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Breeder reactors are ready for development

There is no nuclear waste problem if we complete the nuclear fuel cycle, by reprocessing spent fuel. Nuclear energy is literally a renewable energy source. Marjorie Mazel Hecht reports.

Nuclear energy is unique because of its energy density (its fuel is 50,000 times more concentrated than fossil fuels, for example), and because it is truly *renewable*. Unlike any other kind of power reactor, nuclear breeder reactors can actually create new fuel for other nuclear reactors, in the course of producing power. In addition, the used, or "spent" fuel from conventional nuclear plants can be reprocessed and turned, almost totally, into new reactor fuel—thus, "renewed."

Still another form of renewability is possible with nuclear energy: The tiny amount of high-level nuclear waste that remains after reprocessing can be "mined" or otherwise processed to extract valuable isotopes for medical or industrial use. There is no nuclear waste problem if we complete the nuclear fuel cycle, by reprocessing spent fuel. Nuclear energy is literally a renewable energy source.

For these reasons, in the early years of the Atomic Age, after World War II, there was great hope of finally having a way to provide enough energy, cleanly and efficiently, to light the way out of poverty and misery for most of the world. Today, for the same reasons, if we are to have an economic renaissance, we must go nuclear.

Breeders are essential

The work-horses of a nuclear economy will initially be conventional light-water reactors and high-temperature gas-cooled reactors, for both electricity production and process heat for industry. But, an essential part of any full-scale nuclear development program will be the fast breeder reactor. A primary reason for breeder development is fuel creation. Thus, France and Japan, neither of which has fossil fuel or hydro potential, planned on the breeder to ensure energy self-sufficiency. (France is more than 78% nuclear, and Japan is 36% nuclear, in terms of energy generation.)

As more nations go nuclear, the world's known uranium resources may eventually not be able to keep up with the demand. The International Atomic Energy Agency has estimated that demand will exceed the known uranium resources, for three different, but all conservative, scenarios of nuclear power generation (high, medium, and low), in the years 2030 to 2050—unless there is a recycling of plutonium by reprocessing, and breeder development. (The IAEA's study, it should be noted, does not take into account the energy resources that can be provided by developing fusion or chemically assisted nuclear reactions, also known as cold fusion.)

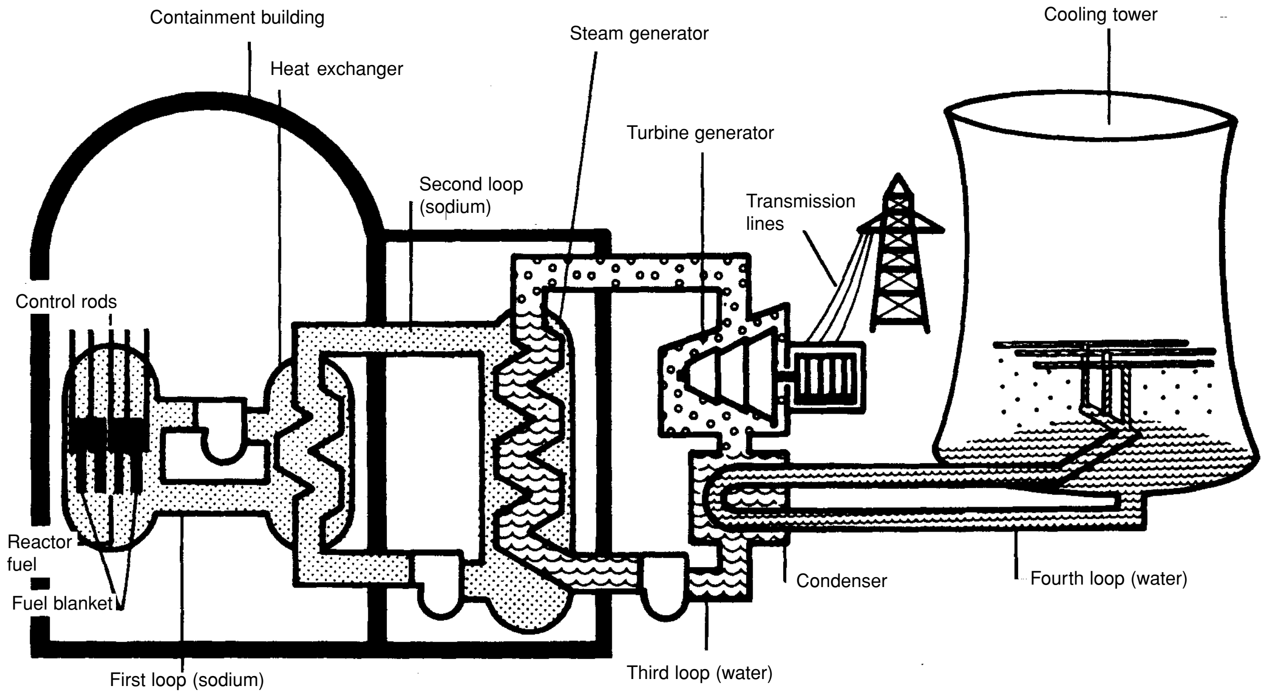
How breeders 'breed'

In the process of producing power, the breeder, unlike any other reactor, creates more new fuel than it uses up. Conventional fission reactors burn only about 2% of the uranium in their fuel rods and produce plutonium as a waste by-product. Breeder reactors burn fuel more efficiently, using up all the uranium fuel.

A breeder uses the neutrons from the fission process to convert the non-fissionable uranium (U-238), into new plutonium fuel. Uranium is found in nature and mined, but natural uranium contains only 0.7% of the fissionable isotope, U-235; the rest, 99.3%, is unfissionable U-238. The fuel in a fission reactor must go through an enrichment process to increase the proportion of the fissionable isotope, so that 3-5% of the fuel is U-235.

Breeder reactors are called "fast" reactors because they produce high-velocity ("fast") neutrons, which are not slowed

How the breeder reactor produces power



In this schematic of a loop-type liquid metal fast breeder reactor, sodium is circulated through the reactor core, which heats it to about 540°C (1,000°F). The sodium then passes through a heat exchanger to transfer its heat to an intermediate sodium loop. From there, the sodium moves to the steam generator where it heats water in a third loop to steam—about 480°C (900°F). The steam then turns the powerplant turbine and is then condensed and cooled in the fourth loop. The breeder reactor fuel assemblies contain a mixture of plutonium-239 and uranium-238. Around the core is a "blanket" of fuel assemblies that contain only U-238. The blanket uranium absorbs the neutrons from the fission process in the core, turning the U-238 into Pu-239.

down or moderated, as they are in conventional fission reactors. The role of the moderator—usually ordinary water or heavy water—is to slow down the energetic neutrons to what is known to be the best speed to encourage the maximum number of fissions of uranium atoms in the fuel. In a conventional fission power reactor, a chain reaction of fissions of U-235 nuclei is set off; each nucleus splits, emitting fast neutrons in the process. These neutrons are moderated, and then produce new uranium fissions.

In the breeder reactor, these fast neutrons are used directly to breed new fuel from the non-fissionable U-238, which is part of the fuel mixture. Hit by a neutron, the U-238 gives off an electron and is transformed into neptunium-239, an unstable isotope. Np-239 then emits an electron to become plutonium-239 (Pu-239), which is fuel usable for fission power reactors.

The breeder reactor fuel rods in the reactor core contain a mixture of Pu-239 and U-238, and around the core is a "blanket" of fuel assemblies that contain only U-238. The blanket is where the breeding takes place, as the uranium absorbs the fast neutrons from the core and turns the U-238 into Pu-239, which can then be used as new fuel.

In the process of creating this new fuel, the reactor also produces heat, which is used to boil water, make steam, and operate turbines by the same methods used in a conventional power plant.

A more advanced breeder reactor is the fusion-fission hybrid, a design studied since the 1950s. The hybrid would be even more efficient than a fission-only breeder, because the fusion fuel—deuterium-tritium, for example—would produce about four times as many neutrons per unit of energy as a fission event. The fusion-fission hybrid was envisioned as a first-generation use of fusion, where a lower fusion performance would be acceptable and achievable. Most of the hybrid plant would use standard fission technology; less than 10% of the plant would use the new fusion breeder technology. But this breeder design has remained only on paper.

U.S. breeder history

For about 30 years, the United States led the world in the development of all aspects of reactor technology, including breeder reactors. The breeder concept captured the imagination of scientists early on. Just after World War II, in 1946, Los

EBR-II, the experimental breeder Reactor No. 2, at Argonne National Laboratory West, operated successfully from 1964 to 1994. It was a pool-type breeder, with a passive safety system, and Argonne called it "the most successful test reactor ever."

Alamos National Laboratory in New Mexico began operating the world's first fast breeder reactor, Clementine, which produced 25 kilowatts-thermal energy. A few years later, in 1951, the United States put on line the Experimental Breeder Reactor (EBR-I), which was the first in the world to produce usable amounts of electricity—200 kilowatts-electric at its peak. EBR-I was followed by EBR-II, which began producing power in 1964, and was connected to the Idaho power grid for three decades.

The next-generation U.S. breeder reactor, the 350 MW Clinch River Breeder Reactor, was subjected to a slow death by budgetary starvation, during both the Carter and Reagan administrations, although it was almost fully completed. Plans for a follow-up Clinch River Demonstration Breeder Reactor died on the vine. Clinch River was a loop-type breeder reactor, and an updated pool-type breeder design was then developed by Argonne National Laboratory, called the Integral Fast Reactor, or IFR. The IFR made use of a new metal-alloy fuel design, which was twice as efficient as the oxide fuels used previously, giving the IFR a 10-year or less doubling time—the time it would take to double the amount of fuel initially invested in the plant. But, the IFR was killed in its first stages of operation by the Clinton administration, this time under the eco-rationale that anything to do with plutonium must be avoided.

And so, beginning in the mid-1970s, with the anti-science administration of Jimmy Carter, and continuing through the Reagan, Bush, and Clinton administrations, the nation that pioneered all aspects of nuclear technology has maintained policies relegating it to a back seat in nuclear development. Advances in nuclear technology and use continued on in the rest of the world, however, led by France and Japan.

In the United States, advanced nuclear technology plans remained on paper only. At the same time, the cost of putting a nuclear plant on line in the United States became prohibitive. This was the result of environmentalist-driven regulatory retrofitting of plants while they were in construction, a deliberate tactic of the Greens, which stretched the completion time for plants from 3 years to 14 or more years, and vastly increased the costs. In tandem with the environmentalist assault, the high interest rates during the Reagan administration raised capital costs for plant construction five to six times, compared to a U.S. plant built in the 1960s.

Fast breeders around the world

A special session on fast breeder reactors at the American Nuclear Society winter meeting in Washington, D.C., in November 1998, reviewed the progress of breeder programs worldwide, and featured both the promise of the technology—and the despair at its paper status in the United States. The poignancy of the situation was brought home by one U.S. nuclear engineer who has worked on improving fast reactor designs since the 1960s, and who discussed the latest modular design for the liquid metal fast breeder. "In my lifetime I want to see a commercial fast reactor," he said sadly.

The chairman of the session, Dr. Bertram Wolfe, who formerly headed up the General Electric nuclear division, noted in his introduction that if we are to provide for the energy needs of the next century, we have to start the development of fast breeder reactors now. There is no way, if we look into the future, he said, that we can meet the uranium needs for the number of nuclear plants we'll need in 2050, without breeder reactors. It takes 30 years to find and work out all the design problems in a reactor, Wolfe said. It was a "bad mistake" that the United States gave up our fast breeder reactor program, he concluded. But other nations did not make that mistake.

Russia, for example, has had its BN600 fast reactor operating for 18 years, with a 73% availability, and Russia is ready for the next generation of fast reactors. Four more fast reactors are planned to be on line between 2010 and 2020, two BN800 reactors in both Belarus and South Urals sites. Russian nuclear official Oleg Sarayev—who could not come to present his paper in person because of a lack of funds—said that the construction was expected to take seven years, and that 80% of the budget was to come from the municipalities involved.

France's 1,200 MW Superphénix fast breeder, the world's largest, came on line in the mid-1980s, and was just shut down last year—for political reasons having to do with electoral compromises with the Greens. It should be noted that this commercial-size breeder was completed in eight years—compared to 14 and more years the United States took to put a conventional reactor on line in the 1970s. Work is continuing on the new European Fast Reactor design effort, a collaborative effort of Germany and France, although the funding for this is uncertain.

Japan has proceeded with fast breeder design, moving from the experimental Jojo to the prototype Monju (which is currently shut down because of a sodium coolant leak). Now, Japanese studies are under way for the Demonstration Fast Breeder Reactor, in a 660 MWe plant and a 1,500 MWe plant.

Breeder economics

The economics of different types and sizes of fast breeders have been studied in detail, both for cost per unit of power production and the length of time required to double the initial input of fuel. Japanese nuclear expert Masao Hori argued at the American Nuclear Society meeting in Washington, that these studies and the experimental evidence from breeder operation have to be put together now in a plan for the next century. Hori proposed, therefore, an international collaborative effort, what he called an "international laboratory," to move the technology forward as fast as possible, making use of each nuclear nation's particular strengths and experience in the breeder area (see accompanying interview). The goal would be to have demonstration reactors on line in the 2000s, moving to series construction a decade later, and large commercial plants by the 2030s.

As Hori has emphasized over recent years, such a plan requires a vision of hope for humanity.

Interview: Masao Hori

'International lab' needed to build fast breeder reactors

Masao Hori

Mr. Hori recently retired from the Japanese Power Reactor and Nuclear Fuel Development Corp., where, during the past 30 years, he had served as the General Technical Adviser on Fast Breeder Reactors, Special Assistant to the President, and Executive Director in charge of fast breeder R&D. Hori now is a researcher with Nuclear Systems Association, based in Tokyo. In the early 1990s, Hori headed a special international committee, composed of members from the nuclear societies of 11 countries, to prepare a "Vision Document" on the second 50 years of nuclear energy. He is on the board of directors of the American Nuclear Society and of the Japanese Atomic Energy Society, whose International Committee he chairs.

Hori was interviewed in February by Marjorie Mazel Hecht.

EIR: At the November 1998 meeting of the American Nuclear Society in Washington, D.C., you spoke at the session on fast breeder reactors, and talked about the need to develop these breeder reactors now, so that they will be commercialized and ready for demonstration reactors in the 2000s, with series construction by the 2010s. What is your sense of how this can happen? Will Japan take the lead internationally in bringing this about?

Hori: If we look at the world accomplishment in fast reactors until now, in terms of plant scale, France has built and operated the 1,200 megawatt-electric SuperPhénix. As for operating experience, the Russians have operated the 600 MWe BN-600 plant for 18 years, with a 73% availability factor. In terms of large plant design, the European countries have developed and designed the 1,500 MWe EFR. As for licensing, the Russians licensed the 800 MWe BN-800 in 1997.

Therefore, technically, we are ready to move into the demonstration stage. However, it has now become difficult for these countries to proceed with the demonstration stage for various reasons. The Japanese fast breeder reactor project,