The Health Hazards of NOT Going Nuclear
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A Post-Three Mile Island
Preface

When this book was first published 3½ years ago, it didn’t have a preface. But since then we have had the Three Mile Island Grand Disaster — history’s only major disaster with a toll of zero dead, zero injured, and zero diseased.

How much of this book had to be rewritten as a result of this Grand Disaster? Not a solitary line; not a solitary word; not a solitary i-dot.

On the contrary, the reader is cordially invited to use the Grand Disaster as an experimental test of what this book asserts, in particular, as a test of the central question of whether the zero casualty toll was “a lucky near miss” or whether it was a logical consequence of the two fundamental pillars of nuclear safety: the defense in depth and the slow progress of a nuclear accident.

The defense in depth, and why no other energy facility of equal size can have one, is described in the book; but perhaps the slow time scale of a nuclear accident should have been more strongly emphasized, so here is an illustration from the TMI episode: Within hours from the beginning of the accident [Hours? How long does it take for an oil tanker to blow up?], the industry had flown in teams of experts; one such team engaged in almost Naderite “what-if” fantasies. What if the pump now slowly cooling the core fails? We use the other primary loop. What if that fails, too? We still have the ECCS. What if both loops fail because the power fails? We have a diesel stand-by generator. What if that fails, too? Let’s fly in another, just in case. And they did. (It was never needed.)

What 843 MW facility, other than nuclear, gives you that kind of time to take countermeasures? What other 843 MW facility will contain a chain of five horrible failures — human and mechanical — without the loss of a single life? How do you evacuate the population when a dam breaks? How do you take preventive measures while a gasoline refinery blows up?

Yet Three Mile Island did not become what it should have — a gigantic field test of nuclear safety. It became the bugle call for the biggest brainwashing campaign in American history.
"Scientists told us an accident of this type was virtually impossible, but now it has happened," is an assertion proved false by this book, published almost 3 years before the TMI accident. An accident like TMI, which resulted in nothing but property damage (and would not have resulted even in that if an operator had not switched off the correctly functioning automatic safeguard) always had and, and continues to have, a significant probability; what is highly improbable is an accident with large-scale loss of life, such as happens very frequently with other energy sources. Since this book was published, dam disasters have killed thousands of people (at least 2,000 in India in August 1979); many hundreds have died in explosions and fires of gas, oil, butane, gasoline, and other fuels; and tens of thousands have died premature deaths, in the US alone, due to the use of coal. Many of these deaths could have been avoided by using nuclear power as a preferred source of electricity; but who cares about safety or public health? Not the politicians, nor the self-anointed Messiahs. The real dangers continue to be covered up; it is, after all, the perceived dangers from which political capital can be made. So let the suckers die for the greater glory of Kennedy, Udall, Hart, Oettinger, Jerry Brown and Tom Fonda.

A meltdown? It was never even close at TMI; and this book will tell you why it would not have been the end of the world even if there had been one.

Radiation? The average dose received by people in the neighborhood of TMI due to the accident was one millirem; the maximum anybody could have received was about 80 mrem. (Just by staying in Colorado since this book was published, I have received 350 mrem more than if I had moved to Harrisburg, Pa.) Off the population now living within 50 miles of the TMI site, approximately 350,000 would eventually have died of cancer if there had been no accident. That number will now be increased by one, possibly two.

And those are the only deaths to be expected, say the official figures. Wrong! Many more than that will die due to the accident, and some of them have already died. What is being covered up is that TMI Unit 2, now crippled, was saving lives which are now being lost in producing electricity by far less safe power sources. Most of the replacement power is coal-fired, and the detailed studies by Brookhaven National Laboratory published in 1978-9 have found more accurate estimates of the death toll due to coal-caused air pollution. The median is 24 per 1000 MW coal-fired electric power (this book is between 40 and 100). That makes about 62 dead for the missing 843 MW of TMI Unit 2 by air pollution alone, or more than 1 death per week.

That cannot be helped, of course; Unit 2 had an accident. But what about TMI Unit 1? This could be saving more than 1 life a week, but it is shut down for no good reason other than to more political mileage out of the accident. For since this book was published, the NRC has changed, at least in part, from a commission of timid experts to a commission of political demagogues: I refer to Commissioner Gilinsky, and above all, to Carter appointee Peter Bradford, a lawyer formerly working for Ralph Nader’s corporation-baiting conglomerate. It is people like Bradford who keep nuclear plants shut down for every conceivable excuse. In August 1979, Bradford acknowledged that he was aware of coal being riskier than nuclear power; so he must know about the 1 death a week due to TMI Unit 1 standing idle. But politics is politics; what’s a few more widows?

Not all casualties of TMI were fatal, or even regrettable. One such casualty was the theory of the inevitable failure of the Cooling System as diligently Prof. Kendall and his Union of Concerned Scientists. He had built a lucrative career on the alleged malfunction of the ECCS, which had never been tested what he considered acts of whitewash. At TMI all of his carefully nursed predictions of doom were shattered in a fraction of a second as the ECCS came in and was later switched off by human wounded this he called for evacuation its inevitable deaths heart attacks of the traffic at a time there was no of a massive radioactive release. He also that a meltdown will cause children under will, and lead to all kinds of horrors that would scare the Count at the same time his assured us that not want to halt nuclear power completely. Artificial earthquakes with rockets the bubonic some other events in the last three years deserve comment. The Rasmussen you would never believe the brainwashers in the national news media - has disassociated itself from the Executive and endorsed the NRC Bradford was in the "..." on that it disassociated itself from the Executive...


about 62 dead for the missing 843 MW of TMI Unit 2 by air pollution alone, or more than 1 death per week.
Summary of the report could not endorse the exact values of the probabilities as calculated in it — as Prof. Lewis, chairman of the review group, testified before a Congressional Committee, the real probabilities could well be more favorable to nuclear power.

The attacks on low-level radiation have reached the borders of sanity — and here I do not merely allude to Dr Ernest Sternglass, whose “findings” on mental retardation, infant mortality and decline in test scores have grown so wild that they have become an embarrassment to the anti-nuclear lobby. As in so many other cases, I must refer the reader to my monthly newsletter Access to Energy* to keep abreast of the latest facts and fictions; let it only be mentioned that Dr Marcuso published his report after his contract was left to expire without renewal because he had not produced results of any kind in many years, and that Dr Najarian was dismissed by a fuming Sen. Kennedy in June 1979 after his testimony on alleged increased cancer incidence among nuclear shipyard workers was demolished by medical experts.

For the rest, the antinuclear thrust has not changed direction; it has only intensified and the antinuclear movement has become part of the political establishment. My contention that this movement is largely fed by members of a class who want to freeze society in the state where they occupy privileged positions has received much supportive evidence, though I still do not claim it to be the only explanation.

One of the important, though usually unreported, developments of the last three years is the extent to which the victims of such policies — those who are denied upward social mobility by the no-growth advocates — have begun to struggle against it. The starting point may well have been the NAACP’s statement on energy in December 1977, by now there is a growing grassroots pro-energy movement which seems to be unrooted, misread or ignored by the current set of politicians. The next set may well reach the troughs of power by recognizing what their predecessors overlooked, and though it is improbable that they will be more moral or honest, the prospect of the current mismanagers being turned out and sent packing is still something to be looked forward to.

Among the more telling glimpses of the antinuclear movement’s concern with social engineering rather than safety is a statement by Amory

* $12 for 12 monthly issues from Box 2298, Boulder, Colorado 80306. (Price will not be increased if the federal budget is balanced.)

Special subjects are treated by this author in his Different Drummer booklets such as 1. Nuclear proliferation — how to blunder into it; 2. Small is Beautiful? Economics as if people mattered; 6. Why “nips” technology will not be America’s energy salvation; 7. The non-problem of nuclear wastes; $2 each from Golem Press, Box 134L, Boulder, CO 80306.
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1

The Nuclear Monologue

How many atomic explosions in our cities would you accept before deciding that nuclear power is not safe — no complexities, just a number?

Question posed to AEC Commissioner DuBois at Ralph Nader’s “Critical Mass” meeting, November 1974.

What is remarkable about the above quotation is not so much its loutish arrogance, nor even the speaker’s preference of political sloganeering over technical complexities; what is remarkable is the speaker’s abysmal ignorance.

For the speaker (or heckler) has based his “question” on two totally false premises: First, that anybody of any consequence ever claimed that nuclear power is safe; and second, that an atomic explosion in a nuclear plant is possible.

Both implications are utterly false. There is no such thing as safe energy conversion on a large scale; it is almost a contradiction in terms. Energy is the capacity for doing work, and as long as man is fallible, there is always the possibility that it will do the wrong kind of work; to ask for absolutely safe energy, therefore, is much the same thing as asking for incombustible fuel.

This book never tries to make the point that nuclear power is safe; the point it makes is that it is far safer than any other form of large-scale energy conversion yet invented.

The other implication, that of an atomic explosion in a nuclear plant is even more preposterous, for such an explosion is physically impos-
sible. Not highly improbable, but utterly impossible: An explosive nuclear chain reaction is no more feasible in the type of uranium used as power plant fuel than it is in chewing gum or pickled cucumbers. And yet these two fallacies, ludicrous as they may be, are not the only ones that have become widespread among the public. Equally ludicrous are the falsehoods that nuclear power is less reliable than fossil-fired power; that insurance companies are unwilling to insure nuclear plants for liability; that nuclear power will lead to a “radioactive society,” and many more such superstitions that will be examined here. Nor are these superstitions shared and disseminated merely by a self-destructive intellectual elite gone berserk in its hatred of the system that elevated it to its present position. These myths have made inroads among honest citizens concerned about the safety of their communities. Even some scientists (though almost none in the field of nuclear power) have become scared of nuclear power.

Politicians, who in the late sixties changed their vocabulary from justice and motherhood to ecology and environment, are pecking up their ears: Ever ready to cater to prejudices that will bring votes, they are probing whether nuclear can be made into a dirty word, as dirty as profits maybe, so that they can gallantly wage an anti-nuclear campaign to save the widows and orphans from the greedy corporations. Several states have already passed legislation curbing the growth of nuclear power; in June 1976, California will vote on the “Nuclear Initiative,” a piece of demagoguery disguised as an initiative for better safeguards, but in fact posing irrational conditions that would effectively prohibit nuclear power in California. Win or lose, the superstition mongers will go on to other states to crusade against nuclear power; to crusade, consciously or not, for increased American dependence on medieval sheikdoms and other unstable nations; to crusade, consciously or not, for increased American dependence on medieval sheikdoms and other unstable dictatorships.

The so-called nuclear debate is replete with myths, distortions and outright falsehoods; but it is compounded by the most exasperating of them all, the myth that there is a nuclear debate at all.

What debate? There is no debate, only a monologue. There have been almost no reasoned debates between proponents and opponents of nuclear power; what there has been in abundance is coverage, especially by the TV networks, of puerile “what-if” fantasies limited exclusively to nuclear power, never applied to fossil-burning plants or other energy sources. There has been, and continues to be, excessive coverage of the hit-and-
1. THE NUCLEAR MONOLOGUE

The utilities are, naturally, aware of the excellent economics, as well as the safety, of nuclear power; at the time of writing, the price of nuclear fuel is about 6 times lower than that of the average fossil fuel needed to generate the same amount of electrical energy (even though the prices of oil and gas are controlled at unrealistically low levels), and even when the depreciation costs of the more expensive nuclear plants are considered, the overall cost of nuclear power amounts to between 50% and 80% of the cost of fossil-generated power.

But utilities throughout the country are in a near disastrous bind of capital shortage and they have canceled or deferred about half the orders for new and badly needed nuclear capacity; and as behooves an industry that is shackled hand and foot by government regulations, price controls, rate controls, and politicized Public Utility Commissions, it keeps its mouth shut. Only very recently, pressed against the wall by the nuclear initiatives, have some utilities begun to speak up. Moreover, the utilities and their PR departments are afraid of "knocking coal." Most of their capacity, and often all of it, is fossil-fired. By pointing out that nuclear power is safer than fossil-fired power, they would admit that their present power generation is not the safest possible; and well knowing that if nuclear power is banned, the activists will next turn against coal (for they are against all large-scale energy conversion, hoping to force their recommended lifestyle on everybody else), the utilities fear that if they lose in the nuclear initiatives, their own arguments will be turned against them, and they prefer to be quiet on the point.

This is, in my opinion, a mistake. It amounts to giving up much of the most effective weapon the nuclear supporters have: the truth. Even if there were a genuine debate and the battle were even, the truth should be the only weapon; but to forego it in a situation without equal access to the mass media, to forego it in a situation which enables the activists to make 30-second statements that it takes half-hour lectures to refute, is suicidal.

Besides which, there is no need to "knock coal." Though fossil fuels are far more dangerous than nuclear power, they save far more lives than they take, as does any form of large-scale energy conversion — one need merely compare the public-health statistics of an advanced, energy-intensive economy with those of a backward economy, no matter whether in the US in the past or elsewhere in the present. And the need for energy to maintain the US standard of public health (as well as the general standard of living) is such that we cannot afford, or even quickly achieve, the exclusive use of the safest; we must settle for the second-safest and third-safest as well. When the entire picture is considered, fossils and hydropower are safe to a very high degree (certainly much safer than the small-scale gadgets advocated by the primitives), and the reader of this book is earnestly requested never to forget that the point of this book is not to argue how dangerous fossils and hydropower are, but to show that nuclear power is safer.

It is an important point, and one that will not be made again, so please forgive me if I emphatically repeat it: The point of this book is not to argue how dangerous fossils are, but that nuclear power is safer.

And finally, there is the scientific community. "Scientists," we are invariably told, "are sharply divided on the issue of nuclear power." What makes this statement so exasperating is that in a certain sense, it is true. What the statement does not say is how the line runs: The opponents of nuclear power are recruited from the ranks of entomologists, anthropologists, biologists, neurologists, chemists, and other non-nuclear disciplines; but there are very few nuclear engineers among them. Typically, the three nuclear engineers who resigned from General Electric in San Jose, Calif., in February 1976, were members of a para-religious organization (the Creative Initiative Foundation, which teaches that "God did not make and therefore it is the whether Our Bread is" and the well-heeled C.I.F. financial for others who would join in this to recruit more than 3 of the 480 other engineers same level for GE's Nuclear which is not. the three nuclear engineers are aware of the fact that the alternatives of nuclear power and indeed more lives.

The scientist nuclear power, sometimes a Nobel Prize winner, is a man of quite a different ilk. He has two
sistent characteristics: First, he made his name in a field unconnected with nuclear power, and second, he has a penchant for embracing political causes.

Linus Pauling, for example, won his Nobel Prize in Chemistry on a subject that has nothing to do with nuclear power, and he is known to the general public mainly for his escapades such as picketing as a one-man picker in front of the White House to protest the Vietnam war. His proposed cure of the common cold (also outside his original field of expertise) has recently been disproved, and there is no reason to believe that he knows more about colds than coolants.

Hannes Alfvén obtained his Nobel Prize for his contribution to plasma physics, particularly as applied to the ionosphere, a set of layers in the atmosphere from 50 to 500 miles above the surface of the earth. His statements on the dangers of nuclear power show that he has not only little understanding of nuclear power, but that he has no understanding of the concept of safety. He evidently believes in the existence of absolute safety and requires it for nuclear, but not for any other kind of power.

Barry Commoner is a biologist who has done important work on genetic mutations induced by carcinogens in bacteria, but he is better known to the public as a doomsday prophet, an opponent of economic growth, an advocate of nationalizing the railroads and the energy industries, and a crusader against "big business" who has recently endorsed Marxist economics. There are many other scientists in this group — scientists who have distinguished themselves in a field far removed from nuclear power, and who have embraced political causes for which to crusade.

Not included in this group are men like Ehrlich, Tamplin or Goffman, who can at best be called ex-scientists. Mediocrities in their own fields, they seem to have tried for a quicker way to glory, and they now specialize in horror stories that are reprinted in Sunday supplements to scare the gullible. The science fiction produced by Tamplin, Goffman, Sternglass and others has been refuted many times by scientific committees and is too ridiculous for all but the politicized environmental organizations. As for Dr. Ehrlich, it is difficult to talk about his "ignorance" of physics, for if he knew nothing about it, it would be a marked improvement; his misunderstanding of thermodynamics, for example, is shocking.

Returning from these ex-scientists to the scientists, one may say that the opponents of nuclear power are not only drawn from the ranks of other disciplines, but they represent a minute fraction of the scientific community. Typically, this small minority sent a petition to slow down nuclear power to President Ford in August 1975 on the 30th anniversary of the Hiroshima nuclear bomb explosion. That in itself shows that the petition was an unprofessional political gimmick, since nuclear bombs are no more related to nuclear power than electric power is related to the electric chair.

Out of a total of 200,000 scientists (counting only the physical and life sciences, and only at the universities), the Union of Concerned Scientists mailed its petition to 15,000 names: members of the American Federation of Scientists and subscribers to the Bulletin of Atomic Scientists, both organizations which have long since forsaken science for politics, and the latter blatantly anti-nuclear. It was much like asking the National Rifle Association what it thought of gun control; but even so, the perpetrators of this gimmick were able to gather 2,300 signatures, or 0.3% of the 770,000 scientists in the physical and life sciences, and that does not include workers in the social sciences, who are usually prominent in this type of petition.

Kendall's petition, then, was a flop in the scientific community, and a total fiasco as far as the hard sciences are concerned. Yet the Washington Post, for example, reported on this petition under the headline Scientists Urge Slowdown of Nuclear Power. And hundreds, perhaps thousands, of local papers that reprint this type of story from the Post or New York Times have used the same headline above the same pap.

As late as March 1976, the Christian Science Monitor, while admitting that the three who had resigned from General Electric were members of a para-religious anti-nuclear group, claimed that scientists were "split down the middle" on the issue of nuclear power and pointed to the 2,300 scientists who had grave doubts about it.

But what about the other side? The scientists defending nuclear power are different from their opponents in almost every respect. They have no political ambitions; they are as yet unorganized; they do not talk about vague dangers, but about hard numbers; they receive virtually no media exposure; they are far less vociferous; but above all, most of them are men who know nuclear power and nuclear hazards, not from political meetings, but from direct and immediate experience. There are as yet few scientists who have taken to the pen to address the broader public outside the readership of the professional literature to defend nuclear power. But unlike their neurologist and entomologist opponents they do know what they are talking about. Dr. Ralph Lapp,
one of the most successful popularizers of nuclear science, is a high-energy physics researcher who has been in the nuclear field for more than 30 years, starting out as a researcher under Nobel Prize winner Arthur H. Compton and successively holding a long series of distinguished appointments at various universities and government agencies, including the post of Assistant Director of the Argonne National Laboratory. He is now an energy and nuclear consultant, and senior member of a non-governmental nuclear corporation.

Dr Richard Hammoud, a nuclear physicist with more than 30 years experience with reactors and fusion waste, is a former professor at the University of California at Los Angeles and now a consultant in the energy field. Where Alfven and Kendall (let alone Tampin or Ehrlich) let their imaginations run wild with sick "what if" scenarios of nuclear accidents, Dr. Hammoud talks like this:

"If I had to contend with such material [radioactive material after a major meltdown accident] — and I have had some first-hand experience in cleaning up radioactive spills — I cannot think of a place where I would prefer to have it than underground... I would be glad to tackle the job of drilling into the spilled fuel and bring it up in small bits for recovery. This could be done safely and completely."

At the time of writing, there have been only a handful of petitions or formal declarations in support of nuclear power (for a good thing does not need such proclamations until a malicious campaign has started against it; but when such proclamations have been made in answer to anti-nuclear attacks, their authors had no trouble finding Physics Nobel Prize winners and scientists directly working in the nuclear field. The 33 outstanding scientists who signed a statement in support of nuclear energy in February 1975 were all directly connected with, and highly experienced in the field. Unlike astrophysicist Alfven, the six Physics Nobel Prize winners among them (Alvarez, Bardeen, Bethe, Bloch, Purcell, Rabi, Wigner) have had practical experience with nuclear power, and some of them, like Bethe and Wigner, are among the original developers of nuclear reactors.

When 700 scientists in Alfven's native country Sweden presented the Prime Minister with a statement supporting nuclear power, they did not have to look among the entomologists and psychologists for support. All of the 700 were active in research and technology relating to nuclear power.

The American Nuclear Society has endorsed nuclear power, of course.

Of course? 

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SPLIT — BUT NOT DOWN THE MIDDLE

No, not of course at all. For 21 years, the ANS adamantly refused to endorse nuclear power, because it was more critical of nuclear safety than any of the Johnny-come-latelies. Only in 1975, satisfied at last, the ANS endorsed nuclear power as the safest form of power generation.

So did the 18,000-member Power Engineering Society.

So did the Energy Committee of the 170,000-member Institute of Electrical and Electronics Engineers (IEEE).

So did the 69,000-member Society of Professional Engineers.

So did the National Council of the 39,000-member American Institute of Chemical Engineers.

So did the Board of Directors of the 3,400-member Health Physics Society.

25,000 scientists and engineers signed a "Declaration of Energy Independence" urging increased use of coal and nuclear power and presented it in the White House in 1975, on the second anniversary of the Arab oil embargo. The signers of the petition had a combined total of two hundred thousand man-years of experience in electrical power generation.^

The "division" among scientists on nuclear power, then, is a peculiar one. To put it brutally, but fairly accurately, it is a division between those who know what they are talking about and those who don't.

The anti-nuclear activists have a way of getting round this, of course, and a better way than the false pretense (also often used) that a large fraction of scientists is supporting them. The experts, they claim, should disqualify themselves for two reasons: One, the matter is not a technical issue, but a moral one; and two, the experts have a career at stake, therefore their judgment is clouded by a conflict of interests.

Lorna Saltzman, an official of the misnamed Friends of the Earth, puts it in the equally misnamed Bulletin of the Atomic Scientists as follows:

"No nuclear scientist with a connection to nuclear power profit making has a right to bludgeon government and citizens into accepting a death-dealing technology, a technology that puts private profits and jobs over human health and lives... All scientists having a personal stake in the development of commercial nuclear power should disqualify themselves from the nuclear power discussion and leave the field to citizens who are perfectly capable of determining what endangers them and their freedom."
We shall not meet Lorna Salzman again until the last chapter of this book, by which time I hope to have shown that it is activists like Lorna Salzman who put their unbridled lust for political power over human health and lives, and who do their utmost to brainwash citizens with amateurish sophistry to prevent them from seeing what endangers them and what protects them.

In the meantime, we will note that the conflict of interest and morality arguments are both false and vicious.

The conflict of interest argument is false because it assumes that the career of a nuclear scientist or engineer is limited to commercial power generation. It isn’t, of course. Nuclear engineering has a large number of subdisciplines — medical diagnosis and therapy instrumentation, for example — all of which are short of manpower. The argument also overlooks the endorsement by the American Power Society, only a small fraction of whose members are nuclear power engineers, and by the American Health Physics Society, which does not live by nuclear power at all, but is, by its statutes, “devoted to the protection of man and his environment from the harmful effects of radiation.”

The argument is also vicious, because it implies that a physician cannot be trusted to cure his patients, for he makes a living only if they are sick. It implies that the police favor crime, for without criminals they would not be needed.

There is no reason to doubt that there are crooks among nuclear engineers, just as there are among nudists, tightrope walkers or diabetics. But the implication that all nuclear scientists, or even a considerable fraction, would put their careers over human lives is one that is repugnant. And so is the “morality” argument. The Friends of the Earth, Ralph Nader, and other anti-nuclear crusaders have been given the facts often enough; the facts that show non-nuclear methods of power generation to be more dangerous to human health and lives. They have never seriously disputed the point; they have merely ignored it. What kind of morality is it that keeps the public death toll unnecessarily high? What kind of ethics is it that sacrifices human lives?

Among nuclear scientists and power engineers, nuclear power is supported by an overwhelming majority. Why, then, is this large number of experts rarely heard? There are several reasons. First, it has become quite common for nuclear power to be attacked by entomologists, chemists, biologists, sociologists, politicians, journalists and housewives; but only nuclear physicists and engineers are “allowed” to defend it (and even then under the stigma that they have an axe to grind), which in itself tips the scales against them by sheer numbers.

Second, nuclear physicists and engineers, being in the know, have (until recently) laughed off the anti-nuclear hysteria in much the same way as astronomers laugh off believers in a flat earth, or as mathematicians laugh off circle squarers, or as more than a century ago, railroad engineers laughed off the Cassandras who predicted death and pestilence from the railroads. Until very recently, few of them have spoken out in defense of nuclear power, and until the California Initiative campaign was well advanced, there was no organized counter-campaign to combat the anti-nuclear hysteria, certainly none with anywhere near the financial and media support the anti-nuclear crusaders are getting.

Third, and probably most important, when the pro-nuclear side tries to turn the monologue into a debate, it is ignored by the mass media, which gives such exaggerated coverage to the blatantly false accusations by Nader and other laymen.

The media bias against nuclear power is evident only to those who have investigated the issue, and remains unknown to millions of TV viewers and magazine readers. The anti-nuclear bias, however, is so strong that in many cases it amounts to censorship — not censorship of the press, but censorship by the press. When in January 1975 thirty-four of this country’s foremost scientists, including eleven Nobel Prize winners, issued an appeal in favor of nuclear power, the media, in particular the TV networks, ignored it.

“The Republic is in the most serious situation since World War II,” said their statement. “Contrary to the scare publicity given to some mistakes that have occurred, no appreciable amount of radioactive material has escaped from any commercial US power reactor... We can see no reasonable alternative to an increased use of nuclear power to satisfy our energy needs...”

Surely the content of the proclamation was newsworthy; the 34 illustrious names signed underneath, if nothing else, made the document unique. But NBC and ABC ignored it; CBS filmed a bit of the briefing by Nobel Laureate Hans Bethe, but never mentioned the statement that had preceded it. Instead, it reported on another of Ralph Nader’s warnings against nuclear power, and this was followed by a filmed report which raised questions about the economics, reliability and safety of nuclear power — leaving them unanswered, as
though the answers were not known and had not been given a thousand times.
That kind of "fairness" is more damaging, and also more common, than outright censorship as practiced by NBC and ABC on that occasion.
It is well known to professional propagandists that there is one falsehood more vicious than the outright lie: the truth, but not the whole truth. For a drastic illustration, the statement "Mr. Smith probably has not raped any women for the last five weeks, at least not in broad daylight" does not leave Mr. Smith many defenses, for if he protests that it is false, the implication is that he rapes women in broad daylight, too.
This example of the lie by the incomplete truth is, of course, drastic. The networks use this tactic far more subtly, but the underlying trick — the truth, but not the whole truth — is the same.
In February 1975, NBC aired an hour-long "documentary" on nuclear power. It never mentioned the appeal of Nobel laureate Hans Bethe and the other 33 outstanding scientists that had been issued a month earlier. The anti-nuclear opinions were given by Prof. Kendall of the Union of Concerned Scientists. The pro-nuclear point of view was represented by bits and pieces, often only single sentences, cut by an NBC editor from an interview with Dr. Dixie Lee Ray, then chairwoman of the Atomic Energy Commission. Dr Ray is, of course, very knowledgeable about nuclear power, but her name was then unknown to most of the millions of viewers, and the alternation of statements, juxtaposed by the NBC editor, came across as a "debate" between the anti-nuclear scientist and the pro-nuclear bureaucrat.
As usual, the authors of the program were careful to keep the artificial association between nuclear power and nuclear bombs alive. The whole program began and ended with a series of nuclear explosions, and the main course was full of them, too: Hiroshima, Nagasaki, Los Alamos, Bikini — the works. One wonders if a documentary on water treatment plants would have been introduced by, interspersed with, and concluded by shots of apartment building fires; after all, in both instances it is a case of oxidation.
After all these explosions, there appears Dr Dixie Lee Ray's face saying "Nuclear explosions in power plants are a physical impossibility." If she explained why this is so, the NBC editor cut it, leaving her statement looking more like an opinion than a scientific fact.
"We are not concerned only with explosions, but also with core melt-downs, which could kill a large number of people," says Kendall's
corporations do better business? And people will answer like a programmed computer, never suspecting that the question itself is a fraud.

The anti-nuclear bias is not limited to the networks or even the "liberal" press. It is all too often found in such journals as Business Week and even the Wall Street Journal. Business Week does not have a high standard in any respect, least of all in its technical reporting, so that its frequent monumental blunders and biased articles in the field of nuclear energy do not particularly contrast against, say, its exhortations to protect the airlines' anti-competitive nest under the cozy wing of the C.A.B.

However, the Wall Street Journal has a reputation of being accurate and publishing corrections on the rare occasions when it does err. That reputation is probably well deserved — but not in the case of nuclear power. The Wall Street Journal's articles on nuclear power and related subjects have included statements that were not merely inaccurate, but utterly false; and in none of these cases did the editors correct the errors when they were pointed out to them.

There is, for example the "case of the 23 nuclear power plants, a case of a colonial, but not at all unique, exaggeration. What had actually happened was that in January 1975 a worker at Commonwealth Edison's Dresden Unit 2 in Illinois had discovered, by visual inspection, a hairline crack in a pipe of the emergency cooling system. The crack was so small that it did not leak any moisture. If it had leaked, the automatic monitors would have detected it. And if they hadn't detected it, and the water had leaked out, still nothing would have happened, for the pipe belonged to the back-up cooling system that just stands by in case the primary system should fail. How much radioactivity would have been released? None; the water in this cooling system is as radioactive as the water you drink with your lunch.

In any case, all that did in fact happen was that a worker discovered, by visual inspection, a hairline crack in the pipe. The "incident" (yes, a minute abnormality of this type is classified as an "incident" in the nuclear industry) was reported to the Nuclear Regulatory Commission, and what the Commission did is noteworthy for the super-strict standards of nuclear regulation. It ordered all nuclear plants in the country with the same type of pipe shut down for inspection. There were 22 such plants besides Dresden 2, and by April 1975, all but one of them had been inspected after scheduled shut-downs (the 22nd was granted a delay because of a potential power shortage in its area). No cracks were found in any of the remaining 22 plants.

However, that one hairline crack that leaked no water at Dresden 2 became, in the Wall Street Journal's words, "mysterious cracks appearing in the cooling systems of reactors at 23 plants;" and while it is true that it was not the only and by far not the worst misinformer on this occasion (the New York Times wrote about failures and consequent shutdowns at 23 plants, for it evidently trusts Nader's hoaxes more than the detailed NRC reports), it once again did not print a correction when the error was pointed out. It would be nice to think that on this and several other occasions, the Wall Street Journal merely misinterpreted something about which its editors know less than nuclear engineers know about stocks and bonds. But that theory must be discarded, for its writers are just as bad when nuclear matters are not linked to but are as non-technical as murder. In a center-page article on plutonium by Burt Schorr, a member of the Wall Street Journal's Washington Bureau, one can read (among several false assertions) about the mysterious fate of an Oklahoma plutonium plant worker, Karen Silkwood, whose body had registered dangerously high plutonium levels, who had been a union activist, who had charged lack of safety provisions in handling plutonium, and who was killed in an auto accident on the very drive she took to meet a newspaper reporter who was investigating plant conditions. The article reports more union charges and is so written as to make the reader suspect foul play. (Nader's "Critical Mass" organization holds memorial ceremonies by candle light for Karen Silkwood.)

Schorr's article does indeed sound ominous — until one examines the rest of the evidence. The Oklahoma state highway patrol reported that an autopsy revealed traces of alcohol and methaqualone (a sedative) in Silkwood's blood, making it most probable that she had dozed off at the wheel (she was killed on the highway by hitting a culvert). But more important in Mr. Schorr's non-technical omissions is his failure to mention the report by a special AEC commission which investigated the union charges of lack of safety. Of the 39 union charges, the commission found only 3 in violation of the tough AEC standards, and the report threw some light on the actions of Karen Silkwood. The monitoring equipment caught her leaving the plant with dangerous amounts of plutonium on two consecutive days, although there had been no accidental release at the plant, and the commission found that her contamination, which included ingested (excess) photo-
nium, "probably did not result from an accident or incident within the plant." Moreover, two of the urine samples that she had brought in for inspection and that turned out to be radioactive were proved to have been contaminated after they were excited, so that they must have been doctored by "someone." Though the careful wording of the commission's report does not say so explicitly, the obvious suspicion is that the urine samples were doctored by Silkwood herself.

Schorr's article made no mention of the commission's existence, report or findings. And that is not poor physics; it is poor journalism. But why pick on the Wall Street Journal when there are so many more and much more blatant examples? The reason is in the little word "even." Even the Wall Street Journal, which on so many other occasions has bucked the fashionable trend, has fallen for Nader's hoaxes, has participated in the anti-nuclear hysteria, and has practiced the new brand of journalism. One does not expect any better from the lesser papers, but when the Wall Street Journal writes that plutonium is "a fuel toxic beyond human experience," it is perhaps time to be alarmed.

Not that I suspect its editors, or even Mr. Schorr, of deliberate foul play. What I suspect is that the nuclear opponents have become so vociferous and numerous (among journalists especially) that when the editors are faced by expert complaint, they no longer know who is right, and they play it safe. For things are so far gone that the hoaxes are "safer" than the truth. Few people outside the networks' newsrooms or the editorial offices of the bigger publications know the details of how these hoaxes and distortions get onto the TV screen or into print, and I claim no special knowledge on the point. But there is at least one instance that has been described in detail by an immediate witness who was, at the time, Promotion Director of Look magazine. He is Melvin J. Grayson, who together with former Look publisher Thomas R. Shepherd authored The Disaster Lobby, 1 a book on the follies of environmental extremism. It includes a chapter on the role of the media, aptly named "The Closed Fraternity," and among the episodes described in it is one concerning an anti-nuclear propaganda piece authored by Look senior editor Jack Shepherd (no relation to author Shepard) in 1970.

The article was called "The Nuclear Threat Inside America" and was a string of vicious halftruths — for example, the statement that in 1966, there were 37 accidents at nuclear plants in the US and 6 of them had more than one. What Shepherd did not say was that neither in 1966 or in any other year (up to the present) had there been any reactor-related fatalities in any nuclear power plant. But there may very well have been accidents in 37 plants — a truck backing into the loading dock, for example, or a worker catching his heel caught in a revolving door. None of which is contained in halftruth or half lie.

When Look Promotion Director Grayson saw the stats of Shepherd's article, he was intrigued one of a of —. Some 325 workers at the AEC Flats have been contaminated by radiation since 1953. Cancer; 14 have died." Now Grayson is no on nuclear power; in even in the book he seems unaware that Flats is a weapon that has to do with nuclear power. But had previous with Shepherd's brand of the 14 cancer deaths him. What exactly was the meaning of that figure in a that employed hundreds of workers and had been in operation for 17 years? He did some checking, and found that the cancer death rate at Flats was no higher in nudist colonies or stock exchanges, in fact, it was lower than the cancer death rate for all American adults (presumably due to the inspections and preventive health care).

Of course, if you will re-read Shepherd's original statement, you will see that he never told a lie, just as he has not raped more than three women in the last two at least not in broad daylight.

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The other allegations were equally truthful, and Grayson pointed out the many halftruths and three-quarter lies in the Shepherd piece to V.C. Myers, President of the Look Division of Cowles Communications, suggesting that something be done about it. "Myers," reports Grayson, "exerted all the pressures he could, but to no avail. The editors, with total dominion over the editorial content of the magazine prevailed, and the Shepherd article went to press in its original form.

Grayson reports a number of other hair-raising distortions (not connected with nuclear power) that were published in Look, in all cases after the authors had been presented with the facts, so that it was not a question of error or incompetence, but of deliberate distortion. Yet look, says Grayson, was not particularly culpable; "the amount of bias in its editorial department was about average for the period."

There was no conspiracy, no meetings on how to slant the no instructions to encourage bias. "What created the bias was the fact that most of Look's editorial much the same lines and those lines skewed to the left. .. The men and women who detested business the eC()10JiZ1Clal and consumerism reformers .. "

SHEPHERD'S CANCER
AND that, one might think, leaves only the scientific and technical journals to be trusted.

Alas, not necessarily so. Only a very small part of electrical engineering (even of power engineering) is nuclear, and only a very small part of physics (even nuclear physics) is concerned with the generation of power. Only 20,000 of the IEEE's 170,000 members belong to the power engineering group, and only a fraction of these work in nuclear power. The remaining groups range from antennas and computers all the way to small of nuclear engineers. These engineers and physicists (let alone biologists, chemists or mathematicians) know little about nuclear power unless they make a special effort to learn about it; yet many of them live in the atmosphere of academia, where the ideologically motivated bias against nuclear power is rife, and the imbalance is reflected in some of the scientific journals. Not in the actual scientific papers; but in the news and comment sections.

Consider a typical case, Science.

In the late sixties, when it was the fashion for young radicals to pelt the presidia of various organizations with eggs and tomatoes at convention time, the presidium of the American Association for the Advancement of Science got pelted with eggs and tomatoes at convention time. It was also the fashion to condemn and capitulate; and the AAAS condemned the hooliganism and largely capitulated to it. If the radical punks no longer pelt the AAAS with eggs and tomatoes, it may be because they no longer need to: The AAAS weekly Science, in its news and comment columns, has grown societally relevant, involved, legitimate, conscious, concerned, aware, sensitive and progressive.

Nuclear news was until recently covered by Robert Gilette (he has now been awarded a year-long fellowship in journalism at Harvard), whose anti-nuclear bias is ill-concealed. Bethe appeal by mentioning it. It was and then most of the to Nader had to say about it. The whole item was tucked away among other run-of-the-mill news. But when Nader and Kendall delivered their gimmicky petition (p.17) to the White House in 1975, this non-event rated two thirds of a page in a box and an headline over a Robert Gilette with the halftruth "The American research community is of polarization over nuclear power." Gilette also gives on the budget of a pro-nuclear Washington lobby, never that Nader's anti-nuclear lobby spends some a year, and finally this Harvard-fellowship winning characterizes the formed Americans for a group spon- sored by nationally known scientists, labor leaders and military men, as an organization "whose contributors range from Westinghouse Corporation to a passel of utilities." In all of these halftruths the implication is that the nuclear "debate" is one between scientists and the big corporations.

Note that I am discussing Gilette's not his scientific competence. The latter was revealed he
I. THE NUCLEAR MONOLOGUE

Since Gillette left for Harvard, his brand of journalism has been ably continued by P.M. Boffey. Science has given space to the portrait of Ed Koupal, the sponsor of the California Nuclear Initiative, who says "The only physics I ever had was Ex-Lax," and when Daniel Ford, the non-scientist from the Union of Concerned Scientists, complained that the Scientific American had refused to let him and Kendall attack an article by Nobel Prize winner Hans Bethe, Science spread this totally unjustified complaint under an 18-point headline spreading across two pages; a strange practice for a journal that has censored pro-nuclear news, such as a proclamation by 11 Nobel Prize winners.

Gillette's pseudo-journalism is, of course, more damaging than that of the gutter press, since it carries the prestige of being printed in a scientific journal. Whether this prestige is still justified is debatable; where nuclear disasters or the glorification of Ed Koupal is concerned, The National Enquirer and Hustler have shown more reticence.*

I WILL take good care to separate the comments on the Bulletin of Atomic Scientists by a new paragraph, for it is a purely ideological-political publication that attempts to masquerade as a scientific journal. Masquerade and deception are, indeed, its hallmarks, for it is not only published under a totally misleading title (it has long been edited by a non-scientist and atomic scientists usually write in it only to refute its alarmist science fiction), but it also carries a proud list of sponsors including Albert Einstein, Hans Bethe, A. H. Compton, Leo Szillard, and other famous scientists. These did, indeed, sponsor the journal in 1945; but when they no longer live, and those that do, either write there to dissent (Hans Bethe) or have themselves forsaken science for politics (Linus Pauling). The most prolific contributor is one D.D. Comey, a Kremlinologist who masquerades as a scientist and, as head of an outfit called "Businessmen for the Public Interest," as a businessman as well. His amateurish sophistry, when refuted by reputable scientists, is given the last word in rebuttal; and when he himself attacks a scientist, he is given the last word again.

The flavor of this "scientific" journal is perhaps best captured by looking at the contents of a single issue (February 1976): "Secrecy and

* I have to eat my words here, for since I wrote this, the National Enquirer (2/17/76) ran a page-wide headline The Horrifying Day A-Burning A-Plant Threatened 11 Million Americans with subtitle People in 9 States Only Minutes From Death. The hair-raising horror story underneath was transparently based on D.D. Comey's version of the Browns Ferry fire (see Chapter 3). Security." (Editorial); "Covert Action: Swampedland of American Foreign Policy" by Sen. F. Church (Insert, in a colored box, a poem called "National Anathema:" Oh C.I.A. can you see / By the Chile dawn light / How profoundly you failed / In your late great scheming ... etc.); "The Week We Almost Went to War" (an article claiming that the Cuban missile crisis was unnecessary and provoked by the US); "The dangerous drift in uranium enrichment;" a four-page advertisement to join and contribute money to the Continental Walk for unilateral nuclear disarmament; and so forth up to the inevitable Comey who argues the public risk from uranium tailings over the next 80,000 years.

And this is the journal quoted incessantly by the nuclear critics with the implication that the quote has scientific authority! It is also the journal from whose subscribers Ralph Nader selected names to which to send his petition against nuclear power, and then boasted of "2,300 scientists" who signed it. Lorna Salzman's in this and other chapters are, of course, taken from that journal, too.

T HE foregoing observations were intended to show that there is no nuclear debate, only a monologue by anti-nuclear laymen. But the truth is that in an objective and dispassionate there could not be much of a debate, at least not between people who share some fundamental values such as the sanctity of human life and the need to minimize the health hazards in an industrial society.

For nuclear power is not abortion, inflation, crime abatement or minority rights, where the problems - let alone the solutions - are ill-defined, unquantifiable and truly controversial. The problems of power are measurable and well understood. There are viable solutions to of them. When the debate a - such as nuclear waste disposal - the reason for the debate is not the absence of a solution, but the number of satisfactory alternatives.

But to make that point, one does not have to compare nuclear power with crime abatement. It is sufficient to compare it with fossil-fired power. Strange as it may seem, far more is known about the health hazards of nuclear power than about those associated with fossil-burning plants. For example, we do not know the exact extent to which some diseases are caused by air pollution, we do not know the exact relative contributions to air pollution by industry and the automobile,
we do not know how to stop air pollution by fossil-burning plants entirely (except to go nuclear), and we do not even know how to accurately measure all of the pollutants emitted by the stack of a fossil burning plant. Recent experiments on the blood of blood donors in large cities, analyzed on weekdays and Sundays, have even challenged the "obvious" assumption that the automobile is the major contributor to photochemicals in the atmosphere and that natural vegetation is not a major contributor to hydrocarbon pollution; and while this is not yet established, the controversy shows how fundamental the gaps in our knowledge about air pollution are.

Not so with nuclear power. The basic hazard is the release of radioactivity, and the effects of radiation on the human body are unusually well understood. Unlike chemical pollutants, which cause cancer and a multitude of other diseases, radioactivity by accidental release from a nuclear plant can cause only two diseases — cancer and radiation sickness (genetic mutations are so improbable that they are omitted in this brief introduction), and unlike the case of pollutants by fossil-burning plants, the relationship between exposure to radioactivity and the incidence of these diseases is firmly established — and not merely by qualitative criteria, but by quantitative relations in hard numbers.

Given these hard numbers of the risks to human health and to the environment associated with nuclear power, and comparing them to the somewhat fuzzier, but still unambiguously high, numbers of the risks associated with other forms of energy conversion, nuclear power emerges convincingly as the safest.

Moreover, nuclear power emerges not as the safest in some aspects, but the safest in all aspects, not excluding terrorism and sabotage, and certainly not excluding major accidents and waste disposal.

That is why there could not be very much of a debate if there were a debate and not a monologue.

However, in the din of the nuclear monologue, the pro-nuclear peeps are difficult enough to hear; but even so, not too many of the peeps have been concerned with the comparison of risks. More often they have compared the risks with the benefits.

That may have been a mistake. If large sections of the population oppose nuclear power, it cannot be entirely due to Shephard and his colleagues in the Closed Fraternity. Of course the Shepherds have it easy. People do not suspect bakers of putting poison in their bread, because they have a rough idea of how bread is baked; but when it comes to neutrons, isotopes, plutonium and fusion products, they have a fear of The Unknown and it is easy for the Shepherds to plant absurd associations between nuclear bombs and nuclear power in their minds. Yet people have grown to accept very dangerous things, such as gasoline refining and air traffic control, about which most of them do not know much, either. And a considerable campaign against the fluoridization of water did not manage to scare them. So something else must be wrong.

It may well be that what is wrong is the nuclear advocates' tactic of weighing the risks of nuclear power against its benefits. There is nothing wrong with that in itself, for such analyses have been made frequently and nuclear power has always come out with flying colors. But these analyses have not managed to reassure everybody.

And no wonder. To say that "a major nuclear disaster every 10 million years is worth the benefits of electric power" is, first and foremost, not a matter of fact, but a matter of opinion, a subjective judgement of values. It is not at all quantifiable and it is highly debatable, especially by one who does not know what else is involved.

To say that "Everybody, consciously or not, weighs risks and benefits every time he gets into a car or an aircraft" is doubtlessly true, but it leaves room for many Yes, but's.

"Yes, but I take these risks voluntarily, nuclear power is forced on me."

"Yes, but an air crash involves tens of a nuclear disaster would involve thousands."

It so happens that both of these sample objections are erroneous. (They are erroneous: When a woman is about to have a baby, how much choice does she really have [in America] whether to walk to the hospital or to go by some gasoline-powered vehicle? And as for aircraft crashes, almost every year there is one with more than 100 deaths.) That is there could not be very much of a debate if there were a debate and not a monologue.

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But these have not to reassure anybody. And no wonder. To say that "a nuclear disaster every 10 million years is worth the benefits of electric power" is, first and foremost, not a matter of fact, but a subjective judgement of values. It is not at all quantifiable and it is highly debatable, especially by one who does not know what else is involved.

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It so happens that both of these are erroneous. When a woman is about to have a baby, how much choice does she have (in whether to walk to the hospital or to go some vehicle? And as for aircraft crashes, almost every year there is one with more than 100 deaths)
Instead of comparing the risks of nuclear power to its benefits, this book will compare the risks of nuclear power to the risks of any other form of energy conversion.

The statement "Per billion megawatt-hours of generated electricity, generated by the corresponding fuel, either 1036 coal miners, but only 20 uranium miners lose their lives" is not a statement of opinion or a subjective judgement of values, but an assertion whose truth can be checked out by universally accepted methods; it deals with hard, measurable, verifiable and comparable numbers. I have no doubt that Ralph Nader has a "yes, but" in retort, but I do not believe it can be very convincing, especially when other, similar statements of risk comparison are considered.

Such a comparison has at least two advantages: First, it compares quantities of the same dimensions. In comparing risks to benefits, one sooner or later runs into the question of how many dollars a human life is worth. In comparing risks only, we shall compare probabilities to probabilities, deaths to deaths, injuries to injuries, and disease incidences to disease incidences. We shall never have to compare apples with oranges.

Second, the comparison will rid us of some irrelevant problems, such as energy conservation. Nuclear power is unnecessary, claims Nader, because we don't need any more energy if we cut our demand sufficiently. The argument is false, but we need not go into it, for besides being false, it is also irrelevant. Indeed, suppose that it were feasible to cut US energy consumption by 50% (which I do not for a moment believe); shouldn't we make sure that the remaining 50% are supplied by the safest possible method?

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**Some Basics**

Plutonium was named for Pluto, the god of hell. It is arguably the most toxic substance known.

Dr Elise Jerard, chairperson of the Independent Phi Beta Kappa Environmental Study Group.

When things went awry at the Enrico Fermi reactor near Detroit, four million people went about their business in happy ignorance, while technicians gingerly tinkered with the renegade's invisible interior. They knew what the public did not—a mistake could trigger a nuclear explosion.


The real dangers of a nuclear power plant arise when something goes wrong, and just like medical students must learn anatomy before pathology, so we must take a quick look at a healthy nuclear plant.

Electricity is, most often, produced by moving a conductor in a magnetic field, and that is essentially what is going on in an electric generator; for our purposes it is sufficient to think of an electric generator as something that produces electricity when its shaft is turned. The turning is done by a turbine on the same shaft; the whole arrangement is known as a turbogenerator.

The turbine, if it is a hydraulic turbine, is turned by water rushing through it from a reservoir behind a dam. But only about 12% of the US electric capacity is hydroelectric, and the fraction is growing smaller as the total capacity grows and the US is running out of sites to dam rivers.

The great majority of power plants are thermal plants: Their turbines are either steam or gas turbines. Steam is, of course, itself a
Sometimes the water is taken from a nearby river and returned to it after it has been heated in condensers. This may warm up the river a few degrees, and has been the ludicrous name of "thermal pollution." The warmer water does indeed drive out some of the life for which the water had been too cold. The warmer water does not kill a habitat for other species for which the water had previously been too cold. The warmer water does not kill aquatic life; it merely shifts the spectrum of species, and very slightly at that (see Chapter 5). Contrary to popular belief, a nuclear plant does not produce much more waste heat than a fossil-fired plant of the same capacity: The most efficient nuclear reactors perform to within two percentage points of the most efficient fossil-fired and the average reactor performs to within two of the average fossil-fired plant (Chapter 5).

"Thermal pollution" is mostly an abuse of language; it has as much pollution as the East European "people's democracies" have democracy.

Another and more common way of preserving most of it to go back to is to let it cool in a cooling tower, where it gives up its heat to the air drawn up its heat to the air drawn past it by natural draft or fans. Towers are most often high concrete structures, often with a white plume of "smoke" coming out of it; on cold days with high relative humidity that rises into the sky and can look like a cloud to local ecologists to protest indignantly about air pollution. But the plume is merely condensed water vapor, the same stuff that clouds in the sky are made of. The pollutants of a fossil-fired power plant do not come out of the cooling towers, but out of the stack (a nuclear plant doesn't have one); and the deadliest pollutants are invisible.

To complete this rough description of a power plant, there remains the first link in the chain: the heat that turns water into steam. In a conventional plant, this is provided by burning a fossil fuel — coal, oil, or gas — under the boiler; the hot combustion gases heat the water tubes of the boiler, though much of the heat is wasted and escapes through the stack.

In a nuclear plant, the heat turning water into steam is generated by a nuclear reactor; the steam then turns the turbogenerators in the

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same way as fossil-fired plants. And that is the first thing to note about nuclear power: Strictly speaking, there is no such thing as nuclear electric power (at present, anyway); there is only nuclear heat, and that heat is used to generate electricity in the same way as in fossil-burning plants. There is no difference in the electricity supplied to the consumer; it may have been produced by either type of plant, and most often it is produced by both — by both types of plant working into a common grid that distributes power to consumers.

There is a nuclear plant now under construction in West Germany that will use hot helium, heated in the reactor, to drive the turbo-generators; but otherwise the world’s commercial power plants using nuclear power use steam to run the turbines. However, even in that German plant the electricity produced will be the same as any other.

The heat produced in nuclear reactors can, of course, be used for other purposes than generating electric power. It is used, for example, for propelling ships and submarines giving them great ranges of operation without refueling, and there are plans for nuclear steel furnaces, for example. However, we shall be concerned only with the issue of generating electric power commercially for civilian use.

To see how a nuclear reactor generates heat, we have to review some elementary physics.

The smallest entity of a chemically homogenous substance — distilled water, say, or pure kitchen salt — that still has the same physical and chemical properties as the substance in bulk is called a molecule. In all but a handful of cases, a molecule is a combination of atoms, of which there are 92 different kinds in nature; they are the atoms of the elements. The lightest atom is that of hydrogen, the heaviest among the natural atoms is uranium. Beyond uranium there are the “transuranic” elements that do not normally occur in nature, but can be artificially produced; one of them is the element plutonium.

Each atom consists of a positively charged nucleus and a shell of negatively charged electrons. In most artists’ conceptions, from comic strips to trade marks, the atom is depicted as a little solar system with the nucleus in the middle and the electrons whirling round it along planet-like orbits. That is not the correct model of the atom, but it will do for our purposes.

The nucleus of an atom is very much heavier than its electron shells — many thousands of times heavier. However, the negative electric charge of the electron shell, in a stable atom, just equals the positive charge of the nucleus, so that the two charges cancel and the atom is electrically neutral.

For example, an oxygen molecule consists of two oxygen atoms; each oxygen atom has 8 electrons whirling round the nucleus whose positive charge equals, except for the opposite sign, the 8 negative electron charges, so that the entire atom is electrically neutral.

To “split the atom” is easy; it is far more difficult to split the nucleus. Indeed, to split the atom, it is sufficient to tear one or two electrons from the shell, and this is done quite easily (for example, in a fluorescent light). To split the nucleus is a different story.

There was a time when people thought that the nucleus consisted only of protons, particles having the same charge as an electron, only positive, but much heavier (about 2,000 times heavier). But in 1932, the existence of another particle was demonstrated: the neutron, which is just as heavy as a proton, but has no electric charge. The presence of a neutron in the nucleus will thus make the atom heavier, but will not disturb the electrical balance between the nucleus and the electron shell.

It would have been a simple world if it had remained at that. But as time went on, more and more nuclear particles were discovered, and more are being discovered all the time. The “nuclear zoo” is now so large and the number of its members so great that it has theoretical dis-
The atomic number is unaffected by the neutrons that may be present in the nucleus; so what do they do? Chemically, nothing. A hydrogen atom with a neutron in its nucleus (in addition to the regular proton) still combines with oxygen to form water, or with chlorine to form hydrochloric acid. What the neutrons do is change some of the nuclear properties of the atom. Obviously, they increase the weight of the nucleus; the "mass number" of the atom, which is the number of protons plus neutrons, or simply the weight of the nucleus in multiples of one proton, will increase by one with every additional neutron. (The atomic mass number is not quite the same thing as atomic weight, but let's not walk off into that side street.)

As far as we are concerned here, the mass number does nothing except to provide us with a convenient way of classifying the different types of chemically equivalent atoms. "Different types of chemically equivalent atoms" can be expressed by a single word: isotopes. Isotopes of an element are atoms with the same atomic number, and therefore with the same chemical properties, but with different mass numbers. Isotopes of the same element have the same number of protons, but different numbers of neutrons in their nucleus.

For example, the isotopes of hydrogen (atomic number 1) are hydrogen proper (1 proton, mass number 1), deuterium (1 proton + 1 neutron, mass number 2), and tritium (1 proton + 2 neutrons, mass number 3). Hydrogen isotopes have their own distinct names, the only ones to be so honored. The isotopes of the other elements do not have distinct names; their mass number is simply added to the chemical symbol. For example, the isotopes of carbon (C) are C12, C13, C14. Since the atomic number of carbon is 6, carbon 14 has 6 protons plus 8 neutrons in its nucleus.

Different isotopes of the same element are chemically indistinguishable, because chemical effects are associated with the electron shell. The difference affects only nuclear properties, in particular, whether the atom is radioactive or stable, and whether it is fissile or not. (We will use fissile and fissionable interchangeably, though professional jargon makes a slight difference between them.)

Radioactivity is a subject that will interest us shortly, especially its effects on the human body. At this point it is enough to say that it amounts to radiation of different types that is emitted when a nucleus disintegrates or decays. In some elements, such as uranium or radium, the decay is natural and proceeds without man-made prodding. In other cases, radioactivity may be artificially induced, most often by shooting a neutron into the nucleus and causing it to fall apart.

The latter case is of interest for self-sustained fission of nuclei. As the nucleus splits into two or more fragments, it may also emit one or more of its neutrons. If these neutrons are absorbed by other nuclei, they will split in turn and emit more neutrons for further splitting of other nuclei. A multiplicative chain reaction will take place. And each time a nucleus splits, energy is released — at least in the nucleus at the heavy end of the table of elements. The released energy was previously pent up in binding the nucleus together.

There are only four types of nuclei that are thus fissionable, and only one of them occurs naturally in significant quantities: uranium 235, i.e., the isotope of uranium with mass number 235 (92 protons plus 143 neutrons in the nucleus). The average number of neutrons available for causing further fissions of a U 235 nucleus lies between 2 and 3, depending on the energy of the neutrons. (The actual number in an individual fission is, of course, an integer; the mean number is 2.07, and the fractional part is due to averaging over the various possibilities in a fission.)

Of course, in practice the two neutrons generated in a fission do not both cause another fission in U 235, even if it were possible to get a quantity of perfectly pure U 235. A lot of other things besides absorption by another U 235 nucleus can happen to a neutron; for example, it can simply fly out of the volume containing the uranium into the adjacent air or other medium.

This is a good place to discuss the A-bomb, made of U 235 or plutonium; not because it has anything to do with nuclear power, but to see why a nuclear explosion cannot possibly take place in a power plant.

In a uranium bomb, the material is purified ("enriched"), at great cost, to more than 90% U 235. In natural uranium ore, almost all of the uranium is U 238, which is not fissionable. The uranium contains only about 0.7% of the fissile isotope U 235, and this small fraction must first be increased, i.e., the uranium enriched, to 90%.

Even so, in a small amount of 90% enriched uranium, there will be no chain reaction, because most of the neutrons shooting out of the nuclei after each fission will simply leave the uranium instead of hitting other uranium nuclei. To get a multiplicative chain reaction, the average number of neutrons absorbed by other nuclei per fission of a nucleus must be greater than one. There must, therefore, be enough of the material, in the form of a sphere (largest volume to surface ratio), to ensure that most of the liberated neutrons will be absorbed by other nuclei before they can escape from the volume. If the sphere can be
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The world of nuclear power is large enough to see; we are used to the idea that the harder we hit something, the more it is to break. It is the impact velocity of a hammer that will crack a nut. But nuclei are not nuts, and they live by different rules. A U 235 nucleus is likely to absorb a slow neutron before it. So if we must absorb one before it will split, like a political agitator who sets out to divide a community from door to door, he may be able to achieve a small result: he is less likely to achieve a small result. He quickly drives through the town in a van. And most of the time he will have no effect either way. So it is with neutrons, and to make them more effective for the uranium nuclei, only 30% of which are anyway U 235 must first be slowed down from the velocities with which they were emitted in the fissions that them. This is done by a material that does not absorb the neutrons, but bumps uranium with a slower velocity. Among the materials that are carbon, beryllium, carbon, but above rather than in water, for neutron reflection is a moderator. After the two things happen: The neutron is slowed down by it, which was the main idea, and the particle that got bumped in the moderator is now itself set into motion. But motion of a particle — up to a molecule — is simply heat: The difference between hot water and cold water is simply that the molecules of the former are wiggling around much faster than those in the cold water. The moderator, then, will heat up under the constant bombardment of the neutrons coming out of the uranium (and even more by the heat from the fuel rods). Some of these neutrons will be reflected back into the uranium, and having given up some of their energy, they now move...
more slowly and are more likely to be captured by a U235 nucleus. If that causes that nucleus to fission (it doesn’t always), the results are, among other fission products, fast neutrons ready to undergo the same treatment. The other fission products, too, collide with whatever they run into (moderator, fuel, other fission products), again turning their kinetic or motional energy into heat. That is essentially how nuclear energy (the energy needed to bind nuclear particles together into a common nucleus) is converted into heat by fission.

The process may or may not continue: it can die out, or it can just be self-sustaining, or it can grow more intensive. Just like a nation grows, remains at a steady population or dies out depending on its average fertility rate (number of children born per 1,000 women of child-bearing age), so the process of fission depends on the number of neutrons produced by one generation of fissions and capable to produce the next generation. If the number of neutrons produced in the next generation is the same as in the last, the process is self-sustaining and heat will be produced at a steady rate; this state is called critical. If the next generation produces less neutrons than the last, the process will gradually die out, and the state is called subcritical; an increase of neutron generation, and therefore of heat production, corresponds to a super-critical state.

The rate of heat production can thus be controlled by controlling the number of neutrons that are allowed to begin the next generation of fissions, and this can be done quite easily by material that absorbs neutrons (and does not fission). There are many materials that have this capability, for example, boron, cadmium, or hafnium.

By inserting such neutron-absorbing material between the uranium and the moderator, the neutrons coming out of the uranium, instead of being slowed down, will be taken out of circulation altogether. In practice, the neutron absorbing material is in the form of control rods, which can be moved so as to let more or less neutrons from the fuel reach the moderator. This provides a continuous range of power output, from total shutdown to capacity power. For any position of the control rods, the process is entirely stable and predictable.

NOW let us take a brief look at how these physical principles are applied in engineering practice. The fuel — uranium oxide — has the form of pellets, which are inserted into stainless steel or zirconium tubes. The resulting “fuel rods” are mounted vertically and parallel to each other to form a precise pattern in the reactor core. The control rods can be slid in or out between the fuel rods; the remaining space is filled by the moderator, and the entire core is surrounded by the reactor vessel, about 20 feet in diameter and 45 feet high, weighing several hundred tons.

There are many types of reactors, but the two types most commonly used in the US at present are the Boiling Water Reactor (BWR) and Pressurized Water Reactor (PWR). Both use water as a moderator, and both use water for a double purpose: moderator and coolant. The water surrounding the fuel heats up, slowly or quickly depending on how far the control rods are pulled out of the core, and the hot water generates steam to drive the turbogenerators.

In a boiling water reactor, the water in the core is brought to a boil and its steam feeds the turbines directly. In a pressurized water reactor, the water is kept under pressure in a closed circuit, so that it cannot turn into steam. It transfers its heat in a heat exchanger (steam generator) to another water circuit, where the secondary water is turned into steam to drive the turbines.
Once the steam has been produced, the generation of electricity is the same as in a fossil-fired power plant.

There are other types of reactors, e.g., the High-Temperature Gas Reactor, which uses a gas (helium) as a coolant; it is both more efficient and safer than light water reactors, and it could be the reactor of the distant future. However, as yet, there have been only two such reactors in commercial operation in the US, and we shall err on the safe side by ignoring this and other types of reactors. Except for breeder reactors, they all work on the same basic principles as the light water reactors. (Light water; "heavy" water contains deuterium rather than hydrogen and is used in the Canadian CANDU reactor, but not in the US.)

The brief description above concerns only those components of a nuclear plant that are essential to its operation. Added to this are the numerous components that serve to enhance the safety of operation. The one that first hits the eye is the containment building, a huge, massive, "fortress-like" structure surrounding the reactor vessel. It is made of four-foot-thick, heavily reinforced and steel-lined concrete. It would protect the outside world from radioactivity released by a reactor after a melt-down; but it also protects the reactor from the much more likely disasters that threaten the reactor from the outside world, such as hurricanes, tornadoes, earthquakes, and aircraft crashes. The tough AEC (now NRC) regulations require the containment building not only to withstand gales of more than 180 miles per hour, but even jetliners crashing into it at landing speeds.

Incidentally, the material and structure of the containment building is not unlike the U-boat pens built by the Germans on the French coast during World War II. In spite of savage round-the-clock bombing and the use of special "blockbuster" bombs, the Allies failed to crack them. This is a thought that comes to mind in view of the latest scare by the nuclear critics—what if civil war comes to America? It is very doubtful that the AEC had this possibility in mind when it drew up the regulations, but it so happens that even in that case nuclear reactors would be safer than most other places—certainly much safer than the neighborhood of large storage facilities of oil and natural gas, for example.

There is only one type of major accident that can happen at a nuclear plant qua nuclear plant, and that is the release of radioactivity. A steam turbine could, of course, be accidentally damaged, or for that matter, the mail truck could run over the security guard at the gate, but these are not accidents peculiar to a nuclear plant. The
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real danger is release of radioactivity — nuclear explosion, as we have seen, is pure horror fiction. The most dangerous accident is LOCA — Loss of Coolant Accident which may (or may not) be followed by a melt-down of the core, which in turn may (or may not) be followed by the release of radioactivity out of the containment building, and that may (or may not) result in deaths among the general public. Even then, however, the corpses would not pile up in the streets as depicted in the sick fantasies of the alarmists, for these deaths would be long in coming — weeks or more for radiation sickness, and 10 to 45 years for cancer.

However, we leave these unpleasant details for later, when we shall compare them with the far more unpleasant details of major accidents associated with fossil-burning plants. In this brief survey of a healthy nuclear plant we will only mention that the reactor vessel — itself a steel vessel with walls between 6 and 11 inches thick and weighing 450 tons — has welded into it not only pipes providing the entrance and exit of the coolant (water), but also the pipes of the ECCS — the Emergency Core Cooling System. This is a system with independent pipes, independent water, independent pumps, and even (if the need arises) with an independent power supply, which forces the cooling water into the reactor vessel if for some reason the regular coolant should be lost — for example, by a pipe of the water circulation system bursting. The ECCS is activated automatically by monitors watching over the state of the reactor, but should the automatic system fail, there are provisions for manual control.

If this were a book on nuclear safety (rather than a book comparing nuclear hazards to alternative hazards), there would follow a long list of the many other safety measures, safety equipment, safety regulations, and a description of the safety philosophy on which all of these are based — defense in depth, redundancy of components, and many more, leaving a minimum to human decisions and providing safeguards if human error does occur. But this is not a book on nuclear safety, and so we will forgo this list, which has been enumerated very often, and with all too little effect on the public.

To give just a little idea of what is involved, we will only take a quick look at how the control rods shut down the reactor automatically if something goes wrong. It is a very unimportant example in itself, but it illustrates the philosophy on which safety measures are based, a philosophy that is also applied in ordinary passenger elevators.

Roughly 120,000 Americans die in accidents every year. The no. 1 killer, of course, are motor vehicle accidents, with some 50,000 deaths; the no. 2 killer is less well known — accidental falls, which in some years kill as many as 20,000. The remainder are aircraft and railroad accidents, poisoning, fire, electrocution, explosions, firearms, blows by falling objects, snake bites, and a lot of others.

Some of these deaths are freakish — people freeze to death by getting accidentally locked into refrigerators, or they are killed by an aircraft crashing into their house. But there is one type of accident remarkably absent from the list — people plunging to their deaths in passenger elevators. Why? Only a small fraction of Americans ever handle firearms, yet some 3,000 are killed annually accidental discharges (not counting homicides and suicides). But everybody, at some time, has used an elevator, and millions use one several times a day. Why aren’t people plunging to their deaths by the thousands?

Because of the regular inspections enforced by law? Hardly; if it were that simple, there would be no failures of critical components in automobiles. The reason is that every elevator has a gadget that prevents it from plunging down the shaft — powerful jaws that grip the guide rails of the cabin and stop it from dropping. And why does this gadget hardly ever fail to work? Because it is not activated when something goes wrong, but it is kept inoperative only if everything is right. For example, the jaws are directly connected to the cable on which the cabin is suspended, and the tension of the cable keeps the jaws inoperative. If the cable should snap, or lose its tension for some other reason, the jaws return to their “natural” position, jamming the cabin in the guide rails long before it can gather additional speed.

It is this philosophy, the philosophy of “don’t activate safety measures when something goes wrong, keep them inoperative only if everything works right” is widely applied in nuclear reactors. The control rods, for example, are (usually) vertical and pulled up to increase power, so that their “natural” position is the shut-off position, to which they will drop back under their own weight. What prevents them from dropping back are electromagnets powered directly by the electrical output of the plant. If for some unknown reason the plant suddenly stops generating electric power, the magnets let go, and the control rods instantly shut off the neutron flow.

This is just one example of one of the principles on which the safety measures of a nuclear plant are based. In the few cases
when a sudden shut-down was needed, this particular device has worked well.

For example, when in October 1966 a metal plate broke loose in the Fermi I reactor, it partially blocked the flow of coolant to two out of 100 fuel assemblies, so that these two overheated and some of their fuel melted. There was no difficulty in promptly shutting down the reactor, and all safety systems worked exactly as planned. The reactor was later repaired and resumed operation.

You may not believe this (and it is hard to believe), but this incident is the subject of the book We Almost Lost Detroit. Its flagrantly false story has been coolly shattered in an expert report. Fermi I was an experimental fast breeder reactor, which uses sodium rather than water as the working fluid, and therefore its safeguards (such as emergency core cooling) were somewhat different from those of a conventional light water reactor.

But among the reasons why we didn't lose Detroit is one that applies to all reactors, conventional or not: the principle of defense in depth. If the reactor had lost its coolant, it would have been automatically replaced. And if it hadn't, the containment building would have contained the radioactivity. And if it hadn't (though it is hard to see why not), it would have dispersed into the atmosphere without doing any harm. And if it hadn't, because a temperature inversion kept it near the ground, a slight wind in an unfortunate direction would have had to blow it 30 miles to Detroit before a Detroit fly got hurt.

Or so it would seem. In the case of Fermi I, as we shall see in Chapter 3, a Detroit fly could not have been hurt even in the worst case, which makes this silly book even more despicable. “An unforgetting technology” says the introduction, implying that nuclear power has no room for human error. In fact, only nuclear power, with its defense in depth, has considerable room for human error. This was borne out by another incident that has been turned into a scare, the Browns Ferry fire in March 1975. An incredible chain of human errors piled up in that case, beginning with a workman inspecting electrical cables, in the last quarter of the 20th century, with a candle. Yet no radioactivity escaped, and would not have escaped if still more errors had been piled on the chain, for not even the first line of defense was ever broken, or even close to being broken.

But what would have happened if some shnook had inspected an oil refinery or a liquid natural gas tank with a candle? He wouldn't be there to tell us, for other energy facilities do not have a defense in depth. There would have been an explosion of the type that happens all the time, and that’s it. There is no room for error in working with large quantities of oil, gasoline or gas, and when they release their energy, they often do (not might) kill more people than a nuclear accident, even if one does happen, is likely to do.

There is one more basic concept that we should briefly visit, and that is the concept of energy itself.

Energy is the capacity to do work. Work and energy are two quite similar concepts (measured in the same units); in fact, the difference between them is simply the algebraic sign — plus or minus, just like the difference between credit and debit or assets and liabilities. So what is work?

Perhaps the simplest type of work is mechanical work, which equals force times distance. Weight, for example, is a force, the force of gravity, and if a man lifts 100 lbs of potatoes 3 feet from the ground, his work done against gravity is 300 foot-pounds.

The foot-pound is not the only unit of energy; there are others such as the BTU, calorie, erg, joule, kilowatt-hour, electron-volt, and more. Since all measures of the same thing, energy, they can be mutually converted, e.g., 1 calorie = 4.18 joules; but why are there so many units? For many reasons, some of them historical; but the main reason is convenience. A British Thermal Unit (BTU) is the heat required to raise 1 pound of water by 1°F, which makes it convenient for heat transfer engineering, but highly inept for a nuclear physicist, who prefers to use the electron-volt — the energy necessary to move the charge of one electron through a potential difference of 1 volt.

We will not let ourselves be confused by all these units. We shall use only one — the kilowatt-hour (kWh), and anybody who prefers joules, BTU's or anything else need only look up a table of conversion factors. For example, 1 kWh = 3,600,000 joules = 3,410 BTU.

To get a feel for the size of a kWh, we first have to go to the watt, which is not a unit of energy, but of power. Lifting the same weight to the same height always results in the same energy, no matter whether it was done fast or slowly. The concept that takes into account the speed with which it was done is power: power is the rate of doing work (expending energy). Power is the work performed per unit time.
If the work of 15 ft-lbs (lifting 5 lbs of potatoes 3 feet high) is performed by a forklift in 1 second, the useful power developed by the forklift is 15 foot-pounds per second whereas if the same work is performed by a small child who lifts the potatoes one by one and takes 100 seconds to accomplish the job, then the (average) power is only 0.15 foot-pounds per second.

There are again many units of power, e.g., the horsepower, which James Watt thought corresponded to the power developed by a horse. Actually, no horse can do work at the rate of 1 HP for very long, and many horses are not able to reach 1 HP even for a short time. However, we shall only use the watt, or more often its multiples kilowatt (1,000 watts) and megawatt (1 million watts).

The precise definition of the watt need not worry us here, and we will only give a few examples to get a feel for its size. One watt is very little power; for example, a light consuming only 1 W can be seen in the dark, but it is not strong enough to illuminate anything.

The most commonly used light bulb in the home consumes 60 W (of which only about 5% are turned into light, the rest is heat). An electric pressing iron consumes about 1 kW, and a clothes drier about 3 kW. An electric kitchen range, with the oven and 4 heating elements turned on will consume about 6 kW. Industry, of course, uses power on a much larger scale. The motors blowing air through a wind tunnel where aircraft models are tested can consume several megawatts, the equivalent of a thousand clothes driers or kitchen ranges.

It follows that even for a small residential community a power plant producing several hundreds of kilowatts is needed. For a city, the plant will have to generate several megawatts; as a very rough rule of thumb, a city of a million will need a plant of 1,000 MW capacity. Capacity power is the maximum power the plant is capable of generating. It will be reached or approached only during the peak hours (time of peak demand). The average power supplied during the whole day will, of course, be considerably smaller.

The base load, or demand that is there throughout the day, is supplied by base plants, the big, reliable plants that pollute little (pollution standards are set by the quantity per day). As the load increases, more generators are brought on line, for example, gas-turbine driven ones. The peak load generators, which work only during part of the day, and some of them only for an hour or two, usually have smaller power; they also tend to be less efficient, less reliable and more polluting. Why? Well if a utility has some excel-

Nuclear plants now range from several hundreds to several thousands of megawatts. They are invariably used to supply the base load. Any utility that has a "nuke" will bring in the inferior stuff only as needed.

And finally, let us briefly look into radioactivity and its effects on human health.

A good way to start is to note that radioactivity is a perfectly natural phenomenon. The ground we walk on is radioactive; so is our blood; so is the food we eat; so is the air we breathe.

Perhaps you say, ah, but that is all negligibly small radioactivity compared with what a nuclear plant puts into the environment.

Wrong. It is the nuclear plants that are negligible. The background radiation for the average US citizen amounts to some 250 millirems per year, of which more than half is due to natural sources, and the remainder is mostly due to medical equipment. What nuclear plants add to these 250 millirems is a "fiddling" 0.003 mrem, a fly sneezing into the wind.

But let's start at the beginning. Radioactivity is the radiation released in the disintegration, or decay, of an atomic nucleus. It spontaneously breaks apart and shoots out particles, and this is what constitutes radioactivity; the remaining heavy fragments (if any) are new atoms, which may be either stable or themselves radioactive, i.e., liable to disintegrate at some future time, in which case they are called "daughters" of the original substance. Naturally radioactive elements go through several generations of such daughters and daughters' daughters; they all eventually end up as lead, which is stable.

There are four types of radioactive radiation — alpha, beta, gamma, and neutrons, depending on what type of particle is shot out from the nucleus in its disintegration. Alpha particles are helium nuclei (2 protons plus 2 neutrons), beta particles are electrons, and a gamma particle is a short burst of electromagnetic radiation — a photon of high energy, or a quantum of light (invisible because of its extremely short wavelength).

Only gamma rays and neutrons are capable of penetrating matter to any significant depth; it takes many feet of earth or several feet of concrete to reduce their intensity to almost nothing. On the other
Hand, beta particles can travel only a few feet in air before they are absorbed, and alpha particles only a few inches; a sheet of paper will absorb them.

A radioactive element can radiate any or all of these types of radiation, but a given isotope always radiates the same type or types. For example, plutonium is primarily an alpha emitter, which means that it is not at all dangerous at a distance, and even close to it, as little as a newspaper will act as a shield against its radiation. Plutonium is highly dangerous when inhaled (and moderately toxic when eaten or absorbed through the skin), though even then to call it "the most toxic substance known to man" is melodramatic nonsense, as we shall see.

The timing of when a particular nucleus will disintegrate is entirely random and impossible to predict, though the probability laws governing its behavior are exactly known. Given a certain amount of atoms of a substance, it is, for example, exactly known how long it will take for half of the original amount to disintegrate. This time is called the half-life of the corresponding radioactive isotope. After a half-life, half of the originally present atoms are still intact in the form of the original substance; another half-life will leave a half of that half, or a quarter; a third half-life will leave one eighth; and so forth.

Different isotopes have different half-lives. Polonium 213 has a half-life of only 4 millionths of a second, but uranium 238 has a half-life of 4.5 billion years (which is fortunate, or none would now be left).

It stands to reason that for a given amount of atoms, the intensity of the radioactivity will be the smaller the longer the half-life — just as the same amount of water in a reservoir can give rise to a short and deadly flood, or to a prolonged and gentle flow if it is let out slowly. Yet this point does not seem to have impressed many environmentalists, whose lamentations grow the more shrill and nervous the longer the half-life of some radioactive isotope. They have never considered what the half-life of stable substances (such as arsenic or cyanide) is — it is infinite.

When a person is exposed to radioactive radiation, the amount received, i.e., the intensity of the radiation multiplied by the exposure time, is called the delivered dose. Doses are measured in roentgens, which are based on the total delivered energy. However, the biological damage to tissue does not depend on the energy alone (which is minute, anyway); a unit that takes into account the relative
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Bumper sticker sold and promoted by Environmental Action of Colorado. By merely
living in Colorado, its inhabitants get between 30 to 100 mrems/year more than they
would get at sea level; the difference amounts to what would be produced by more than
10,000 nuclear plants (all within 50 miles of the "victim").

an annual dose of about 35 mrem; this dose roughly doubles for
every mile of altitude. Altitude is also the main reason, though not
the only one, why the natural background radiation varies from
place to place. For example, in Denver, Colo., the annual dose from
the natural background radiation amounts to 157 mrems, whereas in
Alken, S.C., it amounts only to 52 mrems.
The next largest component usually comes from building mate-
rials, such as granite. Grand Central Station in Manhattan could not
be licensed as a nuclear reactor, because the radiation from its
granite blocks would violate NRC standards. The ground delivers a
dose of about 10 mrems/year, and 5 mrems/year come from the air.
Food is radioactive, too, delivering an average of 25 mrems/year.

To the 130 of natural radiation one

add the dose received from man-made
radiation. This amounts, for
the average US resident, to about 120 mrems/year, bringing the total
to about 250 mrems/year. By far the greatest part of the man-made
radiation is due to X-ray diagnostics (103 mrems/year), and most of
the remainder also goes for medical equipment (therapeutics 6,
radio pharmaceutic al 2). Global fallout, i.e., rain that brings down
radioactive isotopes released into the atmosphere by human activity
(formerly mostly nuclear bomb tests, now mostly industrial releases)
amounts to about 4 mrem/year. Color television watching results in
2. SOME BASICS

Genetic mutations

What exactly are the health hazards of excessive doses of radioactivity, such as might come about by a major nuclear accident?

There are three such possible effects: radiation sickness, cancer and genetic mutations. Please note that in discussing them we will switch from millirems to full rems, units times larger.

Radiation sickness results from exposures exceeding 100 rems (or 20,000 times more than is permitted to accumulate in the course of one year at the boundaries of a nuclear power plant). It is due to the induced malfunction of the bone marrow producing white blood corpuscles, and victims die (if they do die) in a time from a few days to a few weeks after exposure. However, if death does not result (400 rems is roughly the level where half of the exposed victims die), the patient recovers within a few weeks and all symptoms disappear. Radiation sickness is what would cause the "early deaths" in a major nuclear accident; the "delayed deaths" would be due to latent cancers. A dose of more than 100 rems is an improbably strong one, and deaths by radiation sickness among the public could occur only under an extremely unlikely combination of circumstances leading to the contamination of a populated area large of concentrated, high-level radioactive material (Chapter 3). The more important threat is that of cancer.

Genetic defects in offspring due to radiation exposure of the parents are a well known effect produced in experiments with animals; it has, however, never been observed in not even in Hiroshima and Nagasaki, in spite of extremely thorough and intensive investigations. The reason, very probably, is not that such effects do not exist — when it comes to health effects, man is not so very different from other mammals — but rather that they are too small to be observed. Genetic effects due to mutations in the sex cells occur widely in any population even without man-made radioactivity; in the US, no less than 30% of all live births exhibit such effects, ranging from an extra finger or toe to more serious defects such as diseases that show up later in life. It is obviously very difficult to detect any additional effects against this large background even with detailed information and sophisticated statistical methods. In any case, whatever the reason, no genetic effects in humans have ever been observed as a result of radioactivity, and not for lack of trying.

This leaves cancer as the most important health hazard due to excessive doses of radioactivity. Contrary to popular misconceptions, this is a subject which is unusually well understood, no doubt due to the intensive and massive research carried out on the subject during the last 40 years by prestigious institutions all over the world. One experiment at the Oak Ridge National Laboratory involved the irradiation and subsequent microscopic examination of each of mice. 7

A part from the detailed research on general laws and tendencies, there is also a substantial amount of empirical data on the effect of excessive doses on humans. There are the who were exposed to an average of about 130 rems in bomb in and among whom more than 100 excess cancer deaths...
occurred. ("Excess" means the cancer deaths beyond those that would have occurred without exposure; due to the large numbers involved, the statistical estimate of these "normal" deaths is very accurate.) 15,000 people in Great Britain were exposed to heavy doses of X-rays (almost 400 rads) in treating arthritis of the spine before the danger of X-rays was fully known; this again resulted in more than 100 excess cancer deaths. In the US, thousands of miners (mostly uranium miners) inhaled radon, a radioactive gas, and some of them received doses to the lung approaching 5,000 rads. Between 1915 and 1935, there were 775 American women employed in painting radium numerals on watch dials; they used to lick the brushes to point them, and there were similar situations in other countries. Painstaking research of the records in all of these and similar situations has established a relation between radiation dose and excess cancer incidence which is not seriously disputed by any one.  

Not everyone who receives a large dose of radiation dies of, or even contracts, cancer. For a given dose, a certain fraction of the exposed population will contract it, or more to the point, a certain fraction of those who would not have contracted it otherwise will contract it. It is therefore usual to express the hazard due to radiation by the corresponding increase in probability of dying of cancer. The "normal" probability of dying of cancer for the average American now stands at 16.8%; this probability is increased by 0.018% for every rem of radiation absorbed by his body. This is the figure based on the 1972 report by the Committee on Biological Effects of Ionizing Radiation (BEIR) of the US National Academy of Sciences and the National Research Council. It is also in agreement with the figures published by the United Nations Scientific Committee on Effects of Atomic Radiation (UNSCEAR); both institutions are under surveillance of standard-setting institutions such as the International Commission on Radiological Protection (ICRP). The reader is again reminded that our previous discussion of natural background radiation, permissible radiation of nuclear power plants, etc., expressed the radiation in millirems, or multiples of one thousandth of one rem. Now that we are discussing the incidence of cancer, however, we are using the rem a unit one thousand times bigger. Even so, each rem, or 1,000 millirems, of exposure adds only very little to the already high risk of contracting cancer due to non-nuclear causes; in fact, in America, it increases the chance of dying of cancer from 16.8% to 16.818%. This is true if the entire body absorbs one rem of radiation; if the radiation is concentrated onto some organ (for example, the lung, due to radioactive particles that have been inhaled), the risk may be higher, and the interested reader is referred to the BEIR report for details, but even so, the increased risk per rem is very small. Only doses of tens or hundreds of rads of radiation will appreciably increase one's chances of contracting cancer beyond what these chances are already.

These are the naked facts, and they are not mentioned here to play down the danger of radioactivity. Strong radioactivity can kill, and has killed, large numbers of people, though none as yet have lost their lives at a commercial nuclear plant. Besides, there is no need to play down the potential cancers due to radioactive releases. As we shall see, the cancers due to fossil-fired plants are not potential cancers; they are cancers that kill here and now, and they don't kill abstract figures in computer programs, they kill people who were still alive yesterday.

In ALL of the foregoing we have used the so-called "linear hypothesis" that the incidence of cancer increases linearly with the radiation dose, i.e., if the dose is increased by some factor, the probability of contracting cancer will increase by the same factor. This hypothesis agrees well with observation in the region where most data are available, around 0.1 to 100 rem. But for very low levels, we have only one point where we are certain of the result, the point zero: No radiation at all produces no radiation-induced cancers at all.

What about very small doses, like 1 millirem? This is the dose most people get by merely living on earth for a couple of days. How is one to measure such a small amount against the background of a bewildering number of other factors? Although direct measurement is difficult or impossible, the indirect evidence suggests strongly that there is a "threshold" value of radiation below which it is harmless. There are at least three indicators supporting the existence of a threshold: first, the evidence from experiments on animals under strictly controlled conditions; second, the well known fact that tissue slightly damaged by radiation will heal if it has the time — which it does with low doses; and third, radiotherapy on cancerous tissue would not work if there were no threshold, for the radiation damages both healthy and cancerous, rapidly multiplying cells.
Nuclear critics have spent much time disputing the existence of a threshold. For example, Gofman and Tamplin, in their grotesquely biased book *Poisoned Power*, devote much space to arguing (but presenting no evidence) against it.

But the argument is not merely in all probability wrong, it is, above all, irrelevant. For the radiation protection standards and risk calculations — in the US, at any rate — use the linear hypothesis all the way down to zero, that is, just as if the deniers of a threshold value were right. As is customary in US regulation, errors are always introduced on the safe side. Other standard-setting institutions, e.g., UNSCEAR, do not accept the linear hypothesis for low radiation levels, though they have not come up with an alternative, either. The US National Council on Radiation Protection, which sets the standards for maximum permissible exposure, accepts the linear hypothesis, knowing it is erring on the safe side, and acceptance of the hypothesis makes the issue of the existence of a threshold utterly irrelevant.

Owing to the widespread anti-nuclear propaganda, not many people realize that nuclear power is safer than other methods of generating electric power. But even those who do realize it often oppose nuclear power, or are reluctant to endorse it, because they fear a major nuclear accident.

"No matter how small the probability of a major accident," they say, "it is not impossible; and if one does happen, the consequences will be so terrible that they should not be risked at all."

That view is once again based on misinformation, for the risk of a major accident is far higher in the coal, oil and gas cycles (and for hydropower) than it is in the nuclear cycle. Not only are major accidents with fossil fuels and hydropower far more probable, but their consequences can be more terrible, too.

The various scenarios of a nuclear accident leading to a significant number of deaths invariably involve a chain of independent events, each of which has a minute probability. If the same thing
were done for fossil fuels, one would have to consider the number of lives lost in a hypothetical accident in which a jetliner crashes into an oil storage complex whose explosion wipes out a nearby city. There is, however, no need to engage into such fantasies, for simple events such as explosions of oil or gas storage tanks have already cost hundreds of lives and could easily lead to single accidents with a death toll in the tens of thousands.

**Consider** first a major nuclear accident. A nuclear explosion in a reactor is impossible, as we have seen (pp. 41-42). The one and only major threat to the public is a release of large amounts of radioactivity within a short time. There is virtually only one type of accident that can lead to such a disaster — the Loss of Coolant Accident (LOCA). It could happen in the light-water reactors now in use, though even this possibility is greatly reduced in High-Temperature Gas Reactors which, in spite of the financial bind of its producing company, may yet prove to be the reactors of the future.

A loss-of-coolant accident threatens if the water which absorbs the heat from the fuel rods (p. 45) should leak out. The vessel itself, weighing several hundred tons, made of steel several inches thick and subjected to thorough tests before going into operation, could not develop such a leak, but the pipes carrying water to and from the vessel could, even though they are continuously monitored for leaks and designed to withstand earthquakes. The safety measures assume not merely a simple leak such as might result from a small crack, but a "guillotine cut" in which the pipe is cut clean through and the two ends are severed from each other so as to allow the water to gush out without impediment.

If the water were to leak out, and no safety measures were taken to replace it, the control rods, as in all other malfunctions, would drop back under their own weight and shut off the chain reaction in the uranium instantly. However, heat due to the continuing radioactivity in the fission products — the spent fuel in the fuel rods — would continue to be generated, and if no countermeasures were taken, the temperature of the fuel rods could rise to the melting point of the cladding of the fuel rods.

To eliminate this threat, every nuclear power reactor has an Emergency Core Cooling System (ECCS) with independent pipes, pumps and water to pump cooling water into the core if for some reason the normally present water should begin flowing out.

The LOFT (Loss of Fluid Test) facility in Idaho is designed to provide accurate tests of the effectiveness of emergency core cooling during a large simulated loss-of-coolant accident. The first of a series of tests, in March 1976, was a complete success.

The ECCS is designed for some wildly pessimistic assumptions, such as the "guillotine cut" just mentioned. It is required to go into operation instantly and automatically on the occurrence of a leak, but can also be operated manually if the automatic activation should fail.

There has as yet been no sudden leak in a commercial reactor (certainly not at the Browns Ferry fire in 1975), and the nuclear critics claim that no one knows whether the ECCS would work. The AEC therefore built a multi-million test facility in Idaho for an actual test — the equivalent of sinking a ship to see if the lifeboats would work. But already the critics are claiming that the facility is too small and that the simulation will involve much less power to be extinguished than in the usual 1,000 MW nuclear reactor — the equivalent of saying "You will never know whether the lifeboats work if you just sink a small freighter — you have to sink the Queen
3. MAJOR ACCIDENTS

Elizabeth II to be sure." When the tests are carried out in 1976, they will win both ways. If they succeed, they will say the test facility was too small (at 55 MW of heat); if it fails they will say "We told you so."*

All of which are incidental considerations, for what would happen if there were a loss-of-coolant accident and the ECCS failed to replace the lost coolant? In that case, most people think, disaster and massive loss of life would follow.

Not so. The Rasmussen report puts the number of lost lives due to loss-of-coolant accidents, if there is one, at an average of less than one. In most cases the dollar damage would be large, but no lives would be lost among the public, and very probably none even inside the plant. What would happen is that the fusion products inside the fuel rods would (unlike the uranium, which is easily controlled) produce heat without significant cooling until the metal cladding of the fuel rods melted, and a red-hot mass of metal and fusion products would eventually flow down and start melting the steel pressure vessel surrounding the core. This is several inches thick and weighs several hundred tons, so that it takes time to melt through — a marked difference from other accidents—such as explosions or air crashes, in which there is no time for warnings and countermeasures.

In any case, it is not the red-hot and radioactive goo melting through the pressure vessel and flowing down onto the concrete floor that would be dangerous. That would melt through the concrete into the ground, where it would dissipate its heat, and from where it could be removed without major complications.

Dr. R.P. Hammond, a widely respected nuclear scientist with more than 30 years experience, says "If I had to contend with such material — and I have had some first hand experience in cleaning up radioactive spills — I cannot think of a place where I would prefer to have it than far underground. It would be completely shielded by the overlying earth and concrete, it would be enclosed in a thick pocket of fused earth... At a radius of 20 feet or so the system would stabilize and melt no further and would be completely safe until such time as salvage operations might begin."*

Thus it is not the melted fuel that would be dangerous in such a disaster. The danger comes from the gaseous and volatile radioactive materials that would be released after the fuel had melted through the pressure vessel. How could this cause deaths among the public? In most cases, it wouldn't. It is the purpose of the massive containment building — made of four feet thick and heavily reinforced concrete — to contain these gases and volatile particles within its volume and prevent a radioactive release. It is one of the formidable successive obstacles in the "defense in depth" against disaster, a defense unknown to dams, gas tanks, oil tankers and a hundred other possible causes of accidents where only a single "defense" need be punctured to result in disaster.

Could it happen that the containment building fails to contain the radioactivity within its walls? Such an event is very improbable, but it cannot be declared impossible. Since nobody knows for sure, one must further for a blowhole be formed through the soil, steam with radioactive material itself can withstand and even high explosives).

After this entire chain of unlikely events, do we reach disaster at last?

No. Ordinarily, the radioactivity would be released into the atmosphere, violating NRC standards, but otherwise being dissipated into the atmosphere without significant harm. A new and independent event must arise to keep the volatile radioactive particles concentrated: a temperature inversion in the atmosphere above the plant on the day the disaster strikes. It would have to be one of the type triggering pollution alerts in cities because pollutants will not dissipate.

Only then will there be massive loss of life?

No, there still won't be any. A further independent event must occur to lead to disaster: A wind, strong enough to move the suspended particles, yet not so strong as to dissolve the inversion, must blow, and it must blow in the direction of a nearby, large and densely populated area — and not many reactors are located or planned close to populated areas; the number of people living within a 25 mile radius of current (56) and planned (44) reactor sites is 15 million, or a little over 7% of the population.
IN THE following the figures are based on the Reactor Safety Study (Wash-1400), final version of October 1975, generally known as the "Rasmussen Report," since it was directed by M.I.T. Professor Norman C. Rasmussen.

How good is the Rasmussen Report? It involved 60 investigators, various consultants, a total of 70 man-years of effort, and about $4,000,000. Though sponsored by the AEC, the scientists and engineers working on the study came from a variety of organizations, including the AEC, private laboratories, and universities. Large digital computers processed vast data banks of information; for example, 140,000 possible combinations of radioactive release magnitude, weather type, and populations exposed were evaluated to calculate the health effects and their probabilities in a nuclear accident. The two basic techniques ("fault trees" and "event trees") used by the group have proved their worth in assessing system reliabilities in NASA and the Department of Defense; they have also been used for decades in Great Britain, where the predictions of system reliabilities were found to be close to the observed values — if anything, the techniques tend to overestimate the dangers of failure.

A draft report was published in 1974, with a whole year for critics to suggest changes. There were indeed such critics. When definite points were criticized, and material supporting the criticism was presented, the draft version was amended to take such criticism into account. For example, a study group by the American Physical Society held that Rasmussen had underestimated the number of delayed deaths, and the number of injuries due to damage to the thyroid gland. The final version did increase the corresponding number accordingly (though the risk remained minute). Similar revisions were made on the basis of criticism by the Environmental Protection Agency and some other organizations, but the amended values did not substantially change the picture given in the draft report.

The conclusions of the Rasmussen draft report, interestingly enough, were never seriously challenged by the Naderite type of critics. They had plenty of criticism, of course, but all of it abstract, vague, or just plain ridiculous. The study, they charged, did not take into account terrorism — which in itself is true; but then, not only was such a study beyond the mandate of the group, but the group had considered such combinations of circumstances as no terrorist or saboteur could ever "achieve." Ralph Nader charged that the Titanic main survived, British

Ehrlich stated, "diversion of nuclear materials for radiological terrorism or the construction of clandestine atomic bombs is probably the most intractable problem associated with the nuclear power boondoggle. Plutonium, one of the most dangerous substances known to man, will be produced in prodigious amounts as the number of atomic power plants increases."

He declared that the AEc's recently published Rasmussen report on nuclear power plants should have been called "WHITE-WASH 1400." The report, according to technical critics, contains serious technical flaws and its estimates of the likelihood of accidents are based on the assumption that sabotage will not occur. The only way the conclusions are to the together with their probabilities: For example, the of a had been claimed but sank nevertheless - thus demolishing a straw man of his own making, for no responsible scientist, least of all the Rasmussen group, has ever claimed that nuclear power was 100% safe.

The Union of Concerned Scientists bemoaned the fact that did not have the Rasmussen report to refute their claims. David Dinsmore Corney, a grotesque figure even among nuclear-power baiters, came up with a number flatly contradicting the Rasmussen study by a factor of "writes Corney, "of the probability per reactor year of a major reactor accident is one in a thousand." And with man-years of effort are dismissed. one in a thousand? David Dinsmore Corney knows.

Now THEN; suppose the entire chain of the independent and wildly improbable events described on pp.63-69 were to occur, what would be the consequences? How many people could be killed? As in the case of all other accidents, there is no single number that will answer the question fully; the mean or for example, is so small that it may be of playing the game of the truth not the whole truth. The same suspicion might arise if I selected the most probable number of fatalities in a core-melt accident (none). The only way to answer the question fully is to give the fatalities together with their probabilities: For example, the probability of a
nuclear accident, once it has happened, killing 10 or more people is less than 1% (This means: In a large number of core melts, 1% will kill 10 or more members of the public, and 99% will kill less than 10, which includes none at all.) This is the probability once a core melt has taken place — it is not the unconditional probability of a core melt with 10 or more people being killed (which is between 0.1% and 0.001%). That means roughly the following: In a very large number of core melts (most of which would kill nobody, some would kill 2, some would kill more than 50, etc.), close to 0.002 of the total number would kill 100 or more.

Please note that we are concerned with the number of deaths assuming a major accident — a core melt — has taken place. We have not yet looked at a quite different question, namely, the probability that such a core melt will occur in the first place. In other words, we have looked at the consequences of an accident, not at the probability of that accident.

Let us now do just that: What is the probability of a core melt? One in 20,000 per reactor year. And if one does happen, it will probably cost no lives, so that does not tell us much. A better way of gauging the danger is to look at the mathematical risk — the mean or expected number of fatalities per year — in comparison with other accidents. And to prevent nuclear power looking too good (it has no need for that), we will take (again from the Rasmussen Report) the averages not over all of the US, but only among the 15 million Americans who live within 25 miles of the current (56) and planned (44) reactor sites:

**Expected annual fatalities among 15 million people living within 25 miles of US reactor sites**

<table>
<thead>
<tr>
<th>Accident</th>
<th>Fatalities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Automobile</td>
<td>4,200</td>
</tr>
<tr>
<td>Accidental falls</td>
<td>1,500</td>
</tr>
<tr>
<td>Fires</td>
<td>560</td>
</tr>
<tr>
<td>Electrocut</td>
<td>90</td>
</tr>
<tr>
<td>Lightning</td>
<td>8</td>
</tr>
<tr>
<td>Reactor accidents</td>
<td>2</td>
</tr>
</tbody>
</table>
Here and in the following, we consider only the deaths within a short time of the accident (up to 12 months). There are no immediate deaths ("bodies piled up in the streets"), and the deaths delayed from between 10 to 40 years after the accident have already been considered (pp. 59-62). The deaths considered here would be due to radiation sickness, which is fatal to some victims; those who survive it show no further symptoms of the disease.

Is it possible for a nuclear accident to kill as many as 1,000 people? It's possible, just as it is possible for a large enough meteor to kill 1,000 people if it were to fall into a US population center. It so happens that the probability of the two events is the same. There are only two meteors of that size known to have ever fallen on the earth, and both "missed." One lies in the Arizona desert, the other in Siberia. The probability of one of 100 nuclear plants (or a meteor) killing more than 1,000 people in a single accident is one in a million per year, which (in these two cases) is the same as once, on the average, every million years.

In short, the probability of a major accident — a core melt — is minute (about 10,000 times smaller than other accidents or natural disasters with large death tolls); and the consequences, if one does happen, are small compared to other types of accidents.

By now, you may be doubtful whether this is a serious book. What about the Browns Ferry fire? Didn't we almost lose Detroit? If nuclear power is so safe, why do private insurance companies refuse to insure it? And a hundred other statements will probably come to mind to anybody who ever reads a newspaper or magazine or watches television.

Yes, there was a fire at the Browns Ferry Plant in Alabama in March 1975. Yes, it was started by a candle which an electrician used to check whether some cables went through the wall. (Since then, the NRC requires all electrical cables to have fireproof insulation.) And an electrician going about his job with a candle wasn't the only human error. Fire fighters and security were not called in until the guard sounded the alarm some 10 minutes later, and even then only after he had called the wrong number first. For several hours afterward, the plant superintendent refused to let the fire fighters use water on the fire (rather than chemicals); when the fire had been raging for 7 hours, he agreed to try water, and it was put out in 20 minutes. All of which shows, among other things,
WE LOST OUR MARBLES
WE ALMOST LOST DETROIT
by John G. Fuller

WE ALMOST LOST DETROIT

Electricity's possible cost

We Almost Lost Detroit
By John G. Fuller

Readers' Digest Press $8.95

By Mary Ellen Gale

"We Almost Lost Detroit" in the story of how Detroit's nuclear disaster was barely averted. The author, John G. Fuller, recounts the dramatic events surrounding the Browns Ferry Nuclear Power Plant near Decatur, Ala., and how the facility was saved from a catastrophic accident.

The book's title, "We Almost Lost Detroit," is a reference to the serious threat that the Browns Ferry Nuclear Power Plant posed to the city of Detroit, Michigan. The plant's control room was damaged, and there was a risk of a meltdown that could have led to a nuclear explosion.

This is a true story of the Browns Ferry Nuclear Power Plant accident, which occurred on October 5, 1966. The plant was one of the first commercial nuclear power plants in the United States, and the accident highlighted the potential risks associated with nuclear power generation.

The book is a detailed account of the events leading up to the accident, the measures taken to prevent a nuclear disaster, and the subsequent investigations and lessons learned. It is an example of the types of incidents that can occur at nuclear power plants and the importance of safety protocols and emergency response planning.

The Browns Ferry Nuclear Power Plant accident demonstrated the need for improved safety measures and increased public awareness of the potential risks associated with nuclear power. This book serves as a cautionary tale and a reminder of the importance of nuclear safety and the urgent need for progress in this field.


The book has been widely praised for its accuracy and readability. It is written in an engaging and informative style, making it accessible to a broad audience. Readers have expressed appreciation for the author's ability to convey complex technical information in a clear and concise manner.

The book is highly recommended for anyone interested in nuclear power, safety, and the history of America's nuclear energy industry. It provides a valuable resource for students, researchers, and anyone seeking a deeper understanding of the Browns Ferry Nuclear Power Plant accident and its implications.

The book is available for $8.95 from Readers' Digest Press. It can be purchased online or at your local bookstore.

Readers can also find more information about the Browns Ferry Nuclear Power Plant accident by visiting the website of the Nuclear Regulatory Commission (NRC) at nrc.gov. The NRC is responsible for regulating nuclear facilities in the United States and provides detailed information about the Browns Ferry accident and its aftermath.

The Browns Ferry Nuclear Power Plant accident remains a significant event in the history of nuclear power, and its lessons have been applied in the design and operation of subsequent nuclear facilities. It is an important reminder of the need for continued investment in research, development, and education to ensure the safe and reliable operation of nuclear power plants.
raped a woman for more than a week, at least not in broad daylight. Some basic facts that Fuller never contradicts, but only very conveniently omits, have been given on p. 50, but what are the chances that the broad public will ever know them?

And yet the facts given on p. 50 are merely those that would be valid for any nuclear reactor; a lot of other things would have had to occur in an improbable combination before a Detroit fly got hurt.

But at the time of the incident, Fermi I could not have hurt a Detroit fly at all. The reader now knows that the danger of a meltdown does not come from the chain reaction that releases the bulk of the energy in a power plant, it comes from the fission products (p. 64). And Fermi I in October 1966, as pointed out by Prof. W. Meyer of the University of Missouri, had not been in operation long enough to have sufficient fission products to undergo a meltdown, after it was shut down, under any circumstances.

That means that the reviewers whose intellects are on display on the preceding page not only write unmitigated stupidities about nuclear explosions and radioactive releases, but had they been let loose in Fermi I at the time with hacksaws, blowtorches and power drills, they could not have caused a meltdown even if they were technically literate.

Fuller's book was put out by the Reader's Digest Press with an advertising budget of $30,000. And it does its job. The title alone will scare many people into opposition to nuclear power. And the New York Times Book Review of November 30, 1975, plugged the book with a review claiming that it "is a sobering and necessary reminder that democracy has yet to control technology." The reviewer, a staff counsel of the America Civil Liberties Union, reveals a sample of her expertise in the statement "They knew what the public did not — a mistake could trigger a nuclear explosion."

As for the nuclear exclusion clause, the reason is simple: Every resident of the US is already insured against damage by nuclear plants, and with a no-fault insurance policy at that, by the Price-Anderson Act. The statement that private insurance companies will not insure nuclear plants is a pure and simple falsehood. It is two pools of private insurance companies that carry the insurance for a liability of the first $120 million per incident. The US government collects additional fees from utilities to cover excess liability up to $560 million. So far only the private insurance companies have paid $400,000 in 26 minor claims not directly related to reactor incidents. The government has so far made a profit of $8 million in
3. MAJOR ACCIDENTS

RIGHT FOR THE WRONG REASONS

79

let us move on to the major accidents and disasters due to fossil fuels and hydropower.

BEFORE we go into the possibilities — and indeed, the actual occurrences — of major accidents associated with fossil fuels, let us first clear the ground of some misconceptions that confuse the issue.

The death toll in automobile accidents, airline crashes, railroad disasters, etc. (usually) has nothing to do with the generation of electrical power, and the table on p. 70 had no other purpose than to let the reader gauge the numerical value of the risk associated with a nuclear disaster. There is no choice of either being struck or perishing in a nuclear disaster; one can take measures to minimize the dangers, but the two types of measure (say, installing a lightning conductor and voting for a nuclear shutdown) do not involve mutually dependent decisions, let alone exclusive ones.

The anti-nuclear crusaders are therefore in my opinion, when they say that it is unfair to compare the risks in driving an automobile to the risks of a nuclear disaster. Unfortunately, their thinking is so muddle-headed that they are right for the wrong reason. "Exposure to the risk of auto accidents," says Sierra Club Executive Director McCloskey, "is a personal one accepted by those who choose to travel by car; it is not forced on an entire population regardless of their choice." Of course, this is a fallacy. If Mr. McCloskey’s wife has a choice, how much choice does she really have, in the United States, whether to be driven several miles to the nearest hospital or whether to walk there? The real reason why the comparison is unfair has escaped Mr. McCloskey. It is that whether we do or do not go nuclear will make no difference to the death toll on the highways.

But it will make an appreciable difference to the death toll in coal mines and in major accidents due to the explosion of oil and natural gas tanks, oil refineries and oil tankers, for the simple reason that a considerable fraction of these fossil fuels is used as fuel in power plants. If a percent of the US electrical generating capacity goes nuclear, roughly a percent of these fossils burned to generate power will not be needed, and the death toll in major accidents associated with the production and storage of these fuels will decrease, on an average, by the same percentage.

collected fees, and it is not likely to pay anything, as damage beyond $120 million is improbable (the Rasmussen study puts the most likely property damage to the public in a core melt at $1 million). Moreover, the 1975 extension of the Price-Anderson Act legislates a schedule of further increasing the share of private insurance, with the government eventually getting out of the nuclear insurance business altogether. Even if insurability were a good measure of safety (which it isn’t), the nuclear critics would not have a point, for their charges are simply not true.

One might also add that in the case of all other disasters, the no-fault insurance liability limit is not $560 million; there isn’t any no-fault insurance at all.

There are, of course, a thousand more 10-second statements by the nuclear critics that it takes a half-hour lecture each to refute fully, but it is hoped that these three samples will have persuaded the reader that the consequences and probabilities of a nuclear accident described above are credible in spite of the wild claims of the critics. In fact, the discrepancies are rarely contradictions; they are most often due to facts which the critics do not dispute, but on which they conveniently keep silent.

But this is not a book attempting to refute the critics’ 10-second assertions; it is a book on the hazards of not going nuclear, so
In the following, we shall therefore not make unfair comparisons. True, the risk in flying with commercial airlines is not only high, but partly unnecessary. It is high because per passenger-hour it is even greater than driving. (The airlines conveniently give the risk not in passenger-hours, but passenger-miles; by that measure, the safest mode of transportation is a NASA flight to the moon.) And it is unnecessarily high because to this day airliners do not have airborne radars to warn them of threatening collisions, and because the political clout of the environmentalists forces pilots to throttle back their engines dangerously early after take-off. But airliners are none of our business here, for we are interested only in the hazards associated with the alternatives to nuclear power, of which air travel is not one.

A SWIG FROM THE BEER CAN

A SWIG FROM THE BEER CAN

AND YET we must come back to the airlines one last time, for air crashes do have something in common with mine disasters and oil tank explosions that is relevant to our story. And that is the indifference — one might almost be tempted to say callousness — with which news of such disasters is received by the public. No year goes by without major air disasters: 10 dead in a private aircraft crashed in the Rockies; 83 dead in a crash in Florida; 102 dead in a crash in New York; 132 dead in a crash in Lebanon; it has become too common to startle people. Even in the United States major crashes have become so common that a year in which none happens, such as 1974, makes the news by its rarity.

The crashes make the news, too, of course. The TV screen shows the debris scattered in a forest, rescue crews cutting the fuselage with welding torches, and covered bodies being carried away on stretchers. But the TV viewer has seen all this too often before, and the horror of it is forgotten with the next swig from his beer can.

So, too, forgotten are the 400 coal miners killed in a mine disaster in India in December 1975. India, of course, is far away; but how about West Virginia? Only 8 years ago, 78 miners died in the Manington Disaster of 1968; "of 1968" to distinguish it from the Manington Disaster of 1907, when 359 people died. Thirty-eight miners lost their lives in a coal mine explosion near Hayden, Ky., in 1971; and it won't be long before another mine disaster costing tens of lives comes along with the inexorable laws of probability, here in the United States. A * when one considers the major accidents associated with the fuel cycle of fossil-burning power plants, one difference with respect to nuclear accidents stares one in the face: The fossil accident statistics have not come out of computer simulations of hypothetical disasters, and they have not come from probabilistic calculations. They have come from the cold records of the coroners. There is, as yet, only one type of nuclear accident: hypothetical. There are two types of non-nuclear accidents: hypothetical and real. We begin with the real accidents.

Coal mining, as everyone knows, is a dangerous occupation; but few of those who lecture us on the hazards of nuclear power have ever been down a coal mine, and fewer still realize that the miner who has escaped violent death by methane explosion, flooding or collapse of the walls faces even greater hazards from contracting occupational diseases such as Black Lung.
Since 1907, no less than 88,000 miners have died in American coal mines, and even now there are some 200 fatal accidents per year in coal mines, plus another 100 in transporting the coal to the power plants. The average number of fatal coal mining accidents for the 5 years 1965-1969 was 246 per year. There were only 8 fatal uranium mining fatalities per year during the same period, but that is merely due to the fact that far less uranium is mined than coal; as far as the rate of accidents is concerned, the two are about equally dangerous (injuries per million man-hours are 43.5 for coal and 39.8 for uranium, and disability days per million man-hours are 8,441 for coal and 8,702 for uranium). But the question of interest here is this: What is the cost, in accidental mining deaths and injuries, of the production of a given amount of electric power? The answer depends on many factors, but it is dominated by a single aspect: the concentration of energy in a given quantity of fuel. A pound of unrefined uranium ore contains about 100 times as much energy as a pound of coal, so that about 100 times more coal must be mined to generate the same amount of electric power, and one would expect the cost in lives and injuries to be of the same order.

Accidental deaths in mining, per electric energy produced from the corresponding fuel, are about 10 times more numerous for coal than for uranium. Lave and Freeburg investigated the data for 1969, when 54.3% of the mined coal was used to generate 705 million MWh of electric power, and about 3.06% of the mined uranium was used to generate 14 million MWh of nuclear power. There were 8 fatalities in uranium mining (plus an average of 1 fatality in 5 years in uranium milling, which has no equivalent in the coal cycle). The figures we are after, then, are the following:

- Per billion MWh of electric power consumed, the cost in fatal mining accidents is:
  - 189 lives in coal mining for coal-fired power
  - 18 lives in uranium mining for nuclear power (The figure for uranium mining is actually 17.92; however, due to weapons production, storage, non-linear consumption of uranium in the fuel rods, and other factors, the calculation of the power-destined fraction of the mined uranium ore is less accurate than for coal.)

  The ratio of 10 : 1 also holds for injuries:

\[
\text{Per million (not billion as above) MWh of electric energy consumed, injuries cost:}
\]

- 1545 disability days among coal miners for coal-fired power
- 157 disability days among uranium miners for nuclear power

But these are only accidents; and miners are also subject to industrial diseases. Coal miners contract, above all, pneumoconiosis (Black Lung), and uranium miners have a higher incidence of cancer than the average citizen, since they are exposed to radiation (uranium, with its long half-life, is not harmful, but its daughters, particularly radon, are). The toll of these diseases among miners is far greater than that of accidents: There are about 4,000 deaths by Black Lung per year among coal miners, and about 20 deaths by excess incidence of cancer per year among uranium miners. However, it is very much more difficult to estimate the toll per unit power generated, and it is not even easy to estimate the ratio of deaths by occupational diseases per unit power generated for coal versus uranium. (Among the reasons is the delayed and prolonged...
time of a disease, whereas accidental death or injury strikes on a single day.) We shall be content with the estimate of Prof. Richard Wilson of Harvard University, who is a specialist on the epidemiology associated with fuel cycles. Wilson’s estimate is the following:

Per billion MWh of electrical energy consumed, there are
1,000 deaths by Black Lung among coal miners
20 deaths by excess lung cancers among uranium miners depending on whether the power is coal-fired or nuclear.

In fairness, it should be pointed out that these two figures partly rest on debatable assumptions for the reasons pointed out above, and that they are not as accurate as the figures on accidental deaths and injuries. On the other hand, the discrepancies between the results of various investigators involve only the degree to which coal is more dangerous; no one disputes that coal is the much more dangerous of the two. (Wilson’s estimate above implies a ratio of 50 : 1; the lowest estimate I have seen is that by Lave and Freeburg, which is 18 : 1.)

Before we go on to transportation accidents (which kill unin­volved members of the public, not only people who have chosen to become miners or railroad workers), we pause to consider the following argument:

“It is deplorable that mining is such a dangerous occupation; but every miner knows well what the risks are. In the United States, at least, nobody is forced to be a miner, and if somebody chooses to be a miner rather than a shepherd, the choice is his, the responsibility is his, and the consequences are his only.” This type of argument is debated in a hundred versions between libertarians (who believe in freedom of choice and individual responsibility) and liberals (a misnomer for people who believe that all of society is responsible for all of its individuals), and they will argue the point for hours without noticing that the entire debate is pointless because it is based on a false premise.

One can argue the point in the case of a tightrope walker or a person who chooses to go over the Niagara Falls in a barrel, for apart from the bother to a rescue crew and perhaps burial at public expense, the consequences for the rest of us are minimal. But a miner is not a tightrope walker, and the false premise is that the

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Industrial diseases: Black Lung among coal miners vs. excess lung cancers among uranium miners. If the electrical energy produced from the corresponding fuel is 1 billion MWh, each cross represents 50 lost lives.

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COAL

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URANUM

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OCCUPATIONAL DISEASES
In transporting coal from mine to power plants, about 100 people (including members of the public) are killed every year. The corresponding number for uranium is unknown and probably very close to zero. The reason for the disproportion is the high concentration of energy in nuclear fuel: It takes 38,000 railcars of coal, but only 6 truckloads of nuclear fuel, to supply a 1,000 MW plant for one year. For this case, each “R” represents 500 railcars of fuel.

dustry are another myth; but not even in Nader’s mythology do the alleged subsidies amount to $1 billion per year.)

If $1 billion of public money were annually paid out to tightrope walkers, the American taxpayer (one hopes) would object; but in the case of Black Lung, he does not realize that it is a disease whose toll can be cut: Every percentage point by which nuclear power takes over from coal saves approximately 20 human lives from death by Black Lung — not by curing it, but by preventing it. It saves them in addition to the lives saved from death and disablement by violent accidents. And in addition to the lives lost by causes which we are about to examine.

So for those who feel that they are not the guardian angels of coal miners, there is always the prorated amount of $1 billion a year ($80 million additional if the present nuclear capacity went back to coal).

Ralph Nader’s brand of humanitarianism couldn’t care less about coal miners coughing out their lungs; but if people are so hardboiled that they have no compassion for the miners (and I do not intend to moralize), shouldn’t they have a little compassion for their own pocket books?

In any case, once we start looking at transportation, the point becomes moot, because fatalities in fuel transportation involve members of the general public, even if to a lesser degree than truck drivers and railroad workers; the element of choice begins to disappear. There are 100 accidental deaths a year in transporting coal from mine to power station; 7 as for the number of deaths in transporting uranium ore from mine to mill and refinery, and from there (as “yellow cake”) to enrichment plant, I have, frankly, been unable to ascertain and I suspect that it is so small as to elude the record keepers. But when transportation of ready fuel to the power plants is considered, the figures are truly stunning, and they also make it obvious where the 100 deaths in transporting coal to power plants come from. To generate 1,000 MW-years of electricity (this would in practice correspond to the output of two 1,000 MW units working with a plant factor of 50% for one year), the amount of fuel that must be transported to the plant is

either 6 truckloads of nuclear fuel or 38,000 railcars of coal.

I will not insult the intelligence of the reader by commenting on these figures.

The 4,300 people who die in accidents in producing and transporting coal (not counting Black Lung victims) are a small amount compared to the far larger number who die as a direct consequence of air pollution by the combustion products of coal. There is, however, one thing one can say in favor of the safety of coal: Except when pulverized and suspended in air, coal will not explode, and apart from a few fires, it will not cause violent death to large numbers of the public.

The same cannot be said for gas or oil, where the situation is the opposite: Few lives are lost in producing oil and gas, but their transportation and storage are extremely dangerous.

Per unit electricity produced by burning oil, the number of deaths and injuries in producing and refining oil is quite small; it is even
somewhat smaller than the corresponding figures for uranium mining and milling. For example, Lave and Freeburg found 135 disability days per billion MWh of oil-generated electricity (compared to 157 in uranium mining). But the dangers in storage are another matter.

An oil-fired power plant of 1,000 MW capacity burns 40,000 barrels of oil a day. It usually keeps a six weeks' supply on hand, which works out to 2 million barrels of oil. What would happen to the public if such a large amount of oil caught fire is, in one respect, remarkably similar to the case of a nuclear disaster, in that the consequences would depend on the meteorological situation. As in the case of a nuclear disaster, the consequences are worst when the smoke is kept close to the ground by a temperature inversion and a light wind blows it toward a large population center. In that case thousands could die by asphyxiation and by induced or exacerbated lung and bronchial diseases (not counting possible lung cancers).

Such a nightmare was close to coming true on January 6, 1973, when an oil fire started in Bayonne, New Jersey, as a result of the collision of two ships, with oil storage tanks catching fire on shore. The black smoke (see photo on opposite page) was far denser than the notorious air pollution of London in December 1952, which resulted in 3,900 excess deaths there. Fortunately, the wind blew away from Manhattan and was turbulent enough to disperse the smoke, preventing large-scale loss of life. But nobody wrote a book called We Almost Lost New York. If Ralph Nader and his fellow-humanitarians had the slightest interest in safety or human lives, they would have pounced on this near-disaster. They are, after all, so touchingly concerned about this type of catastrophe when it is nuclear and has a probability of once in a million years.

But it didn't take a million years before New York had another close shave of this type. It only took three years, almost to the day: On January 3, 1976, a 90,000-barrel oil storage complex in South Brooklyn caught fire and exploded; but this time it was worse. The fire could not be brought under control, and the next day, a second explosion in the burning tank belched forth a gigantic orange fire ball, igniting a second tank and rupturing a third. The three tanks, though not full, contained a total of 2.1 million gallons of oil. The fire raged several days and was not brought under control until January 7.
garbled, they forgot about the weather, which would have to be such as to get the radioactive cloud into a population center. More significantly, they never noticed that two months earlier the oil fire was the equivalent of having arrived at the fifth and last step, and in the middle of a densely populated area, too, namely, in Brooklyn, a few miles from their editorial offices. (I do not believe Time’s editors did this on purpose; which is to say, I believe they are grossly incompetent.)

But similar as an oil fire and a radioactive release may be in causing massive deaths to the public, the differences are even more striking in underlining the hazards of the former. There is, first of all, no defense in depth for an oil storage complex; there is no equivalent of an ECCS, a steel pressure vessel, or a massive ferro-concrete containment building. An oil storage complex only needs something to ignite it, and that’s it.

Second, the probability of an oil fire is not just “greater” than that of a nuclear accident that kills the same number of people (whether 3 or 300), but it is greater by a factor in the tens of thousands.

Third, there just isn’t a nuclear plant smack in the middle of New York City; the law forbids nuclear plants in or near large population centers. Grand Central Station in Manhattan would break the law if it were a nuclear plant, for even the radioactivity of its granite blocks exceeds NRC standards. Note, however, that I am neither advocating the removal of oil storage complexes (let alone Grand Central Station) from New York City, nor am I opposing it; I am just comparing things with the same yardstick.

But suppose that by some miracle Ralph Nader suddenly got interested in protecting consumers or advocating safety, and that he would use his anti-nuclear lobby for getting oil storage complexes out and away from New York City and other urban areas; would the risks of oil fires drop below those of a nuclear accident?

No, they wouldn’t. The risks from oil fires at power plant storage facilities only — disregarding the tankers and transit storage necessary to get the oil there — are still higher than those due to a nuclear accident; to put it more accurately, the consequences of such accidents are worse than for a nuclear disaster of equal probability. Using American Petroleum Institute fire statistics, Starr and co-investigators' estimate the probability of an oil fire with 10 or more deaths to the public at 1 in 10,000, which is twice as high as the probability of a corresponding severe nuclear accident, even if there
3. MAJOR ACCIDENTS

NATURAL gas is even worse for major disasters, especially in the form now most often used for storage, i.e., liquid natural gas (LNG). Ships containing 1 billion cubic feet of liquefied methane regularly dock in heavily populated areas — for example, in Everett, Mass., 1/2 miles from downtown Boston. To see what would happen if one of these ships exploded, or at least started a big fire, one needs to do little more than strike a match. Nader’s heart does not bleed for the potential victims. Potential victims? The victims of major LNG disasters are not potential, they lie dead in the ground, unbewpt by the anti-nuclear hypocrites. In October LNG tanks exploded in Ohio, killing some of them after the LNG had entered sewers.

Catastrophes with gas, about 100 people a year lose their lives (10 lives per billion MWh of consumed energy, not necessarily electricity). Once again, these are not hypothetical deaths calculated via fault trees and computer simulations. They are corpses counted by American coroners. It should also be remembered that oil tank explosions and fires are not, like nuclear accidents, hypothetical; they take place all the time. But if you do want to speculate about what might happen, consider the energy carried by an oil tanker. A fully laden 200,000 ton oil tanker carries the energy of a two-megaton hydrogen bomb. There are about 60 of these tankers now in service, and others, with 500,000-ton capacities are under construction. The US does not yet have a deep-water port that could receive one of these super-tankers, nor would the energy be released in a small fraction of a second, as is the case with a nuclear bomb. So if a regular oil tanker should explode in Seattle or Baltimore, the consequences would not be as bad as a two-megaton explosion of TNT, and we can all sleep soundly again: The energy released would be no more than a couple of nuclear bombs like the one dropped on Hiroshima...
3. MAJOR ACCIDENTS FATALITIES

spent to save a human life from the radioactive emissions of nuclear power plants.¹¹

When, in 1973, the maximum permissible radiation dose at the property line of a nuclear power plant was reduced from 170 mrem/year to 10 mrem/year, the effect was to reduce the incidence of cancer from 4 to 1 per year (out of a total of 300,000 cancers in the US). The cost of this step worked out to $800,000,000 per saved life.

On the other hand, there are now 75 LNG tanks located in US cities. The cost of moving these tanks out of the cities (calculated in the same way as for the example above) would amount to only $1,000 per saved life; but this cost has not been paid, and the LNG tanks remain in the cities.

Now who is it (and here we are no longer quoting Prof. Wilson) that decides to pay $800,000,000 for saving a human life from one danger, but refuses to pay $1,000 to save it from another?

In legalistic theory, it is the agencies of the US government, by the power delegated to them by the American people. But in reality, of course, we know better. We know that the vast mass of the American people does not know about millirems or LNG tanks, and cares even less. And we know that technical decisions of this type are made, whether by politicians or bureaucrats, under the prodding of pressure groups and lobbies. The anti-nuclear movement has become a powerful political force; there is no comparable movement to get the LNG tanks out of town.

Why not? The answer is painfully obvious. Moving the LNG tanks will do no more than save human lives. But attacking (ridiculously low) radiation levels is a scare tactic that can be used as a crusading horse against the big corporations and the "establishment," and hence for garnering political power.

FOSSIL fuels, then, present a far larger risk of accident, both by their greater consequences and by their greater probabilities, than does nuclear power. And fossil fuels are the only alternative that can completely replace nuclear power; in fact, with oil and gas running out, only coal can replace it completely. Other sources, such as solar or hydropower can supplement the basic energy sources, but they cannot replace them. There are not enough sites for hydropower left in the US to make a decisive difference, and solar power, as we shall see in a moment, can provide at best a small fraction of the total need. Wind, geothermal and tidal power make good conversation pieces, but none of them can reasonably provide more than 1% of the US need, and we shall waste no more space on them (they, too, are more dangerous than nuclear power per energy produced, and environmentally less satisfactory).²

Because of their quantitative limitations, solar and hydropower would be out of the running even if they were safer.

But they are not. Dams are no safer than other energy facilities, and they are grossly less safe than a nuclear power plant. Dams do break and kill people, with a probability about 10,000 times greater than nuclear power plants. A dam failure killing 1,000 people is estimated to occur, on the average, every 90 years; a nuclear disaster of that magnitude, according to the Rasmussen study, would take place once in a million years.

A recent study at the University of California at Los Angeles revealed that the failure of certain dams in the US could cause tens of thousands of deaths, and one of them could cause between 16,000 and 20,000 fatalities.¹² (The Rasmussen study stops at 3,000 deaths, where probabilities are already absurdly small.)

In March 1972, a dam failure at the St. Francis Dam in Santa Barbara, California, collapsed and killed 450; in December 1959, the Malpasset dam in France collapsed, killing 412; in February 1972, coal mine waste waters caused a makeshift dam to break in Buffalo Creek, West Virginia, killing 118 people.

On October 9, 1963, there was a dam disaster in Vaisont near Belluno, Italy, which was not caused by the dam actually breaking, but by a mountainside collapsing into the reservoir and flooding the valley below (just as if the dam had broken). More than 2,000 people were killed, and 50,000 were left homeless.

In the 1971 Los Angeles earthquake, a dam above the San Fernando Valley cracked and would doubtlessly have given way had the reservoir been full of water; but it so happened that due to the high demand for electricity on that early February morning, it was partially empty. Someone forgot to write a book We Almost Lost Los Angeles.

But then there is solar power, the good guy, the one that is not used "for only one reason — that the oil companies do not own the sun" (Ralph Nader, of course).

"Do you want a sunshine future for your children, or a radioactive one?" ask the advertisements of Environmental Action.
There is a very good reason why nuclear power has had such an unparalleled safety record. The strict regulation by the AEC (now NRC) has, so don't, helped, but it is hardly the major underlying reason. If it were that simple to legislate safety, there would not be 50,000 dead on US highways every year.

The underlying reason is quite different: No other power but nuclear has its dangers so concentrated in a very small space - the reactor core. No other fuel but nuclear has its energy so concentrated in a tiny volume. One pound of plutonium has the same energy as the Yankee Stadium full of coal. One hundred people a year are killed merely by transporting 150 million tons of coal all over the country; but virtually nobody is killed by a few truckloads of nuclear fuel.

There is no way of controlling a diluted danger such as presented by 105 million cars on the roads; but one can come close to perfect safety (though never completely achieving it) when the danger is all locked into a few cubic yards of space. It is the great concentration of the danger, and hence the comparative ease of guarding against it, that is the underlying reason for the unusually high degree of nuclear safety.

In that sense, solar power is the very opposite of nuclear power. The salient feature of solar power - one that surfaces in safety, economy, effectiveness, environmental impact, and all other aspects - is its diluteness. At the best of times, on a cloudless day with the rays hitting the collectors perpendicularly, the influx of solar energy is 1 kW per square meter (10.4 square feet), which means that large amounts of power need large collecting areas. For example, with 10% efficiency and 50% spacing (between the collectors), a 1,000 MW solar plant works out to no less than 50 square miles of collecting area (compared to a few acres for a 1,000 MW fossil-burning or nuclear plant). What that means to economy and environmental impact is another matter, but what does it mean for the danger of accidents?

First of all, 50 square miles of area per power plant unit are not easy to come by where electric power is most needed: in the northeastern United States. They are available in, say, the Arizona desert, but it is uneconomical to transmit electric power over very large distances; most probably the solar plant will produce hydrogen (by electrolysis of water) for shipment, and we are back to square one. Transportation in large quantities (except by pipeline) means accidents in large quantities; hydrogen is flammable, and mixed with oxygen, i.e., with air, it is explosive. Like methane, it is liquefied for storage and transportation, and we are simply back to the dangers of LNG and natural gas in general.

But where the diluteness of solar power really touches on safety questions is the 50 square miles of collecting area itself. Fifty square miles will be covered with large structures, which have to be maintained. They have to be kept clean, for one thing — clean of dust in Arizona, and clean of snow in Nevada. And there are going to be plenty of accidents on that 50 square mile area of large structures, especially accidents by the no. 2 killer in the U.S.: accidental falls.

Everybody knows the no. 1 killer among accidents, automobile accidents, with a toll of 50,000 deaths per year. But the no. 2 killer is not only deadly, it is also unknown to most people. Most people, when asked, guess at the small fry: fires (6,500), explosions (500), electrocution (1,000), firearms (2,600), drowning (7,000), air travel (1,700), tornados and hurricanes (200), and so on. But none of these amount to very much unless they are all lumped together as “other accidents.” The no. 2 killer kills about 16,500 Americans a year. The Bureau of the Census modified its classification of accidental falls, and when, for solar collecting structures, we add deaths blows from falling objects, we have a total of or more than twice as many accidental deaths as the next biggest group (accidental drowning).

Not that this makes solar power particularly dangerous. The danger doesn’t even constitute the main objection to solar power. But there is no way one can watch over 50 square miles the way one can watch over a single reactor vessel inside a ferro-concrete containment building. Even if a single accident can be much worse for nuclear than for solar power, the risk (probability times fatalities) will still be smaller for nuclear.
That is the way things look for large-scale solar energy conversion. For small-scale conversion by homeowners, the situation changes significantly — for the worse. Suppose solar-electric conversion came down from its present investment cost of $1,500 per kW so that people could afford it, and suppose they were willing to assume the investment costs (rather than pay about 4 cents per kWh to the utility, with everything taken care of). Then it will be laymen, not professionals, climbing on the roofs to clean off the snow after every storm, and they will climb onto roofs, not collector structures built for that purpose in large-scale conversion.

But above all, they will be risking their lives, not for 1,000 MW of capacity, but for a crummy 5 or 10 kW. One cannot produce a billion MWh by piddling around with 5 kW at a time, but one can use the same unit for the rate, deaths per billion MWh, as we used for coal and uranium mining and other parts of the energy cycle. What that number would be exactly, nobody knows; what is certain is that it would be of carnage proportions.

And we haven’t even considered accidents with storage facilities — sulfuric acid in the batteries, the explosive hydrogen-oxygen mixture arising in charging them, etc., all in the basement, laundry room or otherwise exposed for children to play with.

Solar power may come down in price, and all kinds of technology may be invented for it. But one thing can never change, and that is the incoming 1 kW per square meter. It is this diluteness of solar power which is the ultimate cause of its lack of safety.

Please do not misunderstand me. I am not saying that solar energy is a bad thing, and I am not even saying that safety should be the only consideration in the choice of an energy source. What I am saying is that solar energy doesn’t have a chance of even coming close to the safety of nuclear power.

Waste disposal, so often touted as a bogey by the anti-nuclear crusaders, is in fact one of the prime reasons why nuclear power is so preferable to coal-fired power. If all of the US power capacity were nuclear, the total amount of wastes per person per year would amount to one aspirin tablet, and that can easily be disposed of deep in the earth, where it came from in the first place (for Mother Nature keeps 30 trillion cancer doses of radioactivity in the earth, where it came from in the first place for Mother Nature keeps 30 trillion cancer doses of radioactivity in random places under the US). On the other hand, the amount of wastes generated per person per year by coal-fired plants amounts to 300 lbs of ash and other poisons, of which as much as 10% is spewed into the atmosphere, causing thousands of death by cancer, and by heart, lung and other diseases. The poisons produced by nuclear plants will be with us for centuries; but the poisons produced by fossil-burning plants will be with us forever. Let us look at the details.
When the uranium in a nuclear fuel rod has been spent (after about one year of service), it remains radioactive due to the intense radioactivity of the fission products. The spent rods are then immersed in deep pools of cooling water at the plant site for a few months to allow the high-level, short-lived radioactivity to die down. The rods still contain some unspent uranium, and also plutonium, which is a valuable fission product capable of being used as further fuel. The spent rods are therefore shipped in lead casks to fuel reprocessing facilities, which separate out the uranium and plutonium chemically. The process starts by dissolving the rods in a nitric acid bath — at this stage, there is no way the mythical terrorists could get at the plutonium inside even if the rods were not (intensively radioactive.) A single reprocessing center can handle as much as 5 tons of fuel per day, which corresponds to the output of eighty 1,000 MW reactors. The uranium is enriched and recycled into new fuel. The plutonium (or rather plutonium oxide) will one day be used as pure fuel in reactors which are not yet used commercially; it can also be used in “mixed oxide” fuel rods, in which a mixture of uranium oxide and plutonium oxide is used as the fuel in the rod, thus preventing the plutonium from ever achieving the ratio of volume to surface necessary (but not sufficient) for a nuclear explosion.

The remainder also contains some plutonium, since it is not possible to separate it out completely. NRC regulations require that these remaining wastes be converted to solid form (eliminating the danger of liquid spills) within 5 years after arrival at the reprocessing site, and that they be shipped to a permanent repository 10 years after reprocessing. That is the way it should be, but in fact there is a temporary flaw in the process. At the time of writing, there is an acute shortage of reprocessing capacity, due, in part, to the reluctance of private industry to take over the reprocessing plants (hitherto run by the government) in the present uncertain climate surrounding nuclear technology, but in part also due to the issue of plutonium, which has prompted the NRC to delay recycling until plutonium safeguards have been debated and worked out. The net result is that nuclear wastes are now piling up at power plants, which are running out of space for them, and instead of being reprocessed and disposed of, they are kept in places where they might indeed become dangerous. As in so many other cases, the alarmists have not only cried “Wolf!” but they have brought in a wolf of their own.
102 4. WASTE DISPOSAL

Deposits that are underground naturally, not in carefully selected and monitored places, but utterly at random.

The much used rhetoric about wastes remaining "radioactive for thousands of years," while perfectly true (the half-life of plutonium 239 is 24,400 years), is quite misleading and largely meaningless. As we know from Chapter 2 (p. 54), the longer the half-life of an isotope, the less intense its radiation. Arsenic, which is not radioactive at all, has an infinite half-life, and indeed, while plutonium will be around for a long time, arsenic will be around forever.

Nor is the point about arsenic (for example) a cheap trick of demagoguery. As Prof. B. Cohen of the University of Pittsburgh has pointed out, arsenic trioxide is a poison used as a pesticide. It is not a very commonly used one, but more of it (in weight) is imported every year than all the nuclear wastes would amount to if all US power were nuclear. Arsenic trioxide is about 50 times more toxic than plutonium when ingested (for plutonium being "the most toxic substance known to man" is more melodramatic piffle), but the main difference compared with the threat of wastes is this: Nuclear wastes, when there are enough of them, will be buried deep underground in carefully chosen geological formations. But the arsenic trioxide is dispersed in random places on the earth's surface, mainly where food is grown. Long after the nuclear wastes have decayed to negligible levels, it will still be around in the biosphere.

In all this scare talk about what to do with nuclear wastes without endangering future generations (we will return to that point presently), the main characteristic of nuclear wastes gets lost: Their amount is minuscule. As already mentioned, the volume produced by one person's annual share of the total US output is that of a single aspirin tablet; and this is one of the aspects that make nuclear power so attractive — not in spite of its waste disposal, but because of it. If the entire US electrical capacity were nuclear and ran at the present rate for 350 years, the volume of wastes would amount to a cube 200 feet on a side. After three and a half centuries! (Actually somewhat more space would be needed in practice for cooling passages and accessibility.)

There are several satisfactory methods of disposing of the final nuclear wastes, but if a decision were made by the NRC tomorrow, there wouldn't be enough wastes to implement it. We have some two or three decades before deciding whether there are even better ways than are now being considered, whether the wastes should be disposed of permanently, or whether they should be made retrievable.

103 THE "UNSOLVED PROBLEM"

Apart from a number of highly exotic proposals (which are quite unnecessary), the simplest and evidently most satisfactory is to bury the wastes deep underground, where the chance of them ever being reached by ground water is minimal. The obvious place are salt formations, partly because the salt is evidence that no water has ever been there for at least the last two hundred million years, partly because salt formations are self-sealing in the event of an earthquake. Is it thinkable to make nuclear waste disposable safer than that?

Yes, it is. British scientists have developed a method of sealing wastes into a highly durable glass, making them fireproof, water-proof and earthquake-proof for many centuries.

A similar method of sealing nuclear wastes into glass was announced at the American Chemical Society's Centennial Conference in New York City in April 1976.

If deep burial in salt formations, after sealing in fireproof, water-proof and earthquake-proof glass makes nuclear waste disposal an unsolved problem, what, pray, is a solved problem? The disposal of fossil wastes in people's lungs?

Investigations of salt formations in Kansas proved unsuccessful, because nearby drilling holes were discovered that might have leaked water, but ERDA is now investigating other salt formations in New Mexico. There are about 50,000 square miles of salt formations in the US, so that there is no lack of sites, and burial in salt formations is only one of several viable methods. ERDA is site surveys for three facilities in each of four geologic formations — thick-bedded salt and hard-rock It is, in any case, reassuring that the is investigated decades ahead of its time..

Of course, as in all other aspects of nuclear power, nobody can give a guarantee that the wastes will be disposed of with perfect safety so as never to endanger anybody at all; one can only say that the danger is incomparably smaller than the presently used methods of waste disposal in coal-fired plants, and that the probability of a casualty from nuclear waste disposal is extremely small.

Moreover, as in the case of nuclear accidents, if the improbable happened and the wastes did somehow get into the ground water, the resulting casualties would not constitute the disaster depicted by emotional critics (such as Hannes Alflen who has talked about "poisoning the entire globe"). The journey through aquifers would take at least decades (allowing monitoring and countermeasures) and
during that time the poisons would not only lose some of their toxicity (radioactivity) by decay, but they would also be strongly diluted. To drive this point home, Prof. Cohen made a calculation for a case which is vastly exaggerated, but allows close comparison with situations where numbers are available.6

Cohen assumed that the wastes from a fully nuclear US electrical capacity were to be buried at a depth of 2,000 feet, utterly at random — perhaps under children’s schools, water supplies or any other place where blind chance happened to put them. The result of Cohen’s calculation, which is based on what natural radioactive deposits are known to do, gives the expected (average) number of eventual deaths per year: 1.1 deaths for the first 200 years, declining to 0.4 deaths thereafter. And this, I repeat, under the intentionally absurd assumption that the wastes will not be buried at carefully selected sites and monitored, but that they will be buried in utterly random locations all over the US. It also assumes that no cure for cancer (the only possible hazard of wastes) will be found in the future.

AND yet, and yet, and yet . . . People just don’t like the idea of radioactive wastes being put out of the way for thousands of years, and the reason is one of the many quirks of human psychology: They fear this danger not because it is great, but because it is new. They are used to millions losing their lives in wars, to thousands losing them in famines, and to hundreds losing them in railroad and airplane disasters, mine explosions, floods or hurricanes. But radioactive poisons underground, threatening somehow to get into your food — no matter how absurdly small the probability, it’s new, it’s a danger that wasn’t there before!

The hell it wasn’t. There are some 30 trillion cancer doses under the surface of the United States — the deposits of uranium and its daughters. They are not sealed into glass; they are not in salt formations; they are not deliberately put where it is safest; they occur in random places where Mother Nature decided to put them. And they do occasionally get into water and food, and they do occasionally kill people.

From the large amount of information on the presence of various radioactive isotopes in different parts of the human body (available from autopsies), plus some other well known information, Dr. Cohen found the number of people who die from these natural deposits:

The mean number of Americans killed by ingesting uranium or its daughters from natural sources is 12 per year.7 And the half-life of uranium 238 is 4.51 billion years; U 235 has a half-life of 710 million years. There is, then, nothing new about the problem; man-made deposits need not be as sloppy or as dangerous as natural ones.

“There is nothing we can do about those 30 trillion cancer doses,” some people say when they first learn about them, “but at least we need not add any more to them.”

But we add nothing. We take uranium ore out of the unsafe places where Nature put them, and after we extract some of its energy, we put the wastes back in a safer place than before, though we do put them back in fewer places in more concentrated form.

How concentrated? Within 10 years, more than 99.9% of the original radioactivity of the wastes disappears by decay, and the majority of the waste products then has a half-life of 30 years. In 1,000 years, the wastes are less radioactive than pitchblende (which contains 60% uranium, but also some shorter-lived and hence more intensively radiating elements such as radium). Plutonium, with its half-life of almost 25,000 years, slows the decay process, but it remains there only as an impurity that failed to be recovered for further use as a valuable fuel. And what if the Luddites have their way and of the unused? Like the man who killed his parent and then demanded the Court’s mercy on the grounds that he was an orphan, want to waste and then scare with the half-life of nuclear wastes.

“But how can you go into something dangerous without any practical experience?” Yes, that is a problem that faced Christopher Columbus and the Wright brothers; but it also happens that it doesn’t apply to nuclear wastes.

1.8 billion years before Alfven fantasized about “poisoning the entire globe” and Barry Commoner invoked images of a “nuclear priesthood watching over wastes for thousands of years,” there was a natural reactor in operation in what is now the Republic of Gabon in Africa. Water pockets in a uranium deposit acted as neutron traps, and at least four, perhaps as many as six, “reactor zones” (30 ft by 30 ft by 10 ft thick) went critical 1.8 billion years ago, producing an average of 20 kW thermal power for about half a million years.

The “Oklo Phenomenon” (named after the Oklo uranium mine in Gabon) was discovered when French engineers noticed a slight deficiency of the U 235 content in the ore and scientific investigations
found that it had been burned up by a natural reactor. An international scientific conference, organized by the International Atomic Energy Commission, was held in Gabon in June 1975, and among the facts it firmly established were these:

There had been 12,000 lbs of fission products, and 4,000 lbs of plutonium (virtually all decayed now). All of these have remained completely in place.

In 1,800,000,000 years, 12,000 lbs of waste fission products and 4,000 lbs of plutonium have not budged an inch out of the reactor zones, though the whole phenomenon was produced by blind chance, and there were no particularly favorable chemical or other immobilization mechanisms at work.

CANNOT MAN DO AT LEAST AS WELL?

Waste disposal does, however, leave unsolved problems to future generations, as well as threaten the lives and health of the present generation — when it comes to coal.

The quantity produced by one person's annual share of the output of coal-fired plants in the US is not one aspirin tablet (as in the case of the nuclear cycle with reprocessing), but 320 lbs of wastes, of which often only 90% is in the ash pile; the rest, which includes particulate and gaseous poisons, is spewed into the atmosphere, and it doesn't threaten to kill people; it kills them very definitely. It is these discharges into the atmosphere which are the most dangerous waste products of a coal-fired plant, but we will leave them for the chapter on routine emissions, for they are not deliberately disposed of, and hardly qualify for the name of waste "disposal."

The ash itself is not particularly dangerous, though it is not without its dangers. First of all (though this is not the biggest danger), the ash — and this comes as a surprise to many — is radioactive, too. Both "eastern" and "western" coal contains traces of radium and thorium (as well as smaller quantities of polonium and other radioactive isotopes). Nor is that radioactivity negligible — at least not compared to a nuclear plant. Its total level is higher, and it is more persistent, not only because the radium 226 in coal ash is long-lived (half-life 1,620 years), but because all radium and thorium isotopes are water soluble and chemically very active; some water-soluble radionuclides in coal ash are considered a threat to bone structure. Unlike nuclear wastes, ash with its radionuclides is dispersed or buried without monitoring or control.

However, this aspect is mentioned here only under the "same yardstick" policy, for neither nuclear nor coal-fired plants add significantly to the background radiation present in the environment already, and in the case of coal-fired plants, the radioactivity (though larger than that of nuclear plants) presents a negligible risk compared to the risks associated with air pollution.

As for the coal ash not dispersed into the atmosphere, but disposed of in landfills, the real problem lies in its huge quantity.

For a nuclear plant of 1,000 MW capacity, the annual amount of solid discharges can be taken away in 60 and even in smaller figures is misleading, for the heavy and bulky items of the load are the (reusable) leaden casks in which the spent fuel rods are taken away; if it were possible to load the spent fuel only, a single truckload per year would do it. On the other hand, if the 1,000 MW plant is coal-fired, the annual amount of ash taken from the plant to the dump amounts to no less than 36,500 truckloads.

The tens of millions of tons of ash generated by US coal-fired plants every year are dumped in landfills. There is enough coal in the US to last for at least two more centuries at the present rate of usage. But for how long is there enough space where to dump the wastes?

Let future generations worry.

There are no provisions to prevent the poisons in coal ash being leached out by rainwater (they are dumped close to the surface) and creeping into aquifers. The metals in it (selenium, mercury, vanadium and others) do not, like plutonium, have a halflife of 24,360 years; their halflife is infinite. There are carcinogenic (cancer-producing) hydrocarbons, such as benzopyrene, among the poisons. How many other carcinogens does the ash contain? How many mutagens (substances causing mutations) are among them?

Let future generations worry.

The radioactivity of the radium and thorium isotopes in coal ash exposes the public to at least 180 times the dose received from nuclear plants of equal capacity1 and would violate NRC standards if the NRC were responsible for coal-fired plants, but it isn't. The radionuclides contained in coal ash are chemically active and soluble in water; yet the stuff is dumped close to the surface without strict control and without even any monitoring. Will that be dangerous in coming decades or centuries?

Let future generations worry.
The responsibility of the present generation, it would seem from the publications of Public Citizen, Inc., is to grow hysterical about the one method of waste disposal that is capable of preventing virtually all dangers to future generations.

I have no reason to believe that the present method of coal ash disposal into landfills presents a particularly acute threat to public health, and I am not very worried; but neither are those who get hysterical about the aspirin-tablet equivalents of nuclear wastes to be sealed in glass, deposited in metal cans, thousands of feet below the surface, in salt formations, and continuously monitored — in 10 or 20 years from now when the problem will first arise.

There is no known way of protecting people from the vast amount of wastes generated by fossil-fired plants, but there are several ways of removing the miniscule amounts of nuclear wastes from the biosphere altogether. "And getting rid of the wastes is something else again," says the little figure in the Sierra Club cartoon above. The Sierra Club endorsed a nuclear moratorium in 1974 and its executive director Michael McCloskey declared coal environmentally preferable to nuclear power.7

The type of landfill depicted in this cartoon (Sacramento Bee, reprinted by Critical Mass) is, in fact, used for coal ash disposal, which is neither controlled nor monitored and leaves unsolved problems for future generations. The volume of the high-level nuclear wastes generated in the US up to the year 2,000 will amount to a cube less than 70 ft on a side.

But once again, I neither advocate nor oppose increased concern about coal ash disposal, for my plea is more modest: Use the same yardstick.

The logical counterpart to nuclear waste disposal is waste disposal into the atmosphere (i.e., air pollution) by fossil-burning plants. Inexpertly or not, I have left this to the next chapter on routine emissions; but there is one more point about solid waste disposal, and that is that the entire problem of waste disposal from coal-fired plants is about to be significantly complicated by the use of scrubbers. In the emotional climate of the early seventies, the National Environmental Protection Act was passed in 1970, and its air quality standards are not only unrealistic (necessitating repeated postponement of their implementation), but often based on insufficient, and
in some cases incorrect, data. The Environmental Protection Agency, under strong political pressures, was required to introduce quick and half-baked measures. In the case of automobile emissions, the EPA bludgeoned the auto industry into the catalytic converter, which produces sulfuric acid fumes, a health hazard that was not present in automobile emissions before, and there is also some evidence that its high operating temperatures present a fire hazard when a car is idling over inflammable material such as dry grass.

In the case of coal-fired plants, the EPA has similarly tried to bludgeon the utilities into limestone scrubbers, which are not only costly, but also partly ineffective. Some utilities, particularly the American Electric Power System ("We have more coal than they have oil"), have resisted, but most others have given in to achieve peace, if not clean air.

The logical way to eliminate the poisons put into the air by burning coal is to get rid of them before it is burned, particularly by desulfurizing the coal, or using (Western) coal with very small sulfur content. Desulfurization of coal is possible by several laboratory methods, but an economic method that works on a large scale has yet to be found. Gasification and liquefaction of coal, quite apart from the economic obstacles of enormous investments, may not necessarily guarantee clean air, for it may introduce a number of other substances with which there is little experience.

As for western coal low in sulfur content, the environmentalists (if they deserve that name) have been doing their utmost to prevent its use by doggedly opposing its mining.

The scrubber, therefore, makes use of the dubious and only partially effective method of polluting first and attempting to get rid of the pollution afterwards. It attempts to eliminate sulfurous pollutants (the most easily observable, but not necessarily the most dangerous) by passing the clean gases through a water spray and reacting the sulfurous compounds with limestone. A scrubber of this type is, of course, much better than no pollution control at all, but while it does not eliminate the poisonous fumes completely, it does give rise to a huge quantity of sludge, which is itself a pollutant and must somehow be disposed of.

How? That is another problem for future generations as well as the present one, for no one has yet any idea what to do with all that sludge as it accumulates.

--P. Abelson, editor of Science, considered the point in an editorial in September 1975. He pointed out that the desulfurization systems favored by EPA are costly and unreliable, and that they give rise to a soupy sludge in vast quantities.

"If EPA standards were to be met for all new stationary sources," he wrote, "the production of sludge would rise to 300 million tons a year." In 20 years, the sludge would form a body 10 feet deep covering an area of 240,000 acres.

The editorial provoked the wrath of EPA head Russell E. Train, who fired back an angry letter twice as long as the original editorial, charging that Abelson had grossly overestimated the amount of sludge and that only 120 million tons of it would be produced per year.

That means, as elementary arithmetic will show, the sludge on those 240,000 acres will in 20 years' time be only 4 feet deep, and I hope the thought comforts you; but it leaves me very cold.

I vote for the aspirin tablets.
Routine Emissions

There is more radioactive material in a reactor than 2,000 Hiroshima-sized bombs.

Ralph Nader

Stating that these materials are present in a reactor, if there is no bomb to spread them over an area, is scaremongering. It is equivalent to saying that the chlorine gas stored at the city waterworks and swimming pools is sufficient to poison everyone in the city 8,726 times.

Dr. R. Philip Hammond

A nuclear power plant causes no air pollution, and its only emission is radioactivity, which is quite negligible compared with the radioactive background due to either natural or (non-nuclear) man-made sources; it is also smaller than the radioactive emissions by a coal fired plant.

To repeat some of the figures from Chapter 2, the specific data are as follows: According to the Environmental Protection Agency, the average US resident gets a dose of 0.01 millirems/year from all the nuclear power plants in the country; The NRC allows 10 millirems per year to persons living next to the property line of a nuclear plant, but its guidelines recommend a maximum of 5 millirems/year, and in point of fact, it starts investigating when this guideline limit is even approached.
CLEANER AIR IN SPITE OF THE SIERRA CLUB

Londoners have been, are, and will be dying of cancer and other delayed diseases contracted in the air pollution of December 1952. I do not want to use Naderite scare tactics, and therefore I hasten to add that the London 1952 example is meant to indicate where our knowledge comes from; it is not meant to imply that the conditions of the 50's persist in London or the rest of the industrialized world. They don't; air pollution has been cut very significantly throughout the industrialized world in the last two decades, though it has only been curbed, not eliminated. Indeed, there is little hope of eliminating it by combatting it after it has been created; the only hope is to eliminate its source, and nuclear power is one of the few viable options of preventing rather than curing air pollution. But there is another significant aspect to the point, while we are digressing from the figures, and that is that the abatement in air pollution has been achieved more and better through environmentalists were followed, and technology were curbed rather than augmented and improved, then the catastrophes of the 50's (which were not limited to London) would now be far more frequent. Today's air is cleaner in spite of, not thanks to, the technophobic efforts of the Friends of the Earth or the Sierra Club. Even now they are opposing nuclear power, though by air pollution or any other measure it is the safest form of power available.

But let us return to the facts and figures of air pollution. A coal-fired plant spews all kinds of poison into the air, even when it has been fitted with scrubbers and other pollution control equipment, for none of these gadgets can catch all the pollutants; they curb pollution, but they do not eliminate it. A coal-fired plant produces particulates, sulfur dioxides, nitrogen oxides, trace metals, and other pollutants. Particulates are (or should be) caught by electrostatic precipitators just before the flue gases go into the stack of a power plant. The gases are passed through a strong electric field in which the particles acquire a charge and are attracted to the high potential of the precipitator, usually in the form of a metal rod. When they have accumulated into a thick cluster, they are shaken off the precipitator by mechanical impact and fall into the waste collection space below. In technical terms, precipitators can be pretty good, for they can catch up to 99.8% of the particulates by weight. But that does not at all mean that they prevent 99.8% of the health effects caused by
particulates. Far from it: The big chunks of fly ash and soot may be a nuisance, but their health hazards are probably minor. The really dangerous matter are the tiny particulates that penetrate deep into the lungs; they get past the natural filtering mechanisms in the body, and they get past the precipitators—the ones so good at filtering out the big and harmless particles that they earn the label “99.8% efficient.”

It is known that these small particulates are harmful, that they cause chronic bronchial and lung diseases, including, very probably, lung cancer. But exact figures are not known; there are not even any highly reliable methods of measuring the amount of particulates at the top of the stack. The national air quality standards (primary—human health) prescribe an annual average less than 75 micrograms per cubic meter, and a maximum 24-hour concentration of less than 260 micrograms per cubic meter, but few of the large US cities are able to comply with these standards. One method widely used in other countries, including Britain and Japan, is to require power plants to have very tall stacks. This does not eliminate particulates (or other pollutants), but at least itdisperses them and prevents high concentrations, which is particularly useful when a temperature inversion hovers over a city, trapping pollutants in the city air. If the stacks are high enough to penetrate the inversion, as they often are, the danger of this trapping mechanism is eliminated.

But tall stacks have been ruled unacceptable in the US. The 1970 Clean Air Act was passed in an emotional atmosphere without sufficient technical data and even less regard for realistic limitations. It was so written that courts later refused to accept tall stacks as a genuine method of pollution control (the suits were filed by “environmentalists” who probably thought they were on the side of clean air), and the result is that particulate pollution remains an ugly reminder of what happens when legislation is passed by vote-pleasing politicians who are more interested in poising as corporation-baiters than in clean air.

Sulfur dioxide pollution is the one that has been most intensively studied, and there is a clear correlation between sulfur dioxide concentration and excess deaths by lung, bronchial, heart and other diseases. This is shown, for example, by the figures in Table I on the opposite page.

We note in passing that a disaster like the 3,900 early deaths (the delayed deaths are unknown) in London is virtually impossible for a nuclear accident: The largest consequence considered in the Ras-mussen Report was 3,000 deaths, with the philosophic probability of one per billion years-per plant.

The table above gives a few data from a long list available from many cities in the US, Britain, France, Japan, Norway, and other countries. But all that follows from tables like these is that sulfur dioxide concentration is a good indicator of the health effects of air pollution; it does not in itself follow that the sulfur oxides are their main cause. Correlation is not necessarily a cause-effect relationship. It is, for example, perfectly true that “The more churches in a city, the more crimes are committed there,” for the simple reason that bigger cities tend to have more churches and they also tend to have more crimes than smaller communities, because both are (roughly) proportional to the number of inhabitants. There is a definite correlation, but obviously one is not the cause of the other; one cannot reduce the crime rate by tearing down the churches.

Similarly, the concentration of sulfur dioxide is a good indicator of air pollution, and if the number of excess deaths is compared with it (as in the table above), there appears a definite tendency for the two variables to go up and down together. Moreover, we know that sulfur dioxide is indeed the cause of some adverse health effects—-it is, for example, responsible for forming sulfuric acid vapor in the atmosphere, which in turn causes bronchial diseases and aggravates others. However, we do not know for certain whether, besides being a good indicator, it is also the main cause of deaths and diseases caused by air pollution.

Much less than even that is known about nitrogen oxides, which arise in combustion at high temperatures from the nitrogen in the air. The main culprit is the automobile engine, but fossil-fired power plants produce them, too, and health authorities are growing more and more disturbed about them.
5. ROUTINE EMISSIONS

WHERE CANCER TAKES GREATEST TOLL

Based on cancer mortality rates by county, for white males, according to the National Cancer Institute.

Evidence that cancer may largely be a man-made disease: Incidence correlates well with industrial concentrations. Together with automobile emissions and chemical industries, fossil-fired plants are now among the suspects (see text). Among the few industries clear of suspicion: nuclear.

Respiratory diseases due to air pollution. (Cigarette smoking is not, of course, a protection against disease; the line for smokers is lower because lungs polluted by cigarette smoke are less susceptible to additional air pollution.) CHESS stands for EPA's Community Health and Environmental Surveillance System, whose report on sulfur dioxide emissions has been sharply criticized for systematic distortion, doctored data and willful omissions. However, even large deviations from the curves above will not alter the fact that nuclear power causes no air pollution at all.
Nuclear power saves lives: between 800 and 4,000 lives a year at present, and between 20 and 100 additional lives for every 1,000 MW nuclear plant that will replace a coal-fired plant in the future. That is also the amount of lives sacrificed by each year of delay in constructing a 1,000 MW nuclear plant. For that case, each cross above represents between 1 and 5 such sacrificed lives.

Excess deaths per year by respiratory diseases due to air pollution by US power plants: most optimistic estimate, and exclusive of delayed diseases such as lung cancer. Each cross represents 100 deaths.

All of these emissions cause a number of lung diseases, bronchial diseases and heart diseases, often resulting in early death (i.e., death occurring soon after a high-pollution "episode"); how many delayed deaths there are, e.g., by cancer, with a latency period of up to 40 years, nobody knows.

Now all this is sharply different from the case of nuclear power, where the health effects and risks are known exactly. In part, of course, this is due to nuclear power being a much simpler danger — the only danger is radioactivity, and the only significant health hazard is cancer. But there is also another factor which must have made its contribution: More than $1 billion has been spent on studying nuclear safety. No comparable effort has been made to understand the deadly effects of burning coal and other fossil fuels.

It is, however, possible to measure the effect of burning coal (or other fossil fuels) by plotting the value of an indicator of air pollution, usually the concentration of sulfur dioxide or suspended sul-

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5. ROUTINE EMISSIONS

direction — then the result lies between 50,000 and 250,000 excess deaths per year.

And once more we recall that these are only the early deaths, directly traceable to air pollution episodes. The delayed deaths, particularly cancer, are not included in these figures.

Perhaps the estimates quoted here are exaggerated and on the pessimistic side. But take the most optimistic estimate and make the rosier assumptions: There still remains a risk to life and health compared to which routine emissions and waste disposal by nuclear plants are outright laughable.

WHAT these figures boil down to is this: Every 1,000 MW of nuclear power that replaces coal-fired power saves between 20 and 100 lives a year. The present nuclear capacity of roughly 40,000 MW is already saving between 800 and 4,000 lives every year. These are not lives in hypothetical accidents that might or might not happen, they are lives of Americans who are now among us and who would be lying dead in their graves if Ralph Nader had his way.

Conversely, every year of delay in which a nuclear power plant is not built to replace 1,000 MW of coal-fired power kills between 20 and 100 people. True, cancer, arterial and respiratory diseases kill a total of about 1,300,000 Americans every year,13 and the names of a few hundred among them who were killed by lack of nuclear power are unknown. Their widows and orphans do not come to weep in the offices of Nader’s Public Citizen, Inc.

But that does not make Nader’s or Brower’s attitude any less despicable. Having flatly declared that the nuclear power issue cannot be left to scientists but must be settled by “citizen activity,” they cannot escape moral responsibility for these deaths. It would be callous enough to crusade against a technology that saves hundreds of lives every year, whatever the alleged motivation. But it is vile to crusade against it in the name of safety.

We have seen that the hazards of fossil-fired power to human health and safety are far greater than those of nuclear power; coal-fired plants kill, by air pollution alone, about 100 times as many people as all of the nuclear cycle, including its most dangerous phase, uranium mining. In accidents, minor or major, the ratio is of the order of 100:1, again in favor of nuclear power.

But what about the effects on the land and on nature in general? Here the comparison is again in favor of nuclear power, but by an even greater ratio.

The difference is most striking in the volume of earth that has to be disrupted to mine uranium ore on one hand, and coal on the other. This, of course, is again a consequence of the high concentration of energy in uranium and the low concentration in coal: Vastly more coal must be mined to produce the same amount of electrical energy.
The annual US consumption of electric power is now getting close to 2 billion MW/h/year (by the latest available figures, 1974, it was 1.887 billion MWh/year). The uranium ore that must be mined to produce that amount of energy, assuming the use of breeder reactors, is only 200 feet by 200 feet by 100 feet.

But the volume of coal that must be mined to produce those 2 billion MWh/year is 200 feet by 200 feet by 100 miles! In other words, by mining uranium instead of coal, disruption of the earth could be reduced by a factor of five thousand.

Yet the Friends of the Earth have made it their official policy to oppose nuclear power, and most of their activity is now devoted to that effort. Clearly, the Friends of the Earth are no friends of the earth.

Is it unfair to invoke the breeder, which is not yet in commercial operation in the US? (It is in France and the USSR, and soon to begin in Britain.) Is it unfair to talk about volume rather than the disturbed surface area, regardless of the volume underneath?

Then take the figures used by the Council of Environmental Quality, an official government agency, and one virtually always on the side of the "environmentalists." According to the CEQ, the annual environmental impact in land use for a 1,000 MW coal-fired plant (load factor 75%) is 9.120 acres if the coal is deep mined, and 14,010 acres if it is surface mined. Plus 161 acres for processing, 2,213 acres for transport, and 969 acres for conversion (includes 117 acres for ash storage, 13 acres for coal storage, and land affected by thermal discharges). About half of US coal is surface mined, so that the grand total is 14,635 acres.

For a nuclear plant with the same power and load factor, the annual acreage used in mining is 785 acres, for conversion 314 acres (2.2 times less), for processing 9.12 acres (17.6 times less), and the acreage used for transport is given as zero (evidently meaning negligible — one can load a year’s nuclear fuel supply as an afterthought to a train taking in a day’s supply of coal).

But even neglecting the other components, in mining alone the figures are 11,565 acres for coal vs. 785 acres for uranium ore, a ratio of 14.7 : 1 in favor of nuclear power.

And that ratio would increase to 4,420 : 1 if the uranium were used in a breeder. That must be why the Friends of the Earth are so fanatically opposed to it.

After figures like these, a discussion of oil spills, land use for oil and gas pipelines, and other such items would have the flavor of overkill, but one should mention the biggest environmental booboo of them all, solar energy. The 1,000 MW plant discussed above, whether nuclear or fossil-fired, needs about 25 acres for the plant itself plus storage facilities, rail yards, etc. A solar plant producing that amount of power (with 10% efficiency and 50% spacing between the collectors) would need 50 square miles. This has nothing to do with economics and is a simple result of the fact that solar power comes in at the dilute rate of 1 kW per square meter — at best. This would, in itself, lead to large collection areas, but since the sun is not out at night and during cloudy days, the plant would have to be designed for a much higher capacity, enabling its storage facilities to supply an average of 750 MW as above (1,000 MW times load factor 75%) when the collectors are ineffective due to the absence of strong sunlight.

Fifty square miles! The figure speaks for itself, yet I cannot resist the temptation of reminding the “environmentalists” of one of their most cherished slogans: Small is beautiful.
IT TAKES energy to produce energy: One must burn diesel oil to run the pumps that bring oil to the surface, for there are no more "goshers" in America. This has given rise to "energy accounting," a type of bookkeeping in which the debits and credits are not posted in dollars, but in kWh or other convenient units of energy. It serves various purposes, and it must be modified depending on the purpose. One of its purposes is to give a rough idea of the environmental impact of using a certain energy source; obviously, a source that needs a large amount of "debit" energy to produce only a small amount of "credit" energy is not likely to be very kind to the environment, though there is no one-to-one relationship.

For each kWh of chemical energy contained in the coal underground (1 kWh is contained in about 4 oz of coal), only 80% is recovered by surface mining, the remaining 20% are left in the mine, and 0.8% of the original energy, or 8 watts, are used in mining the coal. In processing, 7.9% of the coal is lost, and 0.1% of the incoming coal is used up in the machinery. In transporting the coal, 1% of the coal is lost, mostly by the wind blowing the coal dust off the railcars, and 0.9% is used in hauling the coal, so that more energy is lost as coal blown off the train than is used in hauling it. (Yes, that surprised me, too, but that is what the US Bureau of Mines statistics say.)

When the coal arrives at the power plant, there are only 71.3% of the original 1 kWh left, and that is now about to be really butchered: The power plant converts 38% of it to electricity, the rest is converted into waste heat; finally, 8.8% of that electricity is lost (as heat) in the transmission lines and transformers before the electricity arrives at the main switch of the consumer. The energy he starts out with (regardless of how much he, too, then turns into waste heat) is 54.9% of the energy that was originally contained in the coal lying underground.

If that sounds like very little, it is more than any other form of electric power generation (except hydropower); the corresponding system efficiencies are given in the table on the opposite page (system efficiency is the fraction of energy available at the consumer's electric meter from the total energy contained in a volume of fuel before extraction).

The fact that the net energy available to the consumer is always less than the original energy contained in the source has led many people astray and to absurd conclusions. The fallacy is that the energy of the coal left in a mine is very different from the energy expended in hauling it to the power plant. The latter was converted and invested by man and represents a genuine loss; the energy in the coal was put there by the sun millions of years ago and is not our investment to lose. (Did I suffer a business loss when I failed to be born into the Rockefeller family?)

With the possible exception of some foods, the energy return on invested energy is always positive, or nobody in his right mind would produce it in large quantities. (Beef is eaten for its good taste, not to keep the national energy balance.) The energy input to the consumer is the energy made available to the consumer divided by the man-converted energy invested in the production chain. In the preceding example the energy gain amounts to 16.2, i.e., the electrical energy delivered to the consumer is 16.2 times larger than the energy invested in the entire production chain from surface mine to consumer terminals.

The energy gains for other production chains (all ending with electric power to the consumer terminals) are the following:

- Deep-mined coal 13.5; natural gas 4.9; nuclear 3.6; oil 2.7.

Why is the energy gain so small for nuclear power, or at least much smaller than for coal? For a single reason: enrichment. More than 40% of the originally present U 235 is lost, together with its energy, in increasing the fraction of the fissile U 235 in the uranium ore, which is mostly U 238, i.e., enriching the original fraction of 0.7% to about 3.5%. The diffusion process which achieves this requires large amounts of energy to compress and pump the uranium hexafluoride gas through thousands of stages and membranes to achieve a partial separation of the two isotopes.

However, it will not always stay that way. There is not much one can do about the energy efficiency of coal mining after many centuries of its evolution. But there is real hope for making the enrichment process drastically more efficient.

Centrifugal separation is basically the same process as is used to separate cream from milk, but requiring vastly higher speeds and far greater stresses on the metal of the centrifuge. Because of the latter
difficulty, enrichment by diffusion was sufficient in the Manhattan Project and it has remained with us ever since. However, centrifugal separation is expected to increase the efficiency of enrichment by a factor of no less than 10, and mechanical problems that were insurmountable in 1942 are now solved, though not yet tested in large-scale and prolonged practice. Centrifugal enrichment will almost certainly be used in Europe, and very probably in the US, too. When that happens, the energy gain of nuclear power will shoot past that of coal.

There is also another method under intensive investigation, though as yet only for minute quantities of uranium in the laboratory. It is based on the ionization of one of the isotopes by laser radiation, and then separating the two isotopes electromagnetically. The energy gain would then increase even more, but the method is not likely to be developed to commercial size in the next decade.

In the meantime, there is a very simple way to decrease the energy used for enrichment, and that is to avoid it altogether in using recycled plutonium oxide for mixed oxide fuel (the uranium oxide still needs enrichment as shown in the figure above). But the "environmentalists" are opposed to reprocessing because of terrorism and sabotage, which we will examine in the next chapter. Heads, they win; tails, you lose.
As the price of fuel increases, it is very likely that some of these methods will be used; there are many reasons why they are not used now, but not one of them has anything to do with the Second Law.

Second, thermal "pollution" is most often based on colossal exaggerations, colossal even by environmentalist standards. It is true that as more and more energy is converted, more and more heat must be generated (the Second Law does come in legitimately here), so that eventually a limit might be reached for large concentrations of industry. But that day, if it ever comes, is very far away. For US consumption of energy to come even within one percent of the energy incident from the sun, every American man, woman, child, and infant on the breast would have to consume, from midnight to midnight, no less than 2 MW of power, which he could do by running 600 clothes dryers all day and all night, or cleaning his teeth twice a day with 15 million toothbrushes. And the rest of the world would still have to consume twice as much.

But no exaggeration is too great for the instant ecologists, especially when they are playing politics. Some years ago, Governor Gilligan of Ohio announced that he would "back legislation making it unlawful to increase the temperature of the water [of Lake Erie] by one degree over the natural temperature." Prof. J.J. McKetta of the University of Texas has calculated that if all the electricity produced in the state of Ohio were used for nothing else but heating Lake Erie (whose temperature changes naturally by more than 40°F from summer to winter), the water would be heated by less than 0.3°F. Please contrast this with the quotation introducing this chapter on page 123.

There may indeed be problems with excessive heat production. For example, Manhattan and the Los Angeles basin have an average temperature that is almost 4°F higher than that of their surroundings. This, of course, is not caused by power plants, but by the large concentration of human population and their activities in general. Whether this poses a health hazard, nobody knows, and the environmentalists are not losing any sleep over it, for they are interested in fish, not people.

But their concern over fish is entirely misplaced, for the fish usually love what the environmentalists have misnamed "thermal pollution." If a power plant uses the water of a nearby river or lake to cool its condensers, it will raise the temperature of the water only in the immediate neighborhood of the plant, and only by a few degrees. (The usual increase in local temperature of the water is 3°F at a point 1000 ft from the discharge.) To speak of the "destruction of aquatic life" is another colossal exaggeration, for what sometimes happens is that one species of fish moves out, but another species, preferring the warmer water, moves in, and one might well ask these muddle-headed friends of wildlife why would deny these fish a living.

In the late 1950's, the construction of a nuclear plant on the English river Blackwater was opposed environmentalists on the grounds that the warm water would endanger the oyster banks lower down the estuary. But the plant was built, and nothing happened to the oysters — until the severe winter of 1962-63, when many of them froze to death and the thermal "pollution" by the plant was unable to save them. It was, in fact, nuclear plants, which often used to reject their waste heat into a nearby river in so-called "once-through cooling," that showed up the highly beneficial effects on fish: They flock to the warm water, grow approximately twice as fast, and to a bigger size than in cold water. (The generally accepted reason is that they spend more time feeding than in cold water.) So successful has thermal "pollution" been in improving the habitat of fish that several fish hatcheries in Britain and the US now use thermal "pollution" (sans nuclear plants) to grow bigger and healthier specimens faster. It is for reasons like these that Prof. McKetta has suggested replacing the term "thermal pollution" by "thermal enrichment."

The witch hunt against thermal "pollution" has mainly been directed against nuclear plants, which supposedly produce much more waste heat than fossil-fired plants. In the first place, this is untrue. The waste heat produced by a power plant can be determined from its efficiency, the ratio of electrical energy produced to the energy contained in the fuel; if a power plant has an efficiency of 40%, then...
6. ENVIRONMENTAL IMPACT

40% of the fuel energy is converted to electricity, and the remaining 60% are lost as waste heat.

The highest efficiency that has been achieved in fossil-burning plants (of very large size) is 41%; the highest efficiency for nuclear plants is achieved by the High Temperature Gas Reactor, and it equals 39%, which is very close to the fossil-plant record. But most commercial nuclear reactors in the US (at present, all but the HTGR in Fort St. Vrain, Colorado) are light water reactors, which have an efficiency of only 31%. But this is again very close to the average fossil-burning plant efficiency. The latest available data (1974) show the average fossil-to-electric conversion efficiency to be 32.53%.

There is, in fact, only one substantial difference in waste heat dissipation between fossil-burning and nuclear power plants. In a fossil-burning plant, one-third of the waste heat escapes through the stack into the atmosphere, and only the remainder offers a choice for dissipation into the atmosphere or into a body of water. The water cooling the condensers (see figure on p. 30) must itself be cooled. In “once-through” cooling, this water comes from, and is returned to, a river near the plant. It can also be pumped from, and back into, a nearby lake (or artificial cooling pond); or it can be cooled by running through a cooling tower, dissipating its heat into the atmosphere.

A nuclear plant, on the other hand, has no stack and has a choice between rejecting all of its heat into nearby water, or into the atmosphere, or into both in any desired ratio. The cheapest and most effective way, of course, is once-through cooling by a nearby river, if one is available. But EPA regulations forbid, in effect, once-through cooling for power plants built since 1970. Electric power, particularly nuclear, is cheap enough to allow environmentalists to saddle the rate payer with the expense of cooling towers, which are, in many cases, giant concrete monuments to the politics of ecological folly.

ONE final remark about the “greenhouse” theory. The carbon dioxide content of the atmosphere has been increasing over the last 100 years, and it is often assumed (without sufficient evidence) that this is due to human activity, particularly the burning of fossil fuels. This, some fear, might lead to a “greenhouse effect” by which too much solar radiation is trapped by the earth, leading to a heating of the atmosphere and a generally hotter climate. (We will not stop to discuss the details of the greenhouse effect, except to remark that it plays no significant part in heating a greenhouse.) The greenhouse effect and its dangers to the environment have been seized upon not only by panicky environmentalists, but also by some advocates of nuclear power, since only fossil-burning plants produce carbon dioxide.

Yet I will not include this possibility as one of the “health hazards of not going nuclear.” The reason is that some of the premises of the theory, and all of its predicted consequences, are largely speculative and full of highly debatable points. It might very well turn out to be true, but at present there is only flimsy evidence to support it. As the preceding chapters have shown, the health hazards of non-nuclear power are so real that the vastly superior safety of nuclear power has no need of such shaky arguments.

GREENHOUSE EFFECT

NO NUKE

Support CRITICAL MASS

The Citizen Movement to Stop Nuclear Power
Terrorism and Sabotage

Among the by-products generated by fission in a nuclear reactor is plutonium 239, which is itself fissile. It is toxic when eaten, and particularly when fine particles of it are inhaled — though nowhere near as toxic as some other substances. It can also, in sufficiently large and pure quantities, provide the raw material for a nuclear bomb.

The toxicity of plutonium and the feasibility of blackmailers dispersing it in a city has been exaggerated to an incredible degree, and we shall return to this point presently.

On the other hand, the threat of nuclear weapons in the hands of terrorists is a plausible possibility and should not be underestimated, though the threat comes from a different direction than the nuclear foes would have us believe.

As in the preceding chapters, we will refrain from comparing risks to benefits, and we will simply compare the risks of terrorism or sabotage by means of nuclear weapons to the risks of terrorism or sabotage by means of blowing up oil and gas storage facilities or hydro-electric dams. It may surprise many readers that the consequences of such acts are comparable, but the nuclear version is far easier to guard against; and the technical difficulties of sabotage and terrorism are incomparably greater in the nuclear version, too.

The reasons why this is so will be discussed shortly, but they will be discussed only for the sake of completeness and maintaining the same approach to the problem in all its aspects, including the present one. However, it should first be stressed that the comparison in the present case, i.e., terrorism, sabotage and blackmail, is largely irrelevant.

In all of the previous points under discussion, we were concerned with genuine alternatives. We either go nuclear or we don’t, or we go partly nuclear. For every 1,000 MW of nuclear power that replaces coal or other fuels, we save some coal miners’ lives, but we endanger some uranium miners; we decrease the risk of major and minor accidents associated with fossil fuels, but we increase the risk of a nuclear accident; we decrease air pollution, but we increase (however slightly) the radioactive background. Whether we consider deaths, injuries, diseases or damage to the environment, we always face a trade-off. It so happens that nuclear power comes out very superior in the trade-off, but a trade-off is what must be faced.

However, there are no genuine trade-offs involved in terrorism, sabotage or blackmail. If for some reason nuclear power were prohibited tomorrow, it would not eliminate the risk of nuclear terrorism; it would not even significantly reduce for it is another Naderite myth that prohibition of nuclear power in the civilian sector only, of a single only, can in any way alleviate, let alone eliminate, the threat.

It is close to impossible for a single person to steal, breed, or otherwise obtain sufficient plutonium to make a bomb. It is also highly doubtful whether a looter, somehow in possession of a sufficient quantity, could manufacture a bomb and an effective triggering mechanism. It is not beyond the realm of possibility for a group of determined and technically erudite madmen (probably idealists) to achieve this, but it is highly improbable that, apart from the enormous technical difficulties, they would choose to do so; for there are far more effective and easier ways of killing, or threatening to kill,
large numbers of people. Even if such a group decided on a nuclear weapon for the purpose (which is unlikely), the easier and more effective method would be to steal, perhaps by force, a ready-made military nuclear weapon, such as a tactical nuclear bomb. With the assumed education and determination of the group, this would present fewer difficulties than the long chain of obstacles associated with manufacturing a crude (and probably ineffective) homemade weapon.

The amount of such weapons in the US (and overseas US bases) is secret, but it is well known to be quite large; the amount of weapon-grade plutonium (not plutonium oxide fuel, badly suited for weapons) is incomparably larger than the plutonium oxide fuel pellets ever likely to be shipped from reprocessing plants to power plants, which is the one and only chance to get at it. Yet for this incomparably larger amount the safeguards have worked, and without a trace of a “garrison state,” a Naderite buzzword. The “plutonium economy” is another such buzzword intended to scare people. If all the US electrical capacity were nuclear, there would still be far fewer shipments of fuel assemblies than of flea collars for dogs. Would it make sense to speak of a “flea-collar economy?”

There is, however, a third possibility, which cannot be taken so lightly, and that is the terrorist, blackmailer or other agent supported, at least in part, by a foreign government. The Palestine Liberation Organization, for example, has shown an utter disregard for human life for objectives as small as getting publicity; they are not only recognized as a legitimate political organization by the USSR, but also supplied with sophisticated weaponry by the Soviets, and largely trained by Soviet military experts. At the time of writing it seems very unlikely that the Soviets would, for reasons of their own, supply the PLO with nuclear weapons (covertly, of course), but whether such a step will be taken in the future rests entirely in the humane and trustworthy hands of the Soviet politbureau.

Nor is this the only example. West Germany is about to supply an enrichment plant to Brazil, and there will evidently be little effective control over it. A secret safeguards agreement was reached among the nuclear powers (other than China) in early 1976, but ultimately it is only up to the good will of, say, Brazil whether she will enrich her uranium to 3% for nuclear fuel or to more than 90% for nuclear weapons. “We would never dream of making a nuclear bomb,” said the Brazilian foreign minister in 1975. “Unless, of course, Argentina made one first.”

France is offering nuclear equipment to the Arab countries in the hope of ensuring its oil supply. It is also perfectly possible to breed plutonium from unenriched uranium ore without bothering to produce electricity in the process. (It would serve no purpose here to go into the technical details of the procedure, which is well known to experts.) There is a whole string of Third World countries close to nuclear capability, and there are not many obstacles in their way if they are determined to obtain it.

The case of India teaches two lessons. First, that it is not all that easy to make a bomb. India, unlike the Arab and other backward countries, has a highly competent scientific elite. It also had full government support in breeding plutonium from unenriched uranium ore by means of the Canadian CANDU reactor. Yet it took them 10 years to manufacture a bomb, and when they had made it, it did not work; it went off only on the second try. The other lesson, of course, is that given government support, it can be done. The danger in all this is that it will take only one precedent to open the floodgates. It matters little whether Brazil supplies a bomb to Libya to use against Israel or whether any other of hundreds of scenarios becomes the first; once the first “little” bomb goes off, none of the members of the “nuclear club,” certainly not the communist ones, will hesitate to arm their clients similarly “in defense,” and the floodgates will open.

Imagine, then, that the PLO or some other terrorist organization plants a nuclear bomb in Manhattan, whether covertly supplied by the Soviets or manufactured by some Third World government; what difference will it make what percentage of US electrical capacity is nuclear and what percentage is coal-fired?

That, and not some horror story about a nut building a nuclear bomb in his garage, is the real danger of nuclear terrorism, and the risks associated with plutonium shipments in the power industry are not only tiny, but above all, irrelevant. We nevertheless discuss them briefly below, after which we will come back to what can be done about the real dangers.

Turning to technical details, there is one scenario of sabotage that can be dismissed quickly, and that is the “shooting up” of a nuclear plant. Although even Ralph Nader has abandoned the idea that a nuclear plant can undergo a nuclear explosion, he now claims that it is possible for a saboteur to “to blow up a plant with
sophisticated weaponry from a hilltop'' and ''rupture the entire pressure vessel'' so as to release its radioactivity.

The containment building is made of concrete 3½ ft thick, with the steel reinforcement mesh so tightly woven (see photo on p. 47) that vibrators must be used to force the concrete through it before it hardens. That makes the walls much stronger than, for example, the roofs of the German submarine bases on the French Atlantic coast, which were bombed round the clock by the allied air forces with ''blockbuster'' bombs, but withstood even direct hits. But suppose this imaginary supersaboteur did have some mysterious missile that managed to blow a hole into the containment building. What next? Would he have a second missile to make the hole larger, and a third to penetrate the remaining concrete structures inside the building, and a fourth to begin working on the steel pressure vessel? Would he wait until the weather is just right so that the fruits of his labors are not dispersed harmlessly in the atmosphere? This does not yet ask all the questions, but the whole idea is too absurd to waste more space on.

**Plutonium** is often called ''the most toxic substance known to man,'' ''toxic beyond human experience,'' the ''fearsome fuel,'' and other such melodramatic nonsense.

Of course plutonium is toxic. Of course it must be handled with care. But the rest is just horror propaganda. Plutonium is primarily an alpha emitter, which means that its radiation is absorbed in the air after a few inches, and a sheet of paper is sufficient to shield oneself against its radiation at close quarters. It is far from being the most toxic substance known to man. When eaten or absorbed in the blood stream, it is ten times less toxic than lead arsenate and hundreds of thousands of times less toxic than some biological poisons such as diphtheria or botulism toxin. Caffeine, some of which you probably had this morning in your coffee, is only 40 times less toxic than plutonium. (Relative toxicity is measured by comparing the weights of 50% lethal doses given to the same type of mammal. The ''50% lethal dose'' is the amount that will kill half of the experimental animals.)

However, though ingestion of plutonium or its absorption through the skin is dangerous, the real danger of plutonium is breathing it in the form of fine dust particles. Plutonium is insoluble in water, and fine particles may stay long in the lung, eventually causing lung cancer. Even so, this danger, which undoubtedly is a serious one, has been exaggerated beyond all reasonable bounds. There are radioactive substances produced not by the Pentagon, but by Mother Nature, which are far more dangerous than plutonium. ''Plutonium is the most toxic of all elements,'' goes one of the scare slogans of the anti-nuclear movement. Why of all elements? There are about 100 of them, and several of them are more toxic than plutonium. Radium has a half-life 16 times shorter than plutonium, so that at first sight it would seem 16 times more dangerous (because for the same number of atoms, its intensity of radiation will be 16 times greater). However, plutonium has a four times longer residence time in the lung, so that it is only four times (16/4) less dangerous than radium. There are many other examples, but this one should be enough to dispel the myth.

A few ounces of this deadly stuff, if properly distributed, could wipe out all of mankind.'' And so could a day's production of sewing pins, ''if properly distributed'' (one into every man's heart). The fact is that the amount of committed to the in the early atmospheric tests of nuclear weapons was not a few ounces, but almost three tons; yet somehow mankind survives.

Statements of this type are made by the Naders, Koupals and Comeys, political propagandists without any scientific training. But how about radiologists like Geesaman, Tamplin and Cochran?

The only thing notable about these ex-scientists is that they get a lot of publicity every time they make one of their wild charges. They have been refuted, time and again, by scientific committees and professional organizations investigating these charges. But these large bodies of scientists and professional organizations do not make the news.
Nazis branded Einstein’s theory a “Jewish hoax,” but their scientists were using it nevertheless.

Second, the discrepancies between old and new theories in cases where they could be put to experimental tests, were very small. The time difference in Galileo’s experiment with the two balls was a fraction of a second, and Einstein, in 1905, had only two experimental results to go on: One was the mere absence of a small effect in a highly sensitive interferometer, the other a difference in an electronic effect so small as to be (at the time) barely detectable. That is hardly the case with the Don Quixotes of radiology. For example, while US safety standards require that a “hot” particle of plutonium be considered to deliver a dose of 0.3 mrem/year, Dr. Tamplin and Cochran calculate the pertinent dose to be 4,000,000 mrem/year, and while the minute discrepancies predicted by Einstein’s theory provoked scientists into heated debates, a discrepancy by a factor of more than 10,000,000 will usually provoke them only to snicker and tap their foreheads.

Third, the genuine scientist who challenges conventional wisdom faces the hostility of a world that does not like to have its sacred cows slaughtered. Galileo had to invoke his statements under threat (perhaps even application) of torture. Giordano Bruno was burned at the stake. Darwin earned the life-long hostility of the Church. Einstein was driven into exile together with many non-Jewish scientists who supported his theory.

But Gofman, Tamplin & Co are in the very opposite position. Today it is the genuine and hardworking scientist whom much of the world regards as some kind of Dr. Frankenstein if he supports nuclear power, and it has taken the Sternglasses and Geesamans to its bosom. They have access to the lavish funds of the various environmental foundations (and the equally lavish funds of the parareligious foundations such as the Creative Initiative Foundation), they travel the lucrative lecture circuit, they bask in the publicity of the mass media, they can not only ride their little pet hobby horses, but they can do so while posing as prophets, martyrs and saviors rejected by a callous, profit-greedy establishment. They have, in short, discovered a shortcut to the glory that they failed to reach by conscientious and responsible hard work.

Given these criteria, it should not be difficult for the layman to decide whether the truth lies with Tamplin & Co or whether it lies with the American Health Physics Society and the Committee for Biological Effects of Ionizing Radiation of the National Academy of Sciences.

CORALVILLE (IA) — Northwest Oregon could experience a crime wave in December when the Trojan nuclear power plant at Rainers goes into operation. That is the behavioral scientist's theory. Daniel J. Darby of the University of Oregon, who has studied Federal Bureau of Investigation statistics on murder, forcible rape, and aggravated assault in cities near nuclear power plants, said his research indicates a connection between violent crime and gaseous nuclear power plant emissions. He outlined his findings just concluded at the American Institute of Biological Sciences convention at Oregon State University.

"His allegations, made in several forms, have in each instance been analyzed by scientists, physicians and bio-statisticians in the Federal govern ment, in individual States that have been involved in his reports, and by qualified scientists in other countries. Without exception, these agencies and scientists have concluded that Dr. Sternglass' arguments are not substantiated by the data he presents. The U.S. Public Health Service, the Environmental Protection Agency, the States of New York, Pennsylvania, Michigan and Illinois have issued formal reports in rebuttal of Dr. Sternglass' arguments. We, the President and Past Presidents of the Health Physics Society, do not agree with the claim of Dr. Sternglass that he has shown that radiation exposure from nuclear power plant operations has resulted in an increase in infant mortality."
Seven. Terrorism and Sabotage

The threat of plutonium dispersal by terrorists or blackmailers has been thoroughly analyzed by Dr. Bernard Cohen, a past Chairman of the American Physical Society’s Nuclear Division, and any terrorist who should read his study will be sharply disappointed, for plutonium is not merely less toxic than some other poisons, but unlike chemical or biological poisons which kill their victims within a few minutes, plutonium-caused death (cancer) is delayed by years and decades.

If, for example, someone were to take Ralph Nader’s irresponsible insinuations seriously and disperse plutonium into the ventilation system of a building, the victims would be left with 15 to 45 years of good health. The type of terrorist who might commit such a senseless and inept crime could be one who has been reading Naderite or similar anti-nuclear hysteria and taking its implications seriously. While Nader or Koopel would be innocent of such an event in the eyes of the law, it is difficult to see what excuse they might hide behind to escape moral responsibility.

The method could not even be used for blackmail, since the threat could immediately be defused by shutting off the power to the building and its ventilation system. Even if the blackmailers did not reveal the specific building, power to all large buildings in a city could be turned off for a comparatively short time, for plutonium differs from biological and chemical poisons in yet another way: Exceedingly small amount of it (or any other radioactive substance) can quickly be detected.

For the rest, we refer the reader to Dr. Cohen’s study; the threat of plutonium dispersal is highly improbable, because so many other more dangerous and more effective methods are available to terrorists and blackmailers with much less trouble and danger to themselves.

The issue of illicitly manufactured bombs is another matter. It has been thoroughly discussed in Nuclear Theft: Risks and Safeguards by Theodore B. Taylor, a professor of law. Quotations from the book have been repeated innumerable times by nuclear critics, environmentalists and political foes of nuclear power. Given the vast quantities of utter nonsense spewed out by the anti-nuclear organizations, the disinformation spread by ostensible documentaries (such as “The Plutonium Connection”) on TV, and the exaggerated publicity given to the discredited theories by Gofman, Tamplin and others, and given, moreover, that the study was commissioned by the Ford Foundation’s Energy Policy Project (which mainly engages in ideological economics), the first reaction of many has been distrust and suspicion that the Willrich-Taylor study is more of the same propaganda.

That is not so at all. It is a serious work by highly qualified investigators who have produced a first-rate document. The quotations taken from it and indiscriminately thrown about (until eventually they become unrecognizable parodies of the original) are most often used by political activists who have never been near the book, or they would realize that it was not written to stop nuclear power, but to make it safer. There was indeed undue laxness in the security of some of the phases of the nuclear fuel cycle when the book was published (1974), and it doubtlessly played no small part in bringing about the remarkable tightening of security at nuclear facilities that has taken place in the last two years.

Indeed, Dr. Taylor has himself stated that with the recent improvements and currently proposed upgrading, he believes the safeguards program will be satisfactory before significant quantities of plutonium
7. TERRORISM AND SABOTAGE

Terrorism and sabotage threaten the public safety and national security of the United States. The fuel cycle is a complex process involving the extraction of uranium, its enrichment, and the fabrication of nuclear fuel. The fuel, once used in a reactor, is mixed with uranium to form plutonium oxide. This mixture is then transported in a lead container to a reprocessing facility. The process is further complicated by the need for secure transportation and handling of the fuel to prevent theft or unauthorized access.

The fuel container is designed to be impenetrable and immovable, with vehicles equipped with alarms to alert authorities of any tampering. However, the general idea is the same for fresh fuel. To achieve a nuclear weapon, the fuel must undergo a series of steps, including the separation of isotopes, enrichment, and conversion into a usable form. The key is the transportation of spent fuel, which is a difficult task.

The fuel is transported in a lead container that is designed to be tamper-proof and equipped with radio alarms. The transportation process is complex and involves the use of escort vehicles and constant radio contact with outside monitors. If there are pass areas where this is not possible, a second escort vehicle must be added. Any unauthorized presence near the fuel is considered dangerous.

The transportation of nuclear fuel is a sensitive issue, and there are various measures in place to ensure its safety. There have been objections to these measures, but the measures in place are generally considered reasonable. The transportation of nuclear fuel is a routine activity, with shipments occurring once a year. Tons and tons of fuel have been shipped to nuclear plants in the US for more than three decades without a safety incident.

The fuel is a host of other terrorist scenarios. It assumes that a team of scientists capable of manufacturing a nuclear weapon would remain motivated without external pressure. It is critical to prevent unauthorized access to the fuel, as the process of converting it into a usable form is complex and requires specialized equipment.

In conclusion, the transportation of nuclear fuel is a complex and sensitive issue. The measures in place are designed to prevent unauthorized access and ensure the safety of the fuel. The transportation process is a routine activity, with shipments occurring once a year. Tons and tons of fuel have been shipped to nuclear plants in the US for more than three decades without a safety incident.
settle on the nuclear option in the first place, and then implement it in the power (rather than weapons) industry. The fact is that there are much easier ways of indiscriminately killing far more people. We shall mention some of them in connection with fossil-fuel storage, since this comes under the main framework of this book, but let it be said that even that is kid's stuff compared to other non-nuclear methods of wiping out people by the tens of thousands. What these methods are, a sufficiently determined terrorist will have no difficulty discovering, but he will have to do so without help from this book. We will merely quote Dr. Cohen, who reports that "Experts on terrorism have stated that they hope terrorists will be attracted to nuclear plants as this might divert them from much more terrible things they could do more easily," and that these experts "consider the plutonium bomb publicity a great asset to society in diverting attention of would-be terrorists away from easier and much more harmful pursuits."

The MAD scientist who crafts a nuclear bomb in his basement, then, is stuff for Sunday supplements and Naderite disinformation; he is not a plausible threat. But what about the political terrorist with foreign support? What about the political terrorist with foreign support? What about the political terrorist with foreign support? What about the political terrorist with foreign support? What about the political terrorist with foreign support? What about the political terrorist with foreign support? What about the political terrorist with foreign support? What about the political terrorist with foreign support? What about the political terrorist with foreign support? What about the political terrorist with foreign support? What about the political terrorist with foreign support? What about the political terrorist with foreign support? What about the political terrorist with foreign support? What about the political terrorist with foreign support? What about the political terrorist with foreign support? What about the political terrorist with foreign support? What about the political terrorist with foreign support? What about the political terrorist with foreign support? What about the political terrorist with foreign support?

Not many years ago, the hijackings to Cuba took on epidemic proportions. Why have they stopped? The metal detectors, luggage inspections and air marshals have helped, of course, but they could never have done it off in Grand Central Station unless certain of their demands are met. The prospect is improbable, but much less far fetched than Dr. Frankenstein with a plutonium contraption in his garage. It is a political problem that must be faced, not by postulates, but by policy. The prospects for failure and punishment does deter crime.

The PLO and other organizations that kill indiscriminately have blackmailed their murderers out of prison in all concerned countries except one: Israel. Israel has, from the beginning, not merely proclaimed that it will not negotiate with blackmailers, but it has stood by its word, and terrorists have fared badly in kidnapping Israeli citizens or otherwise trying to blackmail the Israeli government.

On the contrary, West European governments have not lacked pompous rhetoric on the subject, but when the blackmail was on, they displayed all the spine of an overboiled noodle. Masquerading as "humanitarians," they caved in to blackmail in order to save a handful of lives today, knowing very well that they were encouraging the loss of hundreds of lives tomorrow and thousands on the day after. After hundreds of lives were lost to terrorists and blackmailers, Austrian Chancellor Krausky still lives by the principle "Thou shalt procrastinate the killings until tomorrow," and there are only slight indications that the British, German and Dutch governments are beginning to realize that they cannot escape the political consequences of their ostrich policies.

The record of the US government has not been perfect in this regard, but it has been better than that of most democratic governments in that both the Nixon and Ford administrations have refused to negotiate with blackmailers over blackmail. But it has done nothing to make known its determination - it exists - to take a hard line against blackmail.

The strongest deterrent against blackmail is not the threat of punishment, but the threat that the effort will be ineffective.
7. TERRORISM AND SABOTAGE

policy would have to be reversed for the threat to achieve his purpose."

The second powerful defense against terrorism — not necessarily nuclear — does not require any technology, either: infiltration of terrorist groups. Though not particularly singled out by Willrich and Taylor, it is a weapon that has proved its worth over and over again, and without destroying any civil rights. But it is a weapon that has, at the time of writing, been all but destroyed by an ideological group (usually mislabeled "liberal" or "progressive") in Congress and the press. They had no objections to the FBI infiltrating the Ku-Klux Klan, and neither had any other rational person. But when intelligence organizations try to protect us from the Fascists of the Left, this group wails to high heaven about civil liberties, as though civil liberties were of any use to the dead.

FBI Director Clarence M. Kelley recently stated that terrorism (though not necessarily nuclear) is on the rise and a major threat in the years to come. Yet the FBI and CIA are being bound and blindfolded.

The obvious conclusion is that the big boom to the terrorist is not plutonium; it is Senator Frank Church and his besmirched admirers.

NOW FOR the jolly business of indiscriminately killing large numbers of people by abuseing the facilities and fuels associated with non-nuclear power plants. Wherever there are high population densities and large amounts of stored energy in close proximity, there is an opportunity for terrorism, sabotage and blackmail.

The most obvious case is that of hydro-electric dams (they do not, of course, have to be hydro-electric). A dam failure killing 1,000 people has an average frequency of one in 80 years, higher (for the same number of fatalities) than major fires, explosions or chlorine releases;11 in fact, except war, it is the most probable of all man-caused disasters with large loss of life.

The 1963 Vaiont dam disaster (p. 95) claimed 2,000 lives. Yet this was only an accident, not a deliberate act of sabotage with the express purpose of killing a maximum number of victims.

On the night from May 16 to 17, 1942, a British squadron of 19 Lancaster bombers attacked the Moehne, Eder and Sorpe dams in Germany and succeeded in breaching the Moehne dam, releasing some 30 million gallons of water into the Ruhr valley. There appear to have been several hundred dead, which was chickenfeed as air raid casualties went in those days, but that was not the purpose of the attack; the aim was to deprive the Ruhr (Germany's industrial heartland) of water and hydroelectric power.12 The Sorpe dam received a direct hit, but the bomb hole was slightly higher than the water level. Albert Speer, the man who kept German production going through the air offensives, inspected the damage in the morning and writes in his memoirs: "Just a few inches lower — and a small brook would have been transformed into a raging river that would have swept away the stone and earthen dam. That night, the British came close to a success which would have been greater than anything they had hitherto achieved with a commitment of thousands of bombers... If the Ruhr reservoirs had been destroyed, the shortage of water for cooling the coke works and blast furnaces would have reduced production in the Ruhr district by 65%.

Yet this was an attack designed to paralyze industry, not to inflict heavy casualties on the population; moreover, to breach dams with pinpoint bombing by moonlight (radar was still quite crude) would have been a very difficult task even in the absence of the heavy German air defenses. But destruction of a dam above a populated area by high explosives in peace time involves comparatively little technical difficulty, and runs little risk of being foiled by the lax to non-existent security measures.

An act of sabotage against a dam could result in the death of 100,000 people; in fact, a 1974 University of California study on the risks associated with dam failures showed that there are several dams in the US where sudden failure could cause more than 200,000 deaths, and one of them could cause 230,000 fatalities. One of the authors of the report repeated these figures in a public hearing in 1976. (Once again, identification of these dams or the precise reference to the report would serve no useful purpose here, and they are omitted for obvious reasons.)

How many nuclear-physics PhDs are needed to make this nightmare come true?

IT HAS already been mentioned that an oil supertanker stores the energy of a two-megaton hydrogen bomb, but the really dangerous targets for terrorists would be the ships that bring liquid natural gas from Algeria and other places to US ports — sometimes only a few miles from the downtown districts of metropolitan areas (Boston, for example). Explosion of the cargo could release the
total energy within a few seconds, and according to Dr Edward Teller, this could have the effect of a Hiroshima-type nuclear bomb. It should be noted here that a home-made nuclear bomb would almost certainly not have the effects of a Hiroshima-type bomb. The two nuclear bombs in Japan were detonated high above the target cities, so as to deliver the blast and heat radiation to a maximum area. On the ground, a nuclear bomb would be a block-buster, not a city destroyer. And quite likely it would not even be that, for much of its effectiveness depends on the triggering mechanism. A nuclear bomb explodes by bringing two or more subcritical masses of fissile material together into a single bulk exceeding the critical mass. As soon as the first areas make contact, the subcritical parts must be held together against the force of a nuclear explosion for long enough to consume their unexploded fuel. If this is not done, the explosion will “fizzle,” and the initial small explosion will simply blow the subcritical parts apart and back into safety. Thanks to the humanitarians who are so concerned about plutonium, we now have almost complete instructions on how to prevent that and how to assemble a nuclear trigger in our leisure time; however, the effectiveness of the explosion would be nowhere near that used in military hardware. The triggering mechanism of nuclear bombs is still one of the few remaining and closely guarded nuclear secrets, and it is not even known whether the Western powers, China, and the USSR use the same triggering mechanism.

The near catastrophes of Bayonne, N.J., in 1973, and in South Brooklyn, N.Y., in 1976, when thousands of people could have been asphyxiated in New York City except for the favorable weather situation (pp.88-91), can easily be precipitated by terrorists or saboteurs (though not by blackmailers). They merely have to wait until there is a temperature inversion and the wind blows in the “right” direction; there is not much to stop them setting an oil-storage complex ablaze covertly, and probably nothing to stop a group doing so by force.

This requires a little patience on the part of the terrorists; but nowhere near the patience needed (among other characteristics) to even try making a nuclear bomb.

The remarks on terrorism and sabotage by means of fuels and facilities associated with non-nuclear power plants have been kept short because, as pointed out earlier, these considerations are largely irrelevant. Even so, it is evident that the dangers of abusing the non-nuclear power cycle for terrorism are greater than those of illicit nuclear bombs, for they are at least as great in their consequences, and far greater in their accessibility.

And yet the facilities and fuels involved in non-nuclear power generation are not the only, or even the most ominous, of the roads open to terrorists. There comes a point where analysis becomes a guide to action, and I will not pursue this ugly subject any further, since the point has surely been made. Let me just say that of the two conditions for indiscriminate mass a of and the release of amounts of energy, only the first is essential, and that a high density of people and the release of large amounts of energy, only the first is truly essential, and that a high density of people does not necessarily require them to be in buildings. The erudite terrorist will know what I am alluding to, and it is my sincere hope that he dies before he attempts to try it out.
Reliability, Economy, Conservation

Unsafe, unreliable, uneconomical and unnecessary.
Ralph Nader on nuclear power.

None of the subjects in the chapter heading above, quickly and exhaustively analyzed by Ralph Nader's expertise, are the subject of this book, since they are not intimately connected with the hazards of nuclear and non-nuclear power. Yet at least a few words ought to be said lest the impression arise that safety is the only superior quality of nuclear power, or that it is offset by other disadvantages.

Reliability is (outside the world of mathematics where it is a precisely defined term) a rather general concept, which is measured by certain indicators such as mean time to failure, availability (fraction of time for which a system is available), forced outage rate (duration of unscheduled down times to total time of observation), and several others. Large systems tend to be less reliable than small

From the Edison Electric Institute's Report on Equipment Availability 1965 - 1974. In the final effect, the reliabilities of nuclear and fossil-fired plants are about the same; but if fossil-fired plants were required to shut down for such puny deficiencies as nuclear plants, the reliability of nuclear plants would turn out much higher in the comparison.
8. RELIABILITY AND ECONOMY

one; the reason is somewhat similar to the reason why a city has more cases of fractured legs than a family. New systems tend to be less reliable than moderately old ones; this is a phenomenon well known to every house or car owner — there is a "debugging period" before the system settles down to steady operation.

When comparing the reliability of nuclear plants to fossil-burning plants, one should therefore compare plants of roughly equal capacity. When this is done, nuclear power comes out with a reliability of the same order as fossil-burning plants, as shown by the figures taken from the latest available report of the Equipment Availability Task Force whose ten-year reports are sponsored by the Edison Electric Institute. There are years when nuclear plants do better than the others and years when they do worse; there are utilities whose nuclear plants have a far higher availability than its other plants (Commonwealth Edison of Illinois, Southern California Edison), and there are utilities with problem reactors plagued by particular deficiencies, sometimes even the subject of court litigations (Consumers Power Co of Michigan). But by and large, the two types of plant have about the same reliability.

Or so it would seem at first sight. In reality, of course, the reliability of nuclear plants is far higher, since they compete under incomparably tougher conditions. If all fossil-burning plants of the same type were shut down throughout the country merely because a hairline crack was found in the plumbing of stand-by equipment, the conventional plants could get nowhere near the reliability of nuclear plants.

THE diseconomy of nuclear power is a myth resting on yet another myth, namely that it is subsidized by the taxpayer. Yes, the American taxpayer has paid $1 billion to research nuclear safety, and I consider that a good investment; the American taxpayer also pays $1 billion, not total, but year after year, to Black Lung victims — not to cure or eliminate it, but just to compensate its victims. Nuclear power curbs Black Lung by striking at its cause.

Moreover, your friendly commercial entrepreneur, the US government, which runs such successful enterprises as Amtrak and the US Postal Service (the latter with an annual deficit of $1 billion), has very few enterprises that make money. But one of them is uranium enrichment, for which the fuel manufacturers pay through their noses, and another is Price-Anderson insurance, the premia for
which are paid by the utilities, partly to private insurance pools, partly to the US government. The private insurances pay first, and they have so far paid $400,000 for 26 minor claims; Uncle Sam hasn’t paid anything yet (and probably never will), but sits on a fund of $6 million of as yet unused premia. And, of course, the utilities pay taxes — local, state and federal — with the stockholders paying a second round of taxes from their dividends. You call that a subsidy?

In any case, nuclear power is far more economical than fossil-fired power at present, and likely to remain so far into the future, for the price of uranium has little effect on the price of electricity (the biggest cost is the capital cost, the fuel cost is relatively small, as can be seen from the figure on the opposite page). At present, the cost of a kilowatt-hour of nuclear power is 50% cheaper than fossil-fired power in New England (where power plants depend heavily on imported oil), and 20% cheaper in the Midwest, where low-sulfur coal cuts down on the costs of pollution-control equipment. A little brochure called *How to calculate the costs of electricity* by I.A. Forbes gives a simple way of finding the cost for all methods of power generation and any price fluctuations; the reader can check the economy in his own area and find the price levels to be expected in the future.

The ultimate test, of course, is whether the executives and the accountants of the utilities want nuclear plants, and they do want them very definitely. (Another incentive in the late sixties, now forgotten, was harassment by the environmentalists because of air pollution by fossil-fired plants.) Isn’t there something fishy about the whole issue when Ralph Nader is worried that the corporations won’t make a big enough profit?

**BUT aren’t we running out of uranium ore?**

We never run clean “out” of anything: the price of a commodity just rises as it is more difficult to obtain, until it no longer pays to produce or use it. In the case of uranium, lower and lower grade ore will have to be processed, which will drive up the price. But as a glance at the upper figure on the opposite page shows, nuclear power can take a doubling and even a tripling of the price of uranium without losing its competitive edge over fossils, even under the silly assumption that the price of fossils will not increase.
One should also beware of calculations based on "proved reserves." Proved reserves are the equivalent of inventory "on the shelf" in other industries. The proved oil reserves of the US, for example, amount to only a 11-year supply — the biggest they have been in the last 100 years.

By breeding plutonium from uranium, and breeding uranium 233 from thorium, fuel supplies for fission power can be extended to last not centuries, but millenia. The present uranium resources, proved and potential, are about 3.5 million tons, enough to run 800 Light Water Reactors for their full 40-year lifetimes; but if their U-235 content, now just going to waste as "tailings," were bred into plutonium, it could run those 800 reactors for thirty-seven centuries.

However, only some 600,000 tons are proved reserves; as for the potential reserves, I will frankly admit that my knowledge of geology and other sciences needed to estimate them is lamentably close to zero, and on that point I am myself the one to ask "How is a layman to know?"

There are the three points made above (as well as some others), but for me the "clincher" is this: If it were true that we will run out of nuclear fuel by the year 2,000, would the profit-minded corporations and utilities want a technology that their geologists, financial and planning departments knew to be doomed to run out of fuel? I am perfectly willing to consider the charge that they are all crooks; but not that they are stupid crooks.

**Conservation** is the answer to the energy crisis, say the anti-nuclear crusaders when sufficiently pressed as to what they would suggest as an alternative. Or solar power (which would use 50 square miles per 1,000 MW plant), or wind (which would supply a minuscule percentage if the entire country were plastered with windmills), or tidal energy (which would supply less than 1% if all usable sites on US shores were exploited).

In keeping with this philosophy, Nader has made it known that he has purchased a manual rather than an electric typewriter, and Covey boasts of not driving a car.

It would be easy enough to refute the argument that energy needs can be met by conservation alone; for in spite of all the waste, the US is still among the world leaders in efficiency of energy use when it is expressed as energy needed to create a dollar of and there is just some fat to be trimmed before cutting into the muscle.
disposal; and the damage to the environment is about 10 times greater for coal than for orthodox fission, and about 1,000 times greater than for nuclear power using breeders.

*Per unit consumed energy.* That means that these ratios remain the same, no matter whether the total consumption is halved, doubled, or multiplied by any other factor. Conservation has not the slightest bearing on the point.

Yet Ralph Nader opposes nuclear power on the grounds of insufficient safety, while claiming that conservation makes nuclear power unnecessary. Consciously or not, he is advocating amounts to thousands of needlessly lost lives, the spread of cancer and other diseases, and unnecessary rape of the environment.

Nuclear power is totally incompatible with human life and democracy. Reactor safety has been used, for the most part, as a red herring to preempt public debate.

Lorna Salzman, Mid-Atlantic Representative of the Friends of the Earth.

According to the facts and figures given in the preceding chapters, nuclear power, while not perfectly safe, is about 100 times safer than fossil-fired power. Why, then, should anybody object to it, and on grounds of safety to boot?

That is a far more complicated question than the simple figures indicating the health hazards of various forms of power generation.

First of all, is it possible that the ratio of 100 to 1 in favor of nuclear power is merely the result of distortions, omissions and perhaps even falsifications?

Hardly. In looking back over the past chapters, the reader will see that they are concerned with hard figures; not just with what might happen in nuclear power generation, but with the things that have happened and are happening in non-nuclear power production; with the results of reputable analysts and record-keepers, not political agitators. It is inconceivable that the record-keepers of lives lost in the coal cycle, or the scientific committees issuing radiological protection standards could be very far wrong; but suppose they were wrong by a factor as wild as 10 or 20 — then nuclear power would still be 10 or 5 times safer.
There are, of course, cases where scientists are more or less in the dark. For example, in air pollution, the relative amounts of hydrocarbons, nitrous oxides, sulfates, particulates and other pollutants are well known by weight; but it is a pretty nebulous matter as to what their relative impacts on human health are. Not so with the relative impacts of nuclear and fossil-fired power; the figures here are well known and not at all new. They have rarely been challenged by the nuclear critics, and when they have, the challenge turned out to be another display of scientific incompetence. But more often than challenged, they have been ignored.

These facts are, of course, well known to Ralph Nader and the other agitators; they have been pointed out to them often enough. Whether Nader and a score of similar agitators deliberately distort the facts or whether they are grossly incompetent is a question that may fascinate psychologists, but it has little bearing on the effect that they are having.

And, let's face it, that effect is considerable.

Why?

Because, some say, people love to be scared out of their pants; if they didn't, they wouldn't pay to see Frankenstein, Dracula or The Promethean Crisis. Perhaps so, but this can explain only a small part of the phenomenon. People will pay to see a magician saw a girl in half only until they know he is sawing between one girl whose legs stick out of the box and another who is showing her head; once they know, it bores them. The nuclear box has been open for all who cared to look, so why would so many people prefer to swallow the superstitions instead?

Because, it is often said, the mass media artificially fan the anti-nuclear hysteria. That is certainly true and goes a little deeper, but not deep enough. The exaggerated coverage of the Naderite charlatans warning against nuclear power while the endorsements by qualified scientists and organizations are censored is a double standard so blatant that sometimes the media do not deny it; they defend their attitude by the old rule that "dog bites man" is not news, "man bites dog" is.

It is a false defense. If the media were only sensation seekers, but not otherwise biased, their coverage would be different. The Browns Ferry fire, in which no one was hurt and which never came close to any danger line, was "dog bites man" news, but it is harped on to this day. By contrast, the January 1976 oil fire in Brooklyn, quite apart from the genuine casualties, could have killed thousands of New Yorkers if weather conditions had been unfavorable; had the media been merely sensation seekers, they would have presented it that way, but they didn't.

Was it mere sensation seeking when Edwin Newman (NBC) said that by the end of this decade America's rivers would be boiling, in large part due to nuclear plants? Does it happen every week that 33 outstanding scientists, 11 of them Nobel Prize winners, issue an appeal to the country? But the networks censored it, and CBS brought another of Nader's run-of-the-mill attacks on nuclear power on that day instead. Was it merely rejection of "dog bites man" news that made all three networks censor the news releases of the American Health Physics Society or of the American Nuclear Society? These organizations finally endorsed nuclear power, not after years, but after decades of painstaking studies, during which they adamantly refused to make such an endorsement; when they did finally endorse nuclear power, it was "man bites dog" news.

If the media were no more than sensation seekers, they could find plenty of people who claim that the earth is flat, or that we are about to be invaded by UFO-borne little green men, or that California is about to sink into the sea. They do occasionally report on such items, but they do not give it the repetitious and exaggerated coverage that they accord to the anti-nuclear charlatans, nor do they censor the opposing opinions. Why?

Because the media are not merely sensation seekers, but they are ideologically biased, and unlike the flat earth or UFO's, nuclear power has been made into a political issue.

A political issue? What does nuclear power have to do with politics?

Plenty. Not with small-time politics of Democrats versus Republicans, but with the bigger and deeper issues of ideological politics.

And here, at last, is one point we can agree on with the anti-nuclear crusaders, or at least those of them who have taken off the mask of environmentalism and have openly taken the issue of nuclear power for what it has become and what have made it — an issue? Whether Nader and a score of similar charlatans distort the facts or whether they are grossly incompetent is a question that may fascinate psychologists, but it has little bearing on the effect that they are having.

And, let's face it, that effect is considerable.
body is an environmentalist; but the leadership of the contemporary "environmental" organizations uses clean air and clear water only as a bait to mobilize the gullible for a far-flung campaign against "the corporate state," "big business," "vested interests," "the establishment," and whatever other devils they can wave before their faithful believers.

Even in the late sixties (let alone today) the ideological overtones and social origins of environmentalism were not hard to discern. Environmentalists tended to be against economic growth, for population control, against the Viet Nam war, for rapprochement with the Second (Communist) and Third Worlds, for greater permissiveness in legal and ethical issues, and for or against a wide range of other issues that had little or nothing in common with the physical environment. Those hardest hit by pollution, the poor, were conspicuous in the environmental movement by their absence. (How many chapters does the Sierra Club have in Harlem or Watts?) The typical environmentalist tended to be college-educated and affluent, and the movement was, and still is, strongest in the "information industry"—the media and the universities.

I have put the word tended in italics because I am not, of course, talking about one-to-one correspondences but about statistical tendencies.

This group is sometimes lumped together under the name of "the liberals"—a misnomer, if ever there was one, for their attitude to liberty is ambiguous or hostile, and they are diametrically opposed to the liberalism of Adam Smith, John Stuart Mill or Friedrich von Hayek; while paying lip service to civil liberties, they strongly favor government interference and coercive legislation.

The urge for coercion and the arrogant premise that people do not know what is good for them are, in fact, two characteristics shared by this otherwise heterogeneous group.

These tendencies can, at times, become outright totalitarian. Paul Ehrlich, a population-controller, environmentalist and nuclear foe, probably considers himself a leftist radical and would object being likened to a fascist; but in writing on involuntary fertility control he states "Several coercive proposals deserve serious consideration, mainly because we [who is "we"? P.B.] may ultimately have to resort to them unless current trends in birth rates are rapidly reversed by other means." That, surely, sounds more like an SS-Obersturmführer than an American scientist.

"OBEY HIGHER LAWS"

"All scientists having a personal stake in the development of commercial nuclear power should disqualify themselves from the nuclear power discussion and leave the field to citizens who are perfectly capable of determining what endangers them and their freedom," writes Lorna Salzman, exposing another totalitarian streak: She is quite willing to discuss the matter provided the opposition is silenced.

Other totalitarian trends have surfaced among this group of affluent malcontents, among whom environmentalism is just one facet. Violence "in the defense of higher values" has been tacitly condoned, and on occasions even actively supported. An extreme case (I hope) is that of Daniel Berrigan, an ex-priest, who testified in the defense of a murderer that "sometimes men must obey higher laws." (The man convicted of murder had planted a bomb in the computing center of the University of Wisconsin, killing a Ph.D. student, ostensibly to protest work done by the center for the Pentagon.)

The first unmistakable signs of anti-nuclear violence "in the defense of higher values" have begun to appear: A pipe bomb was found in the reactor building of the Illinois Institute of Technology; dynamite was found at the Wisconsin-Michigan Power Company's Point Beach nuclear reactor; a break-in took place at the fuel storage building of Duke Power's Oconee facility in South Carolina; an incendiary device was detonated in a public area of the Boston Edison Pilgrim nuclear reactor; a fire, possibly arson, occurred in an equipment storage barn at Nuclear Fuel Services in West Valley, New York.

The Naderite and other organizations fanning the anti-nuclear hysteria, far from condemning these acts, publicize them (after extracting details from the NRC under the "Freedom of Information" procedure) as alleged illustration of how nuclear power is becoming a threat to public security.

In the spring of 1974, anti-nuclear activist Samuel H. Lovejoy toppled a tower at a planned site for a nuclear plant (it was a meteorological tower intended for measurement of weather conditions, i.e., exclusively for purposes of safety). In itself, this type of political vandalism is perhaps not very significant; what is significant is the way in which it is glorified by the anti-nuclear movement. A film called Lovejoy's Nuclear War was produced (there never seems to be lack of money for anti-nuclear propaganda), and there is talk of it being broadcast by the Public Television Network. Here is how one environmental journal5 reviewed it: "What Lovejoy did was
wrong, as is the reason why he had to [my italics, P.B.] do what he did." That is all too typical for the "condemnations" of violence by this group of alleged "liberals," whether it involves nuclear power or other issues that provoke their ire.

And these issues are many, most of them having the common denominator of free enterprise and the profit motive. It is by now trivial that environmentalism is being used as a crusading horse against the free-enterprise system. "This thin slice," says Ralph Nader, referring to the biosphere of the earth, "belongs to all of us" in an article called "The profits of pollution." 4

Barry Commoner has a simple recipe for curing the energy shortage and pollution, both of which he alleges to be direct consequences of capitalism: Nationalize the railroads and all energy industries. "Economists and other students of capitalism," he writes, "will recognize that the basic ideas I have discussed are those first put forward by Karl Marx... An explanation of why Marx's prediction [of the collapse of capitalism] failed to materialize — that is, until now — emerges from the improved understanding of economic processes which is a product of the recent concern with the environment."

"The real question we face," writes Physiology-Medicine Nobel Prize winner George Wald (whose many shameless distortions remind one that Nobel Prizes are not awarded for integrity), "is whether nuclear power can be produced safely while maximizing profits. The answer to that question is no." 5

Lorna Salzman speaks of "nuclear power profit-making" and calls it "a technology that puts private profit and jobs over human health and lives, a technology which substitutes man and his social institutions to technological tyranny."

And so forth — the point is too obvious to be belabored. Anti-nuclear attitudes tend (and I am still speaking statistically) to be voiced by people of a particular political persuasion. This has nothing to do with "guilt by association." In fact, it has nothing to do with guilt at all. It is simply a matter of statistical correlation.

It is a weird correlation, one that would have been thought utterly absurd ten years ago: If someone strongly opposes nuclear power, the chances are good that he admires Jane Fonda and dislikes John Wayne (neither of whom, to my knowledge, have ever voiced an opinion on nuclear power).

Like more illustrious writers, I am at a loss to give a name to this group of leftwing, college-educated malcontents who oppose nuclear power as part of a more general opposition to the "establishment." I roundly refuse to call them "liberals;" it would surely be an insult to John Stuart Mill to put him in the company of Lorna Salzman, Claire Booth Luce has called them the "America-stinks" crowd; Irving Kristol calls them "the New Class." In view of Barry Commoner preaching Marxism to the impoverished masses in the New Yorker, where they are also offered African safaris and $6,000 chess sets handcarved from walrus tusk ivory, perhaps a good name would be "the Penthouse-Proletariat." 6

The Penthouse Proletariat is, of course, a very fuzzy concept. I cannot offer a definition, but here are two descriptions that may help to characterize it:

"DDT," writes Prof. E.N. Luttwak, "undoubtedly the greatest lifesaving discovery of the century, is now a dirty word in exactly the same circles where the words CIA and Pentagon are dirty words... The same chorus tells us that we cannot and should not break the oil cartel, that we cannot build more nuclear plants because they are dangerous, that we cannot mine more coal because it ravages the earth, and lately, that we cannot drill for offshore oil because it would devastate the tidelands. At the same time, unemployment at home and the reduced ability of this country to feed the hungry are violently deplored, as if these were not the inescapable consequences of these core attitudes."

"The ruling elites," writes Midge Docter in the same symposium, "... no longer have the conviction that the system, the civilization, is good and no longer wish to assume the responsibility of defending and cherishing it... I can't remember when I last heard [one of
Since the above was written, the Senate Internal Security Subcommittee made public a secret hearing in which a high-ranking Czechoslovak intelligence officer testified that the Soviet-directed spies at the Czechoslovak embassy in Washington (who make up more than half of the total staff) are under instructions to "heighten chaos" in America by any means, and that some of the spy agency's targets are Ralph Nader. This has not changed my expressed above. The contrary, confirms the crude stupidity of the Soviet establishment: Suppose that they were somehow to succeed in recruiting Nader as an agent (which I think highly improbable); what on earth would they expect him to do to "heighten chaos" that the man is not doing already?
charges that nuclear power is a technology putting profits over human health and lives, she cares not two hoots about human health or lives; if she did, she would support nuclear power instead of berating it. She must have seen the facts and figures of the threat to human health and lives by the alternatives, but she evidently dismissed them with the same mental acrobatics that enable the general member of the Penthouse Proletariat to ignore two million people driven at gunpoint into starvation in Laos, but to berate the South Vietnamese and South Korean governments for not living up to the standards of Jeffersonian democracy; to abhor South African apartheid while ignoring the murderous racism on the rest of the African continent; to condemn the torture chambers of Brazil, but not those of the USSR; and so forth.

"The decision to obtain 2% of our energy in barter for the human gene pool is morally indefensible and a national abdication of morality," writes Miss Salzman, this time masquerading in the cloak of morality. As of 1976, the nuclear share of total US capacity (the only pertinent standard) exceeds 8%, and unless Miss Salzman and her co-crusaders succeed in brainwashing the American people, that share is expected to reach 32% at the end of the century. As for genetic hazards, not even the nuclear bombs in Japan (let alone nuclear power) produced any observable genetic effects. The danger of genetic damage from nuclear power is so small that it cannot even be measured, and to be estimated by indirect inference, and Prof. Cohen's estimate is "1 in a cent. hour," i.e., the damage to the gonads by routine emissions of a millirad plant would have the same effect as wearing a pair of pants thereby slightly raising the temperature of the testicles for an extra half hour during a man's life. That is what is morally indefensible to Miss Salzman; but her morality is strangely indifferent to the Untermenschen of Appalachia who are afflicted by Black Lung by the tens of thousands.

"The American public," continues Miss Salzman, "by broadening out the nuclear issue, will refuse to delegate its political power to a scientific elite..."

Note the future tense; she does not hope the American people will refuse, or expect it; no, she is the elected spokesman for the American public and with the confidence that the sun will rise tomorrow; she states that they will refuse. This unt-morgen-die-ganze-Welt attitude is again characteristic of totalitarian propaganda, and its hidden purpose is the same. "The Soviet people will never diminish their vigilance against the imperialist spin and saboteurs" is a state-

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** fullest and most authoritative explanation of the anti-nuclear crusade. Here they need signatures, not facts. The California Initiative was labeled Initiative..." through its terms make it obvious that it is designed to shoot down nuclear power.**

**A SMUGGLING TECHNIQUE**

**TABLE METHODOLOGY**

Two people should work the table, one in front to bring the people to the table, and one behind the table, to make sure people sign properly.

Front person: Approach customer — one on one. Make good eye contact and ask, "Are you registered to vote?" Customer will answer "yes" or "no." If yes, front person turns toward the table with a gesture and says, "Please sign to help get safe nuclear power." (It is positive.)

Usually the person will move into the table at that point, so don't say anything else.

Person behind the table stands (alertly) with the pens clutched in his hand (not strewn around the table) and says, "Are you registered in county?"

The customer will say "yes" or "no."

If yes, hand him a pen, pulling him down toward the petition and say, "Sign the way you're registered to vote." THEN SHUT UP!

**More deception practiced by the anti-nuclear crusaders: Here they need signatures, not facts. The California Initiative was labeled Initiative..." through its terms make it obvious that it is designed to shoot down nuclear power.**

**Any signers should work the table, one in front to bring the people to the table, and one behind the table to make sure people sign properly.**

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The customer will say "yes" or "no."

If yes, hand him a pen, pulling him down toward the petition and say, "Sign the way you're registered to vote." THEN SHUT UP!

Most people will sign or not sign at this point — usually they sign.

**Good Luck from People's Lobby**

**Signature Gathering Tactics**

or, Sign My Petition Please

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responsible scientist ever claimed that the operation of nuclear technology is perfect and permanent, let alone guaranteed it.

There is, however, one point where the anti-nuclear crusaders, as well as the Penthouse Proletariat in general, depart radically from the traits of hitherto known totalitarian ideologies, and that is their technophobia and science baiting. It seems that modern science and technology has wounded this new class of erudite intellectuals with the ultimate insult: They don't understand it any more. Every sentence of Lorna Salzman's little faunium reeks of technophobia and hatred for science; what stirs at the reader from between the lines is her gigantic inferiority complex, probably well deserved.

Now this is not only diametrically opposed to the traditions of fascism and communism, which elevated science to an esteemed position in order to abuse it for its own ends; it is also diametrically opposed to the confessed concern of the elitists for the environment: For all but those capable of the weirdest mental acrobatics, it is axiomatic that to clean up the environment one needs more technology, not less. Automobile-caused pollution is not cleaned up by going back to the buggy and tons of horse manure, but by using lower compression ratios, ventilated crank cases, afterburners, catalytic converters, computer controlled fuel metering and ignition systems, and desulfurized gasoline; and later, perhaps, by switching from gasoline to methanol and other fuels cleanly synthesized from coal in processes that leave the coal in the ground without disrupting the surface of the earth. Pollution is a by-product of poor technology; not of technology as such.

Another front of the fight against the "establishment" is the ostensibly Consumer Movement, which fights the system where consumers vote with their dollars in the market place and seeks to substitute a controlled, even regimented economy instead. The Penthouse Proletariat is at least consistent in its muddleheadedness: The anti-nuclear crusaders oppose the safest form of energy on the grounds that it is unsafe; the environmentalists are against technology, the only hope of keeping the environment clean; and the Consumer Advocates are against the only system where the consumer is king or would be, if a competitive economy were not made uncompetitive by the ICC, FEA, CAB, and hundreds of other tentacles of the federal bureaucracy. All three of these thrusts are personified in Ralph Nader himself, and whenever he wears the consumerist halo of this unholy trinity, he is, of course, advocating more tentacles, more agencies, more regulation and regimentation.

Dr. A.L. Chickering puts it as follows:

The Consumer movement represents not actual consumers, but an abstract class of Consumers made up of upper middle-class reformer types (ostensibly) opposed to bourgeois values. Because "Consumers" don't like tailfins — whatever happened to tailfins? — they accuse businessmen of imposing "useless" (read "bourgeois") products on the public through advertising. The abstract class of Consumers oppose business not because business is indifferent to actual consumers, but if anything, because business serves actual consumers too well. It's just that Consumers don't like the products that consumers want.

Here again we have a trend that, if not totalitarian, is at least anti-democratic and anti-libertarian: It is not the genuine consumer who is to decide with his dollars whether a city needs a new department store, but the Consumer Advocates sitting on planning boards that legislate, regulate, regiment and re-distribute.
There are, of course, individuals who go over the Niagara Falls in a barrel; but they do not build a fanatical following among a considerable section of the population.

And so we are still left with the question: Why?

There are, no doubt, tens or even hundreds of valid answers to that question, and every Penthouse Proletarian combines these motivations in a different mix of proportions. It would be naive to generalize or to present a single all-encompassing motive as the driving force between their seemingly irrational behavior.

Nevertheless, there are some motives more important and more widespread than others. Among the driving forces that I, for one, would not count as overwhelmingly important is the "vendetta" motive; it is certainly characteristic of the leaders of the anti-nuclear movement, but not necessarily of their followers. Ralph Nader is obsessed with the dream of making General Motors squirm; Kendall soured on the AEC when they did not, at first, sufficiently heed his warnings about deficiencies of the Emergency Core Cooling System, and he is still out to get their hide; Sternglass, Geesaman, Tamplin and Gofman all at one time worked for the AEC, and the utter rejection of their fantastic theories by their professional organizations only make them thirst more bitterly for revenge; the authors of Power Over People wrote their amateurish pap after a utility had obtained the right-of-way for a transmission line across their land; and so forth. Hundreds of others may be driven by the "vendetta" motive because they have a personal bone to pick. But there have always been individuals who were hurt justly or unjustly, by some institution of the "establishment," yet they did not succeed in raising a mass movement to avenge their grudge.

The thousands who rail against nuclear power, against the utilities, the corporations, the capitalist system and the profit motive have not been hurt personally by any of these; on the contrary, they have been the beneficiaries of the system they profess to despise. What can perhaps explain the actions of Nader or Tamplin cannot explain the motivation of the entire movement.

The hundreds of thousands in the radicalized sections of the American upper middle class may very well kid themselves that their opposition to nuclear power is based solely on safety and environmental considerations, and such high-minded rationalization makes it easy for this belief to become "sincere;" but objectively, this rationalization is pure nonsense, since nuclear power is demonstrably safer and environmentally sounder than any of its alternatives. Their convictions would soon be shattered if they were willing to look at the facts. But their convictions are para-religious, and they are willing to look at the "facts" only if supplied by the priests of the People's Lobby or the Friends of the Earth. There must be a strong motivation behind such irrationality, and it does not at all follow that the motivation is known to its victims.

But when it comes to motivation, look for the Number One motive of human action: self-interest.

What possible self-interest could there be in opposing the cleanest, safest and cheapest kind of electric power? What possible self-interest could there be in opposing economic growth in general?

Pienly. Perhaps the clearest indication is given by the population controllers, who as often as not are part of the radicalized, environmentalist, elitist, anti-capitalist, "America stinks" syndrome. Their beliefs are no less irrational than those of the nuclear foes. The Zero Population Growth movement in the late sixties, when the U.S. birth rate had been in an unprecedented rapid decline; their activity continued unabated when that decline took the fertility rate below the natural level in 1973; and still it continues today when it is falling toward the point where not even immigration will make up for the eventual decline of the population (unless the old trend about deficiencies of the AEC, but not of their followers. Nader is obsessed with the dream of making General Motors squirm; Kendall soured on the AEC when they did not, at first, sufficiently heed his warnings about deficiencies of the Emergency Core Cooling System, and he is still out to get their hide; Sternglass, Geesaman, Tamplin and Gofman all at one time worked for the AEC, and the utter rejection of their fantastic theories by their professional organizations only make them thirst more bitterly for revenge; the authors of Power Over People wrote their amateurish pap after a utility had obtained the right-of-way for a transmission line across their land; and so forth. Hundreds of others may be driven by the "vendetta" motive because they have a personal bone to pick. But there have always been individuals who were hurt justly or unjustly, by some institution of the "establishment," yet they did not succeed in raising a mass movement to avenge their grudge.

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The privilege of driving to the beach and finding it uncrowded. The privilege of driving rather than walking, and flying rather than driving. The privilege of flying without having to line up and rub elbows with the riff-raff. The privilege of getting away from the riff-raff by flying first class, for coach has already been invaded by it.

The privilege of being fawned over as the people who set the tone. The privilege of esteem accorded to those who drivel rather than produce. The privilege of living the good life of being sensitive, aware, concerned, involved and relevant, without being tainted by "materialistic" subjects such as physics, chemistry, engineering, business or dentistry, let alone by making the vulgar living of a plumber, electrician, printer, radar operator or (horror of horrors!) a wildcarder.

The privilege of being counted something better than "the others." It used to come with money. It doesn’t any more, at least not without an awful lot of it. It used to come with education. It doesn’t any more. The man who made $25,000 a year used to be somebody. So did the man who had written a dissertation on medieval Turkish literature. Not any more. Thirty-five percent of American youth, an unparalleled proportion anywhere or at any time, go to college. They worked just as hard as their parents (they mistakenly believe) to get a degree or to make it to the $25,000 level. But it does not give them the exclusive privileges that it bestowed on their parents. They can still fly to Florida in the winter, but they have to rub elbows with the riff-raff who do not go to analysts, who have not read the latest "in" novel on Lesbian incestuous rape, and who do not subscribe to the New Yorker, or even the Saturday Review. They have been cheated of their right to be somebodies; they have — almost — become nobodies like everybody else. For the nobodies now go to Florida, too. They even go to London, Paris and Rome. They of counted better than "the others." No wonder the Penthouse Proletariat is frustrated. What caused this unnatural state of affairs? Who filled the jetliners with plumbers and printers? Who crowded the beaches with beer-drinking steel workers? Who made cars and gasoline so cheap that an entire nation was put on wheels? What gave people electricity at the laughable price of a nickel a kilowatt-hour? What let them make calls from California to New York for a syllos dollar? What let a third of all American school children eventually pass through the gates of higher education? Capitalism; science; technology. Stop it! Stop the world, I want it all to myself.

Here you have the self-interest of a class whose privileges are about to be cashiered. Not by legislation, not by oppression, but by the relentless advance of "the others," who want a better life, too. A privilege shared with everybody is no longer a privilege at private law; it becomes a lex publica.

I am not, of course, talking about the Rockefellers or the Kennedys; their kind of privileges are not yet threatened, and neither are they (except for some vote-garnering rhetoric by the family politicians) very ferocious environmentalists. I am talking of the upper-middle class intellectuals who last after esteem and influence more ferociously than any robber baron ever lasted after money. The fear of The Unknown explains some of the opposition, but not very much. It is true that people are less frightened of a dam break or an oil fire, even though both of these are more dangerous and more probable than a core melt, because they have a good idea of what floods and fires are like, but they usually have little knowledge of radioactivity. But how come, then, that the microwave oven is catching on fast, when people usually know less about microwaves than they know about radioactivity (and often think it is the same thing)?? How come that they are swallowing tranquilizers, depressants, soporifics, pain relievers and hundreds of other drugs without accusing physicians of being a professional elite that puts profits over health, yet without an inkling of what exactly these chemicals do to their bodies? The association of nuclear power with the first use of nuclear energy, the two bombs dropped on Japan, does not get us very far, either. Would people give up fire and the wheel because both were, at times, used as instruments of torture? Could Ralph Nader make them give up electricity by waging a psychological campaign that associates "electric" with "chair," just as he does with "nuclear" and "bomb"? Yet he has succeeded in turning thousands against nuclear power on the grounds that, paradoxically, constitute the very reasons for its superiority: safety, economy, availability, ease of waste disposal, and low environmental impact. What theory will explain the paradox?
The theory of the endangered class will. Of course the endangered class does not realize what their true motivation is. Of course they kid each other, and above all themselves, that they are motivated exclusively by legitimate humane concerns. Who didn't find wonderful and high-minded rationalizations to defend his privileges when they were threatened? To curb the power of ancient monarchies was to question the Divine Right of Kings and to go against God Himself, claimed those with a stake in the monarchy, and they probably believed it. To resist the New Order of the German Reich was to jeopardize the security of Europe, claimed the Nazis, and they probably believed it. To question the party line as decreed by the Politbureau is to be an enemy of the people, claim the Soviets, and probably they believe it. "There is only one politically, biologically and ethically acceptable solution," crow Lorna Salzman, "total and permanent abandonment of nuclear power." Conceivably, she believes it, too.

But once you discard what is claimed, assured and alleged, and instead watch the thrust of the action and its effects, the seeming self-destructiveness makes sense and the motive, the corporatization, the let-me-be-on-the-planning-board socialism, the fight against economic growth, the maligning of the profit motive, the professed hatred of "materialistic" values, the totalitarian trends, the systematic, destruction-bent harassment of private enterprise — they all fall into place. They are the actions of the somebodies who dread becoming nobodies.

Mass affluence is, by its very existence, destroying affluence as a distinctive sign of a favored social stratum. Economic growth, free enterprise and technology are the culprits who have committed this sin, and they must be stopped dead in their tracks. And they can be stopped by denying them their lifeblood, energy.

Energy generation can be drastically curbed by the legal roadblocks which this group so masterfully puts up via the allegedly environmental organizations, and people can be duped into cooperating by scaring them with horror fiction about safety, environment, corporate greed, even civil liberties (of all things). And energy conversion does have drawbacks: It does have environmental impact, it does endanger safety and health hazards, it does cost money, and much of it does have to be imported from unreliable sources.

Only nuclear power, while not perfect either, has less of these disadvantages than any other, and it has earned the hysterical hatred of the threatened class because it does not fit the campaign plan; they wage war on it not in spite of its superior qualities, but because of its safety, its availability, and its economy.

"Nonsense," I hear the reader saying. "I know several anti-nuclear campaigners who are far from affluent and whose opposition to nuclear power is sincere and solely based on safety considerations."

And so do I. But apart from the fact that, I repeat, I speak of statistical tendencies, not exhaustively of all individuals (and apart from the fact that I also know people who are sincerely opposed to vaccinating children against diptheria), please look again. How sincere is a person (or what use is his sincerity) who has not compared the dangers of nuclear power to those of its alternatives? The fact that the campaigner may not be affluent means very little by itself; remember, Nader's raiders do not lust for money, lust for power. Is he or she interested in no the campaigner asserts and or are the full of the campaigner's assertions true?

We know a few clues where most of the CERN's neutron research is done. Who is it that has so far most benefited from this research? Let me say that in little love for the scientists which should have stood up to the charlatans years ago. But whenever a of the Americans for Energy Independence was formed, who was it that gave not with money but with the actual work to be done? The International Brotherhood of Railroad Workers.

Let me say that I have, in general, little love for contemporary trade unionism, and I have a positive aversion against the American Federation of Teachers (which now recruits among faculty and finds adherents mainly among those who could not make a living off campus and need protection of their incompetence). Yet I cannot help observing that when it comes to defense of nuclear power, the ones up for it are those who are nearest to the neutrons, the radioactive wastes and the emergency switches.

Who, on the contrary, is it that fans the anti-nuclear hysteria? The Sierra Club, whose members live in Beverly Hills rather than Watts, in Long Island Suburbia rather than Harlem; the Creative Initiative...
THE CITEADELS OF UNELECTED POWER

their advertising rate card (left), and you will see the American people staring right back at you.

Look deeper, and for all the exceptions (which I do not deny), you will see an affluent elite afraid that affluence of everybody could engulf them.

Some of the privileges of these upper-middle class elitists have been lost long ago and forever; the privilege of having colored servants, for example. Others are as good as gone — the empty roads, for example. The high-powered propaganda against the ostensible vulgarity of the automobile has not driven the "siss-raft" off the roads, though not for lack of trying. In yet other cases, they have shown themselves willing to sacrifice their privileges at the cost of denying them to everybody else, as in the proposals to forbid roads through national parks, which they would rather leave to the squires than to share them with the plumbers.

But one decisive privilege they still do have, and they will cling to it with the furor of strength of desperation. They are still the tone-setters, public opinion moulders and educators. They still overwhelmingly control the mass media, the schools and universities, and they populate the obese federal bureaucracy. They still sit on all points of unelected power.

The "unelected" is not a fatal limitation, for uninhibited access to the ears and eyes of the voters can often program them for stands on ideological issues. Besides, there are cases when the citadels of unelected power can be stronger than the voting machines. Affirmative discrimination, for example, has been decreed by an unelected agency of the federal bureaucracy not simply ignoring the intent of Congress, but in diametric opposition to the anti-racist intent of the law.

Clearly, then, control of the brainwashing industry is no small asset to this elite whose time has come. They have been surprisingly successful in keeping the health hazards of the non-nuclear alternatives from the public; and they have been surprisingly successful in scaring the public not just with distortions, but with outright falsehoods.

It would be nice to finish this book by saying that in the end, reason will prevail. But will it? By the time you read these lines, the people of California will have voted on the "Nuclear Initiative," whose contents is a cruel hoax. I expect this initiative to be passed. (A pessimist's surprises are always pleasant.) While other industrial-
ized nations are forging ahead, while Britain, Germany and Japan are close to having breeders on line, and France already has had one on line for more than a year, orthodox fission power in the United States is being hounded and harassed to the point where its future is in doubt. The victims of the lack of nuclear power, the dead, the diseased and the crippled, pave the way for an ignorant “America stinks” elite lusting for power. The fact that reason has always prevailed in the past does not guarantee that it will prevail in the future.

Besides, it hasn’t always prevailed. The glory of the arts and sciences in antiquity was buried for a thousand years by a doctrinaire and intolerant institution — the medieval Church — that considered science the work of the devil. For a thousand years, Western civilization was stifled in debilitating ignorance, poverty and backwardness. It was held captive by an institution that had not come to power by the sword. It had merely acquired for itself a monopoly on learning and the dissemination of information.
3. MAJOR ACCIDENTS

7. See note 4.
10. C. Starr and others, Report to the State of California on safety of steam generating power stations, Univ. of Calif. at Los Angeles, 1972.
12. Wilson and Jones (see footnote 4).
13. See note 12 to Chapter 1.
16. I am keeping this reference purposely vague. The intelligent reader will, after some searching of a better college library, be able to verify the statement and find the location of the pertinent dam. However, I do not wish to give easy directions to terrorists. (The latter are urged to try the manufacture of plutonium bombs; that will keep them busy and prevent them doing any real harm.)

4. WASTE DISPOSAL

5. Lave and Freeman, see note 5, Chapter 3.

5. ROUTINE EMISSIONS

1. Countless times, e.g., Hearings before the Joint Committee on Atomic Energy, Jan.22-28, 1974.
3. International Atomic Energy Commission (see note 4, Chapter 2).

6. ENVIRONMENTAL IMPACT

3. Calculated from the data given in note 2.
10. TERRORISM AND SABOTAGE

4. R. Lapp (see note 2).

9. RELIABILITY, ECONOMY, CONSERVATION

8. RELIABILITY, ECONOMY, CONSERVATION
6. "Has America lost its nerve?" (symposium), Commentary, July 1975.

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This is the end of the book
but not of the nuclear controversy, nor of the energy crisis: the crisis that is not due to the lack of energy, but to the lack of access to it. For the access to it is blocked by government interference in free markets and by the roadblocks put up by the vociferous group described in the last chapter. But this book dealt only with some aspects of nuclear power, and only with the situation up to early April 1976. There are new developments in all branches of the energy field almost every day. Will you rely on the Closed Fraternity (p. 26) to inform you fairly? Will you let yourself be browbeaten by the scientific jargon in which Barry Commoner clothes his advocacy of socialism? If you have read this book carefully, you will know that Commoner’s statement on the dangers of a nuclear plant, “There is only one other existing man-made device which has the physical capability of causing such a catastrophe in a single event — a nuclear bomb,” is a flat falsehood, as is his statement that “nuclear reactors have a particularly low Carnot efficiency.” But will you be able to pinpoint his sophistries on coal, oil, gas, hydropower and solar energy? Will you know the facts that he conveniently left unmentioned?

Already Business Week is extolling his new book on energy, which advocates “reorganizing the US economic system along socialist lines” and is brimful of false technical assertions. And Professor Commoner is not the worst of the pseudo-scientific demagogues. To protect yourself against the merciless onslaught of the brain-washing industry in matters of energy, subscribe to the Public-Semester newsletter written for PhD’s before other it can be used as a to bilk the +n"n ....... in-situ of it how solar energy can be .......
But its coverage is not limited to technical matters. The economic and political background of energy matters is reported, too. Who could have foreseen the Arab oil embargo in 1973? Access to Energy could, and did. Two months before the embargo, it warned of the folly of importing ever-increasing amounts of oil from unstable sheikdoms in the Middle East, making the US ever more vulnerable to political blackmail.

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Author, Santa Cruz County, Calif.

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Ronald Reagan

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Petr Beckmann was born in Prague, Czechoslovakia, where he obtained his Ph.D and Dr.Sc. degrees. He worked for a research institute of the Czechoslovak Academy of Sciences until 1963, when he was invited to the University of Colorado and did not return behind the Iron Curtain. He is the author of 8 books and more than 60 scientific papers. Originally working in electromagnetics and probability theory, he became strongly interested in questions of energy and now publishes the monthly newsletter Access to Energy in his spare time.

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He has no personal stake in nuclear power, owns no stocks of any corporation, nuclear or otherwise, and is not involved in any research projects funded by any corporation or the federal government.