India's fast breeder comes on line

Nuclear engineer Ramtanu Maitra reports from New Delhi on the innovative program which has achieved nuclear self-sufficiency.

On Oct. 18, India's first Fast Breeder Test Reactor (FBTR) generated net energy for the first time, one of several recent developments which show that the country's long-sought self-sufficiency in its nuclear energy program has now been attained. The success of this experimental facility in Kalpakkam, Tamil Nadu, can largely be attributed to efforts by Indian scientists and engineers, who took the basic French design for a liquid sodium-cooled fast breeder reactor and developed an innovative program to suit special Indian conditions. A beginning has already been made on the design of a Prototype Fast Breeder Reactor (PFBR), with an electricity generation capacity of 500 megawatts.

The Indian FBTR joined the elite group of less than a dozen breeder reactors operating in the world today. These include test reactors, prototypes, and demonstration reactors. The BN-600 in the U.S.S.R. and the Super-Phénix in France are the leaders in this category; but India's FBTR is the first breeder reactor developed by any developing nation. Further, it is the first reactor to use a unique new plutonium-rich mixed carbide fuel, developed by Indian scientists to solve the problem of India's lack of uranium reserves.

Initially, the FBTR will run at low power, to enable scientists to conduct experiments. A year hence, when the reactor will be coupled with a steam generator and turbine, it will produce about 14 megawatts of electrical power.

Overcoming the uranium bottleneck

India's nuclear energy development program is based on a three-stage strategy formulated in the 1950s, which is primarily oriented to achieving self-sufficiency, including development of an independent fuel cycle. India's reserves of uranium, the atomic fuel used almost universally, are of the order of 67,000 tons of uranium oxides. Such meager reserves would not allow India to sustain more than 7,000 megawatts of electrical power for more than 30 years. However, India possesses almost one-third of the world's thorium reserves, and thorium can be converted into uranium-233, a fissile fuel. The known reserves of thorium contained in monazite sands on India's Kerala Beach alone are estimated at 363,000 tons of thorium oxides.

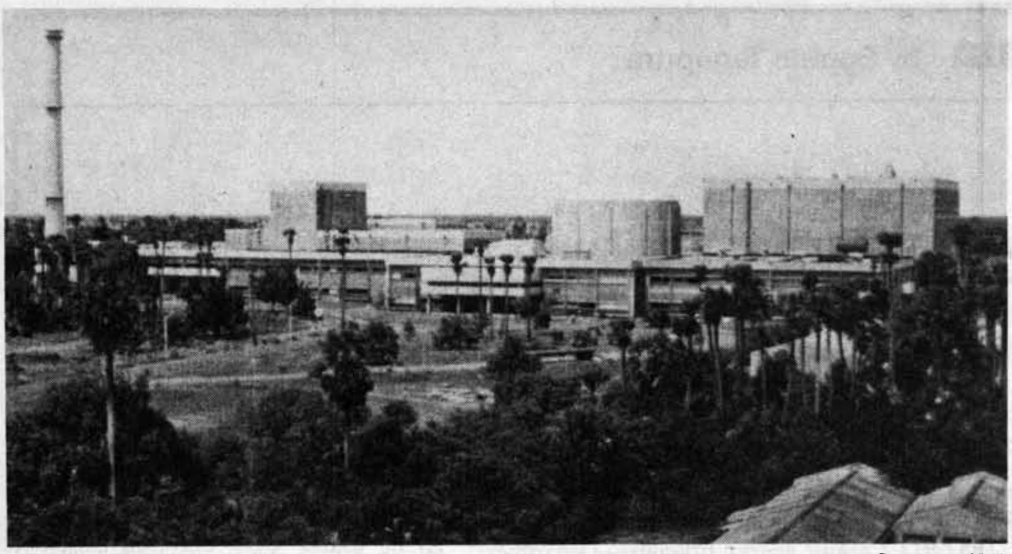
Thorium cannot be used as a fuel in nuclear reactors, because it cannot fission by itself. Thorium-232—the isotope that exists naturally and that needs to be converted into uranium-233—is what scientists call a fertile material. Such conversion can be attained in two ways. One can use a neutron accelerator in the laboratory—an expensive proposition which consumes a large amount of energy. For a power-starved nation such as India, this is not a serious option. The alternative is to irradiate thorium in a nuclear reactor, while generating power at the same time.

Since uranium is abundantly available in all other nations that have nuclear power plants, research work on the thorium cycle has not been given a high priority internationally. To make the thorium cycle work, therefore, became a priority for the Indian scientists. In May 1984, after years of work, Purnima II, the world's only uranium-233-based research reactor, first generated net energy, converting the fertile thorium-232 into fissile uranium-233. Indian scientists designed the uranium-thorium fuel mix required to attain critical mass and produce uranium-233 from thorium-232.

Nonetheless, for the first stage of nuclear power generation, India had to depend upon mined uranium, consisting of 0.7% fertile uranium-238, the average composition of all naturally occurring uranium. Since India decided not to base its nuclear power program on the uranium fuel cycle, enrichment of uranium, an expensive proposition, was rejected at the outset. Heavy water-moderated reactors, which use unenriched natural uranium as fuel, were chosen as the basis of the first stage of the program, and a contract was entered into with Canada to supply the CANDU heavy water reactor technology. The Canadians broke that contract summarily in 1974, leaving India's first heavy water reactor—since then installed at Ranapratapsagar and known as RAPP-1—half-finished. Besides generating electrical power, these first-generation reactors also irradiate fertile uranium-238 into fissile plutonium. But the reactors are relatively less fuel-efficient—they burn up more uranium-235 than they generate in the way of plutonium. The idea is to use the fissile plutonium not simply for power generation, but to irradiate thorium-232 to make uranium-233.

The second stage of India's nuclear program began with the development of the breeder reactor. Besides generating steam for electricity generation, breeder reactors will create net new quantities of fissile material for future use.

© 1985 EIR News Service Inc. All Rights Reserved. Reproduction in whole or in part without permission strictly prohibited.



The Fast Breeder Test Reactor at Kalpakkam, India.

Government of India

The third stage, which would complete India's present nuclear power development program, is to build a string of heavy water-moderated reactors based on the thorium-uranium cycle. Meanwhile, fast breeder reactors would continue to generate more fissile uranium-233 for future use.

The fast breeder reactors

It is evident from the basic philosophy of the Indian nuclear program that the fast breeder reactors are intended to play a major role. They have several distinct advantages, including the fact that the power per unit volume is high, since the reactor core is small and the power density high. Breeders are also highly fuel efficient: In the case of heavy water reactors fueled by natural uranium, no more than 1-2% of the fuel is actually used. In conventional nuclear reactors, accumulation of fission products and the isotopes of heavy elements and depletion of fissile materials such as uranium-235 sharply decreases reactivity, putting pressure on the uranium inventory, and posing an impossible problem for a country which has very little uranium to begin with. Introduction of breeder reactors changes this picture significantly, as it becomes possible to use 60-70% of nuclear fuel resources, and thus considerably enhance power-generation potential. Breeder reactors increase the energy potential of a given uranium resource base by more than 60 times what is possible with thermal reactors.

The fuel used in breeder reactors generally consists of a highly enriched uranium-based fuel composition of 30% plutonium oxide and 70% uranium oxide. Since India does not have enriched uranium, Indian scientists have improvised a unique new fuel mix for the FBTR. It consists of a plutonium-rich mixed carbide driver fuel of 70% plutonium carbide and 30% uranium carbide. Although some investigations had been done abroad on uranium-rich mixed carbide fuel, the credit for developing the plutonium-rich mixed carbide fuels goes strictly to India's scientists.

In at least two respects the carbide fuel is superior to the oxide fuel. It has a much better thermal conductivity value, and therefore, in spite of a somewhat lower melting point, there is no possibility of a fuel melt down. Also, since the carbide fuel is richer in plutonium, it is theoretically a better breeder fuel than oxide fuel.

To build a nuclear reactor and all of its auxiliary components indigenously is by no means an easy task. Besides the technology, the quality of various materials, the machine-tooling requirements, and precision control and installation of the entire system are demanding and expensive. The task becomes even more difficult when the technology itself is not widely in use.

Liquid sodium is used as a coolant in the FBTR, and handling and purification techniques for its use have been developed entirely indigenously. The 150 tons of sodium needed for the project has been procured in India, and purified domestically to the nuclear grade needed for FBTR.

Research breakthroughs

One must look at the two latest research reactors, Purnima II and Dhruva, to appreciate the kind of creative nuclear physics that lies behind these advances: Purnima II is a unique reactor, as Dr. Raja Ramanna, the Indian Atomic Energy Commission chairman and a leading nuclear physicist, underlined in a recent interview. Purnima II is the world's first reactor to use uranium-233 as fuel.

Dhruva, a 100-megawatt research reactor which first generated net power in August, was another milestone for Indian scientists. "It is going to be a major facility for isotope production, neutron beam research, chemical research and for testing materials," said Dr. P. K. Iyengar of Dhruva, one of the 10 largest research reactors in the world. Dhruva will be used essentially for neutron physics. It is expected to be useful in biology, where new studies on the structure of biological molecules are under way.