The Great Nuclear Power Debate (2)

Breeder Reactors

BY JOHN H. DOUGLAS

Conclusion of a two-part series. SN's *John H. Douglas recently interviewed nuclear scientists in the United States, Great Britain and France, and visited the on-line French breeder, Phénix.*

Americans still argue about the breeder's worth, but several other countries have quietly gone ahead with development—years ahead

When American scientists built the first small breeder reactor, in 1951—which generated the world's first electricity from nuclear energy—they placed it in the middle of an Idaho desert, a safe 50 miles from the nearest civilization. Similarly, the Russians have installed their large new breeder on a remote desert peninsula on the Caspian Sea, and the British have built both their breeders at the bleak northern tip of Scotland. But with that supremely Gallic dash of *élan* that says more about their confidence in their technology than any voluminous environmental impact statement, the French have constructed the 250 megawatt Phénix reactor (current leader in the breeder sweepstakes) 15 miles outside a major city, Avignon—in the midst of the famous wine vineyards of Côtes du Rhône.

Now, a quarter century after pioneering the concept, the United States is roughly 10 years behind other industrial countries in developing breeder reactors, even though the breeder program remains the largest item in the U.S. energy research budget (SN: 1/3/76, p. 5). By the time of the announced 1986 deadline for a decision on whether to build a commercial breeder in the United States (SN: 1/10/76, p. 21), Britain, the Soviet Union and a French-led continental consortium may each have commercial-sized prototypes on-line, with Japan not far behind. If these are successful, the countries involved will probably sell various portions of the nuclear power cycle around the world as fast as they can, and developing countries have already begun to line up to buy this new alternative to Middle Eastern oil (SN: 7/5/75, p. 6). The effect on U.S. trade could be severe, and the warnings of American environmentalists about global dangers of nuclear power would have come to naught (SN: 1/17/75, p. 44).

How this unaccustomed position of American technological inferiority came to pass revolves about some of the great conflicts of the past decade, including environmentalism, indecision on energy policy, recession and distrust of science and technology. Where it is likely to lead involves equally momentous considerations: If the rest of the industrialized world succeeds in entering a "breeder economy" in the 1990's, the United States must either have achieved extraordinary energy conservation and petroleum substitution or face a prolonged and socially devisive period of unemployment and recession.

The idea for a reactor that would "breed" more fuel than it burned goes back to the earliest days of nuclear power, to Enrico Fermi, who first proposed the concept in the early 1940's. Conventional reactors use a "moderator" (now usually plain water) to slow neutrons as they pass between rods of uranium fuel, making them easier to absorb and thus maintaining a nuclear chain reaction with a minimum amount of fissile material (usually the isotope uranium 235). But U-235 represents only 0.7 percent of naturally occurring uranium, too little to sustain a chain reaction, so the very expensive and energy-wasting "enrichment" process is necessary to raise the proportion of U-235 to 3.0 percent. In this process, huge amounts of the majority isotope, U-238, are set aside, and after the spent fuel is removed from a reactor, even more U-238 is left over.

The purpose of the breeder is to convert this surplus U-238 to a more useful form. If an atom of this isotope absorbs a neutron, it changes to plutonium 239, which can then be used as reactor fuel. This conversion goes on to a certain extent in all reactors, but it proceeds much faster with unmoderated neutrons. To have a reactor that can produce, say, in 10 years, twice the amount of fuel it consumes, a larger number of fuel rods is needed than in conventional reactors. (Unmoderated,

Electricité de France

Operators sit at computerized control panel of the French Phénix breeder reactor.

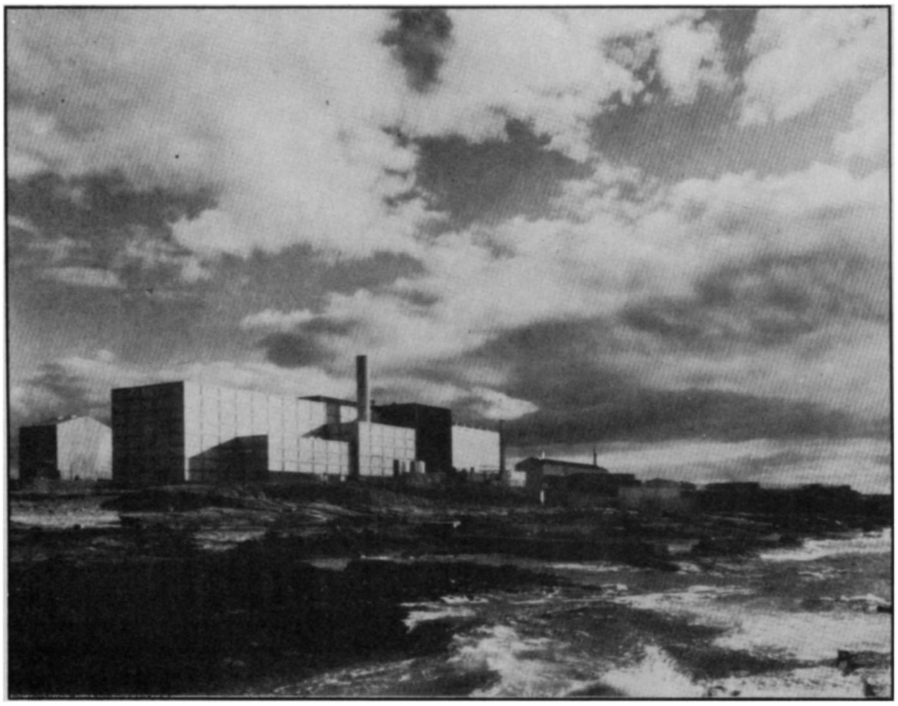
or "fast," neutrons are harder to absorb.) These rods are surrounded by rods of U-238 to be "bred." Since water can no longer be used, heat to drive external electrical generating plants must now be taken from the reactor by circulating a liquid that does not moderate neutrons—usually liquid sodium. Thus, a large and expensive Liquid Metal Fast Breeder Reactor (LMFBR).

The advantages of the LMFBR over the conventional, "light" water reactor (LWR) are considerable—if one assumes all goes well. Aside from breeding, a fast reactor makes more efficient use of fuel. More important, according to the Energy Research and Development Administration (ERDA), even with lower energy demand, uranium will be in short enough supply by 2010 that the cost of nuclear power generation will be around 15 mills per kilowatt-hour, and rising sharply. If breeders are introduced by 1987, however, the cost would be only 12.5 mills and falling sharply. Domestic oil and gas are expected to be pretty well depleted by then, solar and fusion energy would probably still make relatively small contributions, and the cost of coal-generated electricity will be almost 20 mills per kilowatt-hour. [Constant 1974 dollars.]

The disadvantages of LMFBR's hinge mainly on a pessimism about technology or an optimism about society. Theoretically, at least, a breeder could explode (ERDA prefers the term "disassembly process" induced by "autocatalytic recriticality" and emphasizes the chances are *very* small). The amount of dangerous material present is impressive: Each 1,000-megawatt breeder would contain some 50 metric tons of uranium and plutonium and 40,000 cubic feet of radioactive sodium coolant at temperatures up to 1,100 degrees F.—hot enough to catch fire if exposed to air. Fuel would have to be transported to reprocessing and fabrication plants, each of which would handle some five metric tons of combined uranium and plutonium a day. Intense argument continues as to whether the various installations of the nuclear fuel cycle should be clustered together in "nuclear parks," where a freak accident or sabotage might destroy them all, or whether the risk is greater in transporting large amounts of radioactive material about the countryside.

Not to build the breeder, however, also involves some risks, for one essentially has to assume that either a miracle will happen—such as invention of cheap, efficient photovoltaic cells—or that society will accept the changes of life style implicit in stringent energy conservation and neighborhoods built around small solar heating plants. The biggest crunch would come in unemployment. According to nuclear advocate Rep. Mike McCormack (D-Wash.), the energy equivalent of 48 million barrels of oil a day is the smallest amount that can keep American homes heated, cars running and industries going in 1985. For each million-barrels equivalent that supply falls below that, he estimates that some 900,000 people will lose their jobs. Society could, of course, be restructured (smaller cars and better insulated homes seem certain to come); but even assuming an aggressive conservation program, McCormack says, the nuclear portion of the 1985 consumption figure will equal 6 million jobs, "and there is no substitute for it." Such arguments go far with Congress. They probably explain why McCormack could recently tell SCIENCE NEWS, "In every test case we've had in Congress, the vote has been overwhelmingly in favor of nuclear energy and the breeder."

Then why has the United States breeder program apparently fallen so far behind?


UKAEA

The British Prototype Fast Reactor, located on the Scottish coast at Dounreay.

"We've become demoralized and cynical," one leading scientist in the program told SCIENCE NEWS; "We've been raked over the coals." Even before the present antinuclear outcry reached its thunderous proportions, however, the direction set for the American breeder program by its head, Milton Shaw, was being sharply criticized on technical grounds. His own subordinates accused him of overmanaging the development effort, questioned his technical and economic decisions, and opposed his single-handed elimination of alternative designs. The result was an almost academic approach to an essentially mission-oriented problem—a continual series of experiments designed to establish basic knowledge, rather than a progressive set of prototypes aimed from the start at developing a working reactor. Finally, the exceptionally low oil prices of the late 1960's lulled American budget planners into believing there was no particular rush.

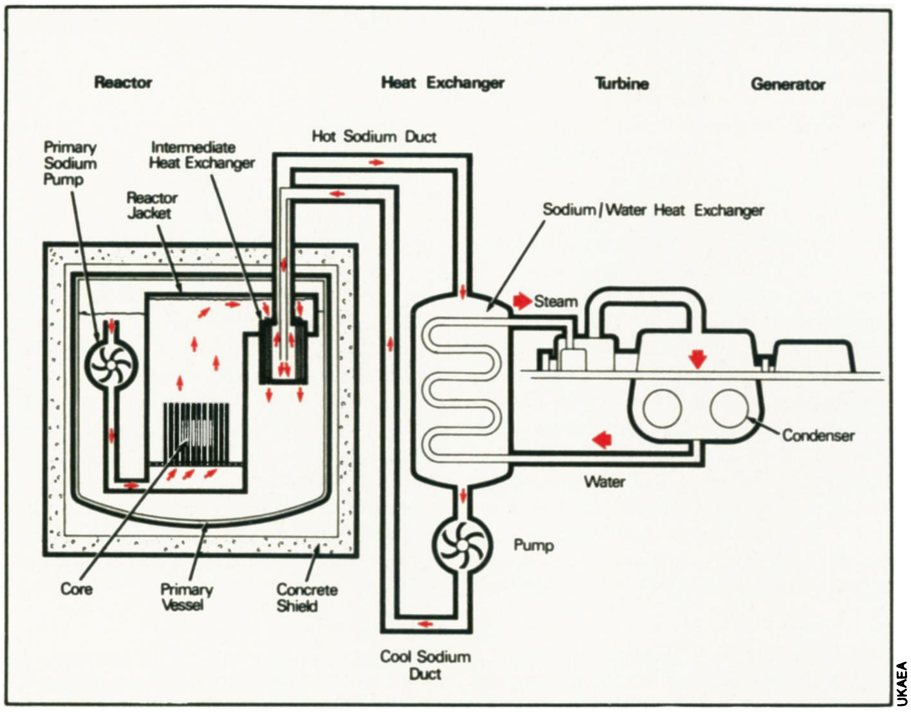
Not so, the Europeans. In France, Charles de Gaulle decreed the same sort of all-out commitment to develop a breeder that John F. Kennedy had commanded for America's race to the moon. In both cases, the secret of success was the experienced teams of scientists and engineers assembled to work together for a decade toward a single goal. (In the American breeder program the technical teams have changed several times.) When a commercial breeder reactor is finally marketed in Europe, perhaps half a dozen countries will be involved in its creation, but as the Phénix chief operating engineer, Bernard Giraud, confidently told SCIENCE NEWS, "The continuity will be French."

Some setbacks have, of course, occurred, as one would expect in a program at least as costly and complex as the space race. The British Prototype Fast Reactor (PFR) at Dounreay, Scotland, should have been completed before Phénix, but industrial problems hindered delivery of some components, and shortly after beginning operations, some 500 tons of seaweed got sucked into the condenser of the power-generating system. PFR should reach full power this spring.

A more fundamental design problem, faced by several nations, was described for SCIENCE NEWS by Thomas N. Marsham, deputy director of reactor development for the United Kingdom Atomic Energy Authority (UKAEA). When a single weld is used to separate water and sodium, tiny leaks can occur ("really more of a porosity than a leak," says Marsham). Reaction between the two chemicals produces hydrogen, which can build up in the heat transfer tubes. In the PFR enough redundancy of parts had been included to simply allow leaky tubes to be plugged, but the new rule of design is never to have just one weld separate sodium and water. French designers reached a similar conclusion, but they place more emphasis on eliminating thermal stresses that result when dissimilar metals or different thicknesses are welded together. (Welding problems are also plaguing undersea oil pipeline designers.)

One possibly decisive factor in allowing other countries to pursue an accelerated breeder program is public acquiescence. Outside the United States, environmental decisions are usually handled like other technical matters—by experts. In Britain, public comment is invited, but the final decision is left up to the Government, without recourse to lengthy court battles that have slowed or halted several nuclear projects in this country. French public opinion has not yet been aroused one way or the other, and if pressure for alternative policies should occur, it would probably be hopelessly enmeshed in party politics. The Russians have reportedly adopted very large safety margins into their reactors through strictly internal technical debate. Their philosophy is to emphasize high quality at critical points (while leaving outside buildings to be crudely built by convict labor), rather than worrying about maximum hypothetical accidents, as American scientists have to do.

Though such attitudes may at first seem cavalier to environmentally conscious Americans, one cannot help being impressed with both the technical achievement and care for safety evidenced by a walk through Phénix. Passing through the double doors of an air lock that allows the entire building to be sealed in case of an accident, one can move freely about the cavernous room surrounding the top of the reactor, receiving less radiation than if the reactor were a conventional, water-cooled type. The uncluttered hardware shows the touch of a well-planned, efficient operation. In the control room, a computer continuously monitors every aspect of the reactor and power generating operation. Some safety procedures are automatic—the computer will shut down the reactor in the event of unexpected temperature rise or power failure—but other variables are put under the operator's direct control, including reactor power, which is controlled by remote manual adjustment of sodium flow.



Schematic of a (British-type) breeder reactor, heat exchanger and power generator.

In its first year of operation, Phénix achieved a noteworthy 84 percent availability. The "doubling time" for breeding new fuel is still far too low, but all designers emphasize the experimental nature of this generation of reactors and expect to concentrate on the breeding and economic aspects in future models.

Many uncertainties remain to be settled before the coming of the Breeder Age, including technical and economic problems of the reactor itself and the relative merits of various countries' approaches. The United States still depends less on imported petroleum than Europe (with the possible exception of Britain, after enough North Sea oil comes on stream), and this might be able to justify some delay. Uranium resources are very uncertain, and some estimates indicate that as long as enough domestic high-grade ore deposits are found, the cost differential between building light water reactors and the more expensive LMFBR's could not be justified.

Most experts think such a bonanza is unlikely, but the inordinate escalation of reactor construction costs worries everyone. One provocative study conducted at MIT's Center for Policy Alternatives (summarized in TECHNOLOGY REVIEW, February 1975) concludes that, unlike the ERDA predictions, capital costs for conventional nuclear plants are rising so fast that coal will be competitive by 1980. At the very least, this conclusion challenges the timing of breeder introduction. (ERDA experts "violently disagree" with these figures.) But perhaps the most interesting conclusion of the analysis is that a principal factor causing nuclear construction costs to rise more rapidly than those of fossil fuel plants is the very process of antinuclear intervention. The authors conclude that the unique regulatory process that governs nuclear energy "has been used as a device to give effect to the view that reactor technology is not as valuable to society as the anticipated cost of electricity from the first-generation plants implied." In other words, nuclear energy's biggest problem is political.

Relative to foreign competition, the fact that the United States will not have an equivalent to Phénix until nearly a decade after the French may be a little misleading. Westinghouse scientists conclude that the French design "could not meet current U.S. safety standards and licensing requirements," and hence it is not yet able to compete in the lucrative American power generation market. (Others disagree.) Furthermore, by taking a somewhat pedestrian approach, American scientists may be able to avoid some spectacular blunders, such as a large hydrogen leak (some say explosion) at Shevchenko and 500 tons of Scottish seaweed. Meltdown of an LMFBR at Newport, Mich., in 1966 does not help this thesis, however.

The key factors to breeder development are commitment and cooperation. Some American experts fear that if the Europeans can manage a truly joint development project—combining the best features of the British and French designs—to market a commercial breeder reactor on their proposed time scale, the United States could suffer a severe economic setback, equivalent to the Arab oil embargo. Likewise, European scientists express apprehension that the American Government could suddenly ease licensing requirements and "let your private companies just get on with it," implying that the U.S. industrial infrastructure is still powerful enough to quickly close the existing gap if circumstances permitted.

Though all the British and French scientists and politicians who spoke with SCIENCE NEWS expressed optimism over more cooperation across the Channel, none would speculate on when or how it might come about. But little doubt exists about the all-out commitment to the breeder; says UKAEA's Marsham, "I can never remember a time there was so much unanimity in the United Kingdom over energy supply." Certainly no American scientist can say *that*. □