves that must be kept open or closed to insure that the safety system works properly can simply be locked into the correct position before a plant is started up, and access to the keys can be limited. Or else more sophisticated safeguards can be placed on the switches in the control room which plant operators use to open and close the valves. One such safeguard consists of electronic interlocks to link the switches that operate equipment with the instruments that monitor plant conditions; these interlocks can be set up to make sure that the operation of key components and systems is always matched to the safety needs of the reactor. One system of interlocks might be installed to prevent the switches that turn the reactor on from working unless all key valves were in their proper positions. A whole series of such interlocks, imposed not only on valves but also on all other safety-related equipment, would insure that the reactor could be started only if all its safety equipment was in the desired condition. Another type of interlock could be installed so that once the reactor was operating, safety-related valves and other equipment could not be switched off or otherwise inappropriately manipulated by a mistaken command from the control room. If the control-room operator tried to execute a wrong maneuver or pushed the incorrect button, the control system could automatically cancel this action and prevent a disruption of the plant.



Instead of incorporating into the plants permanent design features to prevent human errors, American nuclear-utility companies—with the permission of the N.R.C.—rely on one of the weakest of all possible systems: volumes of written procedures that simply tell nuclear-plant employees what they should and should not do. The members of the work force at a nuclear plant cannot be expected to remember each step in the formal rules that guide their every safety-related action. Nor, since they are generally required to have only high-school diplomas, can it be hoped that they will always be able to understand the technical rationale behind the instructions given to them. The plant management, accordingly, is supposed to set up a systematic "quality assurance" program that will supervise the performance of plant workers, will check and double-check to see that procedures are being properly followed, and will maintain careful written records documenting painstaking adherence to all the do's and don'ts that are intended to govern day-to-day nuclear-plant activities. "The watchword throughout the nuclear reactor industry is *quality assurance*," according to the nuclear pioneer Alvin Weinberg, who directed the A.E.C.'s Oak Ridge National Laboratory from 1955 to 1973. In other industries, the quality of workmanship and the resultant product reliability are sometimes uneven and unpredictable, but the nuclear-power industry claims to have achieved an unprecedented level of meticulousness. This (by prevailing industrial standards) superhuman diligence is, according to the government's official safety philosophy, the principal guarantor of nuclear-power-plant safety.

Although running nuclear power plants by the book is a major part of the N.R.C.'s approach to safety, the commission, like the A.E.C. before it, takes little official interest in the actual drawing up of the detailed procedures that nuclear-plant workers are supposed to follow. It delegates the task of writing all procedural manuals to the utility companies, asking them to follow what are sometimes only generalized N.R.C. guidelines. Moreover, even after the utility has prepared its procedural manuals—which cover plant start-up, shutdown, maintenance, equipment installation, emergency procedures, safety reviews, over-all plant quality assurance, and other activities with major safety repercussions—the N.R.C. carries out no comprehensive reviews to determine whether the procedures adopted by the company actually represent sound practice and conform with the N.R.C. guidelines. The agency devotes most of its regulatory attention and safety-review efforts to overseeing how the hardware in each nuclear plant is designed; the construction and operation of the plant is to be supervised by its owners. Federal nuclear-safety regulators, by their own estimates, actually inspect only about one to two per cent of the safety-related activities at a plant. *

The utility companies themselves are hardly enthusiastic about the responsibilities assigned to them in this area. The task of writing procedural manuals is detailed, time-consuming, often boring, and, in the companies' eyes, unproductive; they regard much of the effort as creating useless paperwork that wraps all aspects of a plant in bureaucratic red tape. The net result of the N.R.C.'s dependence on a self-regulating nuclear industry to develop and follow strict safety procedures and of the industry's indifference, and even hostility, to these requirements was evident at the Browns Ferry nuclear plant. The investigation of the Browns Ferry fire disclosed that, contrary to a technical specification in the plant's license, no detailed procedures had been drawn up and put in writing to govern the maintenance activities that caused the fire. In addition, according to the N.R.C.'s private files, the government was fully aware that the Browns Ferry plant did not have a competent quality-assurance program. "An overall QA program acceptable to NRC has not yet been produced by TVA"—the Tennessee Valley Authority, which operates the plant—Dr. Hanauer wrote in an internal N.R.C. memorandum dated July 10, 1975. Accident investigators, he noted in this brief memo, which was sent to senior N.R.C. officials, "asked very embarrassing questions about how [Browns Ferry] Units 1 & 2 had operating licenses without acceptable QA programs." Questions of this nature might also be addressed to the N.R.C. about Three Mile Island.

JUST how carefully the safety-related quality-assurance procedures at Three Mile Island Unit 2 had been prepared, how closely they were adhered to by plant personnel, and what role they played in bringing about the accident can be seen from plant records. At ten on the morning of March 26, 1979—two days before the accident—technicians at Three Mile Island Unit 2 began what the written plant procedures described as routine surveillance testing of the plant's emergency feedwater pumps, which called for the technicians to close two "isolation" valves. The technicians wanted to run these pumps to check on their operability, but they did not want to let water from the pumps be discharged into the plant's cooling network and so interfere with reactor operation. The simultaneous closing of these two valves, however, prevented the emergency feedwater pumps from delivering water to the parts of the plant's cooling system where it would be needed during certain accidents. At a meeting that took place seven months before the accident, a review committee made up of Metropolitan Edison employees had approved the closing of the two valves during pump testing. The employees' decision had received no independent review or checking by Nuclear Regulatory Commission inspectors; nor did the plant's review committee itself, according to plant records, review the safety implications of shutting the two valves simultaneously.

If the committee and the N.R.C. had adequately reviewed the procedures for testing the emergency feedwater pumps, they would have found that closing the two valves during plant operation was a direct violation of conditions that are set forth in the technical specifications incorporated in the plant's federal license. The technical specifications require that three emergency feedwater pumps and the piping system connecting them to the rest of the plant be operable at all times when the reactor is going. (The only exception is that one pump at a time may be taken out of service for maintenance provided that it is restored to operable status within seventy-two hours or the plant is shut down within the succeeding twelve hours.) The complete disabling of the emergency feedwater system is not allowed for any purpose during plant operation, yet plant records show that the system was shut down for testing on January 3, 1979, and February 26, 1979, as well as on the morning of March 26, 1979. And although the N.R.C. did add to the plant's license the technical specification intended to insure the operability of the emergency feedwater system, the N.R.C. required no physical safeguards to be installed at the plant—locks on the two valves or electronic interlocks on their control switches—to make sure that the valves remained open and the emergency feedwater system operable when the reactor was running.

Once the testing of the pumps was completed on March 26th—this took about three hours—the two isolation valves should have been reopened, as the test procedures specified. This is an essential step in restoring the emergency feedwater system to operability. Martin Cooper, one of four plant employees who were involved in the test, has said that he reopened the two valves at the completion of the test. "I actually opened the valves myself," he told a Presidential commission that was appointed to investigate the accident. "I was the control-room operator on duty." Cooper has also explained that a checkoff sheet on which the plant staff recorded its adherence to the procedures for reopening the valves was "thrown in the trash can," and that only the data sheets—the record of how the pumps performed during the testing—were kept in plant files. Moreover, no plant-management personnel reviewed either the actual completion of the procedures or the checkoff sheets; senior officials merely looked at the data on pump performance, and did not certify that the emergency feedwater system had been satisfactorily returned to service.

Both the failure to retain the checkoff sheets and the failure of plant management to oversee the testing are in direct conflict with two fundamental plant-safety procedures. These require that supervisory personnel review not only the results but also the documentation of test procedures, and that records of surveillance of test procedures be retained for at least five years—requirements that keep these activities under careful management control and serve as a check on the management's own performance. The failure to adhere to these two procedures, it has been discovered, was not limited to the particular testing procedure on March 26, 1979. Plant-management personnel have admitted to N.R.C. investigators that, as a de-facto rule, completed test procedures at Three Mile Island Unit 2 were hardly ever reviewed, because of the length of the procedures and the burden of the general management workload. They have also said that the required records documenting the plant testing activities were generally not retained, because of a shortage of storage space.

In sum, the testing of the emergency feedwater pumps on March 26th should not have been done in the first place, since the basic testing procedure violated explicit federal safety restrictions imposed on the plant and, in addition, was carried out in contravention of general plant procedures themselves of considerable importance to plant safety. Despite this serious breakdown in plant safety precautions, the testing personnel still assert that the valves whose closure disabled the emergency feedwater system on March 28th were reopened at the completion of the March 26th testing. To date, however, there is no evidence available beyond the say-so of these employees that this was in fact done. Moreover, plant records show no other maintenance or tests of any type being performed on the emergency feedwater system in the period between the testing on March 26th and 4 A.M. on March 28th which could have resulted in the closure of the valves. Neither these records nor post-accident interviews with plant personnel nor the N.R.C.'s subsequent inspections of the plant have uncovered any other operator actions involving the two isolation valves or any other possible equipment malfunctions in the two valves themselves or in their control mechanisms which would have caused the valves to be closed when they should have been open. The many investigations of the accident have brought forth no new evidence, so the most probable cause for the closure of the two valves appears to be a mistake by the testing crew on March 26th.

The fact is that the valve-related procedural debacle of March 26th and the valve problems that bedevilled Three Mile Island Unit 2 on March

28th, far from being uncommon or unprecedented events, were part of what has come to be an almost everyday problem at nuclear plants.

A VALVE controls the flow of a liquid or a gas. Some valves in a nuclear power plant are no more complicated in design or function than the faucet on a sink, while others, designed to control the flow of millions of gallons of water per hour through a nuclear plant's main cooling-water arteries, are complex giants that weigh many tons, stand several feet high, are opened and closed by powerful motors, and must be precisely controlled and monitored by electrical systems. Such valves must meet a variety of complicated design standards and receive periodic testing and maintenance.

Many of the valves perform tasks other than the regulation of cooling-water flow. Some feed fuel to diesel generators that provide an emergency power supply for plant safety systems. Some control the flow of compressed air, which is used to perform a variety of functions; indeed, certain valves may themselves be opened and closed by compressed air, and thus their proper functioning depends on other valves. The containment building of a nuclear plant is supposed to be sealed in the event of an accident, so that radioactive materials will not leak out, and to this end a variety of containment-isolation valves are installed, which are designed to shut off nonessential piping leading into and out of the containment building at the first sign of a serious accident. In some containment buildings, large valves are routinely open, so that low-level radioactivity, excess air pressure, and heat can be continuously vented to the outside; obviously, these so-called containment-purge valves must close quickly if there is an accident. Certain valves in nuclear plants relieve excessive pressure in the reactor. Some of these valves open automatically when the pressure of the cooling water inside the reactor increases beyond a set point. Others can be opened or closed at the discretion of the operators.

Although valves are an integral component of all major nuclear-plant safety systems, plant owners and operators have not taken proper precautions to insure their reliable performance. As a consequence, the performance of the thousands of valves installed in each nuclear power plant is very much below par—a fact that has been evident for years. According to a short N.R.C. internal memorandum written by Dr. Hanauer—his colleagues sometimes refer to his missives as Hanauergrams—nuclear-plant valves "are still failing too often and for the same reasons over and over." That was written in 1972, and a longer report by Hanauer the same year noted, "Valves do not have a very good reliability record. Recently, five of the vacuum relief valves . . . of Quad Cities 2 were found stuck partly open. Moreover, these valves had been modified to include redundant 'valve-closed' position indicators and testing devices, because of recent [Atomic Energy Commission] concerns. The redundant position indicators"—devices to alert the control-room operators to the fact that the valves were stuck open—"were found not to indicate correctly the particular partly open situation that obtained on the five failed valves." If the valves were in the wrong position, Dr. Hanauer's report went on, the containment chamber could overpressurize and rupture under some accident circumstances, whereas under other accident circumstances the improper operation of these valves could cause the pressure in the containment building to fall so low that the structure might collapse.

Despite these warnings, no systematic remedial action to improve the performance of valves in nuclear plants has been taken in the years since 1972. (Dr. Hanauer's particular recommendations for dealing with the problem affecting Quad Cities and dozens of similar plants were rejected by Joseph Hendrie, the N.R.C. chairman, who was then a senior A.E.C. official. Hendrie wrote, in a memo dated September 25, 1972, that Hanauer's recommendations would reverse "hallowed policy" and would be so embarrassing for the A.E.C. that such a reversal "could well be the end of nuclear power.") N.R.C. records show that valves have remained a major problem for nuclear plants. The switches and the signalling devices that control the opening and closing of the valves fail. The motors and other means of powering the opening and closing mechanisms fail. Even under normal conditions, the internal components of the valves jam, corrode, overheat, freeze, or break apart. Operators test the valves improperly, overlook necessary repairs on them, adjust them incorrectly, and—one of the most common problems of all—forget to reclose or reopen them after testing and maintenance.

The nature and the extent of the continuing valve problems have been well documented by Dr. Hanauer in a special N.R.C. internal file that he personally set up on accidents and safety defects at American nuclear power plants. A man who is able to view the blemishes that compromise nuclear-plant safety with a degree of dry humor, Dr. Hanauer calls this record the Nugget File. Some of the malfunctions documented in the Nugget File involve serious accidents, but the majority of the failures recorded in the file had few or no direct safety consequences. Since the safety apparatus involved was mostly standby equipment—normally inoperative but called into service when a certain type of accident arises—a failure of this equipment that took place during periodic testing or was uncovered in routine inspections obviously involved no immediate threat of the public's being exposed to radiation. Such failures are not instances of near-catastrophes; they merely indicate just how unready the nuclear plants are to cope with accidents when they arise. The Nugget File is chiefly a catalogue of these warning signs—case studies giving evidence or intimations of weak spots in the safety precautions taken at American nuclear power plants:

September, 1968: An operator at Unit 1 of the Dresden Nuclear Power Station, in Morris, Illinois, noticed that the monitoring lights for motor-operated valves in certain cooling systems were not on—indicating a loss of power to the mechanism that opens and closes the valves. Electricians determined that the circuit breakers for these valves were not working, for the reason that an electrical-distribution panel had water leaking into it. During a heavy rainfall, water had accumulated on the roof of the plant, because of a plugged drain, and had subsequently seeped down a building column and into the electrical system controlling the valves.

April, 1969: During the shutdown of a reactor, the name of which was not specified, the heat-removal system did not supply cooling water to the fuel core for two hours. Earlier, while the pump was running, a technician performing routine maintenance had closed a valve supplying water to the decay-heat pump, even though a special maintenance procedure prohibited the closing of this valve without the consent of the control-room supervisor.

April, 1971: Six months after the

Point Beach Nuclear Plant, in Two Creeks, Wisconsin, received its operating license, a test revealed that two key valves in the emergency core-cooling system would not open when they were signalled to open. Both valves were designed to open and close by hydraulic pumps, but the pumps had been installed incorrectly: they were mounted horizontally rather than vertically. On a prior occasion, a short circuit had disabled the hydraulic system, and on another occasion a valve in the hydraulic system that was supposed to open had stuck shut. Neither the utility company's quality-assurance program during the construction of the plant nor an investigation of the two earlier valve failures had disclosed the incorrect installation of the hydraulic pumps.

June, 1973: While the H. B. Robinson Steam Electric Plant, in Hartsville, South Carolina, was operating at seventy-five per cent of capacity, the plant safety committee determined that certain instruments were incorrectly measuring the pressure in the reactor building. The purpose of these instruments was to turn safety systems on in the event of a high-pressure reading, which would be indicative of a pipe rupture in the primary cooling system. The pressure-sensing instruments had failed because three vent valves on them had been left open. The three valves were not on the valve checklist used by plant operators, and were not even on the plant-equipment drawings.

October, 1973: The spray systems for the containment building at the Oconee Nuclear Station Unit 2, in Seneca, South Carolina, were found to be inoperable; these spray systems were intended to prevent the rupture of the containment building during an accident. They were inoperable because their valves were inadvertently left closed after a test that had been conducted eleven days earlier. The company that owns the plant said that as a "corrective action" it would issue a memorandum to the plant staff emphasizing the need for close attention to procedures.

May, 1974: The Browns Ferry Nuclear Plant was notified by the T.V.A. design division that improper valves had been installed in the primary cooling system of the plant's three reactors. The valves were designed to operate at a pressure of six hundred pounds per square inch but the cooling system had a pressure more than twice that. The design division stated that a hundred valves of this inappropriate design had been installed in each of the three reactors; they had been in operation in Unit 1 for almost a year.

JUNE, 1975: The emergency core-cooling systems at the Maine Yankee Atomic Power Station, in Wiscasset, were found to be inoperative, because valves were in the wrong position. The system was designed with a fail-safe valve arrangement that would automatically discharge emergency cooling water into the reactor in the event of a major pipe rupture. The fail-safe design was negated when the discharge valves for all the emergency-cooling-water tanks were closed. The operator who completed the system's valve checkoff sheet noted the locked handwheels on these valves and mistakenly assumed that the valves were locked open when in fact they were locked closed.

SEPTEMBER, 1975: At Unit 2 of the Oconee Nuclear Station, the level of reactor-cooling water was accidentally altered while the reactor was operating at full power. Workers trying to shut off valves so that they could make repairs on a faucet in the plant's chemistry laboratory inadvertently closed valves controlling the air supply to two other valves. These other valves controlled the rate of water drainage from and addition to the reactor's primary cooling-water system. Before this error, the two flows balanced each other, but after the air supply was closed one valve failed in a closed position, preventing drainage, and the other valve failed in an open position, allowing an excess addition of cooling water.

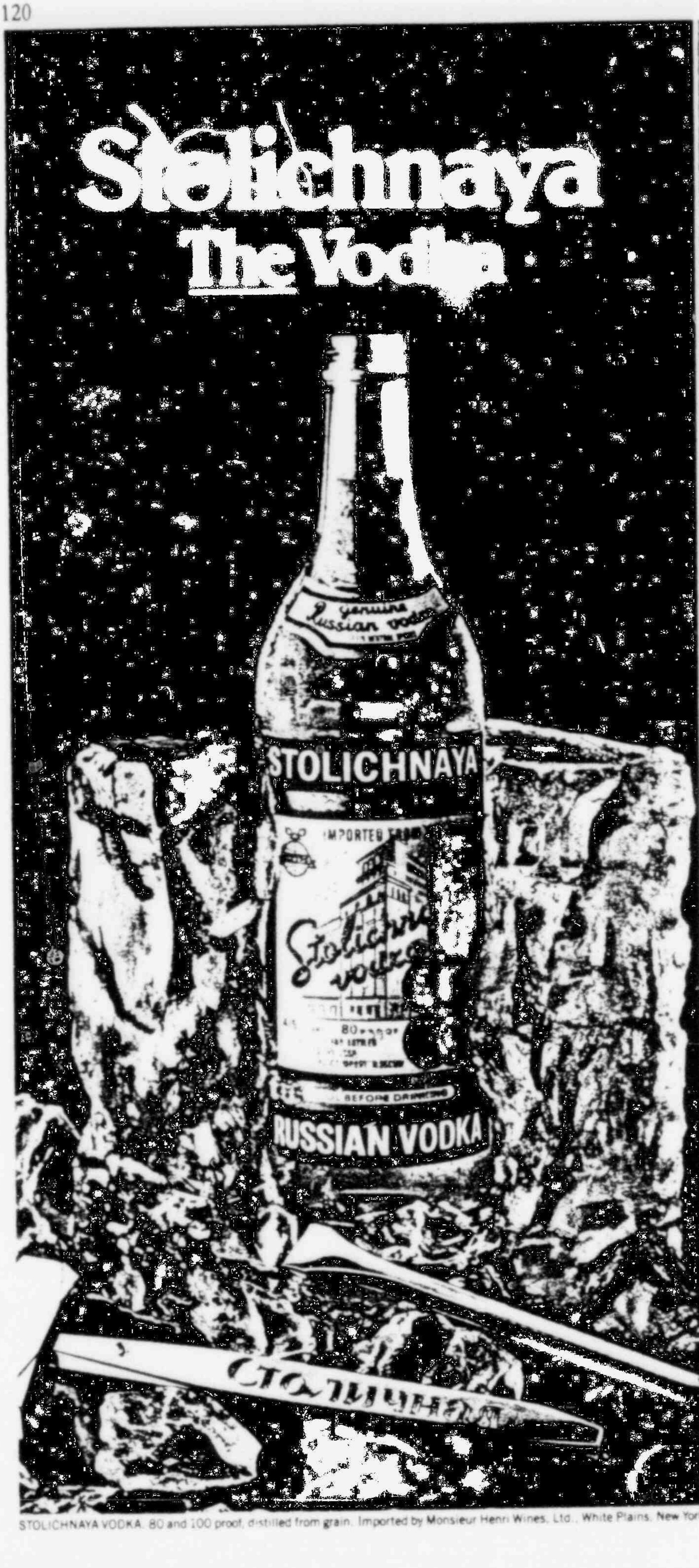
DECEMBER, 1975: A plant operator at the Calvert Cliffs Nuclear Power Plant Unit 1, near Lusby, Maryland, discovered that a water-supply valve to the two emergency feedwater pumps was shut, leaving both pumps without a supply of water. The Baltimore Gas & Electric Company, which owned the plant, concluded that plant operators had "erred" about two weeks earlier, when the valve positions had been changed. The company report on this "occurrence" said that if the emergency feedwater pumps had been needed it was "highly probable" that the operator would have noticed the lack of water supply to the pumps "prior to any serious damage occurring."

MARCH, 1976: At the Prairie Island Nuclear Generating Plant, in Welch, Minnesota, a valve was wrongly closed during maintenance on the cooling-water system for plant safety apparatus. This single valve in the wrong position disabled one of the two cooling systems for the two reactors at the plant.

JULY, 1976: A steam-driven emergency feedwater pump at Unit 2 of the Millstone Nuclear Power Station, in Waterford, Connecticut, failed, because the steam-supply valve would not open. An inspection showed that a steel piece of the operating mechanism had broken off. A subsequent investigation revealed multiple contributory failures. The switch that was used to control the motor that opened and closed the valve had failed. A back-up switch had also failed. In addition, the valve had not been tested; it had initially been installed as hand-operated equipment, and had been returned to the manufacturer so that a motor could be put on to open and close it. The valve had been reinstalled without an adequate inspection or test.

Dr. Hanauer is still enlarging the Nugget File. "Yes, sir, it's still an open file. I just put an item in the other day," he said in a recent interview. Valves, he added, were "one of the continuing problems." Another item that deserves to be included in his collection of valve-related problems occurred at the Arkansas Nuclear One Station—Unit 1, in Russellville, which uses a Babcock & Wilcox reactor. During routine testing of valves on the plant's main feedwater system, technicians mistakenly disabled the automatic controls for the plant's emergency feedwater system—the same system that was rendered inoperative at Three Mile Island Unit 2 on March 28, 1979. In both instances, improper testing procedures were used. The Arkansas Unit 1 problem occurred on June 2, 1979—more than two months after the accident at Three Mile Island.

It is evident from the Nugget File that valve failures, many resulting from improper maintenance and sloppy operating procedures, are endemic to the commercial nuclear-power industry in this country. As disturbing as this finding may be, an even more sobering conclusion emerges if one reads through the several hundred technical reports that are included in the file. What these reports reveal is that the same level of carelessness and management quality-assurance breakdowns which shows up in the records of valve failures apparently also infects every other major aspect of the design, construction, and operation of the seventy-one nuclear plants now in operation around the country. For example, it is not just maintenance on valves that leaves safety apparatus disabled. Electrical-system maintenance, which generally necessitates unplugging equipment or otherwise interrupting power-supply circuits, has a record parallel to that of valve maintenance in leaving safety apparatus inoperable; just as workers forget to reopen valves, they commonly forget to turn power supplies back on or to plug safety devices back in. Moreover, these blunders, according to the evidence in the Nugget File, extend far beyond maintenance and testing activities, and persistently occur in the design of equipment, in plant construction, in equipment installation, and at the operating consoles in control rooms. Thus, according to the Nugget File, key safety equipment is often rendered inoperative for want of fuses. Electrical relays fail because they are painted over or welded together or disconnected—or simply left out when the equipment is installed. Reactor control rods fail to work because their components are installed upside down or because their electronic-control systems pull them out of the reactor when the operator presses the button to put them in. Sensitive pieces of safety apparatus malfunction because they are frozen or burned or flooded or dirty or corroded, or have been bumped or dropped or overpressurized or unhinged or miscalibrated or miswired. In some cases, they are, to cite one of Dr. Hanauer's marginal notes in the Nugget File, "guaranteed not to work," because of bad initial design. This possibility was displayed quite dramatically in June of 1980, when the SCRAM system—a supposedly ultra-high-reliability safety feature that acts as the "emergency brake" that instantly shuts down a reactor—failed at the Browns Ferry Nuclear Plant Unit 3. The system failed repeatedly as the operators, over a period of fourteen minutes, kept trying to insert the control rods into the reactor. One industry newsletter, reporting the dismay in the industry over the failure of



such a basic safety system, described the problem as "mysterious." Actually, what was involved was a simple design error that had been overlooked by federal safety authorities, despite the fact that the SCRAM system had been relied upon for two decades in some twenty-six plants. Of course, there have been other kinds of problems with SCRAM systems over the years, not all of which involved a failure to shut down the reactor. In some cases, the problems have involved the unintentional Scramming of the reactor when it should have been left operating. In one instance at a training reactor, the SCRAM system was activated because of a change in the water pressure in the reactor building—which happened when someone flushed a toilet.

Valve failures, in short, are merely one manifestation of the pervasive breakdown of the "honor system" that the N.R.C. has set up—the loose arrangement under which utility companies are expected to police the safety of their own nuclear plants. This honor system appears to have resulted, in an uncomfortably large number of cases, in little discipline at all being exercised over a wide range of plant activities important to public safety. That the relief valve should stick open and that two key valves in the emergency feedwater system of Three Mile Island Nuclear Station Unit 2 should happen to be in the wrong position on the morning of March 28, 1979, is no more surprising than it would have been if the company that operates the facility, Metropolitan Edison, had decided that day to apply for a rate increase to cover rising costs: such events occur in the nuclear-power business with what seems to be roughly the same frequency. There are "many indications," as Governor Babbitt, of the Nuclear Safety Oversight Committee, observed, "that Met Ed is not an aberration, and that there are other nuclear utilities that do not measure up to even minimal standards." The repeated instances of the disabling of sophisticated safety systems by crude human errors have led to the view, expressed by Henry Kendall, a physicist at the Massachusetts Institute of Technology, that the nuclear-power program may deserve to be described, like the Navy in "The Caine Mutiny," as a system designed by geniuses and run by idiots.

—DANIEL FORD

(This is the first part of a two-part article.)

April 13, 1981

Price $1.25

pp.46 →

THE NEW YORKER

A REPORTER AT LARGE

THREE MILE ISLAND

II—THE PAPER TRAIL

THE safety of the commercial nuclear power plants in this country is the responsibility of the United States Nuclear Regulatory Commission, a small federal agency whose over-all performance—and basic technical and administrative competence—has been widely criticized in light of the accident, two years ago, at Three Mile Island Nuclear Station Unit 2. A Presidential commission set up to investigate the accident, the most serious in the history of the commercial nuclear program, said, "With its present organization, staff, and attitudes, the N.R.C. is unable to fulfill its responsibility for providing an acceptable level of safety for nuclear power plants." The N.R.C. undertook its own post-accident self-examination, conducted by a Special Inquiry Group headed by the Washington attorney Mitchell Rogovin, and this committee, too, passed a strongly negative judgment on the N.R.C.'s regulatory program. "In our opinion the [N.R.C.] is incapable, in its present configuration, of managing a comprehensive national safety program for existing nuclear power plants and those scheduled to come online in the next few years adequate to insure the public health and safety," it concluded. With seventy-one nuclear plants in operation—some near heavily populated metropolitan areas—the lack of effective federal supervision leads to worrisome questions about the safety of millions of Americans.

In one sense, sweeping general criticisms of the N.R.C.'s regulatory program may be unfair, for they may be belaboring "deficiencies" in the N.R.C.'s performance which are not so much a result of sheer regulatory ineptitude as they are the consequence of political decisions about what the agency was expected to do in the first place. The fact is that the N.R.C. was never really intended to tightly constrain the nuclear-power program or exercise ultimate judgment about the acceptability of the risks that might be associated with it. Given the overriding commitment of the federal government to rapid nuclear-power expansion—a bipartisan national goal adopted by Congress in the nineteen-fifties and endorsed by successive Administrations—the N.R.C.'s role in the effort was a largely pro-forma one, the political decision to proceed with a large nuclear program and to accept the (presumably small) risks already having been made. Despite what legislators and bureaucrats refer to as the "boiler plate" language in the statutes that define the N.R.C.'s regulatory powers and duties, the agency, in practice, has been simply the minor government department that hands out licenses to build and operate nuclear plants, much as the State Department's Passport Agency issues passports to travellers. The safety and licensing system set up by the N.R.C., according to Peter Bradford, one of the agency's five commissioners, "was never designed to be an effective regulatory system" but "was constructed for the stamping out of nuclear power plant construction permits or operating licenses at the assembly-line rate of one or two per week for every week in the years from 1975 to 2000." One consequence of the government's single-minded dedication to nuclear-power expansion, Bradford notes, was a regulatory process that fell into "fundamental disarray."

The regulatory arrangements relied on by the N.R.C. are the outgrowth of general policies adopted in the nineteen-fifties and sixties by its predecessor, the Atomic Energy Commission. The A.E.C., which vigorously promoted commercial exploitation of "the peaceful atom," believed that the shortest route to a large nuclear-power program required unleashing "the genius and enterprise of American industry." In order to give the nuclear-power industry the discretion it needed to move ahead swiftly with plant construction, the A.E.C. adopted a relaxed and permissive regula-

"I called you in here, Donaldson, to remind you that you're skating on mighty thin ice."

"Dear, I'm going out now."

tory program. Under the scheme it developed, the government would specify general safety goals but would leave their implementation to the emerging nuclear industry, relying on it to have the common sense to build a high level of safety into each plant. The A.E.C. did have a small number of staff engineers and consultants who reviewed the applications for nuclear-plant licenses, but the commission usually gave short shrift to the safety issues raised by its experts. Since the A.E.C. was convinced that technical solutions to these problems could be found, it did not believe that it was running a great risk by deferring such questions while the industry proceeded with nuclear-plant construction. Moreover, when the industry matured and expanded, the A.E.C. still saw no strong need to develop more formal regulatory arrangements. In 1974, however, Congress decided that the conflict of interest inherent in the A.E.C.'s dual responsibilities—to both promote and regulate the nuclear industry—suggested the need for a new, independent regulatory body. Accordingly, Congress passed the Energy Reorganization Act of 1974 to establish the N.R.C.—a separate agency whose only mission would be to regulate the nuclear industry. Reorganization per se did not mean substantive regulatory reform, however, for there was little Congress could do about the bureaucratic inertia that would inevitably make it difficult to change the ground rules for nuclear-power expansion that had been laid down by the A.E.C. Indeed, the carryover of A.E.C. policies by the N.R.C. was a foregone conclusion, since the N.R.C., according to the 1974 act, would essentially *be* the regulatory staff of the old A.E.C., under a new name. Unsurprisingly, the new agency's first official action was to adopt all the safety rules and policies of its predecessor. As a matter of law, the N.R.C. had full and unambiguous power to develop new regulations governing every aspect of nuclear-plant design and construction, all the way down to rules for the installation of the last nut and bolt. Still, the only basic changes in the regulatory process during the next several years were efforts—prompted by the Ford and Carter Administrations—to streamline it so that nuclear plants could be licensed faster.

With a regulatory process that remained in "fundamental disarray," it was apparent—to some observers, at least—that sooner or later the government's overambitious nuclear program was going to get into trouble. Indeed, looking back over A.E.C. and N.R.C. records, one can follow what one senior N.R.C. official calls the paper trail that documents the detailed foreknowledge, on the part of both the nuclear industry and the federal government, of the specific safety problems that culminated in the accident of March 28, 1979.

THREE MILE ISLAND Unit 2 is one of nine electric-generating plants in the United States that use nuclear-reactor equipment designed and manufactured by Babcock & Wilcox. As is customarily the case with nuclear-equipment suppliers, Babcock & Wilcox provides only the specialized nuclear steam-supply system and the associated control equipment used in these facilities; its portion is estimated to amount to about ten per cent of the total cost of plant construction, with other suppliers, architect-engineering firms, and construction companies providing all the other services and equipment. (Unit 2, for example, was built by United Engineers & Constructors; its turbine was supplied by Westinghouse; its architect-engineer was Burns and Roe; the pressure-relief valve for its primary-cooling system was manufactured by Dresser Industries.) The various companies that participate in the design and manufacture of each nuclear power plant's components and systems have their own design preferences and requirements, and so do the individual utility companies buying these services; as a result, the nine plants that use Babcock & Wilcox nuclear reactors differ in many of their design details. The nine plants were also built at different times and were therefore subject to different federal safety regulations. Even plants built during the same period and under the same nominal safety requirements may display marked design differences, owing to the varying interpretations that can be given to some of the very general design criteria promulgated by the A.E.C. and the N.R.C.

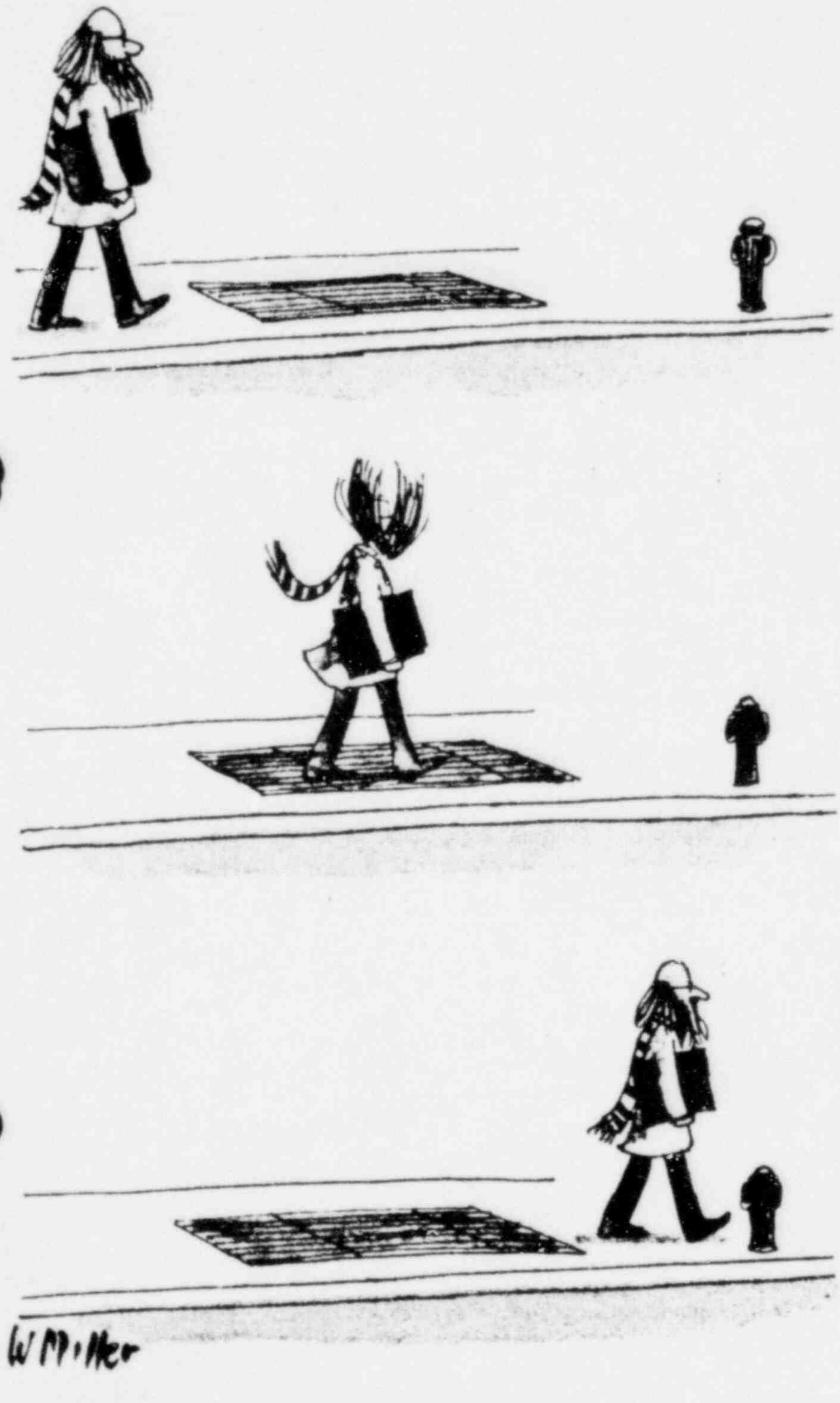
Still, the plants using Babcock & Wilcox reactors do have a large element of similarity—a strong family resemblance. Certainly the Babcock & Wilcox equipment in all of them is essentially the same in most elementary design respects. The official A.E.C. "Safety Evaluation Report" for Three

Mile Island Unit 2, issued in September of 1969, noted, "The nuclear steam supply system, engineered safety features, and reactor building are similar in design to the other Babcock & Wilcox facilities at Oconee Nuclear Station, Crystal River Nuclear Station, Rancho Seco Nuclear Station, Three Mile Island Unit No. 1 Nuclear Station, and the Arkansas Nuclear Station, which have already been issued construction permits."

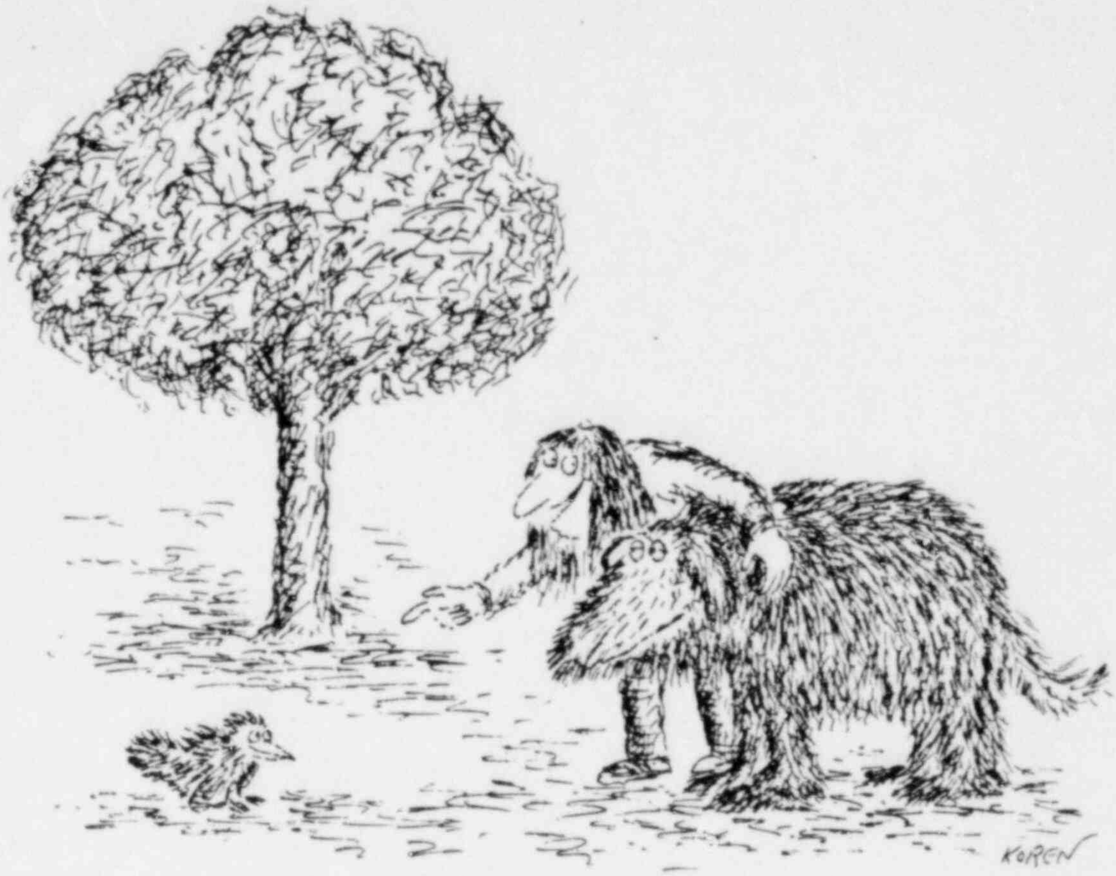
The eight other nuclear plants incorporating Babcock & Wilcox reactors all went into operation before Three Mile Island Unit 2, and as of March, 1979, the nine plants had accumulated some thirty reactor-years of operating experience. The three Oconee plants, which are owned by the Duke Power Company and are situated near Seneca, South Carolina, went into operation in 1973 and 1974. Toledo Edison's Davis-Besse Unit 1, at Oak Harbor, Ohio, between Toledo and Cleveland, has been operating since 1977; the Florida Power Corporation's Crystal River Unit 3, near Crystal River, Florida, since 1976; the Sacramento Municipal Utility District's Rancho Seco Nuclear Generating Station, in Sacramento, California, since 1974; the Arkansas Power & Light Company's Arkansas Unit 1, in Russellville, Arkansas, since 1974; and Three Mile Island Unit 1, which, like Unit 2, is operated by the Metropolitan Edison Company, since 1974.

The operating records of the earlier Babcock & Wilcox nuclear reactors provide concrete, practical information about the performance characteristics and over-all reliability of Babcock & Wilcox systems and components. The design of nuclear power plants is based on predictions of how equipment will behave under both normal and emergency conditions. While laboratory tests and experiments can provide some check on the design engineers' predictions, operating experience affords far more realistic and valuable data. Thus, as nuclear power plants of a given type and design operate, careful study of their cumulative track record can serve a number of ends. The operating history can be used to check design adequacy; it can suggest needed procedural improvements; it can prompt new regulatory requirements or, possibly, the elimination of unnecessary ones; it can be used as a basis for other regulatory determinations (such as the competence of individual utility companies to operate nuclear power plants); and, most important, it can provide possible early-warning signs of developing safety problems.

The N.R.C. has never given high priority to an effort to study and use the operating records of commercial nuclear plants as a basis for its regulatory actions. Its scientists and engineers are otherwise engaged. N.R.C. safety analysts, for example, perform prelicensing safety reviews of each proposed nuclear power plant; they are concerned principally with the general design features of new plants and, as a rule, limit their inquiries to standard questions about safety-system design which have been on the official technical agenda since the mid-nineteen-sixties. Meanwhile, in the various government laboratories where N.R.C. safety research is conducted, scientists and engineers concentrate on a relatively narrow set of technical questions about certain "hypothetical accidents"—advanced scientific issues that have been the dominant interest of these research centers for the last



fifteen years. Thus, the federal agency in charge of nuclear-plant safety, given the duties and preoccupations of its technical experts, has concerned itself only casually with the actual day-to-day safety problems at American nuclear plants. One manifestation of this attitude is in the N.R.C.'s handling of reports of safety deficiencies at the plants. Although the commission annually receives four to five thousand reports on equipment breakdowns, operator errors, and other safety-related or potentially safety-related incidents, it had, before the accident at Three Mile Island, no systematic program to discover what lessons could be learned from the data; that is, there had been no centralized effort to review the data on a regular basis, to extract significant trends, to analyze the fundamental safety issues underlying recurrent problems, and to oversee corrective action.



"That's a bird, spelled b-i-r-d."

• • •

The N.R.C. does have a Division of Operating Reactors and an Office of Inspection and Enforcement, and these presumably are responsible for reviewing the safety problems of nuclear plants already in service. According to Victor Stello, Jr., who was the head of the former division and is now the head of the latter, the N.R.C. "collects, digests, analyzes," and otherwise deals with the reports from the operating plants, but just how these efforts fit together into an over-all system Stello was reluctant to explain. "No, I don't like to summarize it," he said in an interview a few weeks after the accident. The task of reviewing these data, he remarked, is spread among various agency divisions and offices. "There's no assigned group that sits down and is devoted to the task of just looking at all of the licensee event reports from all of the plants—it's not done that way," he said. Some offices do collect the data from the plants, he continued, adding, "I would think" that they "do what they can to analyze it." Other N.R.C. branches, according to Stello, have "a whole host of people" who analyze individual events at the operating plants "fairly comprehensively."

Harold Denton, who as the director of the Office of Nuclear Reactor Regulation supervises these specialized branches, has a different impression of how the N.R.C. safety analysts have dealt with routine reports of equipment malfunctions and other safety problems over the years. The reports "all come in, they all get logged, and identified, and printed up," Denton says, but "some branches are far more interested in operating experience than others." While a few offices have "historically really monitored" and "worried" about such developments at the licensed reactors, he says, "other branches don't tend to think that operating experience is as valuable in input, and it hasn't got done." After the Three Mile Island accident, Denton said, "The commission has asked us on a crash basis now to propose a new scheme to be sure that licensee event reports do get proper attention in the future."

Even Stello conceded that the N.R.C., before the accident, had no coördinated method for identifying patterns in the safety-system deficiencies reported to it. "The individual reports are analyzed," he said. "The trending is not. The trending is ad hoc."

Unless some N.R.C. officials merely happened to discover it, a trend suggesting safety difficulties could easily remain buried in the voluminous reports that the N.R.C. receives from each operating plant. Over the years, Dr. Stephen H. Hanauer, who is an engineer with the N.R.C. and one of the federal government's chief nuclear-safety experts, has sent out memos on the need to review the information flowing into the agency from the plants. "Not a day goes by without one or more mishaps at licensed reactors," he noted in a memo on September 13, 1971, in which he urged the orderly compilation and "periodic review" of these data. Other officials have privately discussed the "gold mine" of safety-related data that was being officially ignored, although a few abortive attempts were made to set up a program for extracting useful—and possibly critically important—information from all the routine reports of nuclear-plant mishaps. Still, the

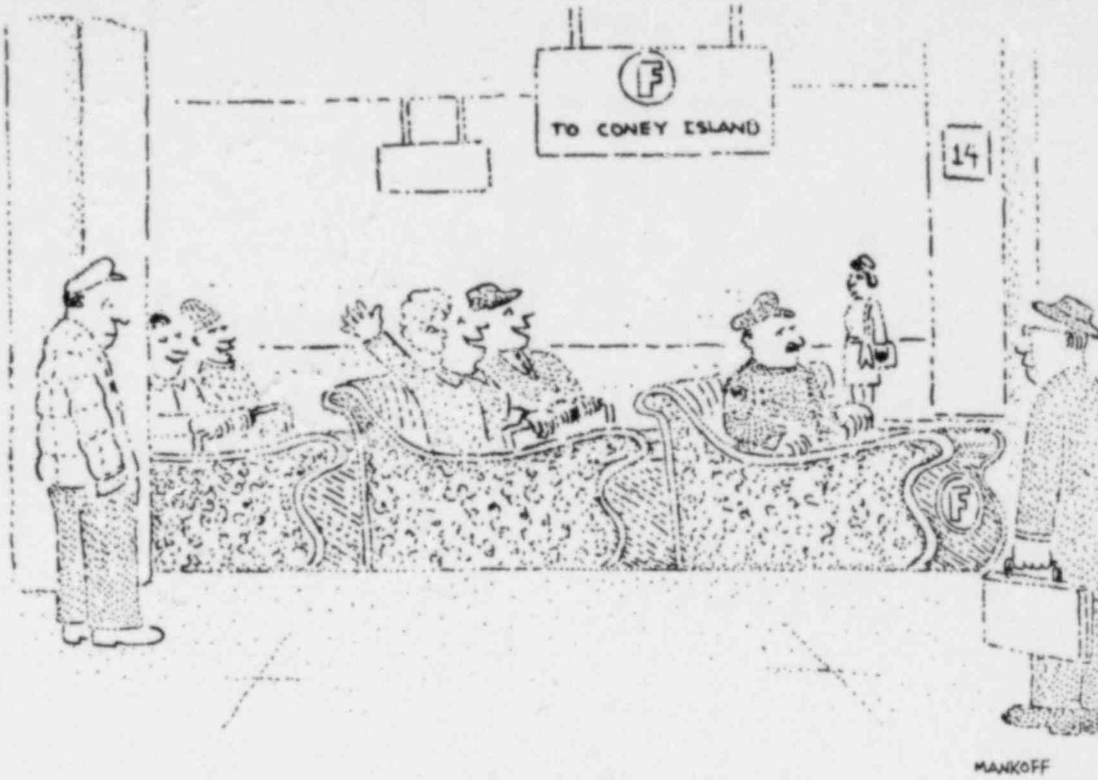
N.R.C.'s safety-review and safety-research priorities had never been amended to emphasize the task of taking a careful look at what was really happening at operating nuclear plants.

A REVIEW of the documents that accumulated in the N.R.C.'s files pertaining to the nine Babcock & Wilcox reactors shows what the N.R.C. would have learned if Stello's division or Denton's other specialized branches had elected to monitor these reports periodically. Although many of them—they are available for inspection at the N.R.C. Public Document Room, in Washington—are fragmentary, containing raw data about specific incidents and malfunctions unaccompanied by engineering analyses or commentary, they nevertheless suggest a pattern of safety problems seemingly inherent in Babcock & Wilcox designs. The problems are not, however, limited to Babcock & Wilcox reactors; the reactors of Westinghouse, Combustion Engineering, and General Electric have also experienced a wide range of safety-related difficulties, as a review of plant malfunctions suggests.

On September 16, 1978, a serious problem developed in the electrical equipment that powers and controls safety systems at Arkansas Nuclear One—Units 1 and 2. Arkansas Unit 1 uses a Babcock & Wilcox reactor, and Unit 2 uses a pressurized-water reactor designed and manufactured by Combustion Engineering. The difficulty, which could result in the disabling of all the safety equipment at both plants, was officially characterized as a case of "degradation of engineered safety features." The accident began with the sudden closing of a single valve in one of the main pipes that delivers steam to the turbine in Arkansas Unit 1, which was operating at full power. Unit 1 should have simply gone into a routine shutdown, leaving Unit 2, which was being tested before going into commercial operation, unaffected. Instead, because of a wrong interconnection of the two units, all of Unit 2's emergency safety systems were activated. Emergency diesel generators started up, valves opened or closed, pumps began pumping; the plant reacted as if there had been a major accident instead of a spurious electrical signal. Moreover, electrical-system problems at Unit 2 signalled certain valves to open prematurely—a development that caused other emergency equipment to operate out of the correct sequence. This meant that if there had been an actual crisis, such as a pipe rupture that required emergency cooling to prevent a core meltdown, the emergency cooling system at Unit 2 would not have worked. At Unit 1, meanwhile, a more routine shutdown occurred, and initially there was no evidence of deficiencies in its electrical systems. But a subsequent N.R.C. review disclosed that in a real emergency the fuses in all of Unit 1's control circuits for safety equipment could have blown, leaving the safety apparatus disabled. On February 16, 1979—five months after the accident—the Nuclear Regulatory Commission issued a notice informing other utility companies of the "unusual sequence of events" that had occurred at the Arkansas plant. Although the N.R.C. has full legal authority to "modify, suspend, or revoke" the licenses for nuclear plants whenever it determines that a safety defect may exist, it allowed all Babcock & Wilcox and Combustion Engineering plants to continue in operation.

The commission's reference to the sequence of events at Arkansas Units 1 and 2 as "unusual" may be somewhat misleading. N.R.C. records reveal that in July of 1976 a similarly widespread electrical-system failure disabled the safety equipment at the Millstone Nuclear Power Station Unit 2, in Waterford, Connecticut, on two separate occasions. That plant's pressurized-water reactor and related control equipment were designed and manufactured by Combustion Engineering. The commission had assigned one of its staff electrical experts to study this type of potential electrical problem long before either of the Millstone incidents. In his reports, the engineer concluded that circuitry failure might be a generic deficiency in the entire nuclear industry—a likely sequence of events in certain circumstances in any plant. The N.R.C. took no corrective action in response to his concern or in response to related safety problems noted soon afterward by other members of its electrical-systems branch. The reluctance of the N.R.C.'s senior management to take action on several dozen safety issues pointed out by N.R.C. engineers—a list that included the problem of mistaken operator interference with the emergency cooling apparatus—led to a decision by five licensing engineers to testify before the Senate Governmental Affairs Subcommittee on Energy, Nuclear Proliferation, and Federal Services, on December 13, 1976, at a hearing chaired by Senator John Glenn, in order to call attention to the problems, explain their seriousness, and possibly help bring about needed remedies. They told the subcommittee that the N.R.C. was "covering up" a set of safety problems that some of its own principal experts believed to be extremely grave. Their testimony stimulated none of the corrective actions they desired, although it did provoke the N.R.C. to reassign four of them two days later. The fifth engineer had already resigned from the agency in protest.

Another significant shortcoming in a nuclear plant using a Babcock & Wilcox reactor was revealed by an accident at the Rancho Seco Nuclear Generating Station, near Sacramento, on March 20, 1978. At 4:25 A.M., an operator who was replacing a burned-out light bulb on the main control panel



dropped the quarter-inch bulb into the panel. The plant, which was operating at seventy per cent of capacity and was supposed to be capable of coping with pipe ruptures, fires, earthquakes, and other contingencies, could not handle this seemingly trivial mishap. According to a description in a private Babcock & Wilcox report, the dropping of the light bulb caused short circuits that in turn interrupted the power supply to "a substantial portion" of the instruments in the control room which monitored key parts of the plant. The instruments included those used to control the main feedwater system, which immediately began to malfunction. Because of the instrument failure, however, the operators did not have the information they needed to determine the appropriate emergency actions. Automated equipment was available to assist in controlling the reactor, of course, but the correct automated actions were not carried out, either, because this equipment also failed to receive the appropriate signals from the malfunctioning instruments. To make this dangerous situation worse, the instruments started sending erroneous signals to the plant's integrated-control system—an automated master control that, among other things, regulates the main feedwater system. The integrated-control system then initiated a series of maneuvers that, according to Babcock & Wilcox, sent the reactor on a "severe thermal transient," which involved a rapid surge in pressure in the reactor—causing a safety valve to open temporarily—followed by a prolonged pressure drop. The emergency cooling apparatus was also activated. "For about the first seven minutes, the two events"—at Rancho Seco and a year later at Three Mile Island—"looked almost identical," according to Daniel Whitney, a Rancho Seco nuclear engineer. The Babcock & Wilcox report on the incident, which was dated August 9, 1978, and was written by Ivan D. Green, the site-operations manager at the company's headquarters, in Lynchburg, Virginia, concluded, "Plant operators had extreme difficulty in determining the true status . . . of the plant . . . and in controlling the plant because of the erroneous indications in the control room." After an hour and nine minutes, the operators finally figured out how to restore power to their instruments, and they were then able to bring the plant back under control. The Babcock & Wilcox report, intended to alert the operators of the company's other reactors to the problem, was sent out to all the utilities except Metropolitan Edison. Babcock & Wilcox officials believed that it was not necessary to inform the company of the problem, since a similar event at Unit 2, on March 23, 1978, had already been discussed with Met Ed officials.

THE copy of the Babcock & Wilcox report on the Rancho Seco accident sent to the Davis-Besse Nuclear Power Station, in Ohio, was ultimately seen by James S. Creswell, a thirty-five-year-old reactor inspector in the Midwest regional office of the N.R.C.—in Glen Ellyn, Illinois, near Chicago—whose duties included overseeing the start-up of Davis-Besse. Although reports of the Rancho Seco accident, and also reports of accidents that had occurred at the Davis-Besse plant, had been sent to the N.R.C., these reports, far from stimulating an N.R.C. review of Babcock & Wilcox plants, had received scant official attention. Creswell was deeply concerned about the accidents, however, and about several other problems that had come to his attention at Davis-Besse. On his own initiative, he raised a number of questions about Babcock & Wilcox reactor problems not only with plant officials but also with officials of the N.R.C. He felt that there might be safety flaws inherent in the Babcock & Wilcox equipment—a view not shared by senior N.R.C. officials.

One of the accidents that worried Creswell had occurred at Davis-Besse on September 24, 1977—an accident that, it is clear in retrospect, bore a striking resemblance to the one at Three Mile Island eighteen months later. At Davis-Besse, the main feedwater system failed—as it did at Three Mile Island—and then a pressure-relief valve opened and, because of a missing electrical relay, cycled open and closed about nine times, finally jamming in an open position. (It is still not known whether the pressure-relief valve at Three Mile Island stuck open because of an electrical-control problem or for some other reason, since the continued high radiation levels inside the containment building have made a physical inspection impossible.) The operators at Davis-Besse, like the operators at Three Mile Island, did not immediately realize that the relief valve was open. At Davis-Besse, it took them twenty-two minutes to discover the open relief valve; at Three Mile Island, it took about two hours and twenty minutes. At both plants, the pressure in the reactor's cooling system increased and then decreased uncontrollably. Part of the emergency feedwater system malfunctioned at Davis-Besse, as it did at Three Mile Island. The Three Mile Island plant, however, experienced a complete, rather than a partial, initial failure of its emergency feedwater equipment. Finally, at both plants the operators mistakenly shut off the emergency cooling pumps—as a result of their mistaken interpretation of the pressurizer-water-level-instrument readings. The main difference between the two accidents—and it is a major reason that the Davis-Besse accident was much less severe and did not result in core damage, as the accident at Three Mile Island did—was that the Davis-Besse reactor was operating at only nine per cent of its full power, whereas the reactor at Three Mile Island was operating at ninety-seven per cent.

Worrying about the adequacy of nuclear plants and their safety systems was something that was supposed to be done by the hundreds of safety analysts at the N.R.C.'s headquarters, and not by a field inspector like Creswell, who was expected to be more of a bookkeeper than an engineer. His principal assignment was to monitor the paperwork connected with a utility company's quality-assurance programs and to review other aspects of its administrative procedures. The N.R.C. had elected not to have its inspectors carry out comprehensive physical inspections of the actual equipment and components installed in nuclear power plants —not to test equipment performance, or periodically check sensitive pipes for cracks, or determine whether specific components had been built and installed in accordance with N.R.C. safety requirements. Instead, as a 1978 report on part of the N.R.C.'s inspection program by the General Accounting Office noted, the N.R.C. preferred to "rely heavily upon the utility company self-evaluation." For all practical purposes, in other words, the commission delegated most safety-inspection tasks to the individual utility company and limited its own role to spot-checking the utility company's records of such work. Without direct inspections and independent testing of the actual equipment, of course, the N.R.C. could not verify the accuracy of the company's records but merely their ostensible completeness. N.R.C. inspectors had complained privately for years that this loose supervision of the industry had resulted in a low "confidence level" concerning the degree to which operating nuclear plants actually complied with federal safety rules. That this indirect system of auditing safety conditions at American nuclear plants may have been responsible for the belated detection of safety defects also prompted the General Accounting Office to recommend that the N.R.C. "improve its basis for judging the quality of nuclear power plant construction." Creswell, in the light of the safety problems that he saw at Davis-Besse, was not content to stick to his narrow formal assignment and overlook what he took to be the possible generic safety ramifications of the September 24, 1977, accident and the problems related to it. Nor was he satisfied that he could rely on the N.R.C.'s determination that the plant's Babcock & Wilcox equipment was adequately designed or on the utility company's own "self-evaluation," which stated that the various "incidents" at the plant were no cause for concern.

"The problems at Davis-Besse just bugged me," Creswell said in an interview a few months after the Three Mile Island accident. His pursuit of these matters, he recalled, began in earnest after a routine three-day inspection that he made at the plant starting on December 6, 1977. The focal point of this particular inspection was an occurrence at the plant a week before, on November 29th. A temporary power failure had caused the plant to shut down suddenly—a

relatively common experience for any type of electric-generating station. As Creswell reviewed the records of the incident, however, he became concerned about the strange behavior of the pressurizer-water-level instrument during the incident. This is a device that reactor operators use in lieu of an instrument telling them how much water is in the reactor. During the November 29th incident, the pressurizer-water-level instrument indicated that the pressurizer—a tank connected to the reactor's primary cooling system—had no water in it. With that instrument showing "zero," the operators had no indication—not even this indirect one—of how much water was in the reactor. Although the incident ended quickly, and with the reactor satisfactorily stabilized, the behavior of the pressurizer-water-level instrument presented several serious problems. Creswell began to worry how operators of pressurized-water reactors could possibly cope with plant emergencies if they didn't know how much cooling water was in the reactor.

Creswell talked with Davis-Besse officials about the pressurizer-instrument problem during his inspection of the plant in December of 1977 and several times afterward, during ten inspections he made in 1978. As he looked over the records for information about how the pressurizer instrument on Babcock & Wilcox reactors behaved, he gathered more details about the September 24, 1977, incident —the one that so strongly prefigured the accident at Three Mile Island. He learned that the operators at Davis-Besse, on the basis of the pressurizer-water-level-instrument readings, had prematurely shut off the emergency-cooling-system pumps—even though the reactor's cooling water was still being lost through the stuck-open relief valve. (This key fact had been omitted in the "licensee event report" on the accident that the company submitted to the N.R.C. on October 7, 1977.) Creswell formally asked Davis-Besse officials to review the operating procedure according to which the control-room personnel had deliberately disabled the emergency cooling system, telling them that the action was contrary to the way in which the system was intended to work. Company officials were not responsive, Creswell says; they replied that a review of the matter was "in process" and, moreover, that it was really outside the scope of Creswell's responsibilities as an inspector, being a subject more properly addressed by safety analysts at N.R.C. headquarters.

N.R.C. headquarters, it turned out, had inquired into the September 24th accident. Denwood Ross, a senior official in the Division of Systems Safety, dispatched Gerald Mazetis, a reactor-systems engineer, to Davis-Besse to attend a special meeting on September 30th, at which the accident was to be reviewed. In his report on the meeting, Mazetis noted that the operators had disabled the emergency cooling equipment and that there were "many questions . . . to be addressed." The accident was then reviewed on October 3rd, at a meeting in the office of Dr. Roger Mattson, director of the Division of Systems Safety, which was also attended by Karl Seyfrit, an assistant director of the Office of Inspection and Enforcement. This office assumed responsibility for investigating the event further—a responsibility confirmed in a follow-up memorandum from Ross. Item 2 in the memorandum, which was dated October 20, 1977, states: "The operator's role in participating in the event should be related. . . . The operator's decision to secure [emergency cooling pump] flow based on pressurizer level indication should be explained." There is, however, no evidence that a satisfactory follow-up investigation was ever carried out. Creswell himself, during his continuing review of the September 24th incident, called N.R.C. headquarters asking for documentation on how the matter was resolved. He was told, he says, that there was none.

Instead of encouraging Creswell to investigate the safety issues raised by the accident at Davis-Besse, his superiors at the N.R.C. were, he says, "quite negative" about his continuing work on these matters. It has been tacit N.R.C. policy, Creswell explains, not to aggressively pursue safety questions that could have a major adverse economic impact on the nuclear-power industry. There is, of course, an obvious trade-off between the safety and the economics of nuclear power—one that the N.R.C. has had to finesse constantly. N.R.C. officials, in view of the long-standing federal policies favoring nuclear-power expansion, and their own personal and professional commitment to the program, have often been sympathetic to the industry when they have decided where to draw the line. This has been especially likely to happen when a safety concern has arisen that might necessitate the shutdown of an operating nuclear plant—something that the N.R.C. is extremely reluctant to order. The agency's tolerant attitude toward newly discovered safety problems has also been influenced by a general complacency, after years of seeing such problems come and go, about the risk that one of them might grow into a serious accident. The N.R.C. has had what Creswell calls the "mind-set" that such accidents just "couldn't happen." Creswell, who in 1978 had been with the agency for only two years, had yet to absorb the official outlook, and could not so easily dismiss the safety problems he saw at Davis-Besse.

For fourteen months, despite the opposition of his superiors, Creswell did everything he could think of within the N.R.C. to call attention to the problems of Babcock & Wilcox reactors. He pestered Davis-Besse officials for more information about the accidents there until they complained to his superiors; he asked for an investigation, under the commission's regulations covering the disclosure of safety defects by the industry, to determine whether Babcock & Wilcox might have withheld information about the safety of its plants; he wrote memos that urged further investigations of various technical issues; and, generally, he pulled every bureaucratic lever he had available to him. He got nowhere. Finally, he decided to press his concerns far outside the normal channels. In a memorandum dated January 8, 1979, he set out his views on the over-all problems at Babcock & Wilcox plants, and formally asked to have this memorandum submitted to the N.R.C. licensing boards considering authorizations for additional Babcock & Wilcox plants. This maneuver would, in effect, make public the concerns he had expressed within the N.R.C., because all correspondence received by the licensing boards becomes public. Creswell hoped that his memo might attract the attention of technically competent critics outside the N.R.C., who would put more pressure on the commission to resolve the problems. Even though official procedures specified that his superiors must transmit his memo to the licensing boards, they were hesitant to do so, since this would mean that the official N.R.C. safety evaluation of Babcock & Wilcox plants would be called into question in public licensing hearings. Creswell's memos were distributed to senior officials throughout the N.R.C., but it was not until March 29, 1979—the day after the Three Mile Island accident began—that they were sent to the licensing boards.

The manner in which the N.R.C. disposed of Creswell's concerns can be deduced from the "Weekly Information Report—Week Ending December 29, 1978," which was sent directly to the five commissioners by the N.R.C. staff, and which refers to one of the major problems Creswell raised. At issue was the performance of the emergency feedwater system in the Davis-Besse plant—the same piece of safety equipment that failed at Three Mile Island three months later and that had partly failed at Davis-Besse on September 24, 1977. The main feedwater system pumps water into the steam generators, where it absorbs heat from the water coming out of the reactor—the primary cooling water—and is thus converted to steam. By carrying off the heat that the nuclear fuel adds to the primary cooling water, the main feedwater system keeps not only the temperature of the nuclear fuel but also the pressure of the primary cooling system under control. So essential are these tasks that all pressurized-water reactors must be equipped with backup feedwater systems—the emergency, or auxiliary, feedwater systems—to compensate for any failure of the main feedwater pumps. If the main feedwater pumps fail, the reactor has to be shut down quickly; that is, control rods have to be inserted into the reactor's core to stop the nuclear chain reactions that generate heat to turn water into steam. The reactor, however, would still be heating up, because of the decay heat from accumulated radioactive waste materials. The emergency feedwater systems must continue to supply water to the steam generators to remove the decay heat and keep the temperature of the nuclear fuel under control. If the main feedwater system fails and the emergency feedwater systems also fail, no satisfactory method for cooling the reactor is available. The uranium fuel could then overheat dangerously, as happened during the accident at Three Mile Island Unit 2. (On some pressurized-water reactors of German design, extra "residual-heat-removal systems" have been installed to cool the reactor in the event of total failure of the main feedwater and emergency feedwater systems. American reactor designers, with the acquiescence of the N.R.C., have chosen not to install this expensive additional equipment; if they had, the accident at Unit 2 would have easily been controlled.)

There was another aspect to the feedwater-control problem noted by Creswell—something that has long been known to reactor-safety experts: too much emergency feedwater flow can be as destabilizing as too little. If more emergency feedwater than is required to remove the heat produced by radioactive decay is pumped into the steam generators, the high pressure in the primary cooling system can be suddenly reduced. Some of the primary cooling water could then start to boil and flash into steam, posing two problems for the reactor's hot uranium core. First, if the core is filled with steam or a mixture of steam bubbles and water instead of just water, the uranium fuel is not as adequately cooled, because water removes heat from the surface of the fuel rods better than steam does. Second, if a large steam bubble develops inside the reactor, it could block part of the piping system and interfere with the circulation of water through the reactor; this would make it difficult to keep the core temperature under control. What is needed, in short, is just the right balance of emergency feedwater flow to keep the pressure and the temperature of the primary reactor system under control. The Rancho Seco electrical failure led to incorrect emergency feedwater flows, and to a dangerous pressure decrease in the reactor system. Similar accidents had occurred at Davis-Besse. Creswell wondered whether there were generic defects in Babcock & Wilcox reactors that allowed these accidents to happen. Babcock & Wilcox denied that any such problems existed.

On December 22, 1978, in response to Creswell's persistent criticism, the owners of the Davis-Besse plant had submitted to the N.R.C. an "Additional Safety Evaluation" prepared by Babcock & Wilcox. This report argued that the plant's emergency feedwater systems were fully capable of dealing with any contingency, including the possibility that "overcooling transients" from "excessive" feedwater might jeopardize plant safety. The report asserted that Creswell had raised "no unreviewed safety question" and no other matter that had not already been satisfactorily taken into account in the design of Davis-Besse and all the other Babcock & Wilcox plants. Point-by-point responses by the company to Creswell's concerns included the declaration that steam bubbles—or "voids," as the company called them—"will not collect in reactor coolant piping and no flow blockage will occur." Further analyzing the contingencies, the company said that "during the course of" such incidents "no core problems develop." The company engineers added, "We conclude that no safety problem exists. . . . No adverse consequences . . . have been shown and, therefore . . . no concerns to the safe operation of the plant."

A day after receiving the Babcock & Wilcox report, the N.R.C.'s Division of Operating Reactors concluded that no action was required. The swift determination in favor of the owners of the Davis-Besse plant was, for this particular N.R.C. division, a routine move—one that it could make without detailed deliberations, and one that squared with the outlook of Victor Stello, its director at the time. Stello, a large man with a broad, swarthy face and a booming voice, is one of the most influential members of the N.R.C.'s top management. He is also a controversial figure, and some of his colleagues have privately criticized his optimistic views on the adequacy of nuclear-plant safety precautions. Like a number of other key N.R.C. officials, Stello was a member of the upper echelon responsible for many of the basic safety policies under which Babcock & Wilcox reactors and dozens of others received their official safety certifications. For these officials, to acknowledge a serious safety problem with one of these units is to raise questions about the correctness of their own past decisions. To admit even broader safety problems, such as generic defects in an entire set of previously licensed plants, is to concede major blunders. Such concessions—what bureaucrats delicately term "backpedalling"—are all the more difficult in the light of the growing nuclear controversy and what one N.R.C. technical-review group in 1978 termed the consequent "siege mentality" of some senior members of the N.R.C. staff.

"After the regional inspector questioned the licensee's determination that no unreviewed safety question was involved," the "Weekly Information Report—Week Ending December 29, 1978" said, the Division of Operating Reactors "requested a copy of the licensee's evaluation and, subsequently, additional information." The report continued, "The additional information was submitted on December 22, 1978. After review on December 23, 1978, D.O.R. concluded that because no fuel damage would occur . . . no unreviewed safety question was involved and no licensing action was required." This summary dismissal of Creswell's concerns left Davis-Besse, Oconee Units 1, 2, and 3, Rancho Seco, Crystal River Unit 3, Arkansas Nuclear One—Unit 1, and Three Mile Island Units 1 and 2 licensed for full-power operation with the approval of Stello's division and the concurrence of the entire senior management of the commission.

Still, Creswell, who was now confronting the heads of staff and no longer merely his immediate supervisors, continued to challenge the N.R.C.'s conclusions about the safety of Babcock & Wilcox plants. It was at this point that Creswell had decided to write the memorandum that would go to the N.R.C. licensing boards and thus, he hoped, put some public pressure on the agency. His January 8, 1979, memo pointed out "certain issues [that] have come to my attention" during "the course of my inspections at Davis-Besse." Creswell mentioned problems, including the feedwater-control problem and a related one—having to do with the pressurizer-water-level instrument. Creswell's memo went from office to office inside the N.R.C. By March 6, 1979, the memo had been delivered not only to Stello but also to Harold Denton, the director of the Office of Nuclear Reactor Regulation; Edson Case, Denton's deputy; Darrell Eisenhut, deputy director of the Division of Operating Reactors; Brian Grimes, assistant director for engineering and projects in the Division of Operating Reactors; Steven Varga, chief of Licensing Branch No. 4; Dudley Thompson, executive officer for operations support in the Office of Inspection and Enforcement; and other senior N.R.C. officials.

"I don't think I had read Creswell's memo at that time," Denton, the most senior N.R.C. official who received it, said in an interview not long after the Three Mile Island accident. Denton conceded that he and other senior N.R.C. officials had "sort of made a misallocation of resources" by not studying the memo. "Creswell was right on in many of his ideas, but for some reason, the system didn't elevate Creswell's concern to a priority where it was recognized above many other ones that were thought to be high priority," he said. Denton strongly resisted any suggestion that the agency was negligent in its handling of Creswell's memos, saying that "whatever the accident" that might strike a nuclear plant, there would always be a "paper trail" in the agency's files showing that somebody had previously worried about that kind of thing. Denton offered no specific reasons that Creswell's memos and such seemingly serious events as the Davis-Besse and Rancho Seco accidents failed to attract his attention or that of others in the senior management of the N.R.C. Nor did he suggest why the officials who received Creswell's memos took no action to see that the safety problems pinpointed in them were corrected. It was only a few weeks after they received Creswell's January memo that all these key officials hurriedly assembled in the N.R.C.'s emergency-response center, in Bethesda, Maryland, or went off in helicopters to Harrisburg, Pennsylvania, to see Creswell's diagnosis of the Babcock & Wilcox safety problems proved right. "Well, in retrospect, Creswell was pretty much on target," Denton said. "It just wasn't recognized."

Creswell was discouraged but not defeated by the response his reports received from the N.R.C.'s top officials. Confident of his technical ground—and relying on a background in nuclear engineering gained during five years in the operations division of the Tennessee Valley Authority, in Chattanooga, Tennessee—Creswell decided to go directly to the N.R.C. commissioners. In a maneuver that a conventional bureaucrat would regard as paralleling an attempt by a corporal to make an appointment with the Secretary of Defense, Creswell set up a meeting for himself with Commissioners John Ahearne, a physicist and former Defense Department official, and Peter Bradford, a lawyer and former chairman of the Maine Public Utilities Commission. He thought that, of the five commissioners, these two, who were the most recently appointed and had no association with the A.E.C., would give him the fairest hearing. He had to take a day off from work to go to Bethesda for the meeting, and he had to make the round-trip flight from O'Hare International Airport, in Chicago, at his own expense. The meeting went well, he thought: the two commissioners agreed to take a close look at the issues he had raised. The following week, Ahearne rewarded Creswell's fourteen months of persistence: he prepared a memo to the N.R.C. staff asking for a report on some of the safety questions affecting Davis-Besse that Creswell wanted answered. Ahearne's memo—the only positive response by any influential member of the N.R.C. to the concerns expressed by Creswell—was too late: the accident at Three Mile Island Unit 2 had occurred the day before.

Six months later, Creswell was given a special N.R.C. award of four thousand dollars, in recognition of his diligence in trying to alert the agency to important safety problems. Stello and Denton, whose two divisions ignored Creswell's warnings, also received awards—of ten thousand and twenty thousand dollars, respectively—for their part in the N.R.C.'s efforts to respond to the accident. The appropriateness of these latter awards has been publicly questioned by Mitchell Rogovin, of the Special Inquiry Group. Rogovin has said that it would have been more fitting for "the senior officials of the N.R.C. to owe the government money," given their performance. They have not done so and remain the most important heads of staff inside the N.R.C. Creswell, on the other hand, recently submitted his resignation, explaining in an interview that he thought there were "greater opportunities" for him outside the agency.

ALTHOUGH Creswell did not know it at the time, he was not alone in his efforts to alert the N.R.C. to the problems that might undermine the safety of Babcock & Wilcox reactors. In late 1977, at practically the same time that Creswell had begun raising the issue, Carlyle Michelson, a senior nuclear engineer at the Tennessee Valley Authority who worked on safety analysis, was completing a detailed technical analysis that emphasized some of the same basic concerns. Michelson had been working on a review of the T.V.A.'s Bellefonte Nuclear Plant, which is now under construction in Scottsboro, Alabama, and which incorporates a Babcock & Wilcox reactor. Along with Jesse Ebersole, a retired T.V.A. engineer, who began serving as a member of the N.R.C.'s Advisory Committee on Reactor Safeguards in 1976, Michelson had been questioning a number of nuclear-safety assumptions—an activity not entirely welcomed by the T.V.A., which is heavily committed to nuclear power—and had been particularly concerned about small loss-of-coolant accidents: leaks in the reactor's primary cooling system caused by ruptures of small pipes or by a relief valve stuck open. Michelson and Ebersole felt that such accidents had been overlooked, or only superficially studied, because of all the emphasis on hypothetical loss-of-coolant accidents caused by ruptures of large pipes. The prevailing assumption behind the official N.R.C. safety analyses was that this emphasis was "conservative," since if a plant could cope with a big loss-of-coolant accident it would presumably have no difficulty in coping with a small one.

In January of 1978, Michelson finished a thirty-four-page technical report on how small loss-of-coolant accidents might affect Babcock & Wilcox reactors—a document that demonstrates just how refined and specific the warnings had been about the type of accident that struck Three Mile Island on March 28, 1979. (The technical analysis of his report is directly related, however, not to a reactor of the size installed at Unit 2—which is described as a one-hundred-and-seventy-seven-fuel-assembly reactor—but to the larger Babcock & Wilcox model, with two hundred and five fuel assemblies, that was being installed at the Bellefonte plant.) The report specifically addressed the "heat-removal problem" that could arise during small loss-of-coolant accidents in two-hundred-and-five-assembly Babcock & Wilcox reactors, and its conclusions were quite straightforward: it might be extremely difficult to keep this reactor adequately cooled during such emergencies. There were "one or more impediments to decay heat removal" in Babcock & Wilcox plants which would prevent the emergency cooling equipment from performing as intended. Among these "impediments" was the formation of a steam bubble that could lodge inside various parts of the reactor's cooling system and prevent the circulation of cooling water. It was, of course, a steam bubble that Babcock & Wilcox had insisted, in its response to Creswell's criticism, could not form but that did form during the Three Mile Island accident. Another serious problem was that the pressurizer-water-level instrument was "not a correct indicator of water level over the reactor core" and that there might not be adequate "emergency operating procedures and operator training" at Babcock & Wilcox plants to allow the operators to handle serious reactor-cooling problems. The operators, Michelson predicted, might mistakenly turn off emergency cooling equipment, because of misleading pressurizer-instrument readings—exactly what happened on March 28, 1979. Michelson recommended that studies be carried out to get more information on the "stability" of Babcock & Wilcox cooling equipment and on the "adequacy of instrumentation and components" used in these systems. In a letter dated April 7, 1979—ten days after the Three Mile Island accident—the Advisory Committee on Reactor Safeguards asked the N.R.C. to carry out some of Michelson's recommendations. Some of the "impediments" to heat removal in Babcock & Wilcox reactors which had been described in Michelson's report had by then been demonstrated.

IN September of 1977, Jesse Ebersole gave a handwritten draft copy of Michelson's report to Sanford Israel, a mechanical engineer in the Reactor Systems Branch of the N.R.C. Ebersole says that he wanted to find someone in the N.R.C. who would be "receptive" to the report and "competent to analyze it." In November of that year, Ebersole again raised some of the issues identified by Michelson at an Advisory Committee on Reactor Safeguards meeting, and his questions were forwarded to Israel's branch at the N.R.C. A few months later, Israel wrote a two-page memo that was sent to other members of the Reactor Systems Branch. The memo, dated January 10, 1978, was distributed over the signature of Thomas Novak, chief of the Reactor Systems Branch—a standard N.R.C. procedure under which the branch chief adds an endorsement to the work of a staff engineer. Israel's memo noted that there were some peculiarities in the pressurizer design at Babcock & Wilcox plants—specifically, in the way this tank was connected to the piping coming out of the reactor. Israel stated that "under ordinary circumstances" these design features were "inconsequential" but that "under upset conditions," such as a "prolonged relief valve opening," the loss of cooling water from the reactor "may not be indicated by pressurizer level," and noted, "This situation has already occurred at Davis-Besse 1 when a relief valve stuck open." A "full" reading on this instrument, he noted, interpreted by the control-room operators in the standard way, could lead them to "terminate" emergency-cooling-system pumps when it was imperative to keep them running. The memo suggested that it was a matter of some urgency to review the pressurizer-design requirements and operating procedures for new Babcock & Wilcox plants to correct this problem. However, the memo made no mention of corrective action on the nine Babcock & Wilcox plants already in operation. This was not a casual oversight on Israel's part. The nuclear industry vehemently opposes new safety requirements—especially retroactive ones entailing basic changes in plants that have already been licensed and put into commercial service. Since it is much easier to make changes when a proposed plant is still on the drawing boards, the N.R.C. tries to limit mandated safety improvements to new plants, thereby sparing the industry what might otherwise become a never-ending program of costly post-construction modifications. By sidestepping the question of the operating Babcock & Wilcox reactors, Israel was simply following standard agency practice. He explained in an interview that he had written the memo simply to remind N.R.C. engineers to look at the pressurizer-instrument problem the next time a new Babcock & Wilcox plant came up for safety review. Israel says that he got "no feedback" from the N.R.C. officials who received it. Certainly none of them took any action—not even the simple precaution of informing the operators of the nine Babcock & Wilcox reactors that a deficiency had been found in one of the key control-room instruments used during emergencies.

The most senior N.R.C. official to receive a copy of Israel's memo was Denwood Ross, who was then assistant director of the Division of Systems Safety. Among other duties, Ross supervised an engineering staff responsible for studying how well the emergency cooling systems in each nuclear plant would function during major emergencies. He has a doctorate in nuclear engineering from Catholic University, in Washington, and, like most other top members of the N.R.C. staff, worked for the A.E.C., which he joined in 1967. Ross took no action in response to Israel's memo—a circumstance that is particularly puzzling in the light of Ross's earlier apparent concern over the Davis-Besse accident of September 24, 1977. It was Ross, after all, who had promptly sent Gerald Mazetis to Davis-Besse to investigate that accident and had written the memo of October 20, 1977, asking the N.R.C. Office of Inspection and Enforcement to find out why the operators at Davis-Besse had shut off the emergency cooling pumps. Israel's memo, on its face, provided Ross with a precise technical answer to his question: the pumps were shut off because of the misleading pressurizer-water-level-instrument readings. Nevertheless, Ross did nothing when he received Israel's memo—an "oversight" that he cannot readily explain, he said in an interview. "In retrospect, I'm not sure why the memo wasn't sent to the Division of Operating Reactors," he said, indicating what he thought was "the right thing to have done with it," since Israel's finding affected the safety of the Babcock & Wilcox reactors then in operation. Ross suggested that his failure to forward the memo through the appropriate channels was—in some measure, at least—a bureaucratic slip-up. "The Davis-Besse analysis was under the jurisdiction of the Office of Inspection and Enforcement, and I guessed that if anything needed to be done they would do it," he said. Ross candidly admitted, however, that his own over-all attitude toward nuclear-plant safety—he had been one of the staunch defenders of the adequacy of the safety rules developed by the A.E.C. and used by the N.R.C.—was also involved in his failure to pursue Israel's memo further and to get to the bottom of the Davis-Besse accident. "We screwed up—and I mean by 'we' the nuclear community, the vender"—Babcock & Wilcox—"and the N.R.C.," he observed. "Davis-Besse was ample warning, and if we had paid ample attention to it Three Mile Island could have been prevented. If you want to use the term 'complacency' to describe our behavior, I won't quibble with you, but the term I'd rather use is 'mind-set,' or 'attitude.' I'd had the attitude that reactors were fairly forgiving, in the sense that they could withstand a lot of problems without having those problems turn into serious accidents. I don't feel that way anymore."

BABCOCK & WILCOX was immediately notified of the incident at Davis-Besse on September 24, 1977—the event that so strikingly foreshadowed the accident at Three Mile Island. Obviously, the company's large scientific and engineering staff was intimately familiar with the features of its nuclear-reactor systems, and therefore was much better equipped than outsiders—such as Creswell, Michelson, and Israel—to assess the implications of the Davis-Besse accident. Babcock & Wilcox records subpoenaed during the official investigations of the Three Mile Island accident show that the company's safety experts quickly appreciated the significance of the Davis-Besse episode and readily understood that remedial action was necessary to prevent an accident like the one at Three Mile Island. Babcock & Wilcox, however, according to their records, never told the operators of the nine licensed Babcock & Wilcox reactors about its findings.

On September 25, 1977—the day after the accident—Joseph Kelly, an engineer in the plant-integration unit, which coördinates the design of the various components used in Babcock & Wilcox reactor systems, was sent to Davis-Besse from the company's headquarters, in Lynchburg, Virginia. No office or individual within the company had formal responsibility for analyzing the accidents that occurred at plants with Babcock & Wilcox reactors, according to the investigation by the President's Commission on the Accident at Three Mile Island, and the company itself did not usually even receive the full reports on such accidents which its customers filed with the N.R.C. Babcock & Wilcox is preoccupied largely with the business of designing and selling new nuclear reactors, and it devotes little time or money to looking over its shoulder, so to speak, at the equipment it has already sold. Still, the problem at Davis-Besse was such a complicated and unusual one that the company's customer-service department, which gives operating instructions to the owners of Babcock & Wilcox reactors, asked to have someone sent to investigate it. Kelly returned to the Lynchburg headquarters after about two days at the Davis-Besse site, and briefed a group of some thirty Babcock & Wilcox employees on the basic details of the accident. In his audience were the heads of several major company departments and the vice-president of the Babcock & Wilcox Nuclear Power Generation Division, John MacMillan. Kelly's report mentioned the problems with the stuck-open relief valve, the misleading indication on the pressurizer-water-level instrument, and the fact that the operators had shut off, or throttled, the emergency-cooling-system pumps. It did not occur to Kelly until after the meeting, though, that this operator interruption of the emergency cooling pumps had serious safety implications—a fact that was pointed out to him by Bert Dunn, the manager of emergency-cooling-system analysis. Dunn explained to Kelly that there were "scenarios"—such as having a reactor at full power rather than at the nine-per-cent power level of the Davis-Besse plant—in which mistaken interference with the emergency cooling equipment could lead to serious difficulties. This was the first of several discussions between Dunn and Kelly on these potential difficulties.

Senior Babcock & Wilcox officials took no formal action after Kelly's briefing, although for the next several months the matter was the subject of memorandums, meetings, and conversations involving officials from at least seven different departments of the company. Kelly himself went to the training-services section in October to discuss the instructions that were being given to plant operators about the proper operation of the emergency cooling pumps. John Lind, the chief instructor, assured Kelly that the correct instructions were being given, but he could not explain why the operators at Davis-Besse had shut the pumps off on September 24th. Kelly also continued his discussions with Dunn and prepared a formal memorandum, dated November 1, 1977, in which he set out some of his concerns. This memo was sent to seven Babcock & Wilcox officials. Kelly briefly summarized the Davis-Besse accident of September 24th, and noted that a similar event occurred at the same plant on October 23rd, in which the operators deliberately prevented the emergency cooling pumps from operating. "Since there are accidents which require the continuous operation" of these pumps, Kelly wrote, "I wonder what guidance, if any, we should be giving to our customers on when they can safely shut the system down following an accident? . . . I would appreciate your thoughts on this subject." He himself proposed that a two-sentence guideline be issued to reactor operators admonishing them, for example, not to prevent the activation of the emergency cooling pumps "under *any* conditions except a normal, controlled plant shutdown." No action was taken on Kelly's memorandum, and none of the seven officials to whom it was sent responded.

Three months later, after discussing the matter further, Kelly and Dunn decided to try to compel some action. Dunn, the senior of the two, wrote a memo, dated February 9, 1978, to James Taylor, the manager of the company's licensing section, who was supposed to inform the N.R.C. whenever any problem was discovered that could create a substantial safety problem at an operating nuclear power plant. (Full compliance by the nuclear industry with this disclosure requirement is an essential element in the N.R.C.'s scheme of industry self-regulation.) Dunn sent copies of his memo to ten other company officials, two of whom had received Kelly's memo on the subject. Dunn, a physicist who had worked on emergency-cooling-system analysis for the company for almost a decade, noted at the outset of his memo that he had "a serious concern" about operator interference with the proper functioning of the emergency cooling system. During the September 24th accident at Davis-Besse, Dunn wrote, the operators "terminated" the emergency cooling pumps because of "an apparent system recovery indicated by high [water] level within the pressurizer," even though, according to Dunn's subsequent analysis, the reactor was still losing its cooling water. "I believe it fortunate that [Davis-Besse] was at an extremely low power" when the event occurred, he continued. "Had this event occurred in a reactor at full power . . . it is quite possible, perhaps probable, that core uncovery and possible fuel damage would have resulted. The incident points out that we have not supplied sufficient information to reactor operators." He concluded his memo with the emphatic observation "I believe this is a very serious matter and deserves our prompt attention and correction." He did not get a written response from Taylor, or, indeed, any reply at all that he can recall. Taylor told Dunn later—after the Three Mile Island accident—that his memo must have been "misdirected," because it had not been submitted on the appropriate form to qualify as a "safety concern."

A copy of Dunn's wayward memo had been sent to the customer-service department, which held a discussion in mid-February of 1978 in which Dunn agreed to a proposed set of new guidelines to be sent to plant operators, telling them how to operate the emergency cooling pumps. Dunn believed that the guidelines took care of his concerns, and so informed Taylor in another memo, dated February 16, 1978. Dunn then considered the matter closed. Unfortunately, the customer-service department had some second thoughts about the proposed guidelines, and they were never sent to the operators of Babcock & Wilcox plants—a fact that Dunn has said he did not learn until after the Three Mile Island accident.

The fitful response by Babcock & Wilcox officials to Dunn's memorandums continued throughout 1978 and into early 1979—long after Dunn had turned his attention to other matters. During the spring and early summer of 1978, for example, the customer-service department sought the assistance of analysts in the plant-integration unit, asking, in particular, for a revision in the operating procedures that were leading plant operators to shut off the emergency cooling pumps. By August of 1978, there was still no response from the plant-integration group, and Donald Hallman, of the customer-service department, sent yet another memo trying to direct some attention to the problem. A memo on August 3, 1978, noted that "to date" the customer-service department "has not notified our operating plants" to change their emergency-cooling-system procedures, as Dunn's memos had suggested. Bruce Karrasch, the manager of plant integration, skimmed the memo and, considering it a routine matter, forwarded it to one of his deputies, who does not remember receiving it. Hallman says that he attempted to discuss the matter with Karrasch several times in the period between August 3, 1978, and March 15, 1979, but had no success. Hallman has said that he did not himself assign a high priority to the issue, and Karrasch has told federal investigators, "All I can remember is that in the fall of 1978 things were very, very busy . . . and my attention and the whole group's attention [was given] to what were perceived to be higher-priority matters." The entire problem, company officials have told investigators, simply fell between the cracks.

Babcock & Wilcox internal documents, which show that company officials knew about the unresolved problem of operator interference with emergency cooling equipment, raise the question whether the company complied with the N.R.C. requirement covering the disclosure of safety-related data. The company, after all, told neither plant operators nor the N.R.C. of the problem, though N.R.C. regulations state that all companies doing business in the nuclear-power industry are required "to immediately notify" the N.R.C. whenever they obtain "information reasonably indicating" that any licensed nuclear plant "fails to comply" with N.R.C. safety regulations or "contains a defect" that could create "substantial safety hazards." (The disclosure requirement is set forth in Part 21 of Title 10 of the Code of Federal Regulations, in a section entitled "Reporting of Defects and Noncompliance.")

In light of the Babcock & Wilcox internal memos, the N.R.C.'s Office of Inspection and Enforcement conducted an investigation and determined that the company had violated the disclosure provision. A fine of a hundred thousand dollars was imposed on Babcock & Wilcox. The company denied the charges but said it would pay the fine in order to avoid the time and expense of fighting the N.R.C. The company did announce, however, that it was instituting new procedures for the "processing of safety concerns," so that in the future it would comply with the N.R.C. disclosure requirement. According to the new procedures, safety concerns were henceforth to be reported by employees on company form BWNP-20208. The concerns would then be logged and numbered and would be distributed within the company, as specified in a twelve-step "flow chart," in accordance with Management Directive 205 T4.4, dated April 10, 1980. At the end of all this, the N.R.C. would be notified, if the company found it appropriate to do so.

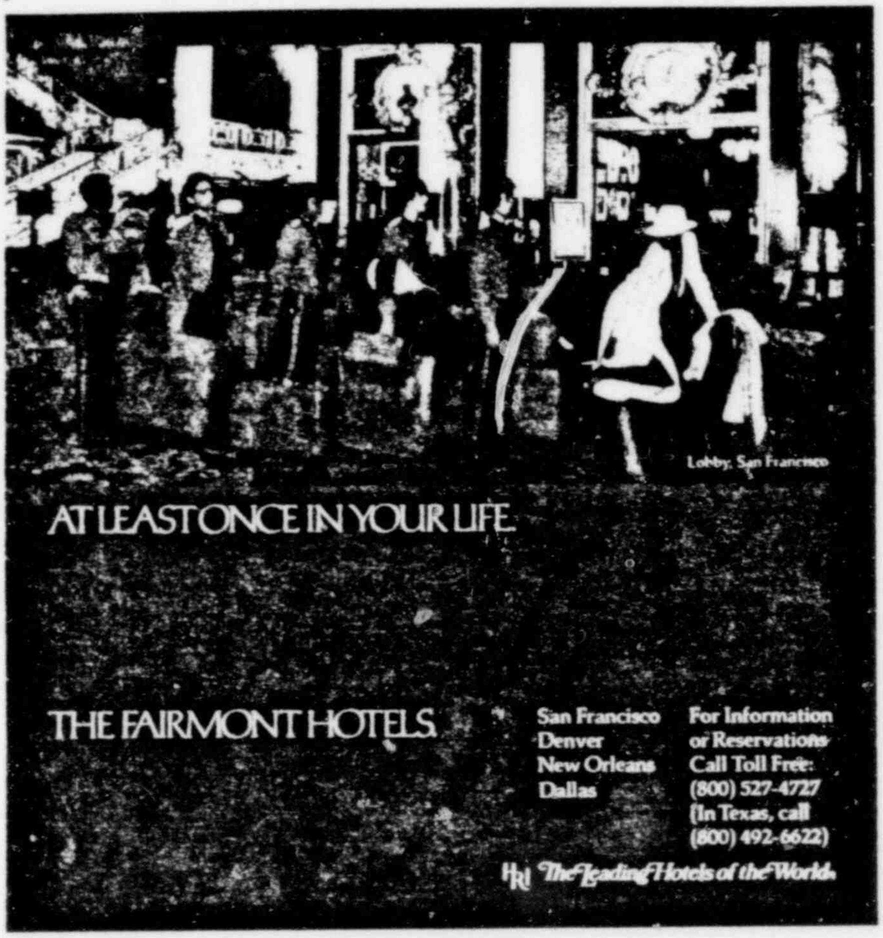
In addition to informing plant operators that the pressurizer-water-level readings might be a misleading indicator of the amount of water inside the reactor, there were other, more positive steps that Babcock & Wilcox could have taken to help the plant operators handle accidents with the reactor-cooling system. One of the most obvious steps, of course, would have been to install instruments that measured how much water was inside the reactor. Measuring the amount of water in the reactor is preferable to having to infer it from the amount inside the pressurizer. The operators would then know, without ambiguity, whether the essential safety goal of keeping the hot uranium fuel adequately covered with water was being achieved. Reliable equipment to measure the water level in the reactor, however, had never been installed on any of the pressurized-water reactors in the United States—including those manufactured by Westinghouse and Combustion Engineering as well as those manufactured by Babcock & Wilcox. Cost-conscious utility companies had preferred not to invest in this "extra" instrumentation, and had been content to rely on the pressurizer-level indicator as a cheap surrogate instrument to give the operators the data they needed about conditions in the reactor. "This problem of what we call vessel-level indication for pressurized-water reactors has been kicked around probably at least for the last ten years," Carlyle Michelson has said. During normal operation, when the reactor is always full of water, he admitted, such a device has no real point, but during a loss-of-coolant accident "it would be awfully nice to know" the water level in the reactor—yet, he added, "it was never deemed to be quite nice enough to know to justify the cost."

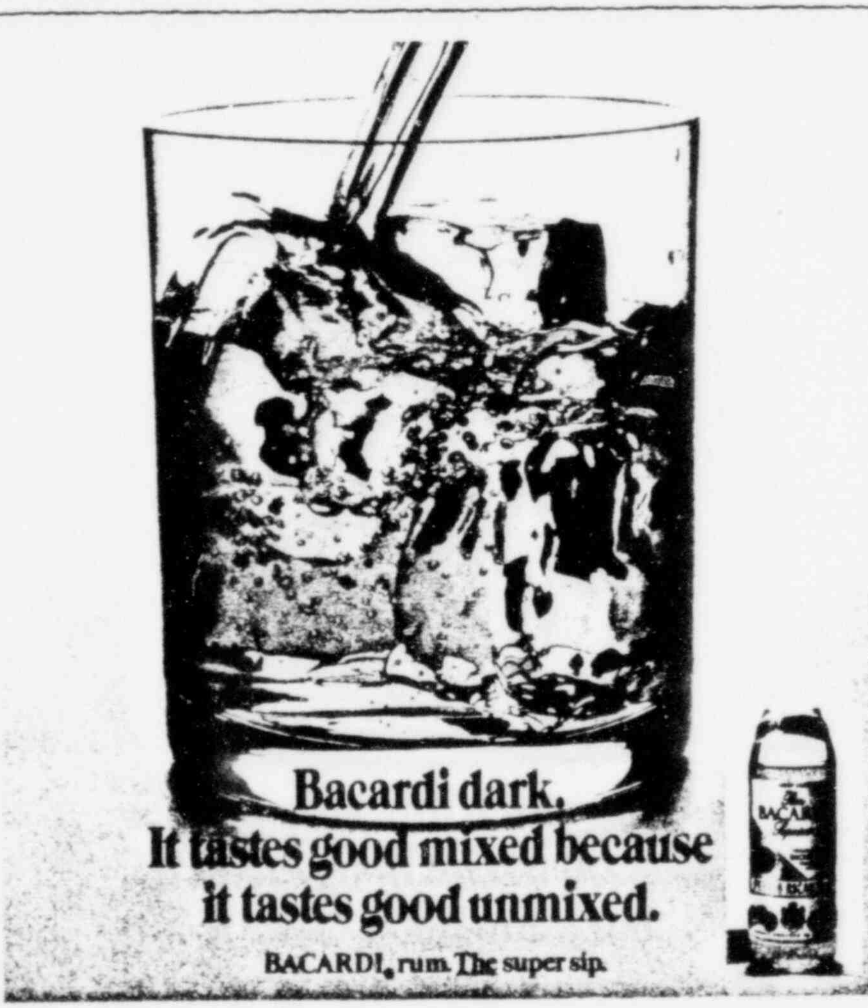
A LOOK at the operating records of the nine nuclear power stations with Babcock & Wilcox reactors underscores the urgency with which the warnings of Creswell, Michelson, Israel, Kelly, and Dunn should have been treated. Summary statistics now available from the N.R.C. show that a virtual epidemic of serious cooling-system difficulties had been occurring at these nine reactors since the first of them—at the Oconee plant, in South Carolina—went into operation, in 1973. Such data, however, were not systematically compiled and analyzed by the N.R.C. or by Babcock & Wilcox, and no official notice was taken of the disturbingly high frequency of these events. One particular statistic, which would have helped the N.R.C. evaluate the problem of small loss-of-coolant accidents arising from relief-valve openings, was the actual rate at which the relief valve was being forced to open at the nine plants. This valve is supposed to open only infrequently—when it becomes necessary to reduce excessively high pressure inside the reactor. The reason for this is obvious: the valve's function is to remove vital coolant from the reactor, and this is hardly something that a prudent designer would wish to have happen very often. Yet, according to belatedly assembled N.R.C. statistics, the relief valves on the nine Babcock & Wilcox reactors had opened on at least a hundred and fifty occasions before the Three Mile Island accident. (The official bookkeeping is not precise, since the utility companies operating the plants did not always notify the N.R.C. when relief-valve openings occurred.) Each of the plants experienced, on the average, five relief-valve openings per year of operation.

The high rate of relief-valve openings is attributable to design weaknesses inherent in Babcock & Wilcox reactors. Unlike the pressurized-water reactors designed by Westinghouse and Combustion Engineering, Babcock & Wilcox equipment has a pronounced susceptibility to sudden increases in the pressure of its primary cooling water whenever a plant has to be shut down quickly. This occurs for two principal reasons. First, the steam generators in Babcock & Wilcox reactor systems contain less water than those of the two other companies. This means less cooling capacity and a greater likelihood, during a sudden plant shutdown, of an increase in the temperature and the pressure of the primary cooling water—which, of course, is the condition that causes the relief valve to open. Second, there was a time delay inherent in the control system that shut off the Babcock & Wilcox reactors whenever common electric-generating-plant malfunctions—such as problems with the turbine—necessitated an unscheduled reactor shutdown. Because a Babcock & Wilcox reactor would continue to operate for several seconds after the turbine had failed, the excess energy in the reactor, which was no longer being used by the turbine, caused the pressure of the primary cooling water to increase. The excess pressure, in turn, caused the relief valve to open. (The reason for the time delay was economic: Babcock & Wilcox designers wanted to avoid a costly reactor shutdown every time a minor malfunction occurred in some other part of the plant.)

Not only had the relief valves at Babcock & Wilcox plants opened with uncommon and undesirable frequency but they had also—on at least nine occasions before the Three Mile Island accident—opened and stuck open. (The valves themselves—which weigh about a hundred and seventy-five pounds each and cost some thirty thousand dollars—are made by specialty valve manufacturers, such as Industrial Valve Operations of Dresser Industries, not by Babcock & Wilcox.) These events were all the more serious because in some cases plant operators remained unaware for appreciable periods that, as a consequence, the reactor was losing its coolant. As the operating records indicate, various conditions were responsible for the failure of the valves to reclose properly. In the Davis-Besse accident on September 24, 1977, a missing electrical relay was to blame; at Arkansas Unit 1 on an unspecified date in 1974, improper venting was the cause; at Oconee Unit 3 on June 13, 1975, a relief valve stuck open because valve components had warped as a result of heat expansion, chemical contaminants had built up on a valve lever, and a bracket in the valve's electrical control system had bent; and at Three Mile Island Unit 2 on March 29, 1978—one year before the major accident—an electrical-system malfunction (a blown fuse) caused the valve to open and remain open. Given the complexity of the valves and their control systems, it is hardly surprising that they are susceptible to many possible types of failure. It is therefore obvious that systematic testing, inspection, and maintenance are essential if this equipment is to function reliably. The failure rate indicates, however, that attention to such tasks has not been a priority of either the N.R.C. or the utility companies involved. The N.R.C. does not classify these relief valves as safety equipment, and so does not review their design carefully in its prelicensing safety procedures. Moreover, the N.R.C. has never required that the valves be tested periodically. After the Three Mile Island accident, the agency did a survey of other Babcock & Wilcox plants, and found that none of the relief valves at the plants had been tested since their initial installation. Such testing requires that a plant be shut down and the valves be removed and checked at a special facility—a procedure that means time and expense for the plant's owners. In sum, the relief valves at these plants—like other "non-safety-related" components—had fallen into one of the large regulatory gaps that exist in the N.R.C.'s program for supervising the nuclear industry.

THE cooling-system deficiencies that have plagued Babcock & Wilcox reactors are not limited to relief-valve malfunctions. If the information that accumulated in the N.R.C.'s own files had been reviewed systematically, it would have alerted regulato





authorities to another safety problem common to these nine reactors—the excessive frequency with which the main feedwater system was malfunctioning. In just the twelve months before the Three Mile Island accident, for example, the main feedwater system at one or another of the nine plants broke down on twenty-seven occasions. In fact, the failure of the main feedwater system—which left the reactors without their normal method of heat removal—was responsible for many, though not all, of the relief-valve openings in these plants. (The reason was that a main-feedwater-system failure, compounded by other design weaknesses, such as the time delay in the reactor-shutdown controls, produced a sudden pressure surge in the reactor.)

The causes of the failures in the main feedwater systems, like the causes of malfunctions in other complex nuclear-plant systems, were varied. Human error, of course, both in the initial installation of the main feedwater systems and in their subsequent operation, played a prominent role. At Three Mile Island on November 3, 1978, for example, an instrument technician working in the basement of Unit 2, near the polishers, accidentally shut off an electrical circuit on the polisher control panel, and so caused all the outlet valves on the polishers to slam shut and immediately stop the main feedwater flow—the same sort of event that brought about the accident on March 28, 1979. On this earlier occasion, the technician mistakenly thought he was turning on a light switch.

Despite Creswell's concern, the N.R.C. did not begin collecting information about the frequency with which the main feedwater system at Babcock & Wilcox plants malfunctioned. This problem was beyond the scope of the safety aspects that the N.R.C. customarily dealt with. Like the relief valves, the main feedwater system was classified as "non-safety-related" equipment, and since the commission had not officially concerned itself with the safety aspects of the main feedwater equipment in the first place, it allowed the individual utility companies, without benefit of federal safety standards or technical reviews or inspections, to design their main feedwater systems as they saw fit. The utilities, in turn, delegated this task to their own designers or architect-engineering consultants. As a result, there is no standard design for the main feedwater system in plants using Babcock & Wilcox reactors.

The N.R.C.'s official justification for exempting the main feedwater system from safety review was its requirement that plants have redundant emergency feedwater systems, the theory being that these would eliminate any safety problem that could otherwise be caused by a failure in the main feedwater system. However, emergency feedwater systems have not always been part of the safety equipment required for pressurized-water reactors. The importance of emergency systems was not fully appreciated until about 1972, when an anonymous letter to the A.E.C. led to the recognition of the role that this equipment would have to play in controlling certain types of accidents. Although the N.R.C. mandated the installation of such systems in all new nuclear power plants, it chose not to apply this decision to plants already operating or under construction. The three Oconee plants, for example, which used the first large Babcock & Wilcox reactors, had been operating until mid-1979 with only a single emergency feedwater pump each, rather than with the duplicate pumps now called for. Moreover, apart from requiring that some type of equipment be installed to provide emergency feedwater, the N.R.C. has left unanswered a variety of questions about how the equipment is to be designed, controlled, and powered to insure its reliability. These unanswered questions have been allowed to remain on the N.R.C.'s official list of generic "unresolved safety issues" for several years—a fact that has drawn repeated protests from a number of the commission's own safety reviewers.

If the N.R.C. had checked on the performance of the emergency feedwater systems at the Babcock & Wilcox reactors, it would have found them to be remarkably unreliable. According to the official records, the emergency feedwater systems at the nine plants had malfunctioned at least fifty-three times before the Three Mile Island accident. (Given the somewhat informal official record-keeping for such mishaps, the actual figure may be much higher.) These malfunctions included numerous occasions when the emergency feedwater pumps failed to start as well as occasions when, having started, they broke down. Other cases involved various deficiencies that could degrade the performance of the system under accident conditions.

There is no single reason that the

emergency feedwater systems in Babcock & Wilcox reactors have malfunctioned. They have failed as a result of operator errors, the improper installation of components, defective electrical switches, jammed valves, improperly closed valves, and other problems. Excerpts from the official records of the Babcock & Wilcox plants show some of these systems' multiple frailties.

On August 3, 1977, when the emergency feedwater system at the Davis-Besse plant being tested, an emergency feedwater pump failed to start. An investigation found that a valve that should have been open was closed, and that it had been stepped on. Plant managers warned workers not to step or lean on these valves in the future.

On July 17, 1977, at the Crystal River Power Plant Unit 3, near Crystal River, Florida, a steam-driven emergency feedwater pump failed to start. The cause was water in the steam-supply line, which prevented a throttle valve from closing fast enough to keep the pump from overspeeding. As a result of overspeeding, the pump automatically shut off.

On November 22, 1977, a steam-driven emergency feedwater pump at Crystal River Unit 3 was tested. The pump started satisfactorily, but after running for ten minutes it broke down. Insufficient bearing lubrication caused bearings inside the steam turbine to fail.

On June 24, 1976, it was discovered that a pipe in the emergency feedwater system at Arkansas Unit 1 was leaking. The leak, which was in the line used to deliver water from the feedwater pumps to one of the steam generators, occurred at a place where the pipe penetrated a concrete floor, and corrosion is believed to have resulted from contact between the pipe and the reinforcement steel in the floor.

In June of 1975, one of the two emergency feedwater pumps at the Rancho Seco plant, which had been started during a test, suddenly stopped. An attempt to re-start the pump was unsuccessful. The pump motor had stopped because of electrical failures resulting from a loose nut.

In April of 1975, the emergency feedwater pump at the Oconee Nuclear Station Unit 3 was tested and found to be inoperable. A leak had been reported in the pump eleven days earlier, and packing had been used to seal the pump and stop the leak; the packing was too tight, and rendered the pump inoperable. The pump had been returned to service after the repairs with no verification of its operability.

In April of 1975, the emergency feedwater pump at Oconee Unit 2 was automatically activated after the main feedwater pumps had been shut down, but the valve supplying emergency feedwater to one of the steam generators did not open. It was jammed.

On August 6, 1977, a steam-driven emergency feedwater pump at the Davis-Besse plant failed to start during testing. A disconnect switch for the main valve that supplied steam to power the pump had been bumped slightly. The switch was on a panel in a narrow corridor.

On February 19, 1977, an operator at the Rancho Seco plant discovered that one of the emergency feedwater pumps was disabled. It had been tested the day before, but after turning the pump off an operator failed to reset the switches properly so it could be turned on again.

In October of 1974, an error by an operator at the Rancho Seco plant destroyed one of the emergency feedwater pumps. While the pump was being used to transfer water from a storage tank to the steam generators, the operator failed to open a valve that would have supplied water to cool it. The pump started smoking, and lead packing inside it melted. Parts of the pump casing were frozen to the pump impeller, and the pump bushings were frozen to the drive shaft.

In 1975, a valve in the emergency feedwater system at Three Mile Island Unit 1 would not remain open, because an electrical switch, which was wet and corroded, had short-circuited.

Although the Nuclear Regulatory Commission had received numerous reports of malfunctioning emergency feedwater systems at Babcock & Wilcox plants, it failed to oversee corrective action. All nine plants using Babcock & Wilcox reactors, which in certain accident circumstances would have to depend on these faulty emergency feedwater systems, were allowed to continue operating.

The N.R.C.'s general failure to alert the operators of Three Mile Island Unit 2 to some of the known or suspected deficiencies in the equipment installed there—and to the findings of

Creswell, Israel, and Michelson, in particular—has been cited in an unprecedented damage claim that General Public Utilities, the owner of the plant, recently made against the agency. The company maintains that the N.R.C. "knew or should have known" from its investigation of incidents such as the one at Davis-Besse in September, 1977, that Unit 2 faced serious, uncorrected safety problems, but that the N.R.C. "negligently failed to warn" the company and allowed the plant to remain in operation. The damage claim seeks four billion dollars from the N.R.C. to cover the cleanup operations—which threaten the company with bankruptcy—as well as other losses and expenses it has incurred or expects to incur as a result of the accident. Some observers believe that the claim—filed on the standard government claim form that might be used, say, by someone who slipped on an icy post-office sidewalk—is merely a ploy in the company's lobbying effort to get federal funds for the cleanup work. Lawyers for the company insist, however, that the damage claim is not frivolous and that it will be pursued through the courts. The N.R.C. has not yet commented formally on the G.P.U. claim, but senior agency officials have privately expressed amazement that, in an industry that routinely protests government over-regulation, a company now argues that it was not actually regulated enough and should not have been allowed to operate its plant. "It seems like the new industry position is a plea to 'Stop us before we kill again,'" one N.R.C. commissioner remarked.

DESPITE the official optimism about safety, there have always been doubts about the hazards of nuclear power plants. Some of these doubts have involved purely technical issues: the reliability of this or that piece of apparatus or the adequacy of the design of some specific safety-system feature. The broader questions about institutional and human performance, however, have been more troublesome. Technical questions are generally amenable to some technical solution—one can seek appropriate answers in laboratory research programs, for example—but, at best, all that scientific prowess can provide is the blueprints for an ideal nuclear-power-plant design. It will then require—and here the preponderant difficulties arise—an unprecedentedly high level of human care and diligence

to translate these theoretical possibilities satisfactorily into actual commercial nuclear power stations. Thousands of people are involved in the construction of each large nuclear plant, and they have to carry out numberless small tasks. There is much room for error and compromise, and how closely the nuclear industry adheres to the expensive safety precautions required and how scrupulously these requirements are enforced by the regulatory authorities will determine the degree of safety that is ultimately achieved. A good scientific theory about safe nuclear-plant design and the best official intentions are not enough.

The institutional setting for the development of commercial nuclear power in the United States was established by the Atomic Energy Act of 1954. This law assigned the Atomic Energy Commission the role of overseer, and provided for what would become a coöperative nuclear-power venture on the part of the A.E.C. and a handful of large corporations with which the federal government had already worked on the development of reactors for nuclear-powered submarines. The parties involved in the emerging nuclear-power business, in both government and private industry, focussed on the goal of making nuclear energy, as soon as possible, a major supplier of the nation's electric power. As plans for this program evolved over the next decade, they eventually encompassed a construction effort that would be one of the greatest industrial undertakings in history. In its official "projections," the A.E.C. foresaw a thousand large nuclear power stations operating in the United States by the year 2000, at which point nuclear power would be the dominant producer of electricity. According to the proposed—and widely accepted—scenario, nuclear plants would be built throughout the country; California, for example, would have an average of one large nuclear plant every twelve miles along its coast, all the way from Mexico to Oregon. For the prospective manufacturers of nuclear-plant equipment, the program entailed future revenues in the tens and hundreds of billions of dollars. With a potential market of this size, the companies attracted to the nuclear industry were eager to proceed quickly—and did so, with the A.E.C.'s unflagging support. The A.E.C., with its policy of industry self-regulation, gave the companies broad discretion in virtually every aspect of the design, construction, and operation of plants. The companies, for their part, were not inhibited by any excessive circumspection about the safety problems they might be creating.

The major challenge to the developers of commercial nuclear power was not safety but cost. Coal-fired power plants provided cheap electricity in the nineteen-fifties and sixties, and the cost of electric power from this conventional source was actually falling during much of the period. The entire nuclear-power industry would come to nothing if nuclear plants proved unable to compete. Accordingly, to improve the economic attractiveness of nuclear power, designers drew up plans for extremely large plants—several times as large as any conventional electric plant then in operation—so that nuclear plants, benefitting from so-called economies of scale, could produce power cheaply. The large, high-powered reactors that would be required would necessarily be difficult to control—for one thing, they could overheat quite rapidly in the event of a cooling-system malfunction—but this risk was accepted by the companies and by the A.E.C. without extensive evaluation. Similar considerations shaped a broad range of other decisions that nuclear-plant designers had to make—for example, how much safety apparatus to include and whether to delay plant construction pending more extensive safety-research programs. Safety was considered by plant designers, of course, but it was never the only factor—or even the dominant one—constraining the development of commercial nuclear power.

The level of scientific ability applied to the development of commercial-power-reactor technology also ultimately affected nuclear-plant safety. During the last twenty-five years, thirty to fifty per cent of the country's scientists and engineers have been employed, directly or indirectly, in defense and aerospace programs. These established programs, vastly larger employers than the nascent nuclear-power industry, absorbed a major portion of the best technical talent. The work in these areas and also in basic scientific research was often more exciting technically than the relatively mundane engineering needed for nuclear-plant design and construction. There was a time, of course, early in the nuclear program, when scientists of the calibre of Enrico Fermi were making the breathtaking discoveries that enabled nuclear energy to become a usable power source for mankind. The detail work needed for the commercialization of the technology, however, such as the design of the plumbing system necessary to cool a large reactor, was regarded as something of a technological backwater. Scientists of the first rank had little enthusiasm for such chores, and they left the program. Most of the technical work was parcelled out to highly compartmentalized engineering staffs of companies that serviced the commercial power industry. Each of the small pieces that make up a nuclear power station was designed by a specialized group, and there was seldom any systems engineering to insure that the pieces would all fit together satisfactorily in a working nuclear power plant. For example, there was so little coördination between plant designers and plant operators that the head of the engineering department of the Babcock & Wilcox Nuclear Power Generation Division, a twenty-year veteran of nuclear-plant-design work for the company, had to acknowledge after the Three Mile Island accident that he had never been in the control room of an operating Babcock & Wilcox reactor. Similarly, the A.E.C., which nominally supervised the commercialization of nuclear power, was no better provided than the industry itself with high-level technical talent. If anything, a regulator's standard technical assignments—such as reviewing someone else's pump designs or wiring diagrams—were even less attractive to skilled scientific personnel than the primary engineering work being carried out by the industry.

"A job with the A.E.C. or the N.R.C. is pretty much like early retirement," someone who has held a position with both told me. "It's an easy, secure job in a big bureaucracy, and that's what most of the people who work there really want. I never saw any top-flight engineers at the N.R.C.—people with real credentials and experience. Of course, there are some good people on the staff who are capable of doing useful work. The problem then becomes the agency's reluctance to let them follow through on safety problems—especially if some plants might have to be shut down as a result." A 1978 survey of employees in the N.R.C. Office of Inspection and Enforcement—in which Creswell worked—reported that sixty-eight per cent of the N.R.C. safety inspectors believed that the N.R.C. management practiced "a don't-rock-the-boat philosophy."

The A.E.C. and the major companies involved in the nuclear-power industry were large, mission-oriented bureaucracies. Focussed on nuclear-power expansion, they had slight regard for the accumulating operating experience of the country's commercial nuclear power plants—whose records disclosed how their nominal safety objectives were repeatedly being undermined by careless human actions permitted by a regulatory system that relied on industry self-regulation. Nor was there enhanced sensitivity toward these continuing safety problems when the N.R.C., in 1975, took charge of safety regulation. Some people who worked in the nuclear program were troubled by the extent to which nuclear safety was being compromised in the rush to expand the industry. Robert Pollard, a safety expert for the N.R.C., resigned in protest in February of 1976, citing among other concerns the nuclear industry's pervasive noncompliance with official safety requirements. At a press conference explaining his resignation, he described the Indian Point nuclear power plant as "an accident waiting to happen." (The plant was built on the Hudson River thirty-five miles north of New York City, and Pollard had been one of the officials supervising its safety equipment.) The safety deficiencies in that plant, Pollard believed, represented the clear warning signs that almost invariably precede major accidents in complex systems. Safety experts generally agree that "routine" safety problems, even if the immediate consequences are relatively minor, can indicate points of vulnerability that make the system susceptible to more far-reaching disruptions. In a carefully managed nuclear-power program, these weak spots would be monitored and corrected before they became so widespread as to jeopardize over-all safety. If not—if they were accepted as routine nuisances and allowed to recur—the cumulative effect of seemingly minor uncorrected safety deficiencies could be the loss of vital safety margins against catastrophic accidents. As more and more plants go into operation "with the customary level of uncorrected safety problems and sloppy operation," Pollard warned, "it will not take very long for the effects of this regulatory failure to be seen in the form of very unpleasant accidents." Pollard, who joined the staff of the Union of Concerned Scientists after leaving the N.R.C., is challenging Metropolitan Edison's plans for resuming operation of Three Mile Island Unit 1.

The A.E.C. and the N.R.C. received related warnings from a variety of informed sources: scientific organizations, congressional committees and subcommittees that oversee the agency, the General Accounting Office, and members of the commission's own technical staff. Few of the recommended reforms have been carried out. In 1975, an environmental group in Virginia asked the Justice Department to investigate the handling of safety problems at a nuclear plant in Virginia that had been built on top of a potential earthquake fault. After looking into the case, the department's attorneys criticized the conduct of the N.R.C. officials who approved the plant as "bordering on criminal neglect," yet this observation prompted none of the required changes in the agency's safety policy. Even the accident at Three Mile Island has apparently not been enough to stimulate a major upgrading of the N.R.C.'s regulatory program. "We continue to be troubled by the lack of an underlying regulatory philosophy," the President's Nuclear Safety Oversight Committee wrote in a recent report commenting on the N.R.C.'s "action plan," which describes its official response to the Three Mile Island accident. "For all its virtues, [the action plan] represents a somewhat more intensive form of 'business as usual,'" the committee concluded. Much of the plan, in fact, consists of a catalogue of technical issues "to be studied further," and it contains few significant corrective actions to be taken to improve the safety of the nuclear plants now operating. The N.R.C.'s diffidence about ordering more sweeping changes may result, in part, from the embarrassment it suffered, immediately after the accident, when it tried to issue new instructions to the operators of Babcock & Wilcox plants on how they were to respond in the future to accidents like the one at Three Mile Island. (The N.R.C. issued the new guidelines, then modified them, and then revoked a major one—after realizing that it had told the operators to do precisely what it had subsequently decided they should *not* do.) In more general terms, however, the N.R.C.'s inaction is the result of the fundamental philosophy of industry self-regulation that still shapes the agency's general outlook. The basis of the action plan, as the General Accounting Office noted last year, is a "major dependency on industry" to "develop and implement the corrective actions." And the G.A.O. auditors concluded, "For the most part, the [N.R.C.] has only scheduled minimal time . . . to develop general criteria and to review the implementation efforts of the industry."

Officials in charge of the nuclear program, though they concede that the objections of Pollard and others are not frivolous, have found it difficult to acknowledge the implications of the various safety deficiencies, many of them attributable to human errors, that beset the industry. Dr. Roger Mattson, who was the director of the N.R.C.'s Division of Systems Safety until his resignation, in July of 1980, said in an interview a few weeks after the accident that he and others in the commission had missed what he called "obvious precursors" to the accident that crippled the plant at Three Mile Island. Speaking of the known problems with Babcock & Wilcox plants, Mattson said, "Why didn't the N.R.C. pick up on these problems? I don't know. I guess we have a poor system for following the licensee event reports"—the routine reports from each nuclear plant describing the equipment malfunctions, operator errors, and other safety problems that have occurred. "The Pollards of the staff for years said, 'Let us review I.C.S.' "—the integrated-control system used by Babcock & Wilcox to coordinate the reactor, the feedwater system, and the turbine-generators—"and the Mattsons of the staff said, 'No, this is a non-safety system. That is ratcheting—an unnecessary addition to the regulatory review process.' Somewhere, somebody should have seen the problems that were developing, but I guess we were busy solving other unresolved problems." Mattson acknowledged that the disabling of safety equipment as a result of testing and maintenance errors—the apparent reason for the failure of the emergency feedwater system at Three Mile Island—was among the best-known safety problems in the industry. He said that the reason the commission had not done anything to correct this situation was that he and others had been "lulled by a conviction that the machines were so inherently safe that even with human failures everything would be O.K.," adding, "This is not an acceptable answer, but it is the answer."

It is evident from the public controversy surrounding nuclear power in recent years that many thoughtful people have not been lulled by any such

sanguine convictions about the inherent safety of nuclear power plants. Ralph Nader, for one, has been gravely concerned about the potential risks. In a brief conversation just the day before the accident at Three Mile Island, Nader noted, with surprise, the lack of serious nuclear-plant accidents in the previous two or three years. Not since the fire at the Browns Ferry plant near Decatur, Alabama, on March 22, 1975, he said, had there been even any particularly "close calls." It was a definite puzzle that needed to be solved, he continued—one that had been obvious for some time: How, despite frequent equipment malfunctions and apparently pervasive safety infractions, had the nuclear industry's record remained so untarnished? The industry itself concluded, not without a certain degree of plausibility, that this record established the over-all resiliency of current nuclear-plant designs and their relative invulnerability to individual component failures and human errors, however alarming these might appear when they were looked at narrowly. Yet one might also reason that, with more plants continually going into operation, sooner or later the cumulative effect of the safety lapses would be a serious nuclear accident. In this vein, a 1969 Atomic Energy Commission report on the problem of human error stated one could conclude that "the absence of more serious effects is largely the result of good luck." The basic answer to the question posed by Nader was, quite obviously, that either concern about the risk of accidents was completely misguided or the country was long overdue for a serious accident at a nuclear power plant. The accident at Three Mile Island, the next day, helped to answer the question.

Like the recapitulation in a symphonic work, the accident at Three Mile Island brought together what had become, by March 28, 1979, familiar themes from the years of experience in operating Babcock & Wilcox reactors. All that was unique about the accident was the combination of events: individual events that had happened repeatedly but separately—at different plants that had Babcock & Wilcox reactors or at the same plant on different occasions—happened together, in one culminating debacle. The main feedwater system failed, the auxiliary feedwater system failed, a pressure-relief valve stuck open, the operators lost control of the unstable reactor. Given the frequency of these problems, the increasing number of Babcock & Wilcox reactors, and the lack of competent federal supervision of the nuclear-power industry, this particular accident was inevitable. The only question, now answered, was when it would occur, and the remaining issue—still far from settled—is whether something like it will ever happen again. Opinion on this matter is divided. The industry is confident that the problems have been corrected; other observers are less sanguine.

Recently, some of the members of the N.R.C.'s Special Inquiry Group, which studied the Three Mile Island accident on behalf of the commission, got together for an informal luncheon in Washington. The discussion was "very gloomy," according to Mitchell Rogovin. In his judgment, the N.R.C. has done "virtually nothing" to carry out the recommendations that he and his colleagues made, more than a year ago, for improving the regulation of the American nuclear-power industry. Rogovin said he was "awfully sad" that instead of adopting a better regulatory program the N.R.C. remained preoccupied with the creation of one that would simply license nuclear plants faster—"expediting the things that made us uncomfortable." Changes in the licensing process proposed by the N.R.C. a few weeks ago—which would cut back on the opportunities for the public to question plant safety—were "very troubling," he said. The American public itself has "an extraordinarily short attention span," and so pressure on the N.R.C. to improve plant safety has greatly diminished in the two years following the accident at Three Mile Island, he observed the other day, adding, "People worried about the Americans held captive in Iran, but they have overlooked the fact that they, too, are hostages, to the nuclear plants operating around the country. No one would question whether there will be another accident. It's merely a matter of when." —DANIEL FORD

(This is the second part of a two-part article.)

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After fifteen years of glamourizing many of the world's most admired and prestigious women, Jeffrey has assimilated his technique and expertise into the creation of his own cosmetic line, to be explored within his stunning, new Studio at 1526 Walnut Street.
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—*Playbill.*

No asides, please.

JUDGE GLEASON: Susan Gennari, please?

LIMITED APPEARANCE STATEMENT OF SUSAN GENNARI

MS. GENNARI: My name is Susan Gennari. I live in Webster Groves.

Members of the Commission, I have not come here to speak today.

MS. DREY: I can't hear here.

MS. GENNARI: I have not come here to speak today, not because I have unearthed some salient piece of evidence not previously considered nor have I come because I owe a debt of gratitude to the few people who have had the foresight and the endurance to challenge the licensing of the Callaway nuclear plant long before I even realized that they were acting to ensure my welfare.

I am here because I want you to know that even thought this room is not overflowing or the list of speakers awesomely long, the few people who have spoken with you and challenged the licensing of nuclear plants are not lone voices crying out in some technological wilderness.

I know this because although those people have my admiration, my respect, and my gratitude, I have much more in common with those people who are not here today. You see, I too believed that the apparent complexity of the field of nuclear energy demanded that I had over such decisions as the licensing of a nuclear power plant to some august body hidden away in a local hotel.

I too was ready to give it over to the experts. Like the absent others I almost was not here, not because I was unafraid of the consequences of licensing the Callaway plant, but because I was afraid of the complexity of the process by which that fear had to be expressed and I nearly let my lack of knowledge make me distrust my own fear, my basic human instinct of self-preservation.

I am here today because I want you to know that in the unthreatening circle of family and friends there are many of us who are coming to realize slowly that the fact that there may be no simple answers has too long prevented us from asking some basic questions.

Why should we be so assured of our safety when the utility specifications are said to meet the NRC standards, when we read in our evening paper that the General Public Utilities Corporation, owners of Three Mile Island, are suing the NRC for negligence and omission?

Why should we believe that the dosage of radiation released from the Callaway plant is harmless when that permissible dosage has changed ten times in the last fifty years. We ask ourselves do we wade through three weeks of testimony matching specification for specification to convince ourselves that Callaway is completel -ucturally sound and that quality control standards are ade ately met?

Or do we listen, perhaps, with more interest to the words of Nunzio Palladino, the director of the NRC, when he himself states his reservations about the quality control standards in nuclear plants throughout this country?

And we have begun to ask ourselves if we should continue to believe that we must license a plant because great risks must always be weighed against the overwhelming need when that projected need no longer exists. And the list of questions goes on and on.

And then we must ask ourselves, as I am sure perhaps you do, how you, this obscure commission of men, came to hold such direct power over the lives of people today and those of generations to come.

Gentlemen, the hundreds, maybe the thousands, that are not here today are not here because they are telling you to say yes to Callaway. They are not here because they feel that they bought the modern myth that they do not have enough answers to say no. And it is here that I part company with my contemporaries, for I believe that I am here because I believe that we have enough questions that we cannot say yes.

JUDGE GLEASON: Thank you, Ms. Gennari.

Off the record a minute.

(A discussion was held off the record.)

JUDGE GLEASON: Bobbie Silverblatt, please?

LIMITED APPEARANCE STATEMENT OF BOBBIE SILVERBLATT

JUDGE GLEASON: Go ahead, please.

MS. SILVERBLATT: My name is Bobbie Silverblatt and I live in Clayton. Having spent a fair number of days at this hearing I would like to share with you just one of the impressions I have received.

I found out that when the quality of the work on the Callaway plant didn't measure up to the specifications, the specifications were changed to fit the work. I can't help but wonder, is this any way to build a nuclear plant?

I observed many men connected with Union Electric and the various contractors and subcontractors, as well as the Nuclear Regulatory Commission members, exchange patronizing looks and snickers as the Intervenors brought out case after case of substandard work.

Gentlemen, even the Chairman of the Nuclear Regulatory Commission has told executives of the nation's utilities and builders of nuclear power plants that he finds the failure of their quality assurance programs "inexcusable."

"During my first five months as NRC Chairman," said Nunzio J. Palladino, "a number of deficiencies at some plants have come to my attention which shows a surprising lack of professionalism in the construction and preparation for operation of nuclear facilities. The responsibility for such deficiencies rests squarely on the shoulders of management."

We're not talking about the construction of office buildings or even coal-fired power plants. We are talking about a plant that is run on and creates deadly radioactivity and we're dead serious about the safety.

I ask that you withhold an operating license on the basis of the information presented by the Intervenors. Thank you.

JUDGE GLEASON: Thank you.

Dorothy Denton?

LIMITED APPEARANCE STATEMENT OF DOROTHY DENTON

MS. DENTON: My name is Dorothy Denton. I am from the city of St. Louis.

I come here concerned about various aspects of the Callaway plant, primarily, I guess, the radiation to the people, the health aspects of the radiation that is coming out of this plant to not only the people who live here now but to future generations.

We are told that the emissions that will come from this plant are in dosages that are safe for everyone. In my own mind I cannot rationalize how you can say that you can give the same amount of dosage to a pregnant woman, a foetus, a small child, a sickly elderly person, the same as you can give to a very healthy adult.

I think children are much more susceptible to all types of illnesses and any amount of radiation over and above normal background is bound to have some type of health defect for them. I have grandchildren that are going to be growing up here and, I hope, great-grandchildren. I would hate to think that their lives will be shortened, they will have mutated children, or any of the other bad health effects that are known to come from radiation because of this plant.

I am also concerned about the waste that this plant is going to make. For over 25 years we have had nuclear waste in our midst and cannot find any safe way of containing it. How can we possibly think of creating more when there is nothing to store it in, no place to put it? What is going to happen to future men? What are we going to do with mankind with all of this waste that is emanating radiation and killing off generations of people?

It is like mass genocide. I find fault with the safety and building of this plant. They are using a Westinghouse reactor which, from reading through articles and magazines and papers, I find to be one of the reactors that have the biggest problems in corrosion of piping and other defects and most plants that have problems have Westinghouse reactors.

I do not see why Union Electric went ahead with this or the NRC condoned it, knowing that there are such problems. If they cannot build something with the safety of the people in mind, then why build it at all? Has the greed for money and power become so great that we are throwing away human lives in order to obtain it worthwhile?

I am also concerned with the fact that there is no emergency evacuation plan for the people of the area. There are schools for deaf children down in Callaway County. There are numerous hospitals. What will happen to these people in case of an emergency accident?

I think all of these factors should be taken into consideration in your decision and I urge you in the name of all Missourians to say no to the licensing of the plant.

JUDGE GLEASON: Thank you.

Arnold Gringewatt?

LIMITED APPEARANCE OF ARNOLD GRINGEWATT

MR. GRINGEWATT: I am Arnold Gringewatt, a resident of St. Louis, a retired clergyman, and having spent most of my years in the administration of different welfare agencies in Omaha, in New York City, and in St. Louis, preceded by two years of public welfare experience in the great depression of the '30s in Minnesota.

For a number of years locally I have served as a member of the St. Louis chapter of Bread for the World, a citizens organization to combat the systemic causes of hunger. My concerns with the nuclear power plants generally and with the Callaway plant in particular is colored by my experience with poverty and its devastation of millions of our people and people around the world.

I see the development of nuclear power as a major part of the military-industrial complex against which President Eisenhower warned so incitefully, saying words to this effect, that every bomb that is made, every ship that is launched, and so forth, is deprivation of the poor. Like we cannot afford both butter and guns, we also cannot afford nuclear power and butter.

Nuclear power and nuclear weaponry are in intimate association politically, economically and militarily. Both need to be seriously questioned and alternatives to them seriously thought, lest, one, poverty and starvation increases as the gap between the rich and the poor widens; second, lest we are not only irradiated gradually but perhaps totally obliterated in a nuclear holocaust.

Thank you.

JUDGE GLEASON: Thank you, Mr. Gringewatt.

Vivian Bradford, please.

LIMITED APPEARANCE STATEMENT OF VIVIAN BRADFORD

MS. BRADFORD: I am Vivian Bradford, from St. Louis County.

You gentlemen are representing the Nuclear

Regulatory Commission and you have a great responsibility. I perhaps, some people would say, should be at home raking the leaves from eight trees or cleaning my house, but I chose to come down here because I feel that I too have a responsibility and I'm simply just going to try to tell you how I feel about this nuclear plant in Callaway County.

Now I don't know who decided that Union Electric was going to build this plant, but I think it would be very interesting to know who decided and what the motivation was. Personally, I don't feel that we need any nuclear plants in this country or any country in the world. I think there's enough other types of energy that could have been developed and perhaps much less expensively.

I was at the beginnings of the hearings at the motor inn, and there was a lady there with her daughter. She expressed to me her concern, not so much for herself perhaps, because she felt that her years were more limited anyway, although she was just approaching middle age. But she had her daughter with her and she had great concern for what might happen to her and subsequent generations.

I left the Riverfront Inn after the first session a bit tired. I have always -- evasion, I would call it, and I stopped at the courthouse. They had or did have -- I don't know whether it's still there or not, but if it is I hope all of you have seen it or will see it -- there is or was a display of the cartoons drawn by Mr. Englehart of the Post-Dispatch concerning all types of dangers to our world.

I found it very interesting and then a few days later, in the Tuesday, December 1, issue of the Post-Dispatch, he has one that sort of sums up the whole thing. Here is the world in a basket and it's titled "Basket Case." Among the things that are afflicting our world he lists the nuclear arms race, nuclear waste, the acid rain, a number of other things.

I totally agree with Mr. Englehart and I don't think a cartoonist, perhaps, are experts, but there are things to be learned even from "Annie". Recently, in the "Annie" cartoon, in nature there are neither rewards nor punishments. There are consequences.

The man that was quoted is Robert G. Ingersoll. In this cartoon, which is a rather peculiar little cartoon these days but nevertheless perhaps the cartoonist had something in mind, Mr. M says, "Annie, it requires no special insight to see the future of this planet, but most people ignore the facts or hope that they are wrong." Still, every tomorrow is a result of what we do today, so there is still hope.

So, gentlemen, when you make your decision I hope you do take everything into consideration. I am heartened by the decision that Union Electric was not going to build the second plant. I am also heartened by the seeming awareness of the people of the world of the dangers of nuclear power.

We hear more and more incidents of the demonstrations in various countries and the opposition to various nuclear things. I almost applauded when Begin did his little job in Iraq. I thought, well, there's one of them gone which won't cause us any trouble.

(Laughter.)

His motivation was very good, I think. He tried to do it when there were no people present and I think there were a few who were there. They weren't supposed to be there and they were, so he had a few deaths, but he took great pains to see that nobody was hurt and he took great care to destroy it before it was filled with radioactivity.

I am constantly aware of the statement of Dr. Carl Z. Morgan, who perhaps had more to do with the beginnings of things nuclear than he would like at this time, but he says that there is no safe level of radioactivity and how it affects each of us is purely a game of chance. And we must remember that because it is going on for generations once we loose more of it into the world.

I would have been much more pleased with Union Electric -- they didn't ask me about this plant -- I would have been much more pleased if they had used all that money to develop solar cells, to improve their use of coal, to make it less a danger to the environment. Our neighbors to the north of us wouldn't be complaining so much about acid rain if they'd done that with some of that money.

I am not a stockholder in Union Electric, but if I were, I think I'd question the use of all this money to build that monstrosity and they are throwing more and more money after it. If something's bad, stop it, for heaven's sakes. Why go on with something that you've already thrown too much money in and, you know, is a bad job? That's the way I would look at it if I was a stockholder.

You could have used your money, or Union Electric could, to develop that plan they had for developing waste in energy. That would have benefitted the whole community. It would have solved the problem that we have of what to do with waste. Of course, it wouldn't have produced enough energy to make a great contribution, perhaps, but it would have helped in two ways.

Then this constant story that we just aren't going to have enough energy unless we have nuclear power, I can't believe it. We have wind power. We have solar power. The source of all energy is the sun, or at least that's what they've always taught me. And I think that there is much that can be done.

Methane gas has possibilities, developed from waste. My son is working in Ecuador with the Peace Corps trying to work out a bio-gas idea down there. I don't know why we couldn't have been doing some of that here.

JUDGE GLEASON: Ms. Bradford, you will have to summarize your remarks now.

MS. BRADFORD: I just think the nuclear power plant at Callaway is not necessary and since there is evidence that it was not built properly I do think that you should not give them a license.

JUDGE GLEASON: Thank you.

Jeanie Fogler, please.

LIMITED APPEARANCE STATEMENT OF JEAN FOGLER

MS. FOGLER: My name is Jean Fogler. I live in St. Louis and I simply want to go on record as stating my opposition to the operating license of the Callaway County nuclear plant.

We, the people of Missouri, and of this country have been told by Union Electric and by other utility companies that we need nuclear power, that we're better off having it because any allegedly small risks will greatly outweigh any benefits that we will receive.

I, for one, find it extremely unfair that this benefit-risk syndrome should be imposed on us without our being asked and I, for one, do not intend to calmly sit back and blindly accept this. Even if I did find it acceptable, it seems to me that the balance of benefits and risks is very negatively tipped.

In doing extensive reading of NRC documents, correspondence between Union Electric and the Nuclear Regulatory Commission, and other similar documents, I have become acquainted with many construction defects in the Callaway plant, things to do with cracks and pitted concrete, faulty embeds, welding problems, piping problems, and many other things that could lead to potential safety hazards.

I think these are areas for great concern. There are also many other sorts of potential problems that I am very concerned about -- things to do with radioactive waste, radioactive water being poured into our drinking supply, and many other things.

Not only are the risks great, but it seems to me that the benefits are becoming smaller and smaller. We have already seen that Union Electric has found fit to cancel the Unit 2 plant because it has become economically unfeasible and I am wondering when Union Electric is going to open their eyes and see that Union 1 is unfeasible as well.

If they cannot see the light, I call upon the Nuclear Regulatory Commission to do it for them.

Thank you.

JUDGE GLEASON: Thank you.

Richard Beatty, please.

LIMITED APPEARANCE STATEMENT OF RICHARD BEATTY

MR. BEATTY: My name is Richard Beatty. My name is Beatty -- Richard Beatty. I live in Crickwood, Missouri.

I would like to add my voice to those opposing the licensing of Callaway. I might say, too, that my ony constituency is layman concern for their lives and the lives of generations to come.

At the very least, I believe you gentlemen should not only postpone the licensing of Callaway but every other plant that may be on-line until such time as safe and adequate means are devised to store radioactive waste.

With your permission and patience, I would like to go over briefly some old ground. You are doubtlessly aware of our frequently criminally-negligent record of waste disposal to date. After approximately thirty years of nuclear power experience we still have no realiable depository.

But the former head of the House Committee on Conservation and Energy and Natural Resources, Leo Ryan, could he have been right that we may have to face the realization that it just may not be possible to guarantee the containment of radioactive waste over the ages until they are harmless to mankind? When he's talking "ages", he is talking hundreds of thousands of years.

Nevertheless, we have some plants. One of them is on a Rube Goldberg order, shooting the stuff at the sun. The other is sinking a ten-foot-wide shaft deep into the earth or into salt beds and these, assuming they proved more feasible than past plans, won't be ready until the 1990s.

In the meantime, we are generating waste from 71 plants at the rate of 33 tons per year, most of it to be stored at the plant sites until a permanent repository is ready.

What we have done with this lethal garbage to date is sickening to contemplate -- ground storage sites that are leached into the earth, much of it into the underground water supply, thousands of gallons actually from accidental spills into the underground water supply, 89,000 barrels of radioactive waste, some of it at high level, dumped into our coastal waters from 1947 to '70 and already contaminating the food chain in some waters where the barrels have ruptured or eroded.

Man must be the only animal that is capable of wilfully destroying his habitat. Nuclear power hasn't even the excuse any more of expediency. The tragic irony of this attempt at a nightmarish solution to the energy problem is that nuclear power efforts, full of bright hopes in the beginning, have probably contributed more to the energy problem than they have helped, what with huge cost overruns, abandonment of plants, cleanup costs following fuel spills, and increased energy prices to the consumer.

And all the while we learn that there's enough natural gas in this country to carry us well into the next century and probably beyond.

This statement represents the preponderance of expert testimony this past summer before the House Subcommittee on Fossil and Synthetic Fuels. The cost of piping in the new fields and the cost of pumps, pumping stations, would be as nothing compared to the cost of a nuclear plant, not to mention the cost of plant accidents and the continuous radioactive pollution of our overzapped environment. There also would be no concern about possible faulty construction and the ever-present danger of another Three Mile Island disaster or worse.

I don't believe that I am being melodramatic to say that the life of a planet may well hang on the courage and will of this and other bodies the world over. We must act now, before it's too late, if it's not already too late.

We must step back from this nuclear abyss on the solid ground of sanity and survival.

Thank you.

JUDGE GLEASON: Thank you.

Daniel Brogan, please?

LIMITED APPEARANCE STATEMENT OF DANIEL BROGAN

MR. BROGAN: My name is Daniel Brogan. I am a resident of the city of St. Louis.

I share most of the concerns expressed by everyone this morning. I have had a chance to look over the Nuclear Regulatory Commission document, Environmental Impact Statement for the Callaway 1 plant. Over and over again, in this document, risks are cited.

Frequently they are dismissed in the Staff's words as small or insignificant, but similar to doses of radiation, such risks are cumulative, whether you believe them to be small or great. At some point the sheer numbers of them should cause concern to anyone.

As you know, public opinion is shifting to a position that the majority is opposed to further construction of nuclear power facilities. With this in mind and the risks cited in the NRC documents as well as other studies, these risks should no longer be considered acceptable.

Whether you believe that the operation of or accidents at the Callaway plant will present in one to ten cancers, genetic effects, or leukemia, or whether you believe, as many responsible scientists do, that such operation will result in hundreds of health problems and eventual deaths, with public opinion, the apparently lack of need for Callaway and alternative energy development, this

Commission need not and should not issue further licenses for such facilities.

Thank you.

JUDGE GLEASON: Thank you, Mr. Brogan.

Byron Clemens?

LIMITED APPEARANCE STATEMENT OF BYRON CLEMENS

MR. CLEMENS: My name is Byron Clemens. I am a member of the Crawdad Alliance, but I'm not here to represent them today.

I have a briefcase full of documents. I have done a lot of research on nuclear power and know too much about piping, honeycombing, weld defects, even what a weld undercut is, but I came here to speak from the heart because you were nice enough to give us that opportunity.

I am concerned about my family. The first nuclear waste generated in the world from Stagg Field are at St. Louis International Airport. The nuclear wastes from Hiroshima and Nagasaki bomb productions are at St. Louis International Airport, at Latty Avenue in Weldon Springs and Broadway and Dusterhan in St. Louis. All these sites are in the process of being considered for decontamination.

My father worked for 25 years next to one of those sites and he has pancreatic cancer. There is no proof that that's where he got it from, but it could be. That concerns me, that we haven't been able to clean up the waste from the first sustained nuclear reaction in the world. They're still there, and now we have a nuclear power plant that Union Electric admits it doesn't really know what it's going to do with the waste. The NRC hasn't come up with a plan yet that is feasible.

Two weeks ago I went to the town of Fulton and there we polled the area. We went from door to door and talked to people and found out how they felt about nuclear power. I have some of those documents in this briefcase. I can say that overwhelmingly the people were not very pleased with the plant. They had many questions about the safety and the construction defects.

One of the people who was an employee for Daniel Incorporated and was aware of many of the problems between Bechtel and Daniel and they expressed to me their concerns. They are in favor of nuclear power, but are concerned about that particular plant.

I have here a newspaper article about Union Electric having to pay a $2,000 fine for exposing some of its workers at a coal-fired plant to radiation. The NRC fined them for that. That doesn't impress me. It doesn't make me feel very good about Union Electric's competency to run a large nuclear facility.

I guess lastly I would like to speak in behalf of Bill Smart and the other workers who have been brave enough to take a chance and contact the Nuclear Regulatory Commission and the people who haven't been. I've gotten more than one midnight phone call and more than once I've talked to people in Fulton and Callaway County.

In fact, I have a hat from the Callaway nuclear power plant that they gave me. They are proud of their opposition but they're not brave enough to come forward and talk about the construction defects. But those people are there. Bill Smart is just the only one who has been willing to and had the courage to follow through.

Thank you.

JUDGE GLEASON: Thank you, Mr. Clemens.

Mr. Bill Freese, please.

LIMITED APPEARANCE STATEMENT OF BILL FREESE

MR. FREESE: My name is Bill Freese and I live at 6805 Washington in University City. I work for the Washington University Medical School as a technician in a research lab.

I have a Bachelor of Arts degree in chemistry and I use radioisotopes regularly in the course of my work. I am also a member of a group called Missouri Energy Action, which responsibly opposes nuclear power while supporting conservation and alternative energy sources.

Although I am not knowledgeable about the Callaway plant in particular, I feel there is enough evidence against the use of nuclear power to justify opposing it in general. I am especially concerned about the dangers in reactor emissions to man and to the environment at this plant.

In my work I deal with very low level radioisotopes, which emit radiation in a micro-curie or rarely in the milli-curie range. This is one-one millionth, or at the most one-one thousandth of a curie. Reactor cores emit radiation in amounts that are hundreds of thousands of times greater than the radioactivity of isotopes used in research, yet the NRC has established strict guidelines for the use of radioisotopes.

We must work in defined areas, clearly mark all vessels with even a trace of radioactivity, dispose of liquid and solid hot waste in special containers, constantly monitor our bench top and work area for radiation, and account for every single microcurie of isotope that we use. All of this is considered necessary, despite the fact that those using radioisotopes in research are allowed a much higher radiation dose than the general public.

Why all of these precautions? We have often heard radioactive pollution compared to the pollution from other coal or fossil fuel plants. What these comparisons ignore is the qualitative difference between radioactive emissions and all other kinds of emissions.

First of all, many of the radioisotopes produced as waste in reactors are long-lived, posing a peculiar threat to this planet and man for thousands of years to come. We can only hope that future generations will find a way to deal with the waste already produced in a safe manner, something we have heretofore been unable to do.

The threat of radioactivity is its incredible potency to create mutancy in our genes. This is the most serious threat posed to man by radioactive emissions. Genetic material is very precisely encoded and by its very nature must resist change, which it does extremely well, except for rare events called mutations, in which light alterations are made in the base sequence of DNA.

Although chemicals can produce the difference in DNA, the splitting of the atom is far more potent than any of them and imposes a qualitatively different threat to human life than other forms of pollution.

Scientists have as yet been unable to determine the threshold dose, that is, the greatest amount of radioactivity the body can safely handle. Most now believe there is no such dose, that any radiation may produce small deleterious effects in a cumulative fashion.

Given these dangers and others which I have no time to enumerate, one would question the ability of any group of [illegible]an men to handle the enormous amounts of radioactivity present in reactors. If we are going to have nuclear power at all, we would at least expect them to be incredibly competent, responsible men.

But what is the actual situation in nuclear power in the United States today? The nuclear industry has repeatedly built nuclear reactors in earthquake-prone areas, relying on such devices as earthquake support systems, as in the Diablo Canyon plant, to protect us from earthquakes which, I fear, don't believe in such systems.

The nuclear industry and government has stored radioactive waste in the most unlikely areas. For example, in St. Louis County the radioactive waste site at the airport contains waste which has the potential to contaminate Coldwater Creek, the county's source for drinking water.

The Three Mile Island plant, two years after that major accident, the utility concerned has yet to clean up the millions of gallons of radioactive water surrounding the core because it doesn't have enough money to do it. And, in fact, it doesn't even know how to do it. So the proposed solution is to charge consumers and other utilities and government for its own irresponsibility.

Finally, the head of the NRC, Nunzio Palladino, has recently criticized the nation's utilities and builders of nuclear power plants for the failure of the quality assurance programs, which he calls inexcusable. Such a blanket condemnation from the Director of the very agency whose responsibility it is, in part, to encourage nuclear power, is very frightening. And now I hear reports of construction defects in the concrete work at Callaway.

Given all that has been said, can you afford to trust the nuclear industry with this enormous threat to human life and their planet? I think not, and so strongly oppose the operation of the Callaway nuclear power plant.

Thank you.

JUDGE GLEASON: Thank you, Mr. Freese.

Ms. Rose Levering, please.

LIMITED APPEARANCE STATEMENT OF ROSE LEVERING

MS. LEVERING: My name is Rose Levering. I live in St. Louis. I am a law student. I am a member of one of the intervening groups, but I'm here to make --

MS. DREY: I can't hear.

MS. LEVERING: But I'm here to make a personal plea. I am somewhat at a loss, coming before the NRC and making such a plea. I have always felt that the NRC was an agency that was concerned with fostering the development of nuclear power.

I am trying very hard to believe that there are indeed responsible people on the Board and that you are concerned with the safety of the plant and not letting a plant with defects go on line.

I guess it's probably been since Three Mile Island that the general public and St. Louis and Missouri have become aware of the dangers of nuclear power. They are aware of deaths that are occurring to native Americans from uranium mining, uranium that is being milled right now for the Union Electric plant, for a plant that we don't really need.

I think people are aware that Union Electric's projected use estimates were grossly overrated several years ago when this plant was in the planning stage. People are aware of the problem of waste in this country, especially in St. Louis, as you've just heard, and Union Electric has no plans for decommissioning.

And I think people are increasingly aware that there are plants in the country right now that are facing problems with decommissioning and they are still not sure what to do.

I think we have all heard about accidents. It seems like every week in the newspaper you can read about accidents, unplanned occurrences in the nuclear power plants. People are aware that on the one hand EPA standards tell us that the lowest permissible dose of radiation is one thing and the radiation that's released from nuclear power plants is higher than that.

People have had an opportunity here in St. Louis to hear Dr. John Kaufman speak about radiation dangers and how we're finding increasingly that there are dangers from low level radiation, levels that would be produced routinely in a nuclear power plant, not just the high levels that might occur in the case of an accident.

I have heard Dr. Mishikakis speak, a nuclear physicist, and I've heard him describe details of nuclear accidents. I have seen slides of the one that happened at the Idaho Falls reactor where three workers were killed and one person was pinned to the top of the reactor dome with a fuel rod and I still hear people in the nuclear industry telling us that there are no deaths attributable to nuclear power.

I have spoken to lawyers, Danny Sheen and others, who have worked on the Karen Silkwood case, and I know what self-serving actions industries are capable of. I know that Union Electric is a company that spent ten years and millions of dollars in litigating to postpone putting scrubbers on the coal-fired plants, and I have no reason to think that they would be overly concerned with our safety in regards to a nuclear power plant.

And we are expected to believe that they are going to monitor their own radiation releases and be honest with us. Increasingly in the past year people in Missouri have become aware of the problems of defects in this particular plant. I have sat in on a couple of hearings and I have spoken to people from UE and I know that people here, people in this room, have been characterized as radicals and bored housewives and I've heard people from UE characterize the points that the intervenors have brought up as trivial.

I don't think that honeycombing in the reactor base mat and dome, cracks in the dome, faulty embeds, faulty piping -- I don't think that these are truly insignificant problems. I think that there are a lot of lay people here who have been trying in a year or so to prepare themselves to try to become experts, to take on experts, to come before you and bring up these issues.

I think a lot more could have been brought up if we had had the time and the money and the technical expertise. As people who oppose nuclear power have been characterized in a certain way, I don't characterize people who work for Union Electric or in the NRC as people with murder in their hearts and dollar signs in their eyes.

And I would like to think that we could meet on some common ground here concerning the Union Electric plant. I think that the issues that have been raised in these past hearings have proved that if any plant does not deserve to go on line today, the Union Electric should be one of them, at least I hope you're not aware of plants that have been allowed to go on-line with problems that are more serious than this.

I think people in Missouri have tried almost every way that they could to stop this plant going on line. We have tried every legal and non-violent way and I think that you are one of our last resorts and I ask you please to help us.

JUDGE GLEASON: Thank you.

Steve Hirsh?

LIMITED APPEARANCE STATEMENT OF STEVEN HIRSH

MR. HIRSH: My name is Steven Hirsh. I am a resident of the city of St. Louis. I'd like to thank the Board for this opportunity to address them.

I work both as a carpenter and as a schoolteacher. My involvement in both of those professions bears directly on my opposition to the licensing of the Callaway nuclear power plant.

As a carpenter and also as someone who has spent more hours than I would like to think about going through documents -- Union Electric documents, Daniel International documents, Bechtel, NRC documents -- related to the construction of nuclear power plants, I know that if I was on a crew doing the kind of work that I read about in those document I would no longer be a professional carpenter. I wouldn't be able to find any work. The crew I was on would not be able to get any work to build anything.

I was absolutely astounded at the continual systematic attempts to underplay what were very obvious defects. I'm real familiar with the welds in the embed plates. The welds, the workmanship, was characterized repeatedly as being of poor quality and yet Bechtel would come out and say well, that's okay. We don't need to worry about it. It's not a concern.

We've got a situation where Bechtel, Daniel and UE are all making excuses for each other. The NRC inspector comes in and finds a problem. Daniel, in the non-conformance report, I believe 831, the 610-page report validating the embed problem, Bechtel spends the next three years trying to prove that Daniel was incompetent in their inspection.

Daniel comes back trying to say that -- I mean, it just goes on and on. These companies have professional people paid very high salaries to generate this enormous volume of paper. The people working against the plant have jobs, have families and have to take time from all of that to try and go through this paper and to try and systematically come up with clear indications of contradictions, of mis-statements, of outright lies, of understatements of problems.

We don't have the resources that Union Electric and Bechtel, the NRC, Daniel International have to pay people to do this. We do this while we're trying to conduct the rest of our lives and I don't like to think of the days that I came straight from work to look over documents and stayed until 3:00 or 4:00 the next morning to go home and take a shower and drink a cup of coffee and go back to work.

That's the kind of pressure the Joint Intervenors have been operating under to try to present to the Board a cohesive argument for why that plant should not go on line.

I also mentioned I'm a schoolteacher. I work with children on a daily basis. I am concerned for those children. I'm concerned that they don't have any say in a decision that is going to affect their lives. They are not asking for this power plant.

Nobody has asked them if they want the power plant. Nobody has asked them if they feel the risks involved in the operation of this plant are reasonable, if they feel that they are willing to take the risk of maybe developing cancer later on in their life so that we can generate power with this nuclear power plant.

No one has asked them, not to mention that no one has asked the citizens of Missouri, the Midwest, whether they want it. The decision was made by the Board of Union Electric and was carried out by them with absolutely no input from the people that were going to be affected by it.

I can't say strongly enough to you how opposed I am to the operation of this plant, to what I see as -- I would like to lessen the impact of the words I have to say, but it's premeditated murder. I don't know any other way to say it.

We know radiation is going to come out. If the plant were built perfectly, it would still release radiation that's going to cause cancer and deaths, but we are saying that's okay. We're going to get power from it; we can accept that number of deaths.

Well, I would like to see how the people who made those standards and decided that those levels, those levels of sickness and death are acceptable, would feel if one of the individuals concerned was somebody in their family.

I can see absolutely no justification for the operation of this plant, both on a generic basis of the problems of nuclear power and the specific problems involved in the construction of the Callaway plant.

Thank you.

JUDGE GLEASON: Thank you, Mr. Hirsh.

Paul April, please.

LIMITED APPEARANCE STATEMENT OF PAUL APRIL

MR. APRIL: Good morning. My name is Paul April. I am a resident of Richmond Heights, Missouri, about five miles from here in St. Louis County.

I wasn't planning to come this morning. I wasn't planning to speak here. I thought about it for a long time and I decided I'm not accustomed to doing this kind of thing, but I decided I would come here for just a couple of minutes and speak with you.

I understand that it is your responsibility to decide whether this plant in Callaway County gets it license to operate. I am not an expert on nuclear power, but I want to tell you that as an individual and, I guess, on behalf of myself and my wife and some other members of my family, I don't want it to operate. I don't want it to go on line. I don't want it.

I have listened to the debate that has gone around the construction of this plant for several years. I am concerned about all I have heard about the construction defects. I have some real serious questions. Again, I'm not an expert, but I am worried. I'm scared.

I heard originally when this plant, when the idea for the plant, was started that this was going to be something real economical for the electrical users in this part of Missouri. Well, everything I hear keeps telling me that the cost of this plant is going up and up and up. And I am a lifelong resident of Missouri. I'm a homeowner. I have a wife. I would like to raise a family here. And I'm scared.

I don't want to have to deal with this terrible risk to my safety and my health. I don't want to have to deal with the spiraling costs. I am sure there has to be a better way and I hope that you gentlemen will see that.

In addition to being a resident of St. Louis County, I'm also an employee of a special kind of place. It's the St. Louis County Special School District. I don't know if you gentlemen are familiar with it, but the major activity of this district is to take care of several thousand children in St. Louis County area who have a number of defects.

They have -- we see individuals who can't walk, who can't hear, who can't see, who can't reason, and it's very curious to me that each year the number of students in St. Louis County special school district, notice that there are more and more of these children every year. I don't knw why that it.

I think it's curious that in these times we have more waste and more pollution in our environment and I believe that that waste and that pollution is the reason why we have more students every year in the St. Louis County special school district. And really it bothers the hell out of me that this plant might increase the number of students like that.

Two days ago I had one student I work with who usually is kind of a joker. He's a real happy guy. He has muscular distrophy, but he's real happy. He's ten years old. But he wasn't very happy on Wednesday of this week and I saw him crying. I asked him why. He told me that a friend, also ten years, had died. This friend had had birth defects, had gone through ten very, very tough years and he died.

Well, I'm thinking about maybe having children someday and raising them here in Missouri and I know we can't guarantee that our children are going to be healthy when they're born, but I would like them to have the best chance possible and I don't think they're going to have the best chance possible if you allow this plant to go on line.

Finally, I get very upset. I'm not a well-known activist against nuclear power, but I get very upset when I hear in the press that the people who are opposed to this plant going on line are just a bunch of radicals or something.

Well, I don't consider myself a radical. As I said, I have a family. I own a home. I pay my bills. I'm a lifelong resident of Missouri. I have a job -- I think a good job. I am also a -- I'll be a small officeholder, political officeholder, in St. Louis County. I'm the Vice President of Hadley-Lincoln Democractic Township, which is an area that covers Richmond Heights, University City, Clayton, and Maplewood, Missouri -- an area not too far from where we are right now.

And I can tell you that almost exactly one year ago at a meeting of that Township, 51 individuals attended. A question was put to those 51 people concerning the dangers around radioactive waste that Callaway plant might generate. Are you in favor of that plant? Forty-nine said no. The other two abstained. No one was in favor of it.

I can tell you a few weeks later, when the people of my township went to the polls and voted about the question of whether this plant should go on line, considering the question of radioactive waste, almost 68 percent of the people in my township, in those four cities in St. Louis County, said no, they don't want it.

I ask you to consider those things and please do not approve the licensing of this plant. And I'd like to thank you very, very much for allowing me the opportunity to speak to you this morning.

JUDGE GLEASON: Thank you, Mr. April

Virginia Harris, please?

LIMITED APPEARANCE STATEMENT OF VIRGINIA HARRIS

MS. HARRIS: My name is Virginia Harris. I live in Creve Coeur City, which is in St. Louis County, and I would like to speak as a concerned citizen.

Three days ago the Chairman of the NRC was reported to have found an inexcusable failure among quality assurance programs of utilities and builders of nuclear power plants in the U.S. I am convinced that his admission on this issue is merely the tip of the iceberg.

We, the citizens and consumers of America, have been reading all along about accident after accident, about mistake after mistake, connected with the building and operating of nuclear plants in the United States.

On top of this, we, the citizens and consumers of America, have been subsidizing and paying for these accidents and mistakes through the Price-Anderson Act, through the Federal budget for nuclear programs, through increased electricity rates, through our own individual medical costs and medical insurance premiums and, occasionally, through the loss of our lives.

We, the citizens and consumers of America, will have to continue to subsidize and pay for these accidents and mistakes so long as you, the NRC, continue to license nuclear plants.

In the past the NRC has strictly limited the kinds of testimony and the kinds of issues that it would permit intervenors to raise in the course of its deliberations about a license. I understand that this is still true today and it leads me to wonder whether nuclear utility companies will ever be required to calculate the total, true costs of using nuclear power plants before pressuring their customers into paying for these monstrosities.

I am referring here to the actual costs which can be approximately estimated of a major nuclear accident or at least the actual insurance costs that if the company's liabilities were not limited by law, for if the nuclear plant's insurance policy doesn't pay for the damage, we citizens will still have to pay for the damage on an individual basis.

I am referring here also to the cost of decommissioning these plants after their useful life is over and the cost of storing the radioactive waste, assuming a method can be found, and the cost of caring for terminal cancer patients among the uranium miners and their families and the cost of lost opportunities.

For example, last month St. Louis newspapers reported that our downsteam steam heating system is drifting towards collapse, whereas in other cities steam heating systems are on the upswing because of their potential for energy efficiency. Highly respectable business leaders were quoted as saying that a major reason for collapse of St. Louis' steam system is that its owner, Union Electric, wants to convert existing steam customers to all electric, and, of course, wants all new downtown office buildings to go electric in order to create an apparent need for more electricity and thereby help to justify its Callaway plants.

These are only some of the costs and while the monetary costs do represent the risks to some extent, they do not adequately convey the message. I think the message is best summed up in the story of Faust. Those who try to make a deal with Pluto or, in this case, with plutonium, end up having the devil to pay.

Unfortunately, those individuals who temporarily profit from nuclear plants are not primarily the ones who will have to pay. It is others, for example, those living downstream or downwind, and it is primarily the future generations of all of us who will have the devil to pay.

JUDGE GLEASON: Thank you, Ms. Harris.

Miss Sandra Jerabek, please.

LIMITED APPEARANCE STATEMENT OF SANDRA JERABEK

MS. JERABEK: My name is Sandra Jerabek. That's J-e-r-a-b-e-k -- and I live in the city of St. Louis.

I am here this morning because I am a concerned citizen. I am also with the Coalition for the Environment. For the past two weeks representatives of my organization and others have been trying to establish that serious construction defects do exist in the Callaway nuclear plant.

We have been so well represented that I am not going to repeat their examples or conclusions. I would like to underscore a point or two and I would like to thank all of those people who have been working so hard and, I feel, serving the community so well here.

I would like to emphasize that this is a almost totally volunteer effort, this intervention before the Nuclear Regulatory Commission, and that doesn't just mean Kay Drey, but that means many, many other people who have devoted countless hours to researching the information which has been presented to you. And I think it's a very impressive volunteer effort.

People have done it because they think that this is important and that there are serious matters for you to consider. I would like to thank the members of the Nuclear Regulatory Commission for your patience and your consideration during this proceeding. The fact that you have spent two weeks listening to our concerns about inspection and construction defects shows that you do take seriously the responsibility of protecting the people of this region.

I would today simply like to urge that you cannot take these concerns too seriously because there is no room for defects or human error with nuclear technology. There is no margin of safety when an accident could disrupt the lives, permanently disrupt the lives, of people for hundreds of miles around the plant.

There is no sense in an attempt at analyzing risks versus benefits, when the risks entail contaminating our environment in a way that will last for hundreds or thousands of years. Your job in licensing this plant could not be more important.

I would like to remind us all, as many people have, that the Nuclear Regulatory Commission this week discussed whether or not there were possibilities for deregulating the nuclear industry in some way. Instead, the Chairman of the Nuclear Regulatory Commission concluded that this was impossible when utilities had been doing such a poor job of constructing and inspecting nuclear plants. In fact, I believe that the statement was that the inspection practices of the industry lacked professionalism.

Gentlemen, it seems to me that you and the Nuclear Regulatory Commission have no choice but to make up for this lack of professionalism. The responsibility now stops with you and with no one else. There is nowhere else to pass the responsibility.

This means, I think, scrutinizing the possibilities for defects in the plants, as you have done, and then this means denying a license to a plant which is unsafe, as I urge you to do.

All of the people who have volunteered many, many hours of their very precious time to this effort are depending upon you.

Thank you very much for this opportunity.

JUDGE GLEASON: Thank you, Ms. Jerabek.

Paul Kranzberg.

LIMITED APPEARANCE STATEMENT OF PAUL KRANZBERG

MR. KRANZBERG: I was formerly with the Post-Dispatch for a number of years in their advertising department in charge of food advertising. After that I had my own advertising agency and I am now retired.

I am going to read from some articles which appeared in the paper within recent days. This one ran a week ago, Sunday, the heading of which is "Public Service Commission Orders Study of Callaway Costs."

"The Missouri Public Service Commission has ordered it staff to study how much Union Electric Company had invested in a second nuclear power unit in Callaway County near Fulton before its recent cancellation of the project. The Commission also examined construction costs of Union Electric's first nuclear unit at the same site.

"Work on the first unit is continuing. Its estimated final cost is $2.1 billion. The staff's study is in anticipation of a company request that the Public Service Commission allow the cost of the units to be passed on to UE customers."

There is more in the article, but I simply want to make this comment. I think it was illegal to pass along to users the cost of construction and UE is hoping to do exactly that with the cost of the reactor that's been cancelled.

On Thursday of this week this article appeared. The heading is "Estimates Soar on Atom Plant in Springfield, Illinois."

"Estimated cost to build a nuclear power plant near Clinton, Illinois, are $1.8 billion, $85 million more than estimates made a year ago by Illinois Power Company. Illinois Power said the single reactor plant's estimated construction cost had risen five percent since 1980's estimate. The company blamed Nuclear Regulatory Commission regulations stemming from power plant accidents at Three Mile Island and Brown's Ferry and installation of additional equipment. The originally-estimated cost for the nuclear plant was $429 million in 1973."

There's more to that article.

On Thursday of this week, on the editorial page of the Post-Dispatch Mr. Englehart had a cartoon, an illustration of a large, very mean-looking genie who had emerged from a bottle marked "nuclear arms". On his head is the one word "proliferation". He is facing a smaller bottle from which two smaller genies had emerged, both very angry and mean-looking.

On the headband of one is the phrase "safety laxity". On the other is "diversion of materials." On the bottle from which they had emerged is simply the phrase "nuclear power."

On Thursday evening, I was listening to Dan Rather, CBS News program, and he said this, which I have written verbatim as checked by the man named Griffin who monitored the program to be sure I had written it correctly. This is what he said: "The company that owns Three Mile Island claims that the Nuclear Regulatory Commission knew about the flaws in the design of Three Mile Island because a similar plant in Ohio had developed similar problems months earlier and had not warned Three Mile Island. Three Mile Island people said they could have taken corrective action had they known."

This article appeared in the Thursday Post-Dispatch, the heading of which is "Third of Aspirants Fail Three Mile Island Exam." The word is "aspirants". "A third of the aspirants failed the Three Mile Island exam, Harrisburg, Pennsylvania, United Press."

"One-third of the potential control room operators at the Three Mile Island nuclear power plant failed qualification tests, utility executives say, but enough passed to run one of the two reactors on the island. The utility wants to restart the plant's number 1 reactor, shut down in April 1979 after a major accident at its twin.

"The tests were conducted in October after cheating was discovered on the original qualification test last April. The utility says it will have just enough licensed operators to run the undamaged reactor. The NRC requires 20 slots to be filled on five control room shifts in nuclear facilities such as Three Mile Island. The plant has 21 licensed operators, just one more than the minimum.

"The reexamination results showed that nine of 19 employees failed tests to become 'senior reactor operators' and that three of fourteen employees failed examinations to become 'reactor operators'." End of article.

I am confused, concerned, and frightened. Thank you.

JUDGE GLEASON: Thank you, sir.

Mr. Grant Williams, please.

LIMITED APPEARANCE STATEMENT OF GRANT WILLIAMS

MR. WILLIAMS: My name is Grant Williams. I am a resident of St. Louis City. I don't represent any of the groups that are involved in the struggle today. What I am is just a concerned citizen.

I'm a young concerned citizen. As a young man I am especially concerned because I and my peers will be the ones who have to clean up after Union Electric's mess. It will be I and my children who will have to live with nuclear hazards that result from today's bungles.

Not until recently was I even aware of the problems and the issues around Callaway. When I heard about them I was outraged. When I tell my friends and family they are outraged. Some day everybody's going to know about this, maybe not now, but later, and when everyone does there will be some questions to answer.

I urge you as guardians of the public interest to not grant this license now, to prevent this.

That's all I have to say. Thanks a lot.

JUDGE GLEASON: Thank you, Mr. Williams.

Margaret Serrano.

LIMITED APPEARANCE STATEMENT OF MARGARET SERRANO

MS. SERRANO: My name is Margaret Serrano and I'm a consumer of Union Electric's energy.

I am opposed to the NRC issuing a license to the Callaway County nuclear facility. My concerns are the inadequacy of construction and the lack of any method of safe disposal of the spent fuel.

Callaway County is an example of the poor quality and lack of standards that Dr. Palladino referred to earlier this week. Union Electric holds it ratepayers, such as myself, responsible for the bills they incurred. Who is to hold Union Electric responsible for the methods they use in constructing a nuclear power plant that is supposed to serve the people?

It would be better for Union Electric to write off the money spent thus far on Callaway than to continue toward operation of this project. I urge you as members of the NRC not to license Callaway County.

JUDGE GLEASON: Thank you, Ms. Serrano.

Nancy Collins, please.

LIMITED APPEARANCE STATEMENT OF NANCY COLLINS

MS. COLLINS: My name is Nancy Collins and I'm a citizen residing in St. Louis.

I'm concerned about the awful consequences of a possible nuclear accident in light of the construction defects and lack of attention to quality control that's been brought out in these hearings. I believe that the risk of accident is too great to allow the operation of the Callaway plant.

I would like to urge you not to license Union Electric's Callaway plant because I just believe it would not be in the best interests of the citizens of this state and this region to allow -- for the health and safety of the citizens, and I would urge you not to license the plant.

Thank you.

JUDGE GLEASON: Thank you, Ms. Collins.

Yvonne Logan, please.

LIMITED APPEARANCE STATEMENT OF YVONNE LOGAN

MS. LOGAN: My name is Yvonne Logan. I live in Webster, Missouri. I am the national President of the

Women's International League for Peace and Freedom. Our organization does have a stand against nuclear power, but I wish to add my personal thoughts on the Callaway County plant.

I oppose the construction of that plant because I believe that we have to have almost perfect technology to be safe with this kind of power. I have the highest respect for the good will of Union Electric and the integrity of the Nuclear Regulatory Commission. I believe this technology was started years ago with the highest hopes for its safety and its use by the citizens of this country.

But I think that the knowledge we have now of the dangers inherent in these power plants makes it imperative that we cancel the rest of them. I read of the accident at Indian Point near New York City in March of 1980 in which 100,000 gallons of 50-degree salt water from the Hudson leaked into and reached the reactor vessel, which was at a temperature of 600 degrees and which contained the radioactive uranium fuel.

That resulted in cracks in that container and if the Consolidated Edison's manager had not returned in time to order shutdown, a horrible accident would have happened right near New York City. As you know, that Indian Point plant has been closed indefinitely.

The mistakes discovered at the Diablo Canyon in the switching plans seems almost incomprehensible and gives me very little faith in the perfect human activity that must be necessary to keep these power plants operating. It is a technology that has fearful consequences for us when it is released.

Our organization concentrates most of its attention on nuclear weapons. I cannot say what I do about your Commission and our utility companies, that they started with the best of will. Nuclear weapons result in more nuclear waste and more danger than we are able to comprehend.

I urge you not to put this plant on line.

JUDGE GLEASON: Thank you, Ms. Logan.

I can't make our the first name here. It is Drey?

MS. DREY: He seems to be gone at the moment.

JUDGE GLEASON: Mr. Nossa or Ms. Nossa.

LIMITED APPEARANCE STATEMENT OF MS. CARRIE NOSSA

MS. NOSSA: It's not my initial down there.

My name is Carrie Nossa -- N-o-s-s-a.

The experiences that I bring to my objection to the plant is graduate training in engineering policy as well as teaching engineering technology and I'm currently writing electronic repair books for computers.

My worries about the plant come mainly from my experience in the engineering field. I have -- there is no question in my mind that the engineers working on the

Callaway plant in the construction, the design, the testing -- all of that -- have been as professional about it, as careful about it as engineers that work on designing electric hair curlers or hamberger cookers or washing machines.

I have no question of their technical integrity. My experience from the field has shown me that everybody is as human as everybody else and that normal care taken in a job always involves mistakes of some kind and that is inevitable.

The difference here is that mistakes, even minor mistakes, that are made in the nuclear field have more serious consequences than they do in other fields.

Another factor that comes to me from my experience of working in the field is something that is within the field among engineer or engineering technologists themselves spoken of as a wild-ass guess. I don't know if you've heard of it before, but it is a means of labeling a particular datum or a particular fact when you don't know exactly what the real datum is or the precise measurement is, and you do an estimate.

It's the field's term for an estimate, because you can't get any more precise than that. But it is presented on technical reports as a precision piece of data and in the scientific reports that I have seen of the documentation on

Callaway I sense a lot of this. I don't sense any more scenarios of scientific reports on industry testing of hair curlers or hamburger cookers.

The point is that normal care or procedure that is taken in the nuclear field is no better than that that has been taken in other types of technology in our culture and this sort of cover or the fact that this is not admitted by the nuclear industry puts forth a sort of aura of professionalism, of assurance of the quality of work that isn't there.

And that's the way I feel about it.

JUDGE GLEASON: Thank you, Ms. Nossa.

Lea Greentree.

LIMITED APPEARANCE STATEMENT OF LEA GREENTREE

MS. GREENTREE: Hello, my name is Lea Greentree. I am a resident of Maplewood, which is right outside of St. Louis.

I am here to voice my opposition to the licensing of the nuclear power plant. I feel like most of my concerns or all of my concerns really have been expressed more eloquently than I am prepared to do today, but I guess I want to speak specifically right now for the unborn and the young children, because I am pregnant and I am very aware that radiation affects children and the unborn far greater than it does us who are the ones who are making this decision.

I feel like the risk is far too great and that we do not have the right to inflict these risks on the rest of the world for generations to come.

Thank you.

JUDGE GLEASON: Thank you.

George Manning or Monning?

LIMITED APPEARANCE STATEMENT OF GEORGE MONNING

MR. MONNING: My name is George Monning. I have a Ph.D. in physics and I am a computer consultant. I have talked to some other experts in the field of civil engineering and concrete.

I had an opportunity to talk to some people at the ASTM meeting and I had an opportunity to read the report by Weiss, Janney and Elster. It was concerned with the possibility of imperfections in the concrete that were not observable from the outside. Some honeycombing had been observed.

In that report I believe it illustrates these concerns about quality control and integrity of the interpretation of data that the previous speakers have been mentioning. The interpretation of the data is based on an assumption that sound travels in a straight line.

Sound is a wave phenomenon and waves will bend around objects, depending upon the relative site of the object in the wave length. That could be illustrated very simply with a couple of pieces of styrofoam and I'll be glad to set that up if anybody's interested in seeing it.

The wavelength involved was not mentioned in the report, but I have talked to Dr. -- Mr. Choy, in Chicago, who is one of the people concerned with the instrument that was used and its 54 kilohertz frequency, which when you combine that with 15 to 16,000 feet per second you come up with a wavelength between three and four feet.

Now sound, having a wavelength of three or four feet in the concrete, bends quite a bit, so the basic assumption of straight line propagation is erroneous. The situation is far more complex than can be adequately covered with a simple interpretation of a straight line propagation and measuring of velocity.

There is a question of measuring the structure itself, the mixture of sound and concrete, so that the sound can get in the steel, which has a higher velocity, and it's a very complicated situation. And more information was thrown away in the shape of the wave form and taking pictures of oscilloscopes to determine wave form would have been a very useful and, I believe, necessary part of this investigation.

And I brought some advertising -- I don't know whether it's appropriate to leave it or not -- concerning the availability of equipment. It's a very standard, inexpensive, much-used laboratory procedure which should have been used in this case.

So I believe that this one investigation substantiates in a detailed way the points concerning the quality and reliability of the design effort that has been put into this effort down in Callaway County.

Thank you.

JUDGE GLEASON: Thank you, sir.

(A discussion was held off the record.)

JUDGE GLEASON: Mr. William Stone, please? Is Mr. Stone here?

MS. JERABEK: Mr. Stone had to leave. I have his written statement.

JUDGE GLEASON: All right. Would you give it to the reporter and we'll have it inserted in the record.

That concludes --

MS. JERABEK: There are some more names.

JUDGE GLEASON: All right, but don't take any more because we're going to have to cut it off at this point.

(The prepared statement of William and Joyce Stone follows:)

12/05/81

To whom it may concern:

We hereby emphatically state that we are adamantly opposed to the operation of the Calloway Nuclear Power Plant.

Problems at nuclear power plants throughout the country, which seem to occur all too frequently, have confirmed to us the dangers related to nuclear power. In our opinion, a "limited danger" is too much of a danger to risk. Instead of investing millions of dollars in nuclear power, an energy force which is becoming increasingly impractical economically as well as increasingly dangerous, this money could (and should) be more wisely spent on alternative energy sources.

As someone who has a brother who has

the misfortune of living in the Harrisburg, Pennsylvania area, I have witnessed first-hand the devastating impact that a nuclear power "accident" has had upon people I care about very much. (My brother has a wife and two children.) The trauma that they went through (and are still going through) is impossible to relate on paper. I sympathize with them not knowing what ~~any~~ the repercussions of this accident will [illegible]e upon their children and future grandchildren. No American, in whatever part of the country, deserves to go through what they have gone through over the past two years.

Do what you can to stop the approval of the licensing of the plant in Missouri

William & Joyce Sto[illegible]
6115 [illegible] Ave.
St. Louis, MO 63112

LIMITED APPEARANCE STATEMENT OF NANCY GROVE

MS. GROVE: My name is Nancy Grove -- G-r-o-v-e -- and I'm a citizen of St. Louis County.

Unlike many of the speakers who have preceded me here today, I have neither a scientific background nor anything remotely approaching a thorough understanding of the very complex technological and safety aspects that are involved in the construction and operation of the Callaway nuclear plant.

That task, the understanding and the careful supervision of those functions, has been delegated in large measure to you and to your colleagues in the NRC. I have been very encouraged by the recent remarks made by the Chairman of the NRC regarding the inexcusable failures in the licensing process for nuclear power plants in this country in the recent past.

These remarks have renewed a faith that I think has been sadly lacking in recent years with respect to the attention paid to the tasks that have been delegated to your Commission.

I hope, therefore, that as a lay person I can continue to become confident that my trust in the responsible execution of those duties continues to be well placed. It is obvious to everyone here and to you that there are certain very powerful interests being served in

Union Electric's unfailing determination to build this plant and to eventually recoup their losses.

I only hope that it will become equally obvious to the public and to people such as myself, who rely on your attitudes, that you will continue to view your mandate in its proper perspective and that means recognizing that if this plant is licensed in its present form with its present very real defects that we the public and the citizens of Missouri may never have a chance to recoup our own losses.

Thank you very much for the chance to speak to you today.

JUDGE GLEASON: Thank you.

Miss Gary.

LIMITED APPEARANCE STATEMENT OF ALICE GARY

MS. GARY: My name is Alice Gary. I am a resident of St. Louis.

I'm here to state my opposition to the licensing and operation of the nuclear power plant in Callaway County, Missouri, for the following reasons.

I am a lay person. Professionally I am a rehabilitation counselor and I am aware of disability and I will state this parenthetically, that I am aware of the fact that in this country disability is increasing faster than the work force and I am concerned professionally as well as personally about the health not only of myself and of people close to me but of society.

But as an informed citizen I am concerned that nuclear power is too costly a means of generating electricity. It's too costly, first of all, because the means of generating it is too costly for the ratepayers to bear, although at one time it was believed nuclear power would be too cheap to meter. Present reality has turned out much differently.

As we all know, the estimates of building the plant have now jumped astronomically. The price of nuclear fuel has also jumped astronomically. Electric bills already take an inordinate amount from the average person's budget. It makes no sense to increase the cost of generating electricity and thereby increase the consumer's bill with the longest credit record in generating nuclear power.

It's costly not only in terms of monetary costs but also in terms of human health and life. As an informed citizen I know the chance of a major accident occurring is small. The chance of a catastrophic failure or meltdown and release of radioactive gas into the air is small.

But as an informed citizen I also know that the chance of a small accident is large. Small accidents happen frequently at one or the other of many nuclear plants around the country. We read about them all the time in the paper.

We are always reassured that they are

insignificant, that no damage to human life could be measured. The truth is that any damage that was done to human life will take many years to show up. Even if no small accident ever occurs at the Callaway plant there would be steady damage to human life from the routine emissions of radioactivity into the Missouri River, which just happens to be the source of our drinking water.

We are assured that these routine emissions are harmless. The truth is, the effects of these radioactive emissions will take many years to show up. Radioactive exposure can cause cancer -- it is a scientific fact -- although it takes many years to show up. It may take twenty or thirty years to develop cancer.

Missouri isn't just interested in so many statistics and the people who will develop cancer ten, twenty, thirty percentage -- whatever the percentage is, it's impersonal. Although we may be mere statistics to the NRC or to Union Electric, we in Missouri regard ourselves as human persons.

We don't want to be a statistic who is exposed to the risk of cancer and who get it. I don't think anyone -- the NRC or Union Electric -- has the right to place that risk on any of us. I happen to have a publication in my possession -- Cancer and the Worker -- in which the nuclear -- in which the New York Academy of Science states that we already have a cancer epidemic in this country.

It will be very expensive to stop the Callaway nuclear plant now. It can be much more expensive to operate and to have to pay for the damage down the line for human health and life which will occur.

It is expensive to admit that nuclear power is a mistake. It is more expensive to throw good money after bad.

Thank you.

JUDGE GLEASON: Thank you, Mrs. Gary.

Mr. Gaminetti?

(No response.)

JUDGE GLEASON: Did he cancel? Looks like you'll have to do it, Vera.

LIMITED APPEARANCE STATEMENT OF VERA FALK

MS. FALK: My name is Vera Falk. I reside in St. Louis County. I am a retired social worker, psychiatric social worker, and at present am working on advanced gerontology. The first will tell you of my interest in people; the second will tell you of how aware I am becoming of the economic effects on older people.

My crusading interest in the nuclear thrust spans three decades-plus. I was a member of the original group who formed the committee of information on Strontium-90 which was the forerunner of the Committee for Environmental Information. This was the organization that did the baby tooth survey that received worldwide attention.

I was a founding member of the Coalition for the Environment and have been active through many years in organizations addressing the moral and economic issues around nuclear proliferation.

As a member of the public who was present for a major portion of the proceedings, I would like my testimony to briefly reflect some of my observations and impressions. In the first place, I want to make abundantly clear that the Chairman of this panel was extremely patient, encouraging, supportive, and fair in his rulings. In addition, he was most lenient in setting boundaries and time frames. In no way is this intended to be an negative reflection upon the handling of the proceedings.

While the rules provide for a public citizen to participate in the role that Mrs. Drey assumed in these proceedings, it seems to me the disadvantages due to her lack of experience and skills in judicial proceedings created serious obstacles in managing information through documents, exhibits, interrogation and cross examination of witnesses.

Is the system so inflexible that it cannot accommodate and enable an individual such as Mrs. Drey to more comfortably share her research and knoweldge without so much stress? In other words, if an individual can shed light upon a potential danger of a nuclear power plant disaster, should rules written by lawyers and for lawyers be flexible enough to e able the non-professional to do so without so much disrespect from the professionals?

The Applicant has unlimited resources which we, the ratepayer, will foot the bill. The Nuclear Regulatory lawyers and witnesses are funded by government. Is it not time that intervenors be given the equal opportunity that only money can buy in terms of high power, expensive lawyers, to present these cases?

We have every faith that the Board will be as careful in their judgment as they have been fair in gathering material to make a decision which will be in the interest of all of us. Nuclear power is not essential to our survival in Missouri. A safe plant is. And from what we have heard in this testimony, a 100 percent safe plant does not exist.

Thank you very much.

JUDGE GLEASON: Thank you, Ms. Falk.

(Applause.)

JUDGE GLEASON: It is probably fitting that this public session should close with Mr. Drey.

MS. FALK: Mr. Chairman, I have one other thing to say. May I say it?

JUDGE GLEASON: Sure. Go ahead.

MS. FALK: This hearing was not unique as a David-Goliath scenario. It was only more pronounced because of Kay Drey's role. For her undaunted courage in acting on her convictions and commitments in this hostile arena, we of the public, and she represents us by the thousands upon thousands, are deeply indebted for her dedication and zeal.

Thank you.

JUDGE GLEASON: Thank you. Mr. Drey.

LIMITED APPEARANCE STATEMENT OF LEO DREY

MR. DREY: Gentlemen, I would like to introduce myself as Leo Drey.

(Laughter.)

MR. DREY: I am the owner of a 150,000-acre tree farm in Missouri on which we are busy producing energy every day, storing energy every day, perhaps you would say. Other than that I know very little about the subject before you.

I am aware, however, of how hard my wife, Kay Drey, has worked to bring deficiencies that she has uncovered to your attention. I am acquainted with some of the people she has worked with. I try to stay out of the basement -- through her labor she has become somewhat overwrought -- the basement, where the documents are stored.

Yet I have to believe that what she as a non-prudential housewife has been able to unearth and bring forward for your consideration is but the tip of a very,

very menacing iceberg.

Thank you.

JUDGE GLEASON: Thank you, Mr. Drey.

(Applause.)

JUDGE GLEASON: That will conclude the public session for limited appearances of this part of the hearing process connected with this application.

I should congratulate the citizens who have testified for what I consider a very reasoned and objective and valuable group of testimony and information.

As citizens know, undoubtedly this hearing has been conducted now in two phases. This concludes the first phase dealing with construction defects. The next phase, which will take place in Callaway County, will deal with the emergency plans sometime next year.

So we will now close the record with respect, the evidentiary record, with respect to this part of the proceeding.

(Whereupon, at 11:37 o'clock a.m., the hearing was adjourned.)

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(Applause.)

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NUCLEAR REGULATORY COMMISSION

This is to certify that the attached proceedings before the

ATOMIC SAFETY AND LICENSING BOARD

in the matter of: Union Electric Company (Callaway Unit No. 1)

Date of Proceeding: December 5, 1981

Docket Number: STN 50-483-OL

Place of Proceeding: St. Louis, Missouri

were held as herein appears, and that this is the original transcript thereof for the file of the Commission.

Jane W. Beach

Official Reporter (Typed)

Jane W. Beach

Official Reporter (Signature)