

# Nuclear Power

Nuclear-fission power plants were initially thought to be the answer to the diminishing fossil fuels. Even though the enriched uranium fuel was also severely limited, it was assumed that a more advanced nuclear technology -- referred to as "breeders" -- would eventually be made commercially viable. Breeder reactors would actually be able to produce more radioactive "fuel," in the form of plutonium, than they consume. As a result, their plutonium fuel would be renewable. This was a great concept in engineering theory, although biologists had continually warned that plutonium is one of the most toxic elements known, it is very difficult to handle, and it would remain deadly for about 250,000 years. In addition, if the "plutonium economy" was ever to become a reality, millions of tons of plutonium would have to be produced and shipped throughout the U.S.

In spite of these long-term and exceedingly difficult and dangerous environmental concerns, conventional nuclear reactors and their breeder offspring constituted America's primary energy strategy since the 1950's to resolve the diminishing fossil fuel problem. However, when the partial meltdown accident occurred in 1979 at one of the new nuclear reactors at Three Mile Island in Pennsylvania, both public and investor confidence in nuclear fission technologies were shattered. And although billions of taxpayers' dollars have been used to develop and promote nuclear energy systems, rather than solving the diminishing fossil fuel problem, nuclear technology has instead created an even more awesome problem of its own -- radioactive waste.

The radioactive waste problem is unique for many reasons, but one of its most insidious aspects involves the fact that it is invisible to the human senses until disease or death occurs. When moisture is present, radioactive isotopes spread in an ecosystem like red dye spreads in a glass of water, and the isotopes will remain toxic for anywhere from a few days to in excess of a million years, depending on the isotope. There is still no long-term storage plan for these waste products and many of the existing waste storage facilities are full and out of control in terms of their ability to prevent the radioactive wastes from leaking and spreading.

This "spreading" problem occurs because under irradiation, all materials change their nature as their atoms become unstable. The world of radioactivity is a world of continuous change. This is why the storage vessels which contain the radioactive wastes are only reliable for short periods of time. Eventually, they too will become radioactive. This, in turn, means the longer a nuclear reactor is operating, the more radioactive it becomes. This is the primary reason why any repair or maintenance of aging nuclear reactors is an extraordinarily hazardous task.

## Radioactivity

The problem of radioactivity in the reactor and the surrounding building is in addition to the liquid, gaseous and solid waste generated by the uranium fuel rods. As the uranium undergoes fission, the uranium atoms split, and in so doing, release neutrons. Some of these neutrons split other uranium atoms, which, in turn, produce the radioactive waste products. The net result of this fission process is the generation of the intense heat that is used to generate steam for the production of electricity.

The difference between a nuclear reactor and a nuclear weapon is measured by the number of neutrons that are released in the fission process over a given period of time. If only a limited number of neutrons are available for triggering the fission chain-reaction the reaction can be controlled for energy production purposes. If too many neutrons are released, the chain-reaction will rapidly accelerate, resulting in an atomic

explosion. To prevent this from happening, nuclear reactors have control rods and water circulation to regulate the fission process by absorbing the extra neutrons.

However, during normal operations, some of the neutrons that are released pass beyond the uranium and into the steel structures which hold both the fuel assemblies and the cooling water which flows between them. Other neutrons penetrate the massive concrete shielding outside the steel reactor vessel. These neutrons are absorbed by the atoms of iron, nickel and other elements that make up the steel, water, and concrete. When atoms absorb neutrons, they are rendered "unstable" (i.e., radioactive) for various lengths of time. In the case of nickel-59, which has a half-life of 80,000 years, it will need to be shielded from humans for about a million years.

## Decommissioning

Decommissioning is the term used to describe what happens to a nuclear reactor complex once its theoretical useful life of 30 or 40 years has been completed. This "back end" of the nuclear fuel cycle is generally not discussed because no one really knows how such a difficult task is to be accomplished, or what it will ultimately cost over hundreds of thousands of years. Utilities and waste processing companies are usually not concerned about the long-term waste storage costs because in most cases, they have no long-term legal or financial responsibility to manage the radioactive wastes. That responsibility is given to the U.S. taxpayers of the future. But if the experience of attempting to decommission a nuclear fuel recycling plant at West Valley, New York is any indication of what is ahead, there are plenty of reasons to be concerned.

The \$32.5 million West Valley Plant, located 30 miles Southeast of Buffalo, was officially opened with much fanfare in June of 1963, although it did not actually begin to reprocess nuclear wastes until 1966. But it was only to operate for 6 years before its operator, Nuclear Fuel Services (NFS), a subsidiary of W.R. Grace's Davidson Chemical Company, abandoned the facility. Left behind were 2 million cubic feet of buried radioactive trash and 600,000 gallons of highly radioactive liquid waste that is now seeping into the Cattaraugus Creek, which flows into Lake Erie, from which the city of Buffalo obtains its drinking water. The cost of cleanup is estimated to be at least \$1 billion, assuming such a cleanup is possible.

The West Valley plant was the world's first commercial nuclear-waste facility that would be able to take the spent fuel from nuclear power plants and reprocess it for renewed use. This recovery and reprocessing of spent fuel rods is an important step in the nuclear fuel cycle because only about 1 to 2 percent of the nuclear fuel is initially consumed in most commercial reactors, and uranium is not a renewable resource. This is particularly true of the reactors in the U.S. that require an energy intensive, highly enriched uranium 239. Unfortunately, the problems associated with trying to handle highly radioactive wastes proved to be overwhelming to the workers and management at the West Valley facility. An extensive investigative report on the West Valley plant titled "Too Hot to Handle," undertaken by *The New York Times*, concluded the following:

*"It is the story of technocrats who assured and reassured the public that nuclear recycling was safe and that a thoughtfully engineered fail-safe system would minimize the hazards of any accidents that might possibly occur -- without making it clear that their assurances were based on extrapolations from premises rooted in probabilities and anchored in uncertainty. It is the story of company officials who repeated such assurances even after scores of incidents -- known only inside the company and to a few governmental*

*inspectors -- had made it clear that leakage of radioactivity in the plant was reaching dangerous levels."*

Radiation at the West Valley facility was rapidly spreading, and the costs of operation were dramatically increasing. Finally, in 1975, NFS announced that it would have to spend at least \$600 million to make the facility manageable, which was nearly twenty times the initial capital cost of the plant. This, plus the fact that operating costs had increased by some 4,300 percent since the plant began operation, caused NFS to shut the facility down, and let the taxpayers of New York figure out what to do with the multi-billion dollar waste storage problem that was left behind.

## Nuclear Waste Storage

As it turns out, the West Valley facility in New York is merely the tip of the nuclear waste iceberg. The U.S. Department of Energy (DOE) spent years and \$700 million to build the nation's first permanent waste storage facility deep in salt beds near Carlsbad, New Mexico. But only after the facility was completed in 1988 did the DOE officials acknowledge that water had somehow leaked into the salty caverns. As a result, the Carlsbad facility has been put on hold, but the nuclear waste problem in the U.S. is so critical that Idaho Governor Cecil Andrus "declared war on the Department of Energy" in October of 1988. Under the governor's orders, state police halted any further shipments of nuclear waste into the State of Idaho.

The nuclear waste problem has been around for decades, and in spite of the fact that thousands of brilliant scientists have been working on the problem, no one in any country has come up with an acceptable long-term solution. Moreover, as the general public learns more about the waste problems, they become more and more convinced that they don't want the toxic dump in their state. Given this bleak outlook, the U.S. Congress decided just hours before the Christmas adjournment in 1987 that a place called Yucca Mountain, located in a remote nuclear test site in Nevada, was to be the nation's final resting place for high-level radioactive waste. Not only was the area already radioactive, but Nevada simply had less clout in Congress than any other state. However, there are two serious environmental problems associated with the Yucca Mountain site.

First, scientists point out that the Yucca Mountain area is in a geologically unstable region with active volcanos and earthquakes. Second, and perhaps more worrisome, is the fact that the containers for the nuclear waste are only expected to last for 300 to 1,000 years. After that, it must be the mountain itself that contains the waste products, and therein lies the problem. Scientist from the U.S. Geological Survey had drilled two small shafts in Yucca Mountain and they found that the mountain "breathes." In the winter, warm air flows out of the shafts from the center of the mountain. In the summer, the pattern is reversed and the air is sucked into the mountain. In a memorandum, 17 scientists from the USGS stated that this air flow could release radionuclides into the atmosphere. In spite of the scientific warnings, Yucca Mountain is still viewed the primary designated U.S. waste storage facility.

If that were not bad enough, in 1989, officials from the U.S. Department of Energy announced that in spite of the critical nature of the nuclear weapons program, all three of the nuclear weapons facilities had to be shut-down due to massive technical problems associated with dealing with the radioactive waste. Department of Energy officials have now admitted that extensive releases of radiation had often contaminated workers and large numbers of U.S. civilians who happened to be living within the proximity of these facilities. The general public was deliberately not informed of these radiation leaks for decades because of "national

security" considerations. As one Federal official put it, the emphasis was not on safety, but on production.

It has been estimated that it will take anywhere from 100 to 150 billion dollars to clean up the existing nuclear weapons facilities, assuming such a clean-up is possible. In reality, such clean-ups have meant collecting and moving as much of the wastes as possible to some other location, which ultimately only creates another problem that will eventually have to be dealt with.

True clean-ups have up till now proven to be beyond the limits of existing technical and engineering capabilities. This unresolved technical problem has led to the concept of "National Sacrifice Zones," which implies sealing off the contaminated areas from the members of the general public, presumably for hundreds of centuries. Such a policy in and of itself, poses some interesting social and ethical problems. For example, imagine trying to figure out how to make a sign or symbol that could explain the radioactive danger which could still be understood by our descendants thousands of years into the future. One can only wonder what the future generations will think of this generation for leaving them such awesome problems.

## Questions of Safety

While nuclear proponents like to point out that it is highly unlikely for a nuclear fission power plant to explode like a nuclear bomb, which of course is true, they never bother to explain that given the amount of radiation in the modern 1,000 megawatt (mW) reactor, a serious loss of coolant accident could result in a melt-down condition which could be as dangerous as an outright nuclear explosion. This is because the amount of radiation in a 1,000 mW reactor is more than a thousand times that which was produced by the atomic bomb that was dropped on Hiroshima in 1945. In a melt-down scenario, this massive amount of deadly radiation could all be released at ground-level, whereas a nuclear or conventional chemical or steam explosion would disperse much or most of the radioactive particles high into the Earth's atmosphere.

There are also other serious problems associated with nuclear fission power plants. Once a nuclear reactor becomes operational, workmen are not able to clean and maintain the critical interior components of the reactor vessel due to the intense level of radiation. This is in contrast to the normal procedure in fossil fuel plants where maintenance personnel are able to shut the plant down periodically to clean and inspect all of the critical interior components. This regular maintenance schedule is a major reason why there are so few accidents or failures in fossil fuel power plants, in contrast to nuclear fission facilities, whose unreliability has become one of their most dependable features.

## Military vs. Civilian Reactors

In contrast to the civilian nuclear reactors that have been plagued by accidents and shutdowns, the U.S. Navy has established a respectable performance record with its nuclear surface ships and submarines. There are, however, distinct differences in the size and quality of the nuclear systems used by the U.S. Navy, in contrast to the much larger reactors engineered for commercial power production. The most obvious differences involve the reactor size, design configuration, and cost per installed kilowatt (kW). The reactors manufactured for the U.S. Navy are all designed to be relatively small; they are all based on a similar design concept; and they were initially about five times more expensive to construct (in terms of cost per kW) than their civilian counterparts.

William E. Heronemus, now professor of civil engineering at the University of Massachusetts, supervised the construction of nuclear submarines for Admiral Hyman