France's industrial fast breeder goes on line

Laurent Rosenfeld reports on the breakthrough acheived by the Super Phénix.

On Jan. 14, 1986, the fast breeder Super Phénix in Creys-Malville started industrial operation and was connected for the first time to the national power grid. The reactor went critical on Sept. 7, 1985, and after numerous tests since that time, the first industrial-scale fast breeder in the world progressively increased its power, finally producing enough steam to drive one of the plant's two turbines. Tests will proceed for several months, and Super Phénix is scheduled to reach its planned power of 1,240 MWe by mid-1986. The Super Phénix is not the usual type of nuclear power plant, the so-called pressurized water reactor (PWR), but a liquid-metal-cooled fast breeder—that is, a reactor which produces more fuel than it consumes.

Uranium-235 is the only fissile isotope of uranium, i.e., the only variety of uranium that can be used to produce power in a conventional type of nuclear reactor. But, enriched uranium-235 only represents 0.7% of natural uranium. The rest, the 99.3% of U-238, like wet wood, is unburnable—at least in ordinary reactors. The task of the breeder is to transform U-238, which is 140 times more abundant than U-235 fission fuel, into a combustible (fissile) material—plutonium-239. If we assume presently known reserves of uranium to represent the equivalent of 40 years of present world electricity consumption, then breeder reactors, at least in theory, can make those same reserves last 140 times longer—5,600 years! In reality, given that conventional reactors do burn a little bit of U-238, breeders are "only" about 100 times more efficient than LWRs—which still leaves us with 4,000 years. Indeed, the relatively small uranium reserves of France represent the potential for more energy than the oil deposits of the entire Middle East!

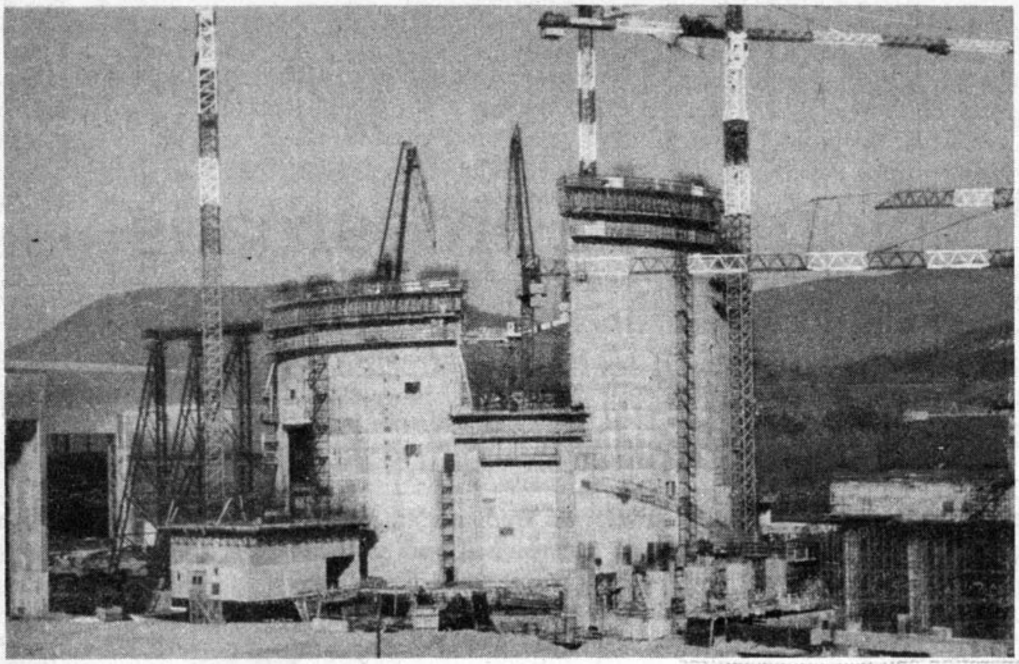
Super Phénix is not the world's first fast breeder. In fact, the first nuclear reactor ever to produce power, in 1951, the EBR-1 (Idaho), was a breeder. But since then, breeder programs have been slowed down in most countries, except perhaps in France and, to a lesser extent, the Soviet Union. After having built several small research fast breeder reactors such as Harmonie, Masurca, Cabri, and Rapsodie, the French Commissariat à l'énergie atomique (CEA) built the 250 MWe Phénix reactor in Marcoule. Phénix produced its first kilowatt-hour of electricity in December 1973 and reached full power in March 1974. It was at that time the largest breeder in the world (and remained so until the Soviets put the 600-megawatt BN600 in Byeloyarsk on line in 1980). Today, the 1,240 MWe Super Phénix is the first industrial scale breeder in the world.

Super Phénix was constructed by a company set up for that purpose, NERSA, whose shares belong to the French national utility company EDF (51%), its Italian counterpart ENEL (33%), and SBK (16%), a consortium of utility companies from West Germany, Belgium, the Netherlands, and Great Britain.

The core of the Super Phénix is composed of 364 fuel subassemblies, each containing 271 fuel rods. The top and the bottom of the fuel rods are composed of depleted uranium; the active core is otherwise surrounded by three rows of fertile subassemblies (a total of 233 fertile subassemblies) containing also depleted uranium. The fertile covers also provide for neutron shielding, protecting the rest of the reactor pool against high neutron fluxes coming from the inner core (there are, however, several additional rows of steel subassemblies, only aimed at protecting the pool and secondary sodium circuits).

For 100 fission reactions occurring in the core, 118 new fissile (plutonium) nuclei are produced: 80 fissile nuclei within the core itself; 38 are produced in the blankets. These figures confirm that it is only the blankets which allow the breeding of more fuel than is consumed. The fuel is slowly depleted in fissile material, while the blankets are progressively enriched, the latter process being significantly quicker than the former.

Besides producing electricity, like other nuclear reactors,



The Super Phénix at Creys-Malville, France, as it appeared under construction in 1978. At that time, it was projected to come "on line" by 1983.

the main interest of breeders is that they convert U-238 into Pu-239. The capacity to effect that is measured by the breeding ratio: that is, if A is the quantity of plutonium produced, and B the quantity of fuel fissioned, the ratio is $(A-B)/B$. In Phénix, the planned breeding ratio was 1.12, and could in fact be enhanced to 1.16. In the case of Super Phénix, the breeding ratio is 1.18. The plutonium produced is then reprocessed to serve as new fuel for reactors, thus closing the nuclear fuel cycle.

What's next on line?

Several plans have been drawn up to follow the Super Phénix. The original concept was called Rapides-1500, a plant with two reactors akin to Super Phénix, but optimized to a power of 1,500 MWe. But lack of determination on the part of the managers of the program has delayed implementation of this plan. The economic crisis has sharply reduced expectations of energy consumption for the decades to come, and most people believe that breeders will therefore not really be necessary for another 20 or 30 years. Since electricity produced by Super Phénix is more expensive than electricity produced by conventional nuclear power plants (although still much cheaper than fossile-fuel power plants), the dominating idea among French energy planners is "just to keep the concept alive," instead of going for a bold development program. This approach ignores the fact that Super Phénix is an industrial prototype, and therefore understandably more expensive than a conventional nuclear plant; if breeders were constructed at the same pace that PWR conventional nuclear plants have been built in France, the price would fall to levels similar to or just slightly above the current nuclear electricity prices.

Under discussion now is the construction of just one additional Super Phénix, perhaps just improved, thus bringing to 1,500 MWe the power for a reactor of the same dimensions. One idea is to have this second reactor built in West Germany, but the officials this writer has spoken to are unenthusiastic about this option, because they fear that opposition by the environmentalist Greens will stall any project there.

In this section

The start-up of the world's first industrial-sized fast breeder reactor is typical of the potentials of the French economy, which was moved to the front ranks of industrial nations by the high-technology policy of President Charles de Gaulle. The report on the Superphénix breakthrough, and the technological overview of the French economy which follows, are most relevant in view of the upcoming French parliamentary election on March 16, which will pose the issue of the future direction of that nation's economic policy.

Neither of the major contenders, the ruling Socialist Party headed by President François Mitterrand, nor the Jacques Chirac-led opposition, has any policy for France other than dismantling this high-technology capability. Unless policies guided by the perspectives in these articles are inserted into this political scheme, France will decline rapidly from the capabilities we describe here—to the immense danger of its own future and that of the Western Alliance.

—Carol White, Science & Technology Editor