R&D Plays Key Role In Japan's Nuclear Future

By Takashi Fujii

Japan operates 27 commercial nuclear power plants—all but one of them light water reactors (LWRs). The one gas-cooled type, installed at Tokai village, was the nation's first commercial nuclear electricity generating plant. It was imported from Britain and went on stream in 1966. Since then, Japan's electric utilities have installed only the LWRs that today form the core of its atomic energy. LWR technology was developed primarily in the U.S., where Japanese power companies obtained their know-how for their nuclear power projects.

Helped initially by this imported technology, Japan's nuclear power generation rose steadily to account for 20.4% of all electricity in fiscal 1983. Atomic energy is expected to continue to play a major role in the nation's energy supply as an alternative to petroleum. Japan's nuclear industry is promoting numerous research and development (R&D) programs, including joint international ones. The objectives include improving plant cost effectiveness and reliability as well as utilization of uranium resources.

Advanced light water reactors

LWRs are forecast to maintain their position at the center of the nation's nuclear power system. But, several improvements are needed: more stable plant runs, better economics and lower employee radiation exposure.

First & second improvement/ standardization programs

Soon after they imported American LWRs, Japanese utilities found that their reactors had to be shut down frequently due to minor incidents and troubles. This situation stimulated Japan's efforts to absorb the imported technology, upgrade it by adding indigenous know-how and help it "take root" in Japanese soil.

The improvement and standardization program, a joint undertaking by the government and private sector utilities and vendors, began in fiscal 1975. It was aimed at improving LWRs using indigenous technology, and using the results to standardize plant design. The whole program was intended to adapt the original imported plants and make them more suitable for Japan.

Three major achievements are expected from the program:

(1) More efficient maintenance and inspection, and greater equipment reliability, both contributing to higher capacity factors (plant utilization rates);

(2) Cutting workers' radiation exposure by upgrading maintenance and operational efficiency; and

Twenty-seven nuclear power plants are now in operation in Japan.

Takashi Fujii is the president of the Nuclear Power Engineering Test Center. He was appointed to his present post in 1980 after serving as an adviser to the Tokyo Electric Power Co., in 1979.

Table Improvement/Standardization Programs: Goals and Results

	Before	First Program	Second Program
Capacity factor	Varied	70%	75%
Regular shutdown period	90-100 days	85 days	70 days

Note: Under Japanese law, nuclear power plants must be shut down at least once every 13 months.

(3) Improvement of reliability and cost effectiveness through production of standardized equipment.

The first improvement/standardization program, carried out in fiscal 1975–1977, and the second program in fiscal 1978–1980 proved highly successful.

Four plants reflect the first program's results: the No.2 plant of the second Fukushima station, which started up in February 1984; Sendai No.1 plant, operational in July 1984; and two more under construction. Four plants now under construction or in planning incorporate the second program's achievements: units Nos.2 and 5 of the Kashiwazaki-Kariwa station, and Nos.3 and 4 plants of the Genkai complex.

Development of advanced LWRs

Development of advanced BWRs (boiling water reactors) and PWRs (pressurised water reactors) is the goal of the third program for fiscal 1981–1985. While this program is geared to the same targets—reliability and safety—as its predecessors, it also has two new features. The current international program is designed to help improve plant operation and expand generating capacity.

(1) Advanced BWR

Meanwhile, development of an advanced BWR began years ago when a conceptual design was completed by an international team of manufacturers: General Electric, Hitachi Ltd., Toshiba Corp., ASEA Atom and Ansaldo Meccanica Nucleare. That was followed by a contract between the Tokyo Electric Power Co. and a vendor trio—GE, Hitachi and Toshiba—for a basic advanced BWR design and its technical and economic evaluation. In July 1984, an effort was launched to further improve the new reactor's economic feasibility.

The advanced BWR's most significant feature is that the recirculation pumps are inside the pressure vessel, hence the phrase: "internal pumps" (Fig. 1). In existing BWRs, the pumps are installed outside the vessel. The Nuclear Power Engineering Test Center was commissioned by the government to confirm the internal pumps' reliability. The funding totals approximately ¥8 billion ($33 million).

Other features include an advanced fine-motion control rod driving mechanism, and a ferro-concrete reactor containment vessel. These new technologies are aimed at substantial BWR improvements: reducing radiation exposure for employees, cutting maintenance and refueling periods, improving plant runs (capacity factors) and easier plant operation, to name just a few.

(2) Advanced PWR

The advanced PWR development project is being carried out by another international team composed of Mitsubishi Heavy Industries, Ltd. and Westinghouse Electric Corp. as well as the Japanese PWR owner/operators. This program covers the whole reactor system and include advanced-design fuel and a larger reactor core among its unique features.

The Nuclear Power Engineering Test Center was commissioned by the government to confirm the advanced fuel and enlarged reactor core's reliability. The grants total about ¥11 billion ($46 million) and ¥5 billion ($21 million), respectively.

These technologies are also expected to give lower radiation exposure, better capacity factors and improved economics. Altogether, the advanced version of PWR should permit dramatic plant improvements.

Advanced new reactors

Light water reactors consume uranium-235 as their main fuel. Natural uranium is composed of 0.7% uranium-235 and 99.3% uranium-238, which has little use in LWRs. But after absorbing neutrons in a reactor, uranium-238 turns into a fissile substance called plutonium-239. As a result, spent fuel from LWRs contain Pu-239, which Japan intends to use in two types of advanced new reactors: fast breeder reactors (FBRs) and advanced thermal reactors (ATRs).

(a) Fast breeder reactors

The FBR has a unique feature—it produces more fuel than it consumes. Fired by plutonium, the fast breeder produces energy from fast neutrons, a product of nuclear fission. Simultaneously, the U-238

Fig. 1 Recirculation and Internal Pumps

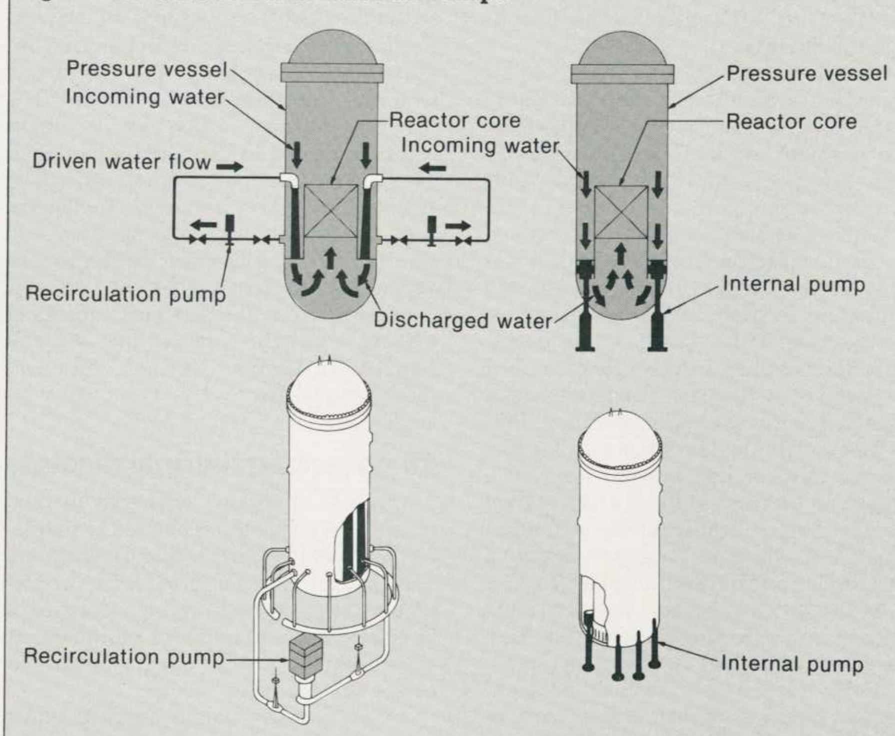
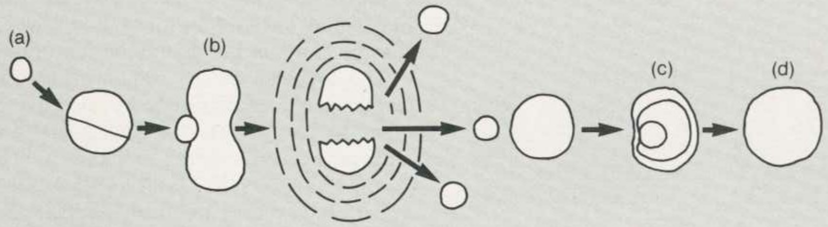


Fig. 2 Breeding Mechanism



Fast neutrons (a) from a nuclear fission reaction cause a chain reaction when they hit plutonium or combustible uranium (U-235) (b). Absorption of fast neutrons into non-combustible uranium (U-238) (c) turns the U-238 into a new fuel, plutonium (Pu-239) (d).
In an FBR, plutonium fuel in the reactor core sustains the nuclear fission reaction while Pu is produced from U-238 blanket fuel. The blanket fuel contributes to the net gain in fuel.

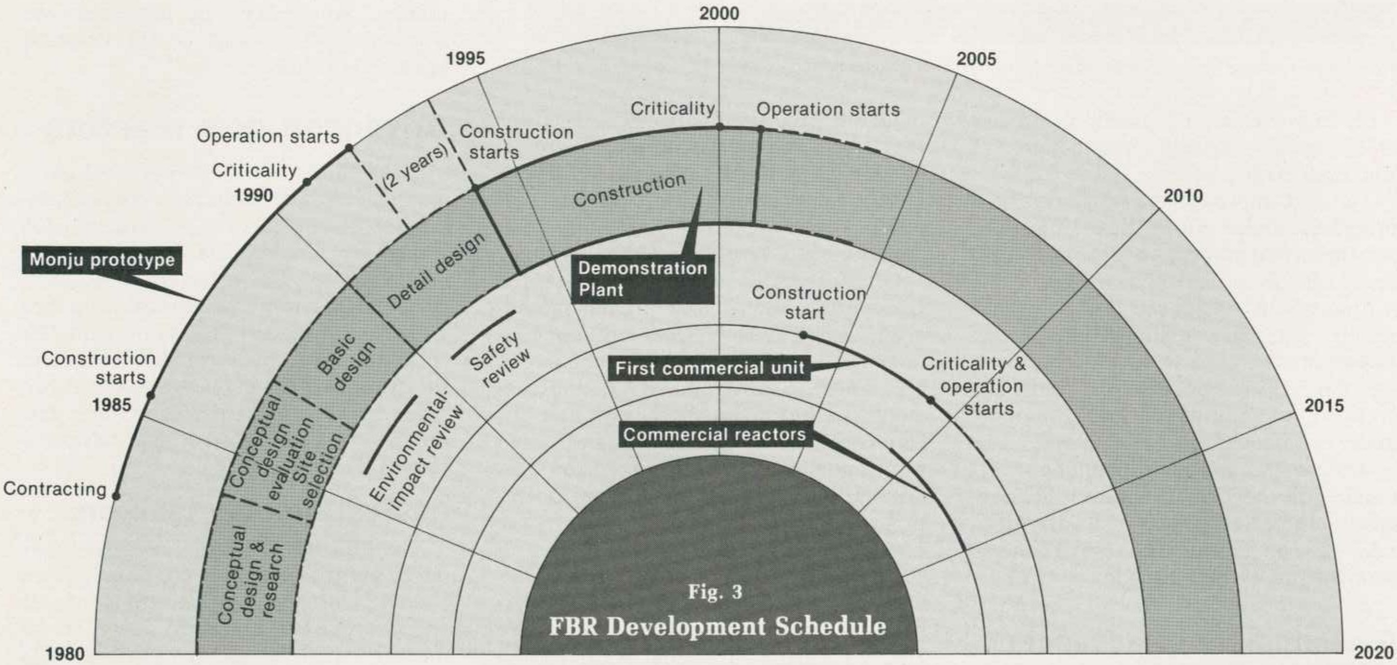


Fig. 3
FBR Development Schedule

that surrounds the Pu fuel, known as "blanket fuel," is converted into fissionable Pu-239 (Fig. 2).

Commercial FBRs promise to utilize uranium at least 60 times more efficiently than LWRs, dramatically increasing effective uranium availability. The FBR has been praised as the "ideal" and "ultimate" reactor.

With inadequate uranium resources of its own, Japan maintains a basic long-term nuclear-energy policy for utilizing plutonium recovered from spent-fuel reprocessing in FBRs. Based on this policy, FBR development efforts have continued for more than 10 years. An experimental reactor, Joyo, is already in operation. Preparatory civil engineering work is being carried out for the construction of a prototype breeder, Monju, with a target for achieving criticality set for the end of fiscal 1990. The FBR program's next goal is to develop a demonstration plant (Fig. 3).

As experts in Japan, the U.S. and Europe agree, the single largest task for a demonstration plant is to improve plant cost effectiveness. International cooperation is expected to increase as nations tackle this problem, and Japan intends to participate actively in such efforts. In November 1984, the Agency of Natural Resources and Energy is holding an international symposium in Tokyo on strategies for FBR cost reduction. The theme was chosen so that expert opinion can be reflected in the conceptual design of a Japanese demonstration FBR. The symposium is also aimed at publicizing Japan's efforts and promoting discussion for further international collaboration. Japanese FBR experts will meet with their colleagues from other leading countries in breeder research: France, the Federal Republic of Germany, Britain, Italy and the United States.

(b) Advanced thermal reactors

The role of Japan's advanced thermal reactor (ATR) project is defined as supplementary, and is seen as helping bridge an anticipated transition period from the present LWR to the FBR. Its significance lies in effective consumption of plutonium as well as the results of indigenous nuclear power development.

As a first step, Japan began building the 165MW Fugen prototype plant at Tsuruga City, Fukui Prefecture, in December 1970. The ¥70 billion facility reached criticality in March 1978, and went into full operation a year later. Running smoothly ever since, the Power Reactor & Nuclear Fuel Development Corporation achieved an approximately 80% capacity factor during 1983.

Another demonstration ATR project is being handled primarily by the Electric Power Development Co. The EPDC is working on a basic design for a 600MW reactor, to be located in Ohma, Aomori Prefecture. Operation is to start in 1994. Recognizing the ATR project's significance, the government is financing 30% of the total cost of the demonstration plant.

The primary objective of nuclear power R&D is to further enhance atomic energy production, which in turn will help reduce reliance on petroleum and diversify Japan's energy sources. Nuclear power thus has top priority in the Japanese government energy policy. Japan's active research and development efforts are indispensable, as is continuing international cooperation, if the world is to enjoy stable energy supplies in the years to come. ●