Nuclear Power Plant Siting: A Handbook for the Layman

Dennis L. Meredith

MARINE ADVISORY SERVICE
SEA GRANT

UNIVERSITY OF RHODE ISLAND

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Photos are by Robert J. Izzo, University photographer.

ON THE COVER, a myriad of dials and alarms keeps operators in a power plant control room in touch with the inner workings of a nuclear power plant.

Additional copies of this publication may be obtained from the Marine Advisory Service, University of Rhode Island, Narragansett Bay Campus, Narragansett, Rhode Island 02882.

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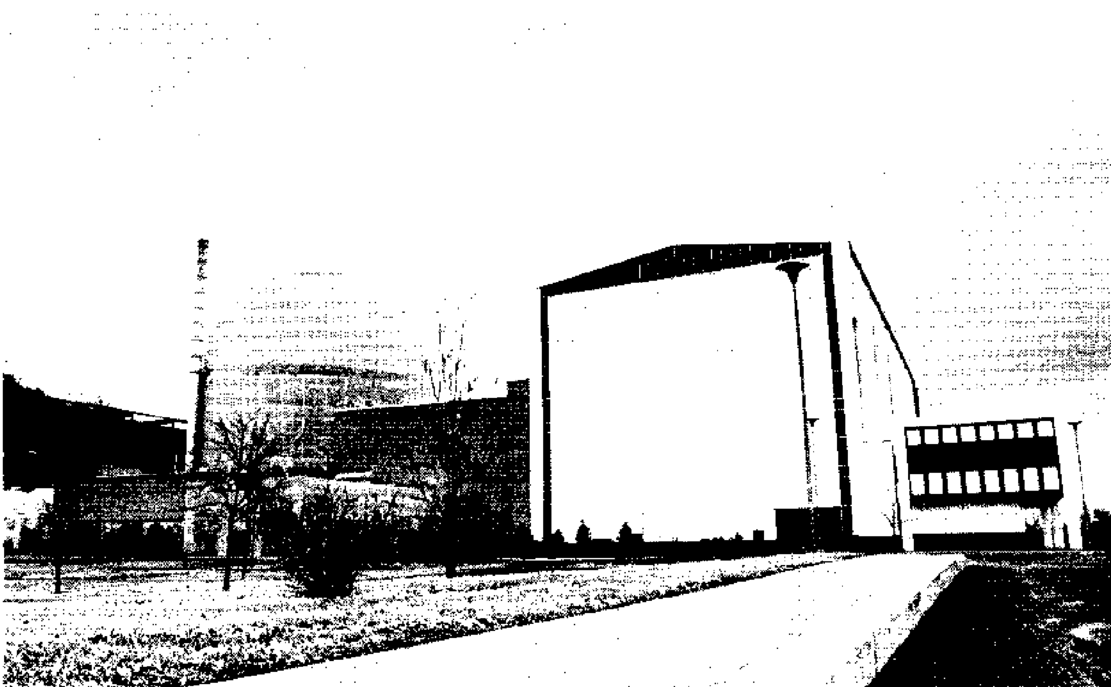


A MODERN NUCLEAR POWER PLANT, Connecticut Yankee Nuclear Power Plant at Haddam Neck, Connecticut, along the Connecticut River supplies 600 million watts of power to the New England power system. On the left is the dome-shaped reactor in which the nuclear chain reaction takes place to heat water to steam. The steam is piped into the building at right where it spews through a turbine to generate electricity.

The Searing Spotlight on Nuclear Power

The rise of public concern for the environment during the last few years combined with society's mounting needs for electrical power have thrust the electric generating plant into a sometimes searing public spotlight. Moreover, the advent of the nuclear power plant with its unfamiliarity and its association in the public mind with the horrors of nuclear warfare has resulted in a controversy often noted for its emotion and, unfortunately, for its lack of sound, scientific reasoning. This booklet, hopefully, will avoid the former and provide a useful source for the latter on its subject—nuclear power plant siting. Though power plant siting is only a part of the overall system of power generation, it is an important part. The actual placement of power plants will probably have a greater impact on more people than any other facet of the electric power generating industry.

This booklet will concern itself primarily with *nuclear* power plant siting because public concern is focused more on this new type of energy source. This is not to say that nuclear plants present the greatest problems of the many power sources, only that the problems are different and often unfamiliar, and need more explanation to the public. Also, nuclear power is expected to undergo an enormous increase in usage during the next 30 years. During the approximately eight-fold increase in power generation expected by the year 2000, nuclear power will rise from about three percent of the total generating capacity at present to as much as half of the total. Other energy sources will increase, but not nearly as dramatically.

Background for this booklet came from technical and popular publications on nuclear power plants, interviews with experts on power plant siting, and a series of seminars on plant siting sponsored by the University of Rhode Island Marine Advisory Service. In a list beginning on page 29 are some of the easier-to-obtain articles and books for those interested in further reading. I have attempted in this booklet not so much to give answers as to raise questions because this nation is at the planning and question-forming stages of a profound change in energy sources from fossil to nuclear. Our dwindling fossil fuel resources and the extensive air and water pollution created by coal and oil burning seem to dictate that the change must be made.

The Philosophy of Modern Planning

Planning for future energy needs, as for any kind of planning in our intricately interwoven society, is an enormously complex undertaking. Such energy resource planning, if done properly, involves economics, law, sociology, physics, engineering and the medical and biological sciences.

The need for wise planning has led scientists and engineers to a new form of thinking to attack problems. Called systems analysis, this kind of thinking rests on the assumption that no single thing exists alone in the world. Everything from the largest building to the smallest blade of grass affects and is being affected by many other things. Thus, to alter any one facet of our world is to cause far-reaching consequences. In the case of nuclear power plant siting, systems analysis means that all the operations of fuel management, electricity generation and delivery, and waste disposal, and their social, environmental, and economic impact must be taken into account. And these operations are all directly connected to overall power generation planning.

Engineers designing nuclear fuel systems, for instance, must devise equipment to safely and economically mine the ore, process it, form it into nuclear fuel, get it to the site, install it, remove it when used, reprocess the useful radioactive material, treat the waste and dispose of it. And the fuel system is only one facet of the total nuclear electrical generating system, all of which must be suitably related to the affected environment. In some areas of concern, power plant siting problems are minor compared to the overall problems of the nuclear power system.

Another concept planners use to evaluate the feasibility of a power plant is that of "cost-versus-benefits." Every project undertaken by man has both drawbacks and advantages, and only after all of these are taken into account should decisions be made. As we shall see in a later chapter, cost-benefit analysis is no simple task.

As mentioned previously, this booklet will attempt to present only part of the total energy system planning picture—what planners take into account when deciding where to put a power plant. To be well-informed, a layman should study the many other areas of energy production technology, for they will all affect him. The final decision on our future energy sources and their use rests with the public. Only an informed public, working through its representatives, can assure this country of both plentiful energy and a safe, clean environment.

How Power Plants Work

All electric generating plants, no matter what kind, have certain features in common. Basically all plants possess an energy source, a method for converting this source into electrical energy, and systems for disposing of waste products.

The energy source for most power plants at present is fossil fuel: coal, oil or gas. Smaller amounts of energy are derived from the flow of water, solar energy, nuclear fission, and volcanic steam.

The conversion method in most of today's power plants is steam. Energy from the power source is used to heat water which shoots, in the form of steam, through the blades of a turbine. The turbine turns a generator, thus generating electricity. In the case of hydroelectric plants, of course, the energy of falling water turns the turbine.

Finally, all power plants have methods of disposing of their wastes. In both nuclear- and fossil-fueled steam plants, excess heat is rejected by transferring it to cooling water and then releasing it into the environment. In fossil fuel plants heat also is released into the environment through smokestacks. This excess heat usually cannot be used further because it lacks "oomph"—it is not concentrated enough to power turbines.

Other major wastes of electricity production include ash, smokestack particles, nitrogen oxides, sulfur dioxide and carbon dioxide from coal and oil plants and radioactive wastes from nuclear plants.

Because of our rapidly expanding population and our consequent need for electric power, we are using our limited supplies of coal and oil at rates which will exhaust our known supplies in less than a hundred years. Long before then, however, the costs of using these fuels in both economic and environmental terms will have reached impossible proportions. Though scientists disagree as to precisely when and how our burning of fossil fuels is affecting us, almost all of them agree that both man and his environment are being endangered. Only ill can come of our releasing millions of tons of particles and gases into the atmosphere and spilling countless gallons of oil into the oceans each year. Our energy sources must be made less polluting, they say. Though nuclear power plants release almost no chemical pollutants into the air and none into the ocean, they do present problems of radioactive waste disposal and heat discharge which must be weighed in any decisions about our energy sources.

A Uranium Shortage and its Alternatives

Like coal and oil, uranium for fueling power plants is in limited supply. Experts project that, if nuclear power plants proliferate, we may have enough uranium for only a few decades. Another type of nuclear reactor being developed may allow us to use atomic power for several centuries. This is the breeder reactor. To understand the workings of the present nuclear and future breeder reactors, some knowledge of nuclear fission is first needed.

Nuclear power plants now in use employ a sustained chain reaction in which atoms of unstable uranium 235 (U235) break apart, or fission, and release heat energy. Along with the heat energy, the uranium atoms release particles called neutrons which collide with and fission even more uranium 235. This process continues until the uranium in a sample is depleted to the point where neutrons encounter fewer and fewer uranium atoms to split, and the chain reaction slows and eventually stops.

Uranium 235, which is so named because it has an atomic weight of 235, is but a small fraction of common uranium ore. It is this supply which scientists say will be quickly used up if we continue to build nuclear plants as we are now. Scientists have found, however, that if they surround a reactor full of U235 with the more common, but less fissionable uranium 238 (U238), extra neutrons from the fissioning of U235 will bombard the U238. This bombardment could change the U238 to heavier plutonium 239 which, like uranium, can be used in reactors. Thus, this type of reactor "breeds" more fuel than it uses, increasing the period of availability of usable nuclear fuel to many centuries. A nuclear breeder reactor, according to latest estimates, will be available commercially in this country in the 1980's. The Soviet Union has already completed its first breeder reactor, a 350-megawatt (million-watt) plant on the shore of the Caspian Sea. Other breeder reactors are under construction in Britain and France.

Lest it seem from the above paragraphs that the development of an American breeder reactor is a foregone conclusion, it should be stressed that criticism is presently surfacing about the program and it must be resolved. Some environmentalists contend that the breeder will be hazardous because of the flammability and radioactivity of plutonium used in the reactor.

Moreover, a study conducted at Resources for the Future, a Washington, D.C., research center, criticizes the breeder on economic grounds. According to the report, the breeder will cost much more than it is worth in terms of reduced electricity costs. The report also contends that the supply of uranium is not nearly as short as the AEC contends, and the U.S. can wait until further feasibility studies are done to proceed with the breeder. The controversy over the breeder, as with that over other facets of nuclear power generation, will be settled only by careful, open debate. And it has only just begun.

The breeder reactor, moreover, is still not the last word in electric power generation. Scientists see our ultimate source of energy as controlled thermonuclear fusion—the combining, or fusing, of light chemical elements at temperatures of millions of degrees in order to release energy. Nuclear fusion, which is the same reaction the sun undergoes to produce energy, is the "cleanest" and safest major source of energy in man's future. None of the elements used in or resulting from the process is greatly radioactive, and scientists say future developments may reduce the amount of excess energy released to the environment. Also, the fusion reaction is so difficult to maintain that, in case of an accident, the reaction would simply stop. But there is an "if" to nuclear fusion; to some scientists it is an "IF!" Nobody has yet shown that it is possible to contain a million-degree plasma at high enough temperatures and long enough to obtain fusion of the atoms and extract energy from it. Glenn T. Seaborg, former chairman of the U.S. Atomic Energy Commission, however, is "optimistic that we'll be able to demonstrate its scientific feasibility by the end of the decade," but, at present, nuclear fusion is but a rosy glow on the horizon.

Power Plants and Air Pollution

As a first step in looking at the environmental effects of power plants, let us examine the changes in air quality brought about by power generation. The reduction of air pollution is the principal immediate reason for the public to consider allowing the construction of nuclear power plants. Other reasons include the reduction of such environmentally hazardous operations as oil drilling and transportation, and strip mining.

The major pollutants in our atmosphere are carbon monoxide, sulfur dioxide, nitrogen oxides, hydrocarbon vapors and particulate matter. Almost all the carbon monoxide and hydrocarbon vapors come from automobile exhaust. Electric generating plants account for about 50 percent of the sulfur dioxide in the air, the rest comes from residential heating.

Nitrogen oxides are introduced into the air in approximately equal amounts by motor vehicle use, home heating, and power generation. These oxides of nitrogen, though not particularly harmful in themselves, are the chief villains in the formation of photochemical smog. Suspended particles come from refuse disposal, motor vehicles, electric generating plants, industrial plants, and space heating.

Although automobiles account for the majority of overall air pollution, from the standpoint of human health, power plants are the most dangerous air polluters. Carbon monoxide, the most dangerous pollutant in automobile exhausts, readily converts to harmless carbon dioxide in the air and has a lower potential for harm to humans than sulfur dioxide. Sulfur dioxide from coal and oil burning can cause humans harm in concentrations thousands of times lower than carbon monoxide. Sulfur dioxide harms humans primarily by restricting breathing passages and, when it converts to sulfuric acid, by severely irritating lungs.

Fossil fuel power plants also release such metals as mercury, selenium and vanadium, substances not of any great consequence now, but possibly dangerous air pollutants of the future.

According to Louis J. Proulx, who is chief of air pollution control of the Connecticut State Health Department, restrictions on the percentage of sulfur in fuels, increased efficiency of power plants, and restrictions on the emission of particulate matter will cause significant improvement in air quality in the short run. "However, with the demand for power doubling every ten years, as has been estimated, we will be back to the present air quality in ten years, unless major amounts of nuclear capacity are developed."

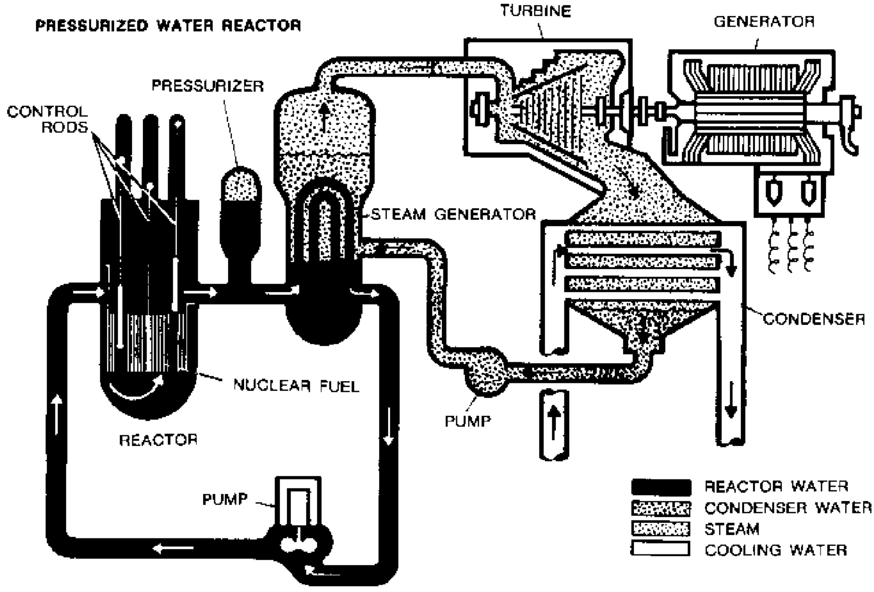
Even with strict emission controls, some scientists doubt the wisdom of burning fossil fuel to obtain energy. They say we are largely ignorant of the effects of even seemingly harmless carbon dioxide on our atmosphere and climate. Carbon dioxide and water are the final end products of any fossil fuel combustion.

The only emissions of any sort into the air by nuclear plants are tiny amounts of radioactivity rejected in the normal course of operation. A discussion of these and other radioactive emissions from power plants follows.

The Scare Word—Radiation

Radiation—to many people this word conjures up visions of Hiroshima and a deadly, invisible killer. Unfortunately such irrational reactions have in many cases prevented a calm, clear appraisal of the radiation effects of nuclear power plants—an appraisal badly needed if we are to plan our energy producing systems wisely.

Scientists measure the damage radiation does to a living tissue in units called *rems,* or roentgen equivalent man. This is because there are many different kinds of radiation which cause different levels of damage to living systems. For example, if someone were to throw a ping pong ball at you and hit you, it would hurt much less than a baseball thrown with the same force. Thus, if the damage by these balls were measured in a radiation scientist's terms, the ping pong ball would have a much lower number of rems than the baseball.



THE PRESSURIZED WATER REACTOR keeps water under pressure to prevent it from boiling. The water flows up through the fuel where it is heated by nuclear fission, which is regulated by the control rods. The water passes out of the reactor and through the looped pipes in the steam generator (the plant will have four of them) and then is pumped back into the reactor to begin another cycle. The pressurizer, to the reactor's right, keeps the pressure of the reactor water constant. At the steam generator, the heat from the reactor water is given off through the walls of the loops, changing the water in the steam generator into steam. Leaving the steam generator, the steam rushes into the turbine, spinning its blades which rotate the generator, and then the steam is channeled into the condenser. Cooling water flowing in tubes through the condenser lowers the temperature, which turns the steam back into water, and the water is pumped back into the steam generator. The cooling water, after passing through the condenser, flows back to the original source.

The Atomic Energy Commission (AEC) sets the maximum permissible dose from all man-made sources to the general public at 170 millirems (mrems) per year. The maximum dose an individual worker in industry may receive is 500 millirems per year. A millirem is one thousandth of a rem.

People living at sea level receive an average of 150 mrems per year from cosmic rays and from the radioactive components of rocks and soil. About 50,000 mrems are required to produce any noticeable medical effect on the body.

Living right next to a nuclear power plant for a year would result in less than a five mrem dose to a person. This radiation results from minute leakages, samples taken from the reactor core for testing, tiny amounts of radioactivity produced in the waste cooling water, and minute gaseous discharges.

It should be stressed that the water which actually goes through a reactor core is separated completely from the outside environment. For instance in a "pressurized water reactor," core water, heated by nuclear fission, circulates through a heat exchanger where it turns water in a completely separate system to steam. This steam turns a turbine, and then is cooled by outside water in another separate system and returned to the heat exchanger (see diagram).

Usually the radioactive emissions from power plants are about one percent of the maximum standard, 500 mrems for individuals, allowed by the Atomic Energy Commission. Recent AEC rulings have stipulated that this one percent level is the maximum radiation which should be allowed from nuclear power plants. One fascinating fact documented in public health reports is that coal-burning plants release more radioactivity than some types of nuclear plants. This is because radioactive particles trapped in coal are released through the smokestack as the coal is burned.

Radiation and Scientific Detection

Regarding radiation standards, we should perhaps discuss developments in radiation monitoring and other scientific detection techniques. In the last few decades scientists have developed methods to detect extremely small quantities, whether they be of radiation, mercury, or bacteria. However, in most cases enough information does not exist on the effects of these quantities on living creatures or ecological systems. It may be that in the wide world of water and air and living things such tiny quantities may be insignificant.

One example where scientists know that something has been done to the environment, but cannot detect the effects, is the impact of radioactive dumping and bomb tests on the oceans. A prominent radiobiologist, Vaughn Bowen of the Woods Hole Oceanographic Institution, expresses frank "disappointment" that he and his colleagues have been unable to detect any permanent change in the ocean environment from any radiation release in man's technologic history. According to calculations, Dr. Bowen said some permanent change in ocean plants and animals should have been found around bomb test sites or radioactive dumping grounds. This is simply another case where scientists know an ecological disruption has been there, but cannot determine whether it has affected the complex and delicate undersea community.

To take into account our ignorance of the effects of low amounts of radiation, mercury, or other potential dangers, we have set standards from interpolation of data; in other words if *x* amount of radiation does *y* damage to a person or ecological system, then half that *x* amount will do half of the *y* amount of damage. After this information was gathered on the damage caused by various amounts and kinds of radiation, the standard of radiation was set at a level low enough so that the benefits of whatever radiation-producing activity we attempt will far outweigh the expected damage to ourselves. Standards are set low enough, not only to prevent medical damage but to prevent subtle genetic damage to a population, meaning the standards are very low indeed.

The scientists setting radiation standards have assumed that any radiation is dangerous, an assumption which may not in fact be true. When the human body is exposed to low amounts of radiation, scientists suspect it may be able to repair the damage. In their caution, however, those who set radiation standards are ignoring this possibility, giving an even greater safety margin.

If setting these standards sounds like a simple proposition, it is not. How do you measure the number of lives saved by a power plant, due to better and lower cost power production, in assessing its benefits? (For instance, lower cost power may slightly reduce hospital costs, in turn allowing better medical care.) Also how can you be sure that errors do not creep into the complex statistics or concepts used to assess radiation damage? This is why continuing research and debate are necessary to make sure that radiation limits are low enough to prevent the most possible damage while not so low as to prevent beneficial uses of nuclear resources.

Gofman, Tamplin and the Debate on Radiation Standards

There has always been debate about radiation standards, but it was more like a genteel sparring match until two scientists from the AEC-sponsored Lawrence Radiation Laboratory in California came on the public scene. Dr. John W. Gofman and Arthur R. Tamplin declared in talks, and in testimony before a congressional committee in 1969, that if everyone were exposed to the maximum permissible radiation dose allowed by the federal government, there would be 32,000 more deaths from cancer per year.

This sensational declaration, containing what have become two of the most frightening words in the English language—cancer and radiation—grabbed headlines across the country. Since then, many scientists have pointed out flaws in the Gofman-Tamplin argument, but the rebuttal has never really caught up with the original statement.

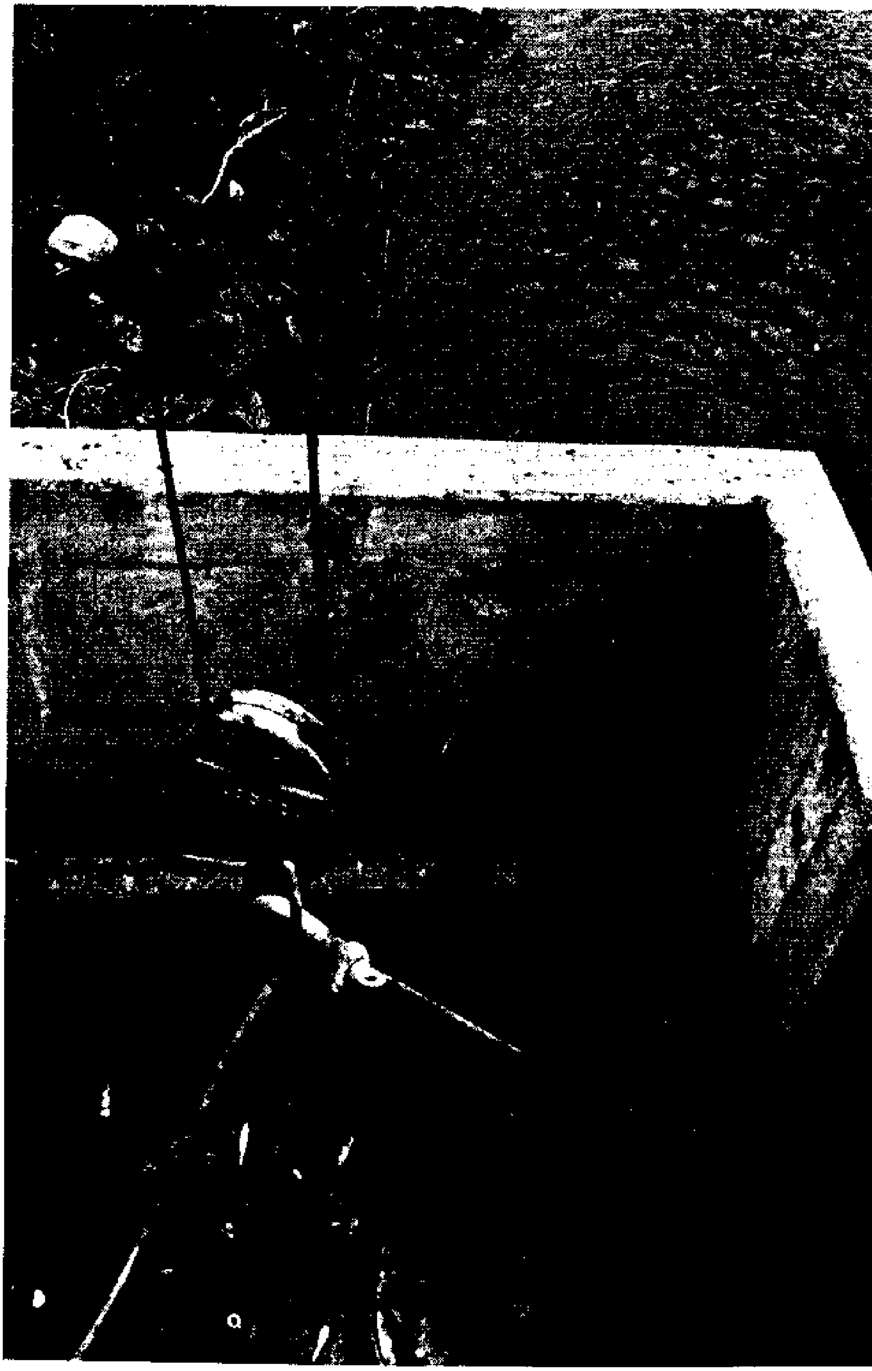
Dr. Victor P. Bond, associate director for life sciences and chemistry at Brookhaven National Laboratory, debated Dr. Gofman at a recent seminar in North Carolina. He pointed out, as have many other scientists, that the possibility of the entire population receiving a maximum permissible dose is nil. Additionally, the number of incidents of cancer used by Gofman and Tamplin is probably many times too large.

Gofman and Tamplin have assumed, as do scientists setting radiation standards, that any radiation is harmful and that the harm is directly proportional to the dose of radiation. Scientists will be the first to admit that this is a gross simplification of radiation hazards. They are still very much in the dark about the effects of low doses of radiation on complex living systems; much too much in the dark, they say, to link certain doses of radiation to certain levels of cancer or any other disease in the population.

In the case of nuclear power plants, the problems of radioactivity are not confined to the generating site. Nuclear fuels must be mined, shipped, refined, installed, removed from the reactor, reprocessed, and disposed of. Most of these functions—which are outside the scope of this booklet—are by no means minor. In fact in some cases radioactivity from these other sources may be much greater than that from a power plant.

According to Dr. Bowen, from 1,000 to 10,000 times as much radioactivity may be released into the environment by fuel reprocessing as by power generation. Fuel reprocessing involves breaking down nuclear fuel pellets and using complex chemical methods to extract useful radioactive compounds. This reprocessing, as well as the other facets of fuel handling, will undergo a very large increase as nuclear power plants proliferate. Radioactive waste storage is an even greater problem. Estimates are that we will eventually have tons of highly radioactive wastes that will have to be stored for thousands of years to allow them to "cool down." The AEC still has not found any satisfactory way to do this.

Because of the low radioactive emissions from power plants and the further restrictions being imposed by the AEC, we see that in power plant siting considerations radiation is not the major concern, though in the overall system of nuclear power generation, radiation problems have and should receive top priority.



LEAVES, STICKS AND DEAD FISH mark the cooling water intake of the nuclear power plant. While not now a major ecological problem, the trapping of fish on intake screens may become one as power plants proliferate.

Power Plants and Water Pollution—A Heated Discussion

A more difficult problem than radiation control for engineers building power plants is how to handle the enormous amount of heated water a power plant produces in its cooling process. This problem is present to some degree in all thermal power plants, but thermal discharge is greater in nuclear power plants because they are not as efficient as fossil fuel plants. A present nuclear power plant rejects from 40-50 percent more waste heat than a comparable fossil fuel plant. Also nuclear plants must be very large to be feasible, resulting in the release of a large amount of heat in a relatively small area. The more advanced reactors and breeder reactors of the future are expected to release about the same percentage of heat as fossil fuel plants, lessening the heat load of individual nuclear plants. But the enormous increase expected in the number of power plants of both kinds in this country during the last part of this century makes thermal pollution a problem we will have to deal with for a long time.

Some of the figures which have been used to depict future freshwater cooling water needs are interesting. By 1980, it is projected, power plants in the United States will require about one-sixth of the nation's total annual freshwater runoff for cooling purposes. Because of seasonal variations in runoff, however, a much greater fraction of the water available is needed at certain times of the year—for instance, a greater percentage of the water is needed during the dry summer months than during the spring snow-melting period. Because of these variations 50 percent of the time 50 percent of the total runoff is required. By the year 2000 from one-half to two times the runoff will be required, it is said. In other words, according to these figures the "average" unit of water in our country's rivers will pass through two power plants on its way to the sea.

At first glance these figures seem staggering, but there are several factors which make it probable that the cooling water problem, though serious, will not be nearly as bad as they indicate, at least not on our inland waters.

For instance, the figures assume that the water in our rivers and streams will be passed through a power plant only once and then released. Actually many future power plants will probably use recirculating systems, designed to use the same water over and over. Such a system would draw water only to make up for evaporative losses. Actual cooling may be done by either cooling ponds or cooling towers, which we shall discuss later. Also it should be pointed out that the use of cooling water by several plants along a river does not result in a cumulative effect—the temperature of the water does not get hotter and hotter as it goes from plant to plant. Much of the heat is rapidly lost through evaporation and in other ways if siting is wisely done.

Developments in power plant siting such as offshore siting, to be discussed in the last chapter, may go a long way toward solving the thermal pollution problem. One estimate of where the power plants built before the year 2000 will be sited is as follows:

40 percent—oceans
30 percent—Great Lakes
20 percent—artificial cooling ponds
10 percent—rivers and lakes

This breakdown seems to indicate that the problems of thermal pollution will be found, not necessarily in our rivers and streams, but in the delicate estuaries along our coasts.

Water passed through a power plant for cooling purposes is raised 15-25 degrees Fahrenheit above the temperature of the main body of water. It is not hot by any means, but certainly warm enough to potentially affect complex aquatic and marine environments.

Three Basic Environmental Effects

There are three basic effects of a power plant cooling system on the environment: 1) the effects of sucking great quantities of water from a river or estuary into a plant; 2) the effects of subjecting this water to a rapid rise in temperature, to turbulence, and to various chemicals used inside the cooling system; and 3) the effects of releasing large amounts of heated water as well as chemicals into a body of water.

Of the three components of power plant cooling systems, the intake is probably the least critical environmentally, and at the same time, the most visible in its effects. This is primarily because fish may be trapped on the intake screens and thus killed. In an average river-sited power plant thousands of fish may be killed annually in this way. Some fish kills on ocean sites have been in the hundreds of thousands. While this may seem like a great number, the effects on the total fish population of an ocean, river or estuary are usually insignificant.

In cases of moderate numbers of deaths on intake screens, total fish populations apparently have little trouble maintaining themselves. There have been, however, individual cases of massive fish kills—the type which may endanger entire fish populations. One such case, which reads like an ecological horror story, has been that of fish kills at the Indian Point Nuclear Power Plant in New York state. This plant has been implicated in several kills involving several-hundred-thousand fish each. These kills have been due, not only to screen deaths, but also to heated water discharge.

The expected proliferation of power plants, moreover, will greatly increase the possibility of water from a bay, river or estuary passing through a power plant. Thus, the possibility of much larger fish kills is with us, making the trapping of fish on intake screens a problem which definitely should be dealt with.

The second effect of power plant cooling systems, called entrainment, is the passing of water through the condenser pipes to carry away excess heat from the plant. This is a more serious problem for environmentalists because this water is subjected to much more than a simple temperature rise. The water and living creatures in it are subjected to pressure changes from pumping, turbulence, contact with metal in the condenser pipes, and intermittent doses of chlorine commonly used to clean aquatic growths from condenser tubes. All these factors combine to create a most complex ecological problem—how these many stresses affect the total marine environment. These problems, once thought to be too minor to arouse serious concern, are only now beginning to be studied in power plants. Many times answers to such questions about a particular power plant may not be possible until experiments can be done with the actual operating plant.

Of the many kinds of marine organisms, plankton are the most likely to pass through a power plant cooling system. These microscopic plants and animals, which form the basis of the food chains of the lakes, rivers and seas, are food for larger creatures, which in turn are food for larger creatures, and so on. Thus, changes in the populations of plankton can have far-reaching effects on life in the water, as well as effects on man.

Because each species of planktonic animal or plant is different, the effects of passage through a power plant on each species may be different. Some species may be able to withstand better than others the "heat shock" caused by passage through the plant, or to withstand better the doses of chlorine used to clean power plant condenser tubes. Pressure, dissolved metal from condenser tubes, and turbulence may also produce different effects in different species.

An example of the complications besetting biologists studying the effects of entrainment is that the death of large numbers of species of marine animals passed through a power plant may or may not mean anything to the overall ecosystem. For instance, in one study it was found that, though a certain tiny animal was injured or killed in large numbers by passage through a power plant, *more* of the animals lived at the outflow of the plant than at the inflow. Why? Because the main predator of the little animal was more likely to be killed upon passage through the plant, leaving the survivors of the first species to flourish at the outflow.

Another example of the questions which marine biologists are asking is whether an animal is just as good dead as alive as far as the overall ecology is concerned. A tiny animal killed by passage through a plant may still be consumed by its natural predator, making no difference to the life of the predator, and thus leaving the biological food chain relatively unbroken.

These are only two examples of the many many questions which biologists studying entrainment must answer. And, as with any scientific topic, more answers generate more questions.

Until much more is known about the ecological and engineering effects of entrainment, scientists will be unable to predict with certainty the precise effects of entrainment or heated water outflow on plants and animals. They can and do, however, use present knowledge to predict whether gross disruptions of the ecology are likely to occur before a plant goes into operation. As with many of the aspects of power plant siting, should an unforeseen entrainment effect be found after a plant is built, immediate steps should be taken to rectify the problem.

The third aspect of a power plant cooling system is the outflow of heated water into the environment. Several deleterious changes in local ecosystems may be created by this heated outflow. These include death to plants or animals, disruptions of the food chain, a reduction of diversity of species, interference with the migration of fish past the outflow, and changes in annual reproduction cycles, in the chemical signals which animals use to find food, and in growth rate and spawning times for fish.

These disruptions due to water discharge are brought about by the scouring of the bottom of the body of water, at the plant intake and outfall, as well as the discharge of chlorine and heated water. Scouring of the bottom, which is limited to areas immediately around the plant, removes the soft sediment on which clams and other bottom-dwellers can thrive, leaving a bottom of gravel. While this and other effects of water discharge are local, and probably not significant, other effects such as overall temperature increases in the receiving body of water may be very significant ecologically. Generally, outright death to animals from the heated discharge is rare, occurring mainly in southern climates where the receiving water is already near the temperature beyond which few animals can survive. There may be, however, a proliferation of local warm-water-loving species at the immediate outflow, and the animals may undergo physiological changes because of the heated water. For instance at one plant "skinny" fish have taken up residence in a canal through which heated outflow water passes. The warm water has speeded up their metabolism causing them to use up their food energy faster and, thus, remain unable to gain weight.

In other plants fish that normally migrate south in winter may remain near the warm water outflow. There have been cases in which these fish have been killed when the plant shuts down for maintenance or repairs.

It should be stressed, however, that with proper plant design, it should be possible to eliminate or alleviate most of the effects of cooling water discharge. Heat released into the water can be made to dissipate rapidly into the atmosphere by wise siting and engineering.

Lessening the Impact of Cooling Systems

Overall, there are several general principles which ecologists have agreed upon to lessen the impact of cooling systems:

1. Intake velocities should be very low to avoid trapping fish on intake screens.

2. Rotating screens, escape routes, a bubble curtain and other diversionary structures should be provided to allow fish and other animals to escape the intake unharmed.

3. Chemicals used to rid condenser tubes of unwanted growths should be specific for the growth to be eliminated. Chlorine used in many power plants is not a specific pesticide—it kills most plants and animals exposed to the high concentrations of it in the tubes.

4. Cooling water should be subjected to a heat rise of as short a duration as possible. This means a rapid flow through the plant, and the elimination of long canals, effluent ponds, or dikes which would cause organisms to be subjected to heat for a long time.

5. Discharge of cooling water back into the environment should be at as high a velocity and heat concentration as possible. High velocity ensures quick mixing, and the hotter the water the quicker it will be cooled by outside water. The body of water into which coolant is discharged should be large enough to accommodate the discharge with only a small temperature increase.

6. In order to protect clams, lobsters and other bottom-dwellers, care

should be taken to see that discharge water does not disturb the bottom of the body of water.

7. In rivers and other relatively narrow bodies of water, the water discharge should be arranged so that organisms such as migrating fish can avoid the warm water discharge.

Assessing thermal effects of power plants, like other plant siting considerations, must be done on a site-by-site basis, and the costs carefully weighed against benefits of each site.

Cooling Towers and Cooling Ponds

Besides careful engineering to reduce the impact of power plant cooling on the environment, two other principal remedies exist that should be discussed here—cooling towers and cooling ponds.

One type of cooling tower, the "wet" tower, works by breaking the outflow water into small droplets which lose heat rapidly. Then the cooled water is released back into the environment. The "dry" cooling tower works like an automobile radiator by passing enormous amounts of air over cooling fins through which power plant cooling water circulates. Since it evaporates no water, a dry tower may be ecologically better than a wet tower. A cooling pond holds water so that it will cool before being released into a receiving body of water. As said previously, both cooling ponds and cooling towers can also be used in recirculating systems.

Those who hail cooling towers or ponds as panaceas which will eliminate the problems of heat discharge from power plants are mistaken. Cooling towers, while useful in some cases, merely transfer heat discharge, along with considerable warm vapor, from the body of water to the air. While power plant heat and water vapor are eventually released to the atmosphere in any case, cooling towers cause the release to be concentrated at one spot.

A question which, thus, must be answered when considering a cooling tower is that of the effects on local meteorology of releasing those large amounts of concentrated heat and water vapor into the atmosphere. Just as a carelessly designed warm-water-discharge cooling system may affect estuarine or river ecology, so unwisely used cooling towers may produce fog, change air temperatures, or change rainfall patterns. In cooling towers situated on bodies of salt water, salt is spread around the plant area by escaping cooling tower vapor and may affect vegetation and freshwater supplies. In a cooling tower for one large plant, for instance, about one million gallons of water and ten tons of salt are released into the air every day. Devices do exist to eliminate salt spreading, but they increase already large cooling tower costs by about 25 percent. As yet, large saltwater cooling towers are only in the planning stages.

As we have said, many tiny plants and animals may be affected by the heat of passage through a power plant. Thus, most biologists recommend that exposure of cooling water to high temperatures be as brief as possible. However, cooling ponds may extend the heat exposure time, resulting in ecological damage to inhabitants of cooling water that might not have occurred otherwise.

Another problem associated with both cooling towers and ponds is size. A cooling pond of from one-to-two acres per megawatt of power plant output is required to cool the outflow water properly. This means that an 800 megawatt plant would require a 1600-acre pond, an extremely difficult engineering problem even where the geography lends itself to large pond construction.

A cooling tower for a theoretical 800-megawatt plant would be just as difficult and expensive an engineering project. Such a tower might be about 325 feet high and 250 feet in diameter. A wet cooling tower for such a plant would cost about 2 million dollars more than a system using an ocean or river water system; while an ecologically more desirable dry cooling tower would cost about 43 million dollars more. In terms of increased electricity costs the latter tower would add about 25 cents per month to the average electricity bill.

Though heat discharge ponds might be suited to boating, swimming, fishing, or aquaculture, cooling towers can be used for none of these things and, additionally, are a rather unattractive addition to a landscape.

In the final analysis, where should cooling towers and ponds be used? Generally if heated water discharge increases the temperature of the body of water so much that any local species are endangered, cooling towers or ponds should be considered. An example is the large Turkey Point power plant complex being built in Florida, where water temperatures exceeding the upper limits of the ability of living things to survive are reached with the addition of a heated power plant water outfall. Factors such as the ability of migrating species in a river to get past a heated discharge plume must also be considered.

Where any heated water outflow would result in an unavoidable warm water plume, cooling ponds or towers would have to be considered.

Nuclear Power Plant Safety

Many statistics have been bandied about purporting to demonstrate either the extreme safety of nuclear power plants or the possibility of an extremely dangerous accident. Proponents of nuclear power often speak of the chances of a dangerous accident being one hundred thousand, or one billion, to one and some even speak of no danger of major accidents. Critics of nuclear power, on the other hand, cite figures depicting the possible loss of thousands of lives and millions or billions of dollars in property from a nuclear accident.

Both are wrong in trying to set quantities on power plant safety. The fact is that nobody knows just how safe nuclear power plants are, because there have never been any major accidents. The safety record of nuclear power plants has been excellent. No worker in a commercial nuclear power plant and no member of the public has ever been injured or endangered by a nuclear plant operation. Nuclear-powered submarines have logged millions of miles without nuclear accident.

There have been several accidents, some fatal, in nuclear facilities. None of these, however, has been in U.S. commercial-type reactors, a fact which some popular writers have overlooked. All of the accidents occurred in experimental or first generation reactors. These reactors are to commercial reactors as experimental airplanes are to commercial airplanes.

Engineers stress, however, that there is nowhere near enough experience with nuclear power plants to allow valid statistics to be drawn on reactor safety. According to Walter H. Jordan, senior research advisor at the AEC's Oak Ridge National Laboratory, commercial nuclear power plants have an accumulated operating time of about 100 reactor-years. The target for a good statistical analysis of safety is 10,000 reactor-years.

Commercial power plants are engineered super-conservatively—that is, to prevent or contain even the worst possible accident. In fact, engineers designing power plants begin by postulating the "maximum credible accident"—the worst thing that could happen to a power plant. Then they work backward in their planning so that the whole plant is built to prevent or contain that accident and all the less dangerous ones.

The Containment Concept

One of the principal concepts used in power plant safety engineering is that of containment. Nuclear power plants are designed so that the nuclear core is housed in a many-layered containment system which prevents the escape of any but the most insignificant radioactivity into the environment, even in the event of a radioactive spill or other accident. This containment system consists of five main components. First, the fuel pellets are made of hard ceramic material which retains radioactive fragments. Second, the collection of pellets which comprises a nuclear fuel element is housed in a steel tube about 12 feet long, constituting another secure barrier against radioactivity. A third barrier is the closed-circuit water cooling system surrounding the fuel assemblies. Another is the containment vessel, a thick dome constructed of painstakingly welded steel plate and reinforced concrete. Finally, the whole dome enclosing the radioactive core is kept under a slight vacuum, so that if a leak does occur, the vacuum causes outside air to be sucked into the dome rather than possibly allowing radioactive air to escape.

It is an absurd myth, though still believed by some, that a nuclear power plant can become a nuclear bomb. Nuclear weapons produce explosions because of an extremely violent compression of a very large amount of highly concentrated radioactive material. In nuclear power plants the amount and concentration of bomb-type material is very low by comparison, and this, together with the fuel's diffuse arrangement, makes the occurrence of a nuclear explosion impossible.

Perhaps one of the major natural safety features of a nuclear power plant is the stubbornness of the nuclear chain reaction. In order for a chain reaction to continue, three very strict criteria must be met: the fuel must be in a dense enough package so that the released neutrons are likely to collide with other atoms to continue the chain reaction; a moderator such as water must be present to slow the neutrons down enough so they will interract with other uranium atoms; and finally, there must be plenty of uranium so that the reaction doesn't quickly run out of fuel.

If the worst possible accident were to occur in a reactor—the loss of cooling water—the first two criteria would cease to be met, and the chain reaction would stop. This is because the heat buildup due to a loss of coolant would act to decrease the density of the fuel, thus decreasing the likelihood of neutrons striking uranium atoms to continue the chain reaction and also because the water would not be present to slow the neutrons.

The Melt-Down Danger

Though a reactor cannot undergo a dangerous increase in the speed of its chain reaction, a rapid loss of coolant from the reactor core could result in a rapid heat buildup causing the core to melt. This loss of coolant could be caused by a rupture in a water line, a broken weld, or a key valve opened in error. An advisory group of the Atomic Energy Commission described the possible result of a rapid, unchecked heat buildup as being a massive melt-down of the several-hundred-ton core, which could end up in a molten pool on the bottom of the reactor vessel within an hour after coolant loss.

Such a melt-down, together with the heat from the slowing chain reaction and the violent chemical reaction between the leftover water and molten metal, could be enough to cause the core to melt through the containment vessel into the earth. Steam explosions and gas pressure could combine to rupture the containment vessel, scattering radioactive material.

This sequence of events, though extremely unlikely, is guarded against by an emergency core cooling system (ECCS). This system is designed to react immediately to loss of coolant by activating a backup cooling system, causing it to flood an overheating reactor core with coolant.

This backup system, though thoroughly tested in computer simulations, has never been called upon to function in an actual reactor, because no reactor has yet suffered a coolant loss severe enough to call it into action. In fact recent failures of the ECCS in scale-model tests have caused the AEC to order the backup systems of older reactors to be modernized and to have their inspection of pipes and valves tripled. Some new plants, because of the new results of the cooling system tests, have been ordered to reduce their operating temperature.

The incriminating tests were done with a small-scale mock-up of a reactor pressure vessel at the AEC's National Reactor Testing Station in Idaho in 1970. The tests, which revealed the possibility that the emergency cooling system might be defective in its engineering, showed that when the reactor cooling water was cut by 30-100 percent, as might happen in a reactor accident, the pressure of steam inside the reactor vessel might prevent emergency cooling water from reaching the core. The model reactor, engineers say, was far from an actual scale model of a real power plant and probably did not behave like one. Nevertheless, because of the failure of the emergency system in the tests, there now exists uncertainty about it. The small-scale experiments were part of a preliminary project aimed toward construction of a full-scale test facility to resolve the emergency cooling system question. The facility, called the Loss of Fluid Test, will be a small reactor which the operators can subject to controlled "accidents" to test the emergency cooling system.

Other safety features of nuclear reactors include many independently wired radiation monitors, coolant level gauges, and temperature-detecting instruments connected to automatic shutdown mechanisms. Most reactors are controlled by neutron-absorbing control rods which must be withdrawn to allow the chain reaction. In these reactors the control rod system is so designed that in the event of a power failure the rods will drop into the reactor, shutting it down. In any case, extremely elaborate systems are installed in reactors to allow immediate shutdown by many different methods, both automatic and manual.

Many scientists believe the AEC's reactor safety research program has been inadequate, and the confusing record of ECCS testing would seem to bear this out. Several scientists have expressed concern over the fact that the AEC is sponsoring considerable nuclear safety research in a period when large numbers of commercial reactors are planned, and nuclear safety supposedly already has been thoroughly investigated. Although nuclear reactors have had an admirable safety record, and indications of possible safety shortcomings have been far from unequivocal, nuclear reactor safety should be a question of "guilty until proven innocent." Emergency cooling systems and all other functioning parts of a nuclear reactor should be tested under actual operating conditions before they are brought into general use. Some scientists, it should be noted, who have expressed doubts about the AEC reactor safety research program, are prominent AEC researchers.

Safety and Plant Siting

In siting a nuclear power plant safety is taken into account primarily by locating a plant at a distance—usually a minimum of several miles—from large population centers. The Atomic Energy Commission requires that a plant must be surrounded by a certain number of acres, usually about 400, on which nothing may be built and nobody may live. Beyond this, the population should be minimal—a small enough number to be evacuated if necessary.

Another safety consideration in siting a plant is meteorology; prevailing winds, humidity, frequence of air-trapping inversions and other weather phenomena around a plant site should be such that any radioactivity is carried away from population centers.

Besides meteorological conditions, other siting considerations include the effects of such possible calamities as earthquakes, plane crashes into a plant, or sabotage. To guard against these events, however unlikely, plants are sited on firm bedrock, well away from air lanes, and are subject to rigid security measures. Additionally, designers must build plants to withstand the maximum earthquakes which could be expected in the siting area.

Where does this leave the public in trying to assess power plant safety? It leaves it in somewhat the position of the driver of a new car engineered to be the safest in the world. The driver has an enormous amount of security, but since he has never experienced an accident with the car, there is no certainty that some defect in engineering or some possibility of human error has not been overlooked. In a cost-versus-benefits analysis of safety, the car would, in any case, emerge with a heavy benefit side.

Socioeconomic Considerations in Plant Siting

A breakdown of the costs of power production reveals that there are few economic restraints on where a power plant may be built. The largest part, about 40 percent, of the cost of power production is due to actual generating expense and fuel costs. In contrast, one of the major economic factors in plant siting, transmission cost, normally requires only about two percent of total power costs. Other factors such as land value differences, or changes in construction or operating costs from site to site, also usually are not significant in terms of overall costs. Thus, a power plant site may be feasible in many areas of a state as far as transmission and other costs are concerned, even several miles out in the ocean. This is not to say power plant planners have a great deal of leeway in deciding where to place a plant. Land and cooling water availability, meteorological and geological restrictions and many other factors go into the plant siting equation in addition to the costs of a site. Power plant builders certainly could not run power lines through a residential area, nor could they place a plant hundreds of miles out into the ocean. But, as we have said, they do have leeway in terms of costs in placing a plant.

Though the electricity producers are relatively unaffected economically by where a plant is placed, a nuclear power plant can have a considerable economic impact on a community. Perhaps the most noticeable of such effects is the enormous tax return from a plant. Even at low tax rates, the great value of a power plant will result in a windfall of tax money for the average community.

Such tax windfalls sometimes lead to remarkable contrasts between the income of citizens and the income of a town near a power plant. For instance, in Big Bend, California, a tiny logging town in the northern part of the state, about half of the 125 residents were on welfare, as of late 1971. Because of taxes from three giant power plants constructed by the Pacific Gas and Electric Company in the 1950's, however, each student in the town school has about one million dollars in annual tax valuation for his educational support. The elementary school children of Big Bend have an almost palatial school with an indoor heated swimming pool, tennis and archery courts, provisions for private music lessons, the best of health care, and countless other luxurious educational benefits.

A more indirect impact on a town is the effect of a plant on land values. Depending on the particular town, there might be either an increase or decrease in land values. For instance, one town with considerable residential property near a plant might undergo a decrease in land values because people might not want to live near a nuclear plant. On the other hand, a factor which might contribute to increased land values is the relative attractiveness of a nuclear power plant. A 3,000-megawatt fossil fuel plant requires about 1,200 acres of land, which is usually filled with coal piles, ash storage dumps, oil storage facilities, railroad sidings, or shipping docks. In extreme contrast, a similar nuclear power facility would require about 400 acres of land, most of which is unused exclusion area around the plant. This exclusion area is usually either left in its natural state or turned into a park.

Costs to a community of an industrial facility may include road, water, fire, and police services for the plant, and educational and utility services for employees of the plant and their families. In the case of power plants, however, these are not usually large expenses, because few people are employed at a nuclear power plant and safety procedures are carried out at the expense of the plant owners.

The impact of a power plant on the general economic activity of a town is often complex. Local industry seldom sells equipment to a plant, because power plants are highly complex technological systems requiring specialized equipment. Few local citizens can expect to be employed by the plant, also because of the complex technology involved which requires only a few specially educated personnel. Industry may be attracted to the general region of a power plant because of the low cost, plentiful, dependable power. Some of this industry may, though not necessarily, move into the immediate area of the plant, thus indirectly increasing employment and stimulating local industry. Also, waste heat from a power plant may come into wide use in industrial processes in the future, providing a strong attraction to industry.

On the other hand, in some cases industries such as nature-dependent shellfishing or water-based tourism may be alienated by a new plant which releases waste heat into the environment and may be an unwanted addition to a natural shoreline.

Dollars and Sense

Probably the thorniest problem facing planners of power plants, or for that matter any industrial development, is how to work into their facts and figures the unpriceable environmental advantages or disadvantages of a project.

It is possible, for instance, to put a price on clean air to some extent—if one calculates such things as reduced medical costs, lower laundry costs, and reduced building deterioration resulting from a clean atmosphere. But it is impossible to say what dollar value to place on the enjoyment or the esthetics of clean air. Planners already burdened with figuring the dollar costs-versus-benefits of a power plant have many times in the past either done an incomplete assessment of environmental factors, or tried to ignore the whole area.

Perhaps the best method for overall power plant or other project planning, economists say, is to take the dollar assessment of the costs or benefits of a plant as far as it will go, and then make value judgements about environmental costs-versus-benefits. For instance, a local government considering the siting of a nuclear power plant should assess how the local economy would be affected by the plant—its dollar value—and then learn as much as possible about the good or bad environmental effects of the plant—the non-dollar value. Then the planners simply have to sit down and judge whether the whole project is worth it or not—in terms of dollars and such unpriceables as environmental quality. This same analysis also should be made by the state and national governments and regional commissions when considering a plant, because each of these political units has a somewhat different scope, and, thus, each body should make its own decision.

Politicians, Laws and Power Plants

The previous discussions of how decisions on power plants should be made bring us to the questions: who should decide questions of power plant siting and what laws govern those decisions. One definitive work on power plant siting rules is *Laws and Procedures of Power Plant Siting in New England* published in 1970 by the New England River Basins Commission (NERBC). Much of the background for this discussion is taken from that publication.

A power plant must satisfy the requirements of literally dozens of regulations before construction or operation is begun. The principal laws governing power plant construction include the National Environmental Policy Act, the Federal Power Act, the Atomic Energy Act, federal and state water and air quality laws, the Federal Aviation Act, U.S. statutes for conservation of navigable waters, state dredge and fill laws, public utilities regulations, state wetlands protection laws, and local zoning or building codes. Regulatory agencies enforcing each of these laws subject the proposed power plant to close scrutiny within their own areas of interest.

Of special interest to those concerned with *nuclear* power plant siting are the procedures required by the Atomic Energy Commission for licensing. Briefly they are as follows:

1. A formal application is submitted describing the design and location of the proposed plant and the safeguards to be provided. The application also covers the applicant's technical and financial qualifications.

2. The AEC's Division of Reactor Licensing makes copies of the application available to the public and to the AEC's statutory Committee on Reactor Safeguards, a committee of independent experts. The Licensing Division studies the application and prepares an analysis.

3. The Licensing Division analysis is submitted to the Reactor Safeguards Committee. The Committee studies the application and the Licensing Division analysis and issues a report to the AEC which is made public.

4. A public hearing is held, usually near the proposed site, by an AEC-appointed Atomic Safety and Licensing Board.

5. After reviewing hearing testimony and the Licensing Division and Reactor Safeguards Committee findings, the Board decides for or against granting a construction permit.

6. The Board's decision is subject to review by the five-member Atomic Energy Commission.

7. A construction permit is then granted or denied and public notice is given. If granted, construction of the plant may begin, subject to inspection by the AEC's Division of Compliance.

8. As construction progressses, additional information is developed and an application is made to the AEC for an operating license. Once again the Licensing Division makes a detailed review of the information and presents an evaluation of it to the Reactor Safeguards Committee. The Committee again

makes an independent evaluation and issues a report to the AEC which is made public. A public hearing is not required by law on an application for an operating license. After the Reactor Safeguards Committee and the Licensing Division have completed their reviews, the AEC either publishes a 30-day public notice of the proposed issuance of an operating license, or it schedules a public hearing on the application. In the event of no hearing, the published notice states that in the absence of a timely petition to intervene and a request for a hearing, the license will be issued. If a hearing is held, it is before the Board and the Board's decision is subject to Commission review. Any operating license issued may be provisional for an initial period of operation, at the end of which time a review is made to determine conditions for the issuance of a final operating license.

The Calvert Cliffs Decision

These procedures have been greatly extended by a recent court decision of the U.S. Court of Appeals for the District of Columbia. The decision in the case of *Calvert Cliffs Coordinating Committee* vs. *AEC* directed the AEC to drastically revise its plant siting rules to include assessment of all environmental effects of proposed nuclear power plants, in addition to assessing the radiological standards of plants. This far-reaching decision could have two major impacts—increasing public participation in the licensing process and lengthening considerably an already long and complicated licensing process.

Another recent ruling by the U.S. Supreme Court stipulated that the states cannot set radiation standards stricter than the AEC's. This ruling will probably be applied to other nuclear plant standards such as those governing heated water discharge.

The fact that nuclear reactor licensing by the many agencies involved is long and complicated is indisputable. However, even with the many steps required for licensing, it is still doubtful whether power plant siting regulation is done in the best way possible. A more streamlined process, more visible to the public and better organized to obtain and use information on a power plant site, is clearly needed.

Most state agencies do not have the personnel or funds to undertake the complex studies required to properly assess a power plant site. Additionally, since those agencies are often concerned with only the portion of the siting procedures which pertains to their rulings, the overall decision of whether a plant site is good or bad may not even be made at the state level. Undoubtedly the recent court rulings directing the AEC to include environmental costs in its licensing procedure will make more information available to state agencies, and will also give the public more chance to learn about the effects of a power plant. However, a state agency is still needed in each state, which can oversee all aspects of power plant licensing.

The NERBC Proposal

An interesting proposal to this effect by the New England River Basins Commission (NERBC) is that the public utilities commission (PUC) in a state could become overall coordinator for power plant licensing, as is done in Vermont. Under this proposal the PUC would coordinate the handling of many other permits, such as dredging permits, air emission permits or zoning permits, for greater efficiency. The River Basins Commission recommends that the PUC not exert any control over individual state agencies. It would only serve as a coordinator and to remind the state or local agency that the public interest should be taken into account along with its other considerations.

While the individual state and local agencies would be thus concerned with their own areas, the PUC, under the River Basins Commission proposal, would coordinate overall environmental consideration. It would act as a "traffic manager" in coordinating the efforts of various state and local agencies. For instance, if a state air pollution control agency and a state water quality agency were asked by a power company for a permit simultaneously, the PUC could confer with both agencies simultaneously and reach firm understanding on how the plant should regulate its overall waste emissions. Additionally the PUC would have the power to regulate any factors, such as esthetics or wetlands protection, not covered by other state agencies.

The PUC would also have the authority to set up environmental studies of a power plant site. Thus, the studies could be organized to get all the information required for the many different state and local agencies at the same time.

Finally, according to the River Basins Commission recommendation, when the PUC hands down a decision, the decision could be appealed in the courts should environmental or other groups wish to do so.

An additional duty of the strengthened PUCs would be to oversee long-term power development. The PUC could advise power companies, state agencies, and other research and development groups where best to concentrate their efforts toward investigating and developing state power resources.

The NERBC also suggests that a region-wide staff of ecologists, economists, and other experts be set up to serve the public utilities of all the New England states when they need expertise in deciding on a power plant site request. This way an individual state would not have to wholly maintain the large technical staff needed. Some states, including Rhode Island, have coastal marine resources management councils which, it is expected, will have considerable powers to regulate ocean-sited power plants. Many of the duties outlined by the NERBC for the public utilities commissions may be reserved to such councils.

Other states, such as California, entrust siting regulation to the state secretary of resources and a power plant siting committee consisting of representatives of each major natural resources agency. Whatever method is used, clearly an overall state authority for power plant siting is needed.

Several problems are suggested by the NERBC proposal as well as many of the other plant siting regulation methods. One is that the public seems not to have been included in decision-making on an early enough and extensive enough basis. Even though the AEC conducts public hearings, which in the future will be concerned with all phases of power plant siting, state hearings by the public utilities commission or other regulatory agency also would be advisable. Further appeal might be through the state legislature, which would be empowered to block agency decisions should its members feel proper consideration of some factor has not been given.

Another problem stems from the fact that the power company acquires the site to be considered for a power plant. Even though power companies do preliminary site analyses, many unanticipated environmental factors may become obvious later. Also power companies seek sites that are easy to purchase and inexpensive, thus limiting their possible choices. When the power company finally begins applying for permits and conducting further research on a plant site, the company, the government, and the public are all "boxed in" to a site that may not be the best possible.

A remedy for this would be to have a governmental agency acquire plant sites, as is being done in New York state. The governmental agency could do thorough site analyses and would have access to land through condemnation that power companies would not have. Cost for the program of site acquisition would be reflected in prices charged the power companies for the sites.

This would have advantages for both the government and the power producers. The government would have a wider choice of sites and would have accurate information on a site early in planning procedures, and the power company would acquire a site already thoroughly researched as to its feasibility for a power plant. Additionally the power company might obtain a much more desirable plant site than if it had sought land on the open market.

Advanced Siting Concepts

Some siting concepts, while not immediately applicable, appear to have a bright future in power plant planning.

The first, and probably most imminent, is the siting of nuclear power plants offshore. This concept could alleviate many of the most troublesome problems facing both planners and environmentalists, and hopefully it will be explored thoroughly.

Siting costs would be greatly reduced by offshore placement of plants, for land acquisition costs would be virtually eliminated. Moreover, since offshore sites, if far enough out, might be under federal jurisdiction, state agencies might not have to be involved in siting procedures.

The problems of releasing large amounts of heated water into estuaries, rivers, and lakes, which are a country's most productive and ecologically delicate bodies of water, would be greatly alleviated by offshore siting. An offshore plant could draw relatively "barren," cold, deep-bottom water for cooling purposes, and return the water to the environment near the temperature of surface ocean water. Finally, a plant situated miles off the coastline would pose much less of a hazard in the event of an accident.

One floating power plant program is being instituted by Westinghouse Electric Corporation and Tenneco, Incorporated. These two companies have begun preliminary studies of the feasibility of an enormous assembly line for floating platform-mounted nuclear power plants. The construction facility would be equipped to install standardized components weighing as much as 600 tons as a platform was floated from station to station in the assembly plant. After testing, the entire plant would be towed to an offshore site and permanently anchored inside a stable, man-made breakwater. If feasibility studies prove the concept, the first 1200-megawatt plant could come off the assembly line in 1979, engineers at the companies say.

The Westinghouse-Tenneco plan is attractive, not only because of the offshore siting, but because standardization of plants would make ecological and other impact studies much easier.

The Public Service Electric and Gas Company of New Jersey has exhibited perhaps the most interest in offshore power plants. They have conducted preliminary studies with several companies on two major sites off the New Jersey coast.

A possibility being investigated by the Electric Boat Division of General Dynamics, Incorporated, under contract from the Department of the Interior, is the siting of power plants underwater. Though the technical problems would be greater than for floating plants, underwater nuclear power plants would have the added advantages of being impervious to weather changes and being even more remote from population centers than floating plants. Under the grant, General Dynamics is determining the feasibility of placing 1000-megawatt plants at depths of 250 feet up to 25 miles from shore.

Perhaps the overall conclusion to be gleaned from this booklet is that power generation will always have some impact on the environment; there is no escaping this fact. However, power plants can be sited, built and run to have a minimal impact, and such operations can be accomplished safely, efficiently, and economically. This should be the aim of all the parties involved in power generation planning—environmentalists, power companies, and government. The public should not settle for less.

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