JAPAN'S NUCLEAR PROGRAM STRESSES BREEDERS, PLUTONIUM AND SAFEGUARDS

Japan's Atomic Energy Commission has prepared a new long-term program for nuclear energy that anticipates a doubling of installed generating capacity between now and the year 2000, implying that nuclear power plants will produce about 40% of the nation's electricity at the end of the century.

The "Long-Term Program for Development and Utilization of Nuclear Energy" was submitted to the Prime Minister last June by the head of Japan's Atomic Energy Commission, Y. Mitsubayashi, who also serves in the Cabinet as Science Minister. The program, which is binding on the Prime Minister under legislation governing Japan's AEC, recently became available in English translation.

Japan's pilot reprocessing plant, located at Tokai-Mura and owned by the Power Reactor and Nuclear Development Corporation, opened over opposition from the Carter Administration.

The program puts great emphasis at the outset on improving safety, by building on what it claims is already an excellent record by international standards, and on helping to strengthen barriers to the proliferation of nuclear weapons or the misuse of nuclear materials. Even as Japan is "required to play a still more important role in promoting the development and utilization of nuclear energy based on a philosophy of harmonization and mutual understanding with foreign partners," the program says, "it becomes particularly important for Japan to . . . take the initiative in promoting and demonstrating [in] practice [the] peaceful use [of nuclear energy] compatible with nonproliferation."

The program calls upon the Japanese government to become a member of the Convention on the Physical Protection of Nuclear Material, an agreement that was negotiated under the auspices of the International Atomic Energy Agency with strong support from the United States, and it calls for the "establishment of a domestic system to cope with it." The convention was opened for signature in the early 1980s and took force on 8 February 1987, after 21 countries—the required minimum number—had signed and ratified it. Twenty-five other countries and EURATOM have signed but not yet acceded to the convention.

The prominence Japan's long-term program gives to the protection of nuclear materials represents a marked change in attitude for a country that initially adopted a very skeptical attitude toward safeguards and joined the Nuclear Non-Proliferation Treaty only after obtaining extensive assurances on the subject of safeguards. Leslie Thorne, a high IAEA official who was responsible for safeguards in Asia for about 15 years, considers Japan to be one of the agency's "big success stories." He attributes Japan's more forthcoming attitude toward the safeguards system partly to the IAEA's growing technical professionalism and partly to the Soviet Union's more positive attitude toward the agency, but also to Japan's own growing technical self-confidence. A country that once worried that safeguards might cripple its competitiveness vis-à-vis the nuclear-weapons states now "is probably the world leader in advanced nuclear technology," Thorne believes.

Japan's 33 light-water reactors provided nearly 25% of the country's electricity in 1986, and they operated that year at 76% of their rated capacity, one of the world's best records. The long-term program calls for nuclear power plants to generate 40% of Japan's electricity by 2000 and 60% by 2030.

Plans for plutonium

At a time when the Europeans are revising plans for breeder reactors in the wake of an accident at France's Superphénix (see box at right), Japan remains firmly committed to the development of breeders and to the commercial use of plutonium as fuel for both breeders and light-water reactors, as well as to vigorous research on fusion (see next story). "The commercial deployment of fast breeder reactors will be determined by the market mechanism, and it is difficult to forecast their epoch at the present time," the program says. "But . . . basic policy will be to take a positive attitude with the objective of establishing the plutonium utilization system by means of fast breeder reactors. . . ."

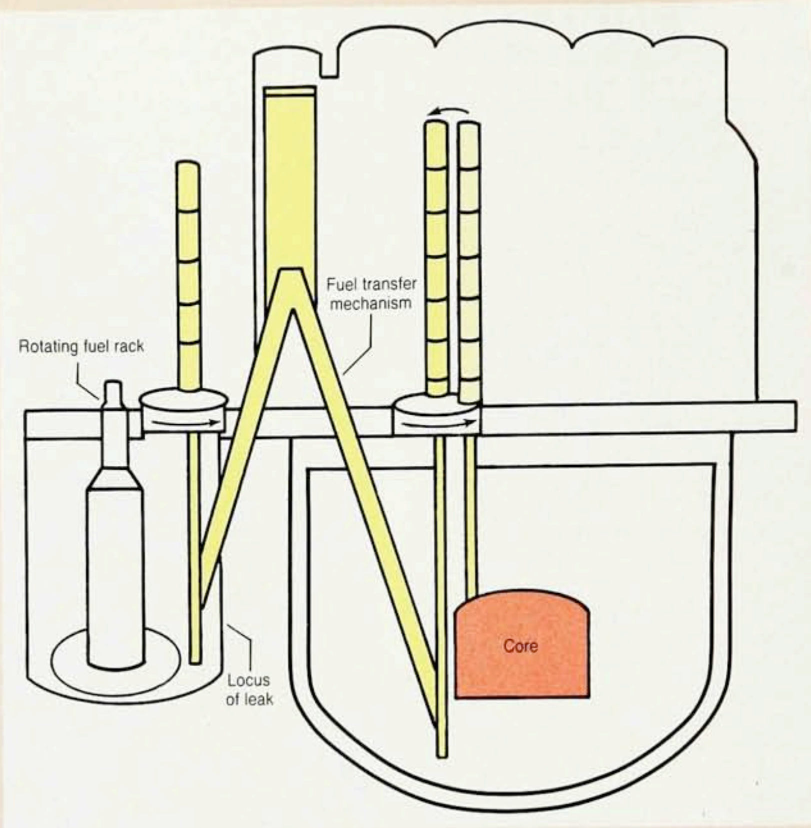
The long-term program anticipates that the 280-MW Monju breeder reactor will go critical about 1992 and that construction will start in the late 1990s on a demonstration reactor comparable to the Superphénix. The plan aims to establish an energy system involving use of plutonium in fast breeder reactors between 2020 and 2030.

In November, Japan and the United States signed a controversial long-term agreement concerning the transport of Japanese nuclear fuels to and from Europe for reprocessing, a practice that has been a bone of contention between the two countries since the late 1970s. In recent years, Japan has contracted with reprocessors in France and Great Britain to treat more than 5500 metric tons of spent fuel from Japanese light-water reactors. "An estimated 25 000 kg of plutonium will be separated [from the fuel] over the next 15–20 years," according to a report by the US Arms Control and Disarmament Agency.

Critics of plutonium recycling have argued for many years that plutonium would be most vulnerable to theft by terrorists or "diversion" by wayward governments following its separation from the highly radioactive components of spent nuclear fuel and during its transport to fuel fabrication, storage or power plants. This consideration, combined with the darkening outlook for breeder economics, prompted Britain's Royal Commission on Environmental Pollution and the Ford Foundation's Nuclear Energy Policy Group to issue reports in 1976 that were highly critical of reprocessing and recycling. The same year, a group at Princeton University that included physicists Frank von Hippel, Theodore B. Taylor and Robert H. Williams and political scientist Harold A. Feiveson published a series of influential articles in the December issue of the *Bulletin of the Atomic Scientists*, collectively entitled "On the Brink of the Plutonium Economy," in which they recommended the evaluation of alternative technologies.

The following spring, months after President Carter took office, he unilaterally terminated commercial reprocessing in the United States and curtailed breeder development work, saying that he wanted to set the world an example. During the following decade, some countries such as Swe-

Superphénix Incident and New European Plan



A leak of liquid sodium, which explodes on contact with water and burns on contact with air, was detected and reported last May at France's 1200-MW Superphénix, the world's first full-scale commercial breeder reactor. At the beginning of September the source of the leak was identified as a hole near the base of a tank adjacent to the reactor in which spent fuel elements are stored. The hole is near the point where spent fuel enters the tank via an elaborate fuel transfer mechanism (yellow-shaded areas). Spent fuel rods are lifted from the core through a plug, rotated to the compass-shaped transfer device, inserted into the storage tank and finally removed through another rotating plug.

From the point of view of safety, the leak is not nearly as serious as it would be if it had taken place in the much more sensitive reactor vessel or in the secondary circuits, which are equipped with devices for fast dumping of sodium in the event of trouble. But repairing the leak is greatly complicated by the fact that the storage tank can be accessed only via the plugs at the very top. The entire storage tank may have to be replaced, at a cost of around 400 million francs, or it may be possible to do without the tank and store spent fuel assemblies in the containment structure itself.

The accident has drawn renewed and closer attention in France and other European countries to the failure of the Superphénix to live up to early hopes for its economic performance. Because the Superphénix produces electricity at about twice the cost achieved by French light-water reactors, Electricité de France, the customer for all French nuclear power plants, is reevaluating its long-term plans for breeders. Meanwhile, the nuclear authorities in the United Kingdom, West Germany and France have delayed plans to build a demonstration breeder in each country and instead for now will build just one successor to Superphénix.

On 1 December, representatives of the European Fast Reactor Utilities Group met in London and decided to launch a two-year program to develop a single conceptual design for the next European breeder reactor. In a follow-up meeting that took place a week later in Lyon, representatives of European R&D organizations, utilities and design companies met to hammer out details for the collaborative design program.

den and Canada chose to follow the US example, and everywhere plans to introduce recycling operations were severely delayed because of adverse economic and technological developments (see PHYSICS TODAY, September 1986, page 53, and October 1986, page 115). On the other hand, countries such as France, Great Britain, West Germany, Belgium, Italy, Switzerland and—not least—Japan stuck with plans to reuse plutonium in mixed-oxide fuels for light-water or breeder reactors. According to research done last year by Feiveson and David Albright, a physicist with the Federation of American Scientists, if these countries continue with current plans, by the end of the century more than 300 000 kg of plutonium—enough to build about 30 000 small atomic bombs—will have been separated from spent fuel and placed into commerce.

In early November, the same week the United States and Japan signed the agreement granting Japan blanket approval to reprocess and recycle US-origin nuclear fuels for the next 30 years, the US Department of Defense delivered a report to the House Foreign Affairs Committee in which it warned that "opportunities for terrorist acts, including attempts to steal civil plutonium, will increase substantially as a result of the increased commercial use of plutonium." The report estimated that by the late 1990s as many as 300 shipments of plutonium annually will leave reprocessing plants in Europe for destinations in Europe and Japan.

The Nuclear Control Institute, a watchdog organization in Washington headed by Paul L. Leventhal, a veteran Congressional staffer who has concerned himself with proliferation for many years, claims that under the US–Japan agreement there will be flights of cargo planes carrying about 230 kg of plutonium to Japan from Europe via Alaska every two weeks. The institute has raised questions about the adequacy of current plutonium casks to survive realistic flight tests. In September, the State of Alaska filed suit in a Federal district court to block the flights, arguing that there is no way to guarantee safe air transport.

Toichi Sakata, who is responsible for nuclear affairs at the Japanese embassy in Washington, has the impression that the first transport flights will not take place for a couple of years in any case.

Fuel-cycle facilities

However Japan's near-term plans for transport of plutonium are affected by action in US courts or Congress, the fate of its program to establish a plutonium-based economy in the 2020s may ultimately depend more on its own development efforts and on its stated commitment to keep building a credible safeguards system. The long-term program seems in fact to adopt a somewhat standoffish attitude toward the international transport of fuels. It says that "reprocessing of spent fuels should be undertaken in Japan, in principle," and that "new commitments [for] overseas reprocessing should be treated with careful consideration."

Japan brought its first small commercial reprocessing plant into operation at Tokai-Mura in the late 1970s (over objections from the Carter Administration), but the plant only recently has begun to operate close to its design capacity of 700 kg of heavy metal (uranium and plutonium) per day. The program calls for Japan's private sector to construct a reprocessing plant with a capacity of 800 tons at Rokkasho-Mura, in Aomori Prefecture. The plant is to start operating by the mid-1990s. Meanwhile, at the same site, the country's first large-scale commercial enrichment plant is to be constructed. Also a private sector venture, the plant is to have a capacity of 1500 tons separative work units and is to start partial operations around 1991 or 1992. The program calls for a total Japanese capacity of 3000 tons SWU by 2000.

Among the major fuel-cycle technologies, only fuel fabrication has been commercialized so far in Japan. A major plant is located near Osaka, and Japan has the capacity to produce fuel rods for all 35 of its nuclear power plants currently operating. In addition, a test facility coupled to the Tokai reprocessing plant produces fuel for the experimental test-bed breeder Joyo (100 MW thermal), and for a prototype advanced thermal reactor (165 MWe) that runs on mixed- oxide fuel. A larger plant at Tokai-Mura will produce fuel for the Monju breeder and for a 600-MW advanced thermal reactor.

Under an agreement concluded recently by the US Department of Energy and Japan's Power Reactor and Nuclear Development Corporation, each of the two parties contributes $5 million annually to a joint research program on the breeder fuel cycle. The program involves the transfer to Japan of breeder-fuel technology developed at Oak Ridge National Laboratory. William D. Burch, director of the fuel recycle division at Oak Ridge, has argued in an Oak Ridge publication that the collaboration "will allow the United States to maintain a core of expertise" in reprocessing and advanced reactor fuel technologies. A similar US–Japan collaboration covers fuels for high-temperature gas-cooled reactors.

Safeguards

Bulk fuel-cycle facilities such as reprocessing and enrichment plants have always been considered the most difficult to safeguard. The conventional wisdom in recent years has been that nuclear materials can be accounted for at such facilities with an accuracy of no more than $\pm 1\%$—implying that if ordinary methods of material accountancy were used in a sizable fuel-cycle facility, enough material to build a bomb could disappear from the plant without international inspectors being able to draw any conclusions. Accordingly, innovative techniques, procedures and arrangements are called for.

Thorne, currently director for safeguards standardization, training and administrative support at the IAEA, concedes that "it's a bit of a business getting everything you want" at a facility such as the Tokai-Mura reprocessing plant, even given Japan's improved posture toward safeguards. But Thorne believes that significant strides have been made. IAEA inspectors are at the plant, where they have their own offices, 24 hours a day. Certain points are under continuous surveillance by cameras, and increasingly sophisticated devices are promising to reduce the margin of error in material accountancy. For example, high-performance neutron time correlation counters developed by Howard Menlove and James Swansen at Los Alamos National Laboratory can measure plutonium in any facility processing nuclear materials. This type of equipment is being interfaced with the robotic systems in a new automated fuel fabrication facility in Japan.

Similar instruments and arrangements will be employed when Japan completes its first large centrifuge enrichment plant, Thorne says. Under agreements negotiated between 1980 and 1983 by the six major countries that do enrichment, a common instrumentation approach has been developed involving, among other things, a "device for measuring enriched uranium that was invented in Australia, tested in the United States, refined in Japan, and first applied in the Netherlands." The six countries have agreed that IAEA staff will have the authority to make snap inspections on one hour's notice at all enrichment plants.

At a time when the Soviet Union and United States have just concluded an agreement on short- and medium-range missiles amid much fanfare about provisions for on-site inspection of rocket production plants, it is noteworthy that on-site inspection of sensitive facilities already has been pioneered in countries like Japan under the auspices of the IAEA. But the IAEA's system is only as strong as its weakest link, of course, and facilities such as enrichment plants can only be subjected to snap inspections if additional countries building such facilities agree to accept safeguards in the first place.

A noteworthy aspect of Japan's long-term program for nuclear energy, in this context, is its endorsement of "full-scope safeguards"—the principle that nuclear equipment, fuel or services will be exported to a non-nuclear-weapons state only if that country agrees to accept IAEA safeguards on all its nuclear facilities, regardless of whether it is a party to the Non-Proliferation Treaty or not. "Effective measures will be taken for full-scope safeguards ... to be accepted by the non-member countries of the NPT," the program says. More generally, the program says that nuclear cooperation with other countries will depend on each country's nonproliferation credibility, that Japan will pay close attention to sensitive items contained on lists prepared by the so-called London supplier group, that "cooperation in fields related to the utilization of plutonium will be considered with utmost care" and that "handling of sensitive nuclear technology will be studied hereafter also with utmost care."

When the principle of full-scope safeguards first was incorporated by the US Congress into the Nuclear Non-Proliferation Act of 1978 as the result of efforts by individuals like Leventhal, it was widely dismissed as unilateralist and unrealistic. Its growing acceptance by supplier countries such as Japan is one measure of the safeguards system's increased strength.

—WILLIAM SWEET

SUPERPOWERS PROMOTE DESIGN EFFORT FOR FUSION DEMONSTRATION REACTOR

Representatives of EURATOM, Japan, the Soviet Union and the United States have ageed to recommend to their governments participation in a three-year collaboration on the conceptual design of an international fusion experiment, the International Thermonuclear Experimental Reactor. The objective of ITER is to demonstrate the scientific and technical feasibility of fusion power.

The recommendation to proceed with the design of ITER was reached by representatives of the four parties meeting under the auspices of the International Atomic Energy Agency in Vienna on 19 October. According to an official announcement from the IAEA, the International Thermonuclear Experimental Reactor is to demonstrate the feasibility of fusion power by "demonstrating controlled ignition and extended burn of the deuterium–tritium plasmas, with steady state as an ultimate goal; by demonstrating technologies essential to a reactor in an integrated system; and by performing integrated testing of the high heat flux and other nuclear components required to utilize fusion power for practical purposes."

In INTOR (the International Tokamak Reactor), the international collaboration that preceded ITER, national teams designed a reactor that would be capable of 100-second self-sustaining plasma "burns." A report on phase 2 of the design concluded that such a reactor might cost $2.7 billion to build. While the objectives of ITER are broadly similar to INTOR's, they focus more sharply on a machine capable of a longer burn and, ultimately, steady-state operation.

IAEA Director General Hans Blix has issued an invitation to the executive authorities in the European Communities, Japan, the US and the USSR to participate in the ITER design program. The US government has accepted the invitation, and in a communiqué issued on 10 December at the end of the Reagan–Gorbachev summit in Washington, the two leaders "affirmed the intention of the US and the USSR to cooperate with EURATOM and Japan, under the auspices of the IAEA, in the quadripartite conceptual design of a fusion test reactor." The key decision that led to ITER was made by the two leaders in Geneva in November 1985 during their first summit.

If the other parties accept Blix's invitation, each would contribute activities at a level of $16 million per year to the program. Joint work to initiate the design will take place at the Max Planck Institute for Plasma Physics in Garching, where conceptual design work for the Next European Torus is being conducted by a 50-member team headed by Romano Toschi. The goals of NET are almost identical to those of ITER.

The joint ITER design work is to start this April. Participating scientists will reside at Garching for at least four months in 1988 and will specify the major design parameters for the experiment by the end of the year. More detailed design work at the various major fusion laboratories will be supported by the participating countries.

"This is the first time we've tried to put together a completely integrated international team," notes John Gilleland, manager-designate of the American ITER team. Gilleland, who left a senior vice presidency at GA Technologies to take his current position at Lawrence Livermore National Laboratory, says that in INTOR the pattern was for people to work furiously before and during meetings and then to rush back to catch up on regular jobs, where their INTOR efforts would be more or less unappreciated. "It was very useful, but it was largely a volunteer effort," Gilleland says. This time, he says, there will be a more highly organized ongoing effort with a division of labor and assigned tasks.

In the meetings that led to the ITER recommendation in October, the US participants emphasized the desirability of a machine that would operate at steady state and satisfy both engineering and physics objectives. The American participants were much influenced, Gilleland says, by studies showing that variations in the size of current machines result not so much from differences of opinion about fundamental physical principles, as such, but from differing objectives or engineering practices. Hence the belief of the US participants that a machine meeting all major objectives could be built at acceptable size and cost.

Gilleland anticipates that all the major magnetic-fusion devices currently operating or under construction, including France's Tore Supra (Cadarache) and Europe's JET (Cul-