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The Rise and Fall of Fast Breeder Development in Japan

An accident involving the sodium-leakage and fire at the prototype fast breeder reactor(FBR) 'Monju' ('Manjusri' in Buddhist terminology) on 8th December 1995 had a strong impact on the future use of plutonium as nuclear fuel in Japan. This accident may well have dealt a fatal blow to the plutonium breeding development program in Japan.

Moreover, this implies the end of plutonium breeding development in advanced industrial nations, since Japan is the last nation to oppose the world-wide movement to stop such programs. The U.S. abandoned their program in the mid-1970s. All European nations who had committed themselves to plutonium breeding programs (i.e. France, the United Kingdom, and the Federal Republic of Germany) abandoned them in the early 1990s. If Japan follows the same path, the world history of plutonium breeding will end.

Of course, there remains a possibility that some less-developed nations may take up plutonium breeding in the future, but this is highly unlikely. The poor results of half a century of international development of the fast breeder reactor (FBR) strongly suggest little chance of technical and social success for the FBR.

The purpose of this article is to outline the history of fast breeder reactor (FBR) development in Japan, and explain the reason why the Monju accident in the end of 1995 will put a halt to the continuation of the plutonium breeding development in Japan.

The Dual Structure of the 'Nuclear Development Community' in Japan

To evaluate the impact of the accident of 'Monju' on nuclear development in Japan, especially on the Science and Technology Agency (STA) and on the Power Reactor and Nuclear Fuel Development Corporation (PNC), the operator of 'Monju' under the control of STA, we have first to understand the basic structure of the 'nuclear development community' that emerged in Japan in the late 1950s, and has continued to exist for about forty years. The main promoters of nuclear power in the country

Science Studies, Vol. 9 (1996), No. 2, 14—26.

have been the government and industry. Their close relationship resulted in the formation of a government-industrial complex. We call this government-industrial complex the 'nuclear development community' (Genshiryoku-mura).

This community can be divided into two groups: (1) The electric-government league, of which the Ministry of International Trade and Industry (MITI) and electric power companies are the leading members; (2) the STA-group, of which the Science and Technology Agency (STA) and two public corporations, the Power Reactor and Nuclear Fuel Development Corporation(PNC) and the Japan Atomic Energy Research Institute (JAERI), under the umbrella of STA are the leading members.

A characteristic of nuclear development in Japan has been its dual organizational structure (Low and Yoshioka, 1989). Each group has had its own territory, and they have promoted nuclear development almost independently of each other. The main task of the electric-government league has been the gradual expansion of the commercial nuclear enterprise, whereas the STA-group's mission has concentrated mostly on the research and development of commercially unproven technology. In terms of nuclear fuel reprocessing, the STA-group introduced the Tokai-mura pilot plant from France, and has conducted R&D for improvement purposes only. But in every other case, the STA-group has independently developed reactors, plants, and facilities starting from the design and specifications stage.

The electric-government league can be said to have achieved satisfactory success, having constructed 49 commercial power reactors, of which 48 are light water reactors(LWR), by the end of 1995. The net equipment generating capacity amounted to 41,356 MWe in the end of 1995 (including a 165MWe prototype Advanced Thermal Reactor, heavy water moderated and light water cooled reactor, 'Fugen') (JAEC, 1996). The power reactor density of Japan (1.30 reactors/10000 km^2) is second only to Belgium and Taiwan. The electric-government league has naturally required much enriched uranium in order to operate many LWRs steadily. But there has been little in the way of obstacles for signing contracts with foreign companies or organizations regarding the purchase of natural uranium, or the consignment of enrichment services.

On the contrary, the latter group has met with little success and long delays. For example, the scheduled year for the completion of the first commercial fast breeder reactor (FBR) was 1970 according to the Japan Atomic Energy Commission's (JAEC) first Long-term Plan for Nuclear Development and Utilization(Genshiryoku Kaihatsu Riyo Choki Keikaku) in 1956 (JAEC, 1956). According to the 1994 Long-term Plan for Nuclear Development and Utilization, the scheduled year for the establishment of technology for the commercialization of FBR, not the completion of the first commercial FBR, is 2030 (JAEC, 1994). Moreover, the STA-group's national projects, other than the FBR, have generally experienced long delays, and the Advanced Thermal Reactor(ATR) development project finally ended in failure in August 1995.

Because there is a sharp contrast in the commercial benefits arising from the activities of these two groups, the electric-government league has been the leading actor in nuclear development in Japan, and the STA-group has been satisfied with the role of a supporting actor.

The decisive step in the separation of the two groups was the establishment of the Japan Atomic Power Company (JAPCO) in October 1957 as the owner company of a British Calder-Hall type (graphite moderated, CO_2 cooled), a commercial power reactor introduced from the U.K. The company was established as a joint effort by the government and industry, of which 20 % was funded by government, 80 % by industry including electric power utilities.

JAPCO has been for the most part administrated by electric power utilities, notably the Tokyo Electric Power company (TEPCO). Matsutaro Shoriki, the first minister for nuclear power, promoted a private management strategy for commercial nuclear power, by establishing JAPCO almost as a private company. This enabled the formation of the electric-government league. After that time, the STA-group was also formed as a domestic R&D oriented group. This dual system was further nurtured in the mid-1960s, with the establishment of the Power Reactor and Nuclear Fuel Development Corporation (PNC).

The Role of the Science and Technology Agency (STA) and the Power Reactor and Nuclear Fuel Development Corporation (PNC)

The main promoter of FBR development in Japan has been the Power Reactor and Nuclear Fuel Development Corporation (PNC). As the central nuclear R&D laboratory under the control of the Science and Technology Agency (STA), PNC has promoted four major national R&D projects: (1) the fast breeder reactor (FBR), (2) the advanced thermal reactor (ATR), (3) nuclear fuel reprocessing, and (4) uranium enrichment.

Although these projects, with the exception of the FBR development, have already been transferred to the electric power utilities or related corporations since the 1980s, the historical role of the PNC has been prominent. Moreover, the greater part of PNC'n current work is related to the four mainstream projects mentioned above, and the current role of PNC is also maintained by those projects. In August 1995, the Japan Atomic Energy Commission (JAEC) decided to discontinue the ATR project, but the other three major projects remains still unfinished.

There have also been other large-scale national R&D projects such as nuclear fusion research project or the development of high-temperature gas reactor (HTGR) promoted by the Japan Atomic Energy Research Institute (JAERI). But these projects have not been part of Japan's mainstream nuclear development. Consequently, the significance of the role of the Power Reactor and Nuclear Fuel Development Corporation (PNC) has been far greater than that of JAERI, another major nuclear R&D laboratory under STA control. The final goal of nuclear development in Japan, as well as in other industrialised nations, has been the completion of the 'plutonium economy', i.e. a self-sustaining plutonium breeding system that could provide all of the required nuclear electricity. Only projects that relate to this goal are 'mainstream' projects.

To fulfil the goal of the completion of the 'plutonium economy', it is essential to build commercial (or economically competitive) FBRs. The role of the three other major national projects, i.e., the ATR, the nuclear fuel reprocessing plant, and the uranium enrichment plant, was considered merely supplementary in relation to the FBR. The main purpose of the ATR (that uses heavy water as a moderator, and light water as a coolant) had been the promotion of technology for the use of MOX (mixed oxide) as a nuclear fuel. The purpose of the reprocessing plant has been to supply plutonium for the MOX fuel that is loaded into the core of the FBR, and the main purpose of the domestic uranium enrichment plant has been the protection of Japan's independent reprocessing policyfrom intervention by the U.S..

If the Japanese government decides to discontinue the FBR development project, there will be no need to continue the construction of the reprocessing plant (800tHM/year) and the uranium enrichment plant (1500tSWU/year) at Rokkasho-mura in the Aomori-prefecture. This underscores the historical significance of the impact of the sodium-leakage accident and the fire that occurred at the FBR prototype 'Monju'. If the Japanese government discontinues FBR development, the past and present role of the PNC will be completely denied, and a dissolution or radical restructuring of the PNC will be inevitable.

The termination of FBR development will also have a very serious impact on the STA. The STA will lose the major part of it's largest policy domain: nuclear development. The scale of nuclear development under the control of STA would be reduced at least by half. Considering the uncertain future of the space development program, STA's second largest policy domain, in the post-Cold War era, STA may have to change into an agency mainly dealing with planning and regulating.

A Brief History of Nuclear Development in Japan

Japan's history of nuclear development can be divided into the following six periods (Yoshioka, 1996b).

(1) Military Development(1939–45)
(2) Prohibition(1945–53)
(3) Institutionalization(1954–65)
(4) Takeoff(1966–79)
(5) Steady Expansion and Privatization(1980–94)
(6) General Stagnation and Decline of Plutonium Breeding(1995–)

The periods are marked by the following events: the defeat of Imperial Japan in the Asian-pacific War (in 1945); the approval of the first national budget plan for nuclear power research proposed by Yasuhiro Nakasone and others (in 1954); the conclusion of a contract to introduce the first American light water reactor and the government's decision to establish the Power Reactor and Nuclear Fuel Development Corporation (PNC) (in 1966); the recovery of the technological reliability of the light water reactor (LWR), the fall of the Canadian Deuterium Uranium (CANDU) reactor as a LWR competitor, and the beginning of privatization of major STA-group national projects (in 1980); and finally, the end of steady growth in a number of commercial nuclear power reactors, the termination of the ATR and the 'Monju' accident (in 1995). Interestingly, the years 1966, 1980, 1995 are turning points for both of the groups.

Before the mid-1970s, the relations between the electric-government-league and the STA group were relatively good. Since there was a clear division in their business territories. There was hardly any possibility of conflict of interest, the electric-government league dealt with the commercial stage of nuclear development, and the STA-group's activity was in a stage of infancy. Moreover, there were closely connected personnel changes between MITI and the STA. Because the STA, established in 1956, was a young agency in the Japanese government, it was dependent on other ministries, notably MITI, as a source for its staff. Before the 1970s, the STA was like a colony of MITI. (Only after the mid-1970s, the STA-trained staff begin to be promoted to leading positions, and it was only then that the independence of the STA was established).

Nevertheless, only after the mid-1970s did the STA national projects begin to approach the 'commercial' stage. Unable to purchase expensive facilities with funds from the national budget, the only way to overcome financial difficulties was to transfer the projects to the electric power industry, i.e., 'privatization'. The electric-government league had to decide whether or not to take the projects over from the STA group. The electric-government league had legitimate grounds for declining to take on the STA-group's R&D projects, for the economic viability of them was questionable. The electric-government league did, however, eventually agree to take over all the STA-group projects.

Although the conflict of interest between the two groups has grown more intense, it didn't take a serious form until the decision to discontinue the ATR project in 1995. This reflects the essential solidarity of the nuclear development community in Japan. Any conflict between the two groups should not be over-emphasized.

The Beginning of Fast Breeder Reactor Development in Japan

The beginning of the development of the fast breeder reactor (FBR) can be traced back to the mid-1960s. After the failure of attempts to develop the aqua-homogenous core reactor or the quasi-homogeneous core reactor, the Japan Atomic Energy Research Institute (JAERI) began the design work for an experimental fast breeder reactor in 1965. Before the establishment of the Power Reactor and Nuclear Fuel Development Corporation (PNC) in October 1967, the central R&D laboratory to develop the FBR was JAERI. JAERI completed the conceptual design work of the experimental FBR 'Joyo' in June 1968, and transferred it to the PNC. Since then, the PNC has promoted the project tenaciously for about thirty years. In the early days of development, JAERI contributed to the FBR project by supporting research, and sending many experts to the PNC.

Although the starting date of the FBR development project in Japan was far behind that of the U.S. and European countries, the Japan Atomic Energy Commission (JAEC), established in January, 1956, had a plan to develop the FBR. But there were two serious obstacles. One was the lack of technological information about the design and specifications of the FBR. Worldwide concern about the diffusion of militarily-sensitive information obstructed the free flow of technological information. Another obstacle was the difficulty in acquiring plutonium for the experimental reactor. As it is considered a sensitive nuclear material, the international trade in plutonium was almost totally forbidden prior to the mid-1960s. Because of these obstacles, the development of FBR in Japan started in the late-1960s.

The standard form of management of national projects was established in the JAEC's third Long-term Plan for Nuclear Development and Utilization in 1967. There were three main characteristics in the of management of national projects (Yoshioka, 1993). Firstly, the institutionalization of the national project system itself. Before that time, no formal mechanism existed. Secondly, the introduction of a schedule/timetable of development designating the final goal (completion of a commercial reactor or a plant) and halfway goals (completion of experimental, prototype, demonstration reactors or plants) concerning the scheduled periods of construction. Thirdly, the introduction of the 'check and review' system. This system was applied by JAEC every time some halfway goal of a project was reached. If the result of JAEC's assessment of a project was promising, JAEC would decide to construct the next stage facility. But if the result was not favourable, the JAEC might decide to discontinue the project. In every case reviewed, the JAEC decided to advance the project. From a critical standpoint, the 'check and review' system did not work properly.

Of course, JAEC could decide to discontinue or delay the project any time when it wants to do so. In many cases, it did so when the Long-term Plan for Nuclear Development and Utilization was revised. Generally speaking, every time the revision was executed, the scheduled periods of commercialization of the fast breeder reactor (FBR) became more and more distant from the time of each revision.

Fast Breeder Reactor Development Meets with Difficulties

In the Long-term Plan for Nuclear Development and Utilization of 1967, the JAEC designated the first official 'timetable' for FBR development. According to this plan, the scheduled period of completion of the experimental reactor (about 100MWt) was to be the early 1970s, and that of the prototype reactor (about 200–300MWe) in the late 1970s (JAEC, 1967). In other JAEC plans (1966, 1968), the scheduled period of completion of the prototype reactor, that was called 'Monju' in 1970 was 1976 (PNC, 1978).

The JAEC also stated that the scheduled period for the commercialization of the FBR would be the late 1980s. During the stage between the prototype reactor and the commercial reactor, JAEC had also planned to construct a demonstration reactor, but it did not specify the generating power nor the scheduled period for the demonstration reactor in its 1967 long-term plan.

This timetable illustrates that the JAEC had planned to advance from one stage to another in the construction program of FBR development every five years. Of course, this was an unrealistic plan. In the light of present-day common sense, it would take fifteen to twenty years to move from one stage of development to another, e.g., from the experimental reactor to the prototype reactor, or from the prototype reactor to the demonstration reactor (Yoshioka, 1993).

The construction program for the experimental reactor 'Joyo' ('eternal sunshine' in English) started in March 1970, and 'Joyo' (50–75MWt at Mark-I core, 100MWt at Mark-II core) succeeded in becoming critical in April 1977. The next stage of FBR development was to construct the prototype reactor 'Monju' (280MWe). Fortunately for the PNC, the result of 'check and review' on the FBR project was favourable, but the PNC spent several years in search of a site for 'Monju', and the government license to establish 'Monju'.

Construction work began in October 1985, and ended in April 1991. After various tests, 'Monju' succeeded in becoming critical in April 1994. At this time, the 'timetable' of the FBR development project suffered from long delays. At the beginning of the project, namely in the late-1960s, the scheduled period of completion was the year 1976. After eighteen years, 'Monju' became critical. 'Monju' succeeded in generating electricity in August 1995, but after three months, before its full-power operation, a sodium-leakage and a fire took place. It is not certain whether the PNC will be able to operate 'Monju' again. Even if the PNC will able to do so, it will take at least several years of investigations, inspections, and repairs.

Moreover, the projected cost of FBR power generation has risen rapidly. For example, the construction cost (excluding the cost of R&D) of 'Monju' was 590 billion yen. The unit construction cost was 2140 yen/watt. Compared with this, the unit construction cost of the latest light water reactor (TEPCO's Kashiwazaki-Kariha power station reactor No. 6 and 7) was only 282 yen/watt (Yoshioka, 1996a). This means that the unit construction cost of the FBR is about 7.6 times higher than that of the LWR.

The calculation of the fuel cost of FBR is not so simple. But we can roughly estimate the cost of one kilogram of heavy metal of MOX (containing 20 % of fissile plutonium) as 8 million yen in Japan. This is about 11.6 times higher than one kilogram of heavy metal of the 20 % enriched uranium. We can use another method of calculation: the unit energy per cost of MOX (containing 20 % of fissile plutonium) is about 1.83×10^7 Joule/yen, and the unit energy per cost of 3 % enriched uranium is about 2.93×10^8 Joule/yen. The latter is just sixteen times greater than the former (Yoshioka, 1996a).

In short, the cost of FBR power generation is about ten times higher than that of the LWR. Of course, as the generating capacity increases and better technology is developed, the cost of FBR power generation will slowly decrease. But in the future there will be little possibility for the FBR to compete with the LWR or fossil fuels.

What Constitutes a Demonstration Reactor

As it has been mentioned above, the electric-government league had already agreed to take over the STA-group's national projects. Even though the owner and developer of the demonstration FBR was not yet determined by the end of the 1970s, it seemed inevitable that the electric power utilities would agree to construct the demonstration FBR sooner or later. If so, the utilities had to draw up a construction plan for the demonstration FBR, and begin the design and specification work sooner or later. Under these circumstances, the Electric Power Utilities Union (Denki Jigyo Rengokai) established the Preparatory Office of Fast Breeder Reactor Development in June 1980.

In 1982, the JAEC officially decided to leave the development work of the demonstration FBR for the electric power utilities. The utilities accepted this request, and decided that the Japan Atomic Power Company (JAPCO) should become the proprietor and developer of the demonstration FBR in 1985. With this in mind, JAPCO established the Fast Reactor Development Section in December 1985. Although the PNC and the Preparatory Office had promoted conceptual design work since the mid-1970s, it had been only preparatory. The decision to establish the Fast Reactor Development Section of JAPCO was the true starting point of demonstration FBR development.

However, concerning the technological difficulties (notably that of handling sodium) and the seemingly hopeless economic outlook of the FBR, electric power utilities became more hesitant to promote the work on design and specifications for the demonstration FBR. In October 1992, after some seven years of design work, the Electric Power Utilities Union submitted a report on the preparatory conceptual design of the demonstration FBR based on the work of JAPCO.

This report contained two questionable points. Firstly, the generating capacity of this demonstration FBR was specified as 660 MWe. As a demonstration reactor of any type, it was too small. According to any plausible concept of a demonstration reactor, generating capacity would have to be equivalent to that of a standard commercial reactor, namely 1100 to 1300 MWe. The French 'Superphenix' was the only demonstration FBR in the world, and its generating capacity (1240 MWe) entitled it to be called a demonstration reactor. In contrast, the proposed Japanese demonstration FBR was virtually a half-sized demonstration reactor. Or to put it more precisely, it was only a large prototype reactor. The purpose of this decision might have been to reduce surplus expenses by reducing the size and construction cost of the reactor.

Secondly, the reactor type, namely the 'top-entry loop type', of this demonstration FBR was also questionable. There have been two main types of FBR: tank type and loop type. In the former type, the main devices, namely the reactor, the heat exchangers and the circulation pumps, are located in a large container. In the latter type, the main devices are independent of each other, and connected by long pipes. The construction cost of the former is relatively low, but this type is also more susceptible to earthquakes. The 'top-entry loop type' is a variation of the loop type, in which the connecting pipes are U-shaped. By introducing this type, the total length of connecting pipes can be shortened, and the cost can be lower than with the normal loop type. But because it has no precedent elsewhere in the world, it would take at least several years to prove its technological soundness and reliability, and the outcome of this experiment would be uncertain.

Why did the Electric Power Utilities Union chose such a time-consuming and unreliable reactor type? The reason might have been the intention of the electric power utilities to delay the beginning of the construction work of the 'so-called' demonstration FBR for as long as possible. This might well have been a back-lash by the electric power utilities to the request of STA's request to promote FBR development as a national policy.

As discussed above, the demonstration FBR (660 MWe) plan was actually aimed at the development of a half-sized quasi-demonstration reactor. Consequently, the JAEC had to make construction plans for a genuine demonstration reactor. In the Long-term Plan for Nuclear Development and Utilization of 1987, the JAEC did not explicitly state that the next demonstration reactor was indispensable. In the Long-term Plan of 1994, the JAEC officially noted for the first time the need for a 'second demonstration reactor' (Jisshoro Nigoro) and the reactor previously called as 'demonstration reactor' was renamed the 'first demonstration reactor' (Jisshoro Ichigoro) (JAEC,1994).

Although the JAEC did not officially indicate what the generating power of the 'second demonstration reactor' would be, and who its proprietor might be, it was commonly known that the generating power would be around 1000 MWe, and that the reactor would be owned by the electric power utilities. It will be necessary for the electric power utilities to cover most of the construction costs, because the national budget for nuclear development will be severely reduced. However, as in the case of the 'first demonstration reactor', the PNC will have a central role as an R&D laboratory.

It is useful to consider the relation between electric power utilities and the PNC in national projects. In Japan, all the tasks of nuclear development, including privately managed enterprises, are under the control of the JAEC. The JAEC is authorized to determine basic development plans of various kinds of nuclear facilities including the FBR. The Long-term Plan for Nuclear Development and Utilization, first announced in 1956 and thereafter revised at four to seven year intervals, has served to publicize the latest policy in various areas.

The JAEC makes decisions according to the principle of consensus among the promoters of nuclear development: namely, the electric-government league and the STA-group. Even though the STA controls the executive office of the JAEC, the STA cannot make any decisions without the agreement of the electric-government league. From the standpoint of the electric power utilities, the agreement of MITI and the STA is indispensable to their own projects. Of course, it is very difficult to decide termination of their projects.

For this reason, the 'privatization' of PNC's national projects are only of nominal significance (Yoshioka,1995). According to the basic plans of the JAEC, electric power utilities have to cover most development costs, and the PNC can continue R&D activity on the basis that it supports the development work of electric power utilities. In short, the development projects of the electric power utilities are essentially national projects under government control.

According to the Long-term Plan of 1994, the scheduled period of the establishment of technology for commercialization is around 2030. This can be interpreted to mean that the JAEC plans to complete construction of the 'second demonstration reactor' around 2030 (JAEC, 1994). Of course, there is no guarantee that the 'second demonstration reactor' will demonstrate sufficient technological reliability and economic competitiveness.

Change in the Global Tendency to Breed Plutonium

In addition to the decline of the prospects for FBR development, two other problems emerged in the early-1990s. One was the change in the global tendency to breed plutonium. Every advanced industrial nation other than Japan abandoned their plutonium breeding development programs, and the very rationality of this tendency has been proved by closer and critical inspection of the situation. The other problem is that the electric power utilities have refused to participate in national projects because they are not economically viable.

Since the beginning of research on the civilian use of nuclear power in the late-1940s, the final goal of nuclear development has been the completion of the 'plutonium economy'. The FBR has been called the 'dream reactor' because it can generate inexhaustible quantities of electric power. However, India's nuclear explosion test on May 17th, 1974 changed the U.S. policy on civilian use of plutonium. After a few years of political controversy, in June, 1978 the U.S. finally decided to discontinue the development of the Clinch River Breeder Reactor (CRBR, 380MWe). Even though European nations continued the FBR development program in the 1980s, by the end of 1994 first Germany and the the U.K. abandoned the the development of the prototype reactor, and France stopped using the demonstration reactor Superphenix as a plutonium breeder, and changed its role to that of a 'research reactor'.

After the end of the Cold War, we can

identify three global trends in military and civilian nuclear development: (1) balanced reduction in nuclear arms between the U.S. and the former Soviet Union, (2) the strengthening of the global nuclear non-proliferation regime, and (3) the abandonment of plutonium breeding development. These trends are closely related to each other. The nuclear arms reduction is absolutely necessary for the nuclear weapons states to persuade other countries to accept the non-proliferation regime. The non-proliferation regime cannot function effectively, as long as civilian use of plutonium continues to increase. Moreover, the problem of controlling and safeguarding plutonium has become more serious since the generation of surplus plutonium from dismantled nuclear warheads. Therefore, plutonium has become a burden in the global peacekeeping efforts. Considering the gloomy prospects of the commercialization of the FBR, the discontinuation of its development seems to make more sense than ever. From this analysis, we can conclude that the end of the Cold War dealt a fatal blow to plutonium breeding development in Europe.

In contrast with trends in Europe and the U.S., the Japanese government has promoted programs for the civilian use of plutonium, including FBR development. Until the early 1990s, Japan strived to catch up with American and European plutonium technology. But suddenly, the historical process lead to the state of 'international isolation' in Japanese plutonium policy.

This persistence by the Japanese government seems strange from the standpoint of rational policy makers. Moreover, Japanese plutonium policy has a negative influence on the establishment of an international nuclear non-proliferation regime. For this reason, Japan's plutonium policy has become a focal point of international political concern.

Not only has Japan increased its nuclear capacities sharply, but its action may also encourage others to follow. As long as the Japanese government persists in promoting an aggressive plutonium policy, the international community cannot deny the right of other nations to develop or introduce plutonium technology.

Concerned about this possibility, the Clinton administration in the U.S. began to emphasize the danger of diversion of such plutonium for military purpose, and requested the Japanese government not to produce surplus plutonium. It seems inevitable that the international community will keep an increasingly strict watch over Japanese plutonium policy. Even if the Japanese people themselves are not terrible concerned about the dangers of this 'international isolation' and the negative global effects of the aggressive development of sensitive nuclear technologies (SNT), the rest of the world has not lowered its guard.

Change in the Domestic Conditions of Plutonium Breeding

The other problem that surfaced in the Japanese plutonium breeding industry was that electric power utilities refused to co-operate in national projects because they weren't economically viable. Although the utilities had agreed to take over all the projects of the STA-group in the 1980s, they have had the potential to veto participation in national projects originated by the STA.

On July 11th, 1995, the Electric Power Utilities Union (Denjiren) exercised the power of veto for the first time in the history of nuclear development in Japan. It declared that it had decided to decline from participating in the construction program of the ATR demonstration reactor promoted by the Electric Power Supply Development Inc. (Dengen-kaihatsu) under the control of MITI. Although electric power utilities were not the proprietors of the demonstration ATR (606MWe), they had agreed to cover 30 % of its construction cost. (Another 30 % was to come from the national budget, and 40 % from the Electric Power Supply Development Inc.). With the withdrawal of the electric power utilities, the JAEC decided to discontinue the construction program in August 25th, 1995.

The reason for this decision by the electric power utilities was the unlikely success of the commercialization of the ATR. Because the ATR uses heavy water as a moderator, the size of the reactor is large compared to the LWR. Moreover, the cost of large quantities of heavy water is very high. According to an estimate by the Electric Power Utilities Union on March 1995, the construction cost of the demonstration ATR amounted to 580 billion yen (JAEC, 1996). The unit cost per watt is 957 yen/watt. This figure is 3.4 times larger than that of the latest LWR (282 yen/watt). Based on this figure, the unit generation cost for the first year of operation is estimated to be as 38 yen/kWh, whereas that of the latest LWR is only 12 yen/watt. Based on this calculation, electric power utilities refused to participate in the national ATR project.

How were the electric power utilities able to take such a strong stance? The reason was the sharp rise in the persuasiveness of economic rationalism. After the 1980s, and as the yen exchange rate increased rapidly, Japanese people become increasingly concerned about the inordinately high cost of commodities and services in Japan, including the price of electric power, compared to other countries. At the same time, the relaxation of excessive government restrictions began to be seen as the most powerful way to, not only relieve international trade tensions and economic frictions, but also to reduce the domestic prices of commodities and services.

Due to these circumstances, MITI began to investigate ways of revising the Electric Power Utilities Law in order to relax excessive government restrictions and improve the economic efficiency of the electric power supply industry. it was very important for MITI to make known the actual results of this investigation, and demonstrate the strong commitment of the Japanese government to promote the structural reform of the Japanese economic system. It was a very favourable climate for the electric power utilities to appeal to economic rationalism.

As the estimated cost of construction cost and fuel for the demonstration FBR will be much higher than that of the demonstration ATR, electric power utilities will almost certainly withdraw from the project. The other members of the Japanese Nuclear Development Community, notably the STA, will not be able to change the stance of the electric power utilities, for they approved the right of the electric power utilities to exercise power of veto, and also allowed the discontinuation of the ATR. This case was a precedent in nuclear policy decision making.

It will be very difficult for them to forbid electric power utilities from withdrawing from the project. To make matters worse, the proprietor of the demonstration FBR will be the Japan Atomic Power Company, which is controlled by the electric power utilities. This means that the electric power utilities have more authority to decide on the development of the FBR, than the ATR. The only way to save the FBR development project will be the transfer of its ownership from the electric power utilities to the STA. Although it will be very difficult to do so because of the limits placed on national budget expenditure, it will really be the avenue of last resort.

As discussed above, FBR development faced three major obstacles at the time preceding the the 'Monju' accident. Firstly, the prospects for the commercialization of the FBR were poor. Secondly, there was a rise of international concern about Japanese plutonium policy. Thirdly, the electric power utilities revolted on the grounds of economic rationalism. With the surfacing of these three problems, Japanese plutonium policy faced an unforeseen crisis. The government had to make a choice between two alternatives. One was sustained promotion, and the other was the abandonment of plutonium breeding.

The Impact of the Accident of 'Monju' on 8 December 1995

In the evening of December 8th, 1995, the prototype FBR 'Monju' suddenly began to leak sodium from its secondary cooling system. The sodium immediately reacted with oxygen in the air and started a fire. The quantity of leaked sodium was estimated by the STA to be about 700 kg. No damage or injuries from nuclear radiation occurred.

Nevertheless, this accident dealt a serious blow to FBR development in Japan. Moreover, the damage was further amplified by the PNC's attempt to conceal some significant parts of the videotape record of the accident that occurred. It was revealed that the PNC intended to keep secret the real damage and deceive the public into believing that the accident was not serious. They insisted at first that it was only an incident, not an accident.

This accident, together with the concealment affair, brought along two other major obstacles in Japan's to FBR development. The number of major difficulties obstacles from three to five. One of the additional obstacles was the widespread knowledge among Japanese that FBR lacked reliability and safety, compared to the conventional LWR. Another obstacle was the loss of trust in the PNC, or other such organizations who promote national projects while keeping certain information secret. The former is the result of the accident itself, and the latter stems from the attempt to conceal the facts of the accident.

Let us first analyse the technological dimension, and then review the organizational one. This accident strongly suggested that the FBR lacked reliability and safety. Among a number of other problems, the most difficult one is the prevention of sodium leakage. Metallic sodium reacts violently with air (oxygen) or water and can cause a fire. The experimental FBR 'Joyo' has so far never experienced a sodium-leakage, but 'Monju', like most electric power generating FBRs in the world, could not avoid this kind of an accident.

Until recently, the level of Japanese nuclear technology, including that of FBR technology, was said to be the highest in the world. The spokesmen for nuclear development propagated this myth on the grounds of (1) the excellent operational record of homemade LWRs and experimental FBR 'Joyo',and (2) the excellent reliability of high-tech goods and systems made in Japan in general. However, the 'Monju' accident revealed the fact that the design of the thermometers was faulty, and the PNC, STA and the Japan Nuclear Safety Commission(JNSC) could not find the defect.

All things considered, the technological level of Japan cannot be said to be the highest in the world, for the Japanese engineers have little experience in FBR design work. 'Monju' is the first power generating FBR in Japan. Moreover, with the collapse of the myth of the technological excellence of the Japanese FBR, it became clear that any nation could not necessarily overcome the technological difficulties related to the FBR.

The result will be very serious for the FBR promoters. With this accident the Japanese people now know that the FBR lacks the technological reliability and safety of the conventional LWR. People will strongly oppose the continuation of 'Monju'. If the PNC operates 'Monju' again, the acquisition of a site for the 'first demonstration FBR (660MWe), slated for construction by JAPCO, will be almost impossible. This is especially true given that the acquisition of new sites for conventional LWRs has been extremely difficult since the late-1960s.

To make matters worse, not only ordinary people but also the promoters themselves began to become concerned about the lack of technological reliability and safety of the FBR, compared with the conventional LWR. The fast breeder reactor has begun to be seen as a troublemaker, or more correctly a 'problem child', for the advancement of nuclear development as a whole. If sodium-leakage accidents or other accidents specific to the FBR occur hereafter, the trust that the entire nuclear development enterprise holds will be ruined. Until recently, the nuclear-powered ship 'Mutsu' was the main source of anxiety among promoters. But the FBR will take the place of 'Mutsu' sooner or later.

To maintain public confidence in nuclear power as a whole, it may be advisable to close down the FBR. If the majority of members of nuclear development community decide to do so, the STA and PNC will be isolated, and after a prolonged controversy, forced to accept the decision to discontinue FBR development.

In addition to the difficulty caused by technological problems, another problem surfaced that was brought about by the concealment affair. With this affair, the possibility of transfer of proprietorship of the 'first demonstration FBR' (660MWe) and the 'second demonstration FBR' (around 1000MWe) from JAPCO to the STA-group no longer existed. This means that the decision of electric power utilities to withdraw from FBR development automatically causes the end of FBR development in Japan.

If this concealment affair had not occurred, there would have remained only one way to save the FBR project: the PNC taking back the proprietorship. However, people's trust in the PNC was definitely lost due to the affair. The reorganization of the PNC will never be a solution, since the Japanese distrust not only the PNC, but also similar organizations who promote national projects veiled in secrecy.

All nuclear development organizations in the world have naturally represented a 'culture of secrecy', since they often are entrusted with militarily sensitive information. Of course, military or quasi-military organizations have followed the strictest codes of secrecy. But the civilian organizations who have dealt with Sensitive Nuclear Technology (SNT), notably plutonium-related technologies, have abided by the same codes and culture. The PNC is clearly the most qualified organization to handle plutonium in Japan.

Conclusion

As we have seen, the 'Monju' accident and the concealment affair caused serious damage to the FBR development project. The JAEC has freezed FBR development and has investigated counter-measures. It seems unlikely that the Japanese government will any longer be able to promote plutonium breeding development. Even if the PNC should reoperate the 'Monju', FBR 'demonstration reactors' will never be constructed. However, it is impossible to imagine that the JAEC will officially decide to discontinue the FBR development project in the near future. We can indicate two reasons for this.

Firstly, it is vital for the JAEC to get the approval of every major member of the nuclear development community involved, i.e. the STA, MITI, and the electric power utilities. But the STA will strongly oppose the decision of discontinuation. Because the decision making system of the government is highly 'decentralized', and every ministry or agency adheres to its own territory, it is impossible for the JAEC to force the STA to give up FBR development. Also, the executive office of the JAEC is the STA itself.

Mutual assistance among the members of a community is the leading principle of political decision making in Japan. At least theoretically, the Cabinet or the National Diet can decide to withdraw from FBR development. But under the 'decentralized' structure of political power and the culture of mutual assistance, this cannot occur. After several years of virtual moratorium in FBR development, the JAEC is likely to decide an 'indefinite freeze'.

Secondly, as decisions relating to the FBR project will effect commercial nuclear power generation, it is absolutely necessary for the electric-government league to keep any bad influences of FBR decisions from affecting the commercial enterprise. For example, electric power utilities are gravely concerned about potential difficulties in the management of nuclear waste and spent fuel. Plutonium breeding policy is closely connected with reprocessing policy, and reprocessing policy in turn has a close connection with nuclear waste and spent fuel policy. Therefore, unless they can make plans for the management of nuclear waste, they cannot afford to ask the JAEC to discontinue the

FBR development project. Accordingly, the best choice for electric power utilities is 'freezing' the program. For them, a rash decision to withdraw is not advisable.

From the standpoint of foreign observers, Japanese plutonium policy may be seen not only as unusual, but also as a threat to global security. Nevertheless, despite many difficulties in plutonium breeding, the Japanese government presently adheres to this line. Why is the Japanese government so fond of plutonium? Some observers conclude that Japan is preparing to go nuclear. However, this conclusion is unfounded. The greater part of the enigmatic behavior of Japanese government can be explained on the basis of three facts: (1) the peculiar dual structure of nuclear development, (2) the 'decentralized' structure of political power , and (3) the predominance of the culture of mutual assistance in political decision making.

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