The Present Status and Prospects of Nuclear Power Generation in Japan

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The nightmare of the Chernobyl nuclear power plant accident in the Soviet Union in April 1986 is still throwing gloom over the nuclear development programs throughout the world. The present article will deal with the nuclear power generation in Japan. The country has literally no natural resources, especially, considering energy resources, no coal, no oil, no gas, no uranium. The country will have to rely on nuclear power, including the fast breeder reactor. For energy independence I believe there is no other choice for Japan.

Japan looks very calm on the surface in the wake of the Chernobyl accident, mainly because the accident occurred in a Communist country on the other side of the earth, and Japanese mass communications did neither report the news extensively nor hysterically. Of course, in Japan there is a strong antinuclear feeling or rather a nuclear allergy and therefore we have to promote a nuclear power policy that clarifies the difference between the peaceful use of nuclear power and the construction of nuclear weapons.

We have achieved and are continuing to improve on a remarkable record of safety of nuclear power generation which is highly appreciated worldwide. The Soviet accident unfortunately drove the concerned Japanese nuclear industrial people into a corner, though it is unlikely that we could reproduce such an accident in Japan even by artificial means.

For Japan, as I have already suggested, nuclear power generation is a *must* and *no choice*. We cannot conceive of the possibility of such an accident as the Chernobyl failure judging from present Japanese procedures for licensing requirements and safety regulations associated with the construction of nuclear power generation facilities. If there are any facts from the accident which should be considered in the context of Japanese plants, they will be rigorously pursued to promote safer nuclear power generation.

Energy Status in Japan

As shown in *Fig.1* the energy supply situation in Japan has remarkable features of high dependence on oil and high percentage of imported energy sources, especially oil. In other words, the Japanese energy supply structure is far weaker than that of other leading countries of the world and in order to secure a stable energy supply, Japan, firstly, has to economize energy consumption and stabilize its energy supply struc-

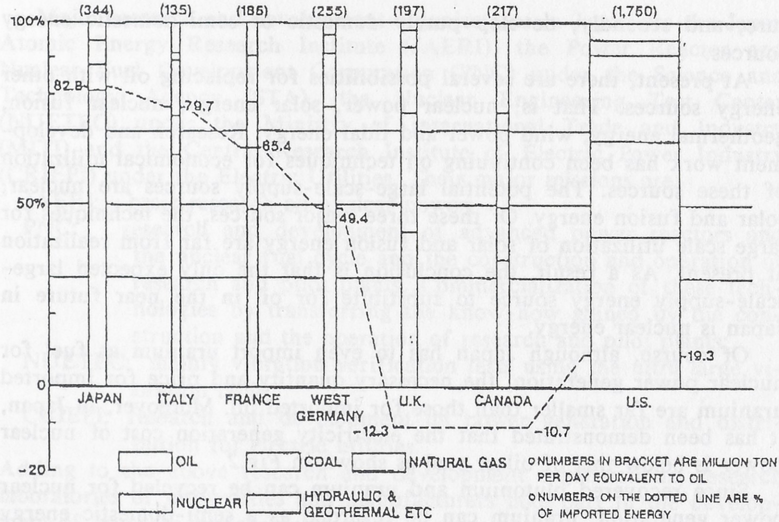

Fig. 1: Composition of the Primary Energy Supply in the Major Countries (1982)

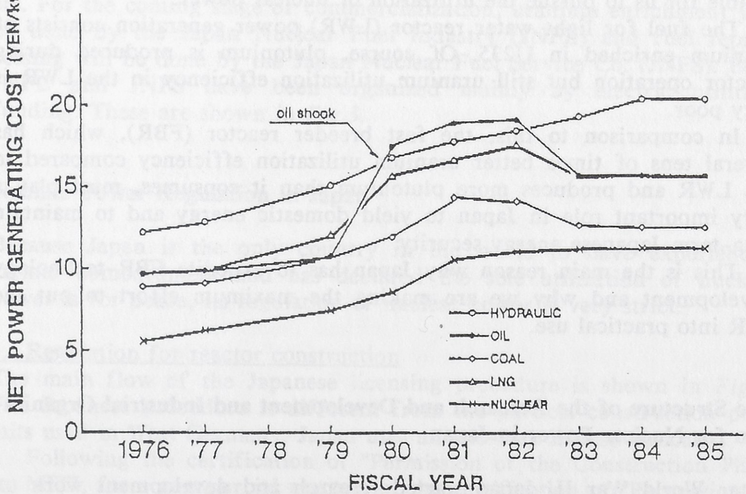

Fig. 2: Electric Power Generating Cost of Difference Fuels

ture, and secondly, develop purely domestic or semi-domestic energy sources.

At present, there are several possibilities for replacing oil with other energy sources. That is, nuclear power, solar energy, nuclear fusion, geothermal energy, wind power and tidal energy. Research and development work has been continuing on techniques for economical utilization of these sources. The potential large-scale-supply sources are nuclear, solar and fusion energy. Of these three major sources, the techniques for large scale utilization of solar and fusion energy are far from realization at present. As a result, the conclusion is that the only expected large-scale-supply energy source to substitute for oil in the near future in Japan is nuclear energy.

Of course, although Japan has to even import uranium as fuel for nuclear power generation, the necessary quantity and price for imported uranium are far smaller than those for imported oil. Moreover, in Japan, it has been demonstrated that the electricity generation cost of nuclear power is below that of oil or coal as shown in *Fig.2*.

Since recovered plutonium and uranium can be recycled for nuclear power generation, uranium can be regarded as a semi-domestic energy source in Japan. In addition, the main costs of nuclear electricity are investment costs, that means work which is provided mainly in Japan and is not imported. For the same reason, to keep a steady supply of economical energy to Japanese industries and public utilities, it is inevitable for us to pursue the utilization of nuclear power.

The fuel for light water reactor (LWR) power generation consists of uranium enriched in U235. Of course, plutonium is produced during reactor operation but still uranium utilization efficiency in the LWR is very poor.

In comparison to this, the fast breeder reactor (FBR), which has several tens of times better uranium utilization efficiency compared to the LWR and produces more plutonium than it consumes, must play a very important role in Japan to yield domestic energy and to maintain long-term Japanese energy security.

This is the main reason why Japan has to expedite FBR-technology development and why we are making the maximum effort to put the FBR into practical use.

The Structure of the Research and Development and Industrial Organisation for Nuclear Power in Japan

After World War II, Japan started research and development work on nuclear power in 1949. Since then, Japan has strived for the development and commercialization of nuclear power limiting its use to peaceful purposes.

Major research and development organizations in Japan are the Japan Atomic Energy Research Institute (JAERI), the Power Reactor and Nuclear Fuel Development Corporation (PNC) under the Science and Technology Agency (STA), the Nuclear Engineering Test Center (NUETEC) under the Ministry of International Trade and Industry (MITI) and the Central Research Institute of Electric Power Industry (CRIEPI) under the Electric Utilities. Their major missions are:

JAERI: basic research on nuclear power;

PNC: research and development of advanced power reactors and the nuclear fuel cycle and the construction and operation of research and pilot plants. Commercialization of these technologies by transferring the know-how gained by the construction and the operation of research and pilot plants;

NUETEC: mainly vibration verification tests using the ultra large vibration table;

CRIEPI: research and development on power generation and distribution for electric utilities.

Adding to the above research and development organizations, research laboratories of universities and manufacturers take part in the development of Japanese nuclear power.

Commercially, electric utilities play the major role in the construction and operation of nuclear power plants including the demonstration plants of advanced reactors. The LWR (light water reactor) fuel is manufactured by the companies established by the reactor manufacturers. For the coming stage of commercialization, uranium enrichment will be done by the Japan Nuclear Fuel Industry (JNFL) and fuel reprocessing will be done by the Japan Nuclear Fuel Service Co. (JNFS). Both JNFL and JNFS have been organized mainly by electric utilities' funding. These are shown in *Fig.3*.

Nuclear Power Regulation in Japan

Because Japan is the only country in the world to have experienced atomic bombardment and has declared the sole utilization of nuclear power is for peace, its regulation of nuclear power is very strict.

1. Regulation for reactor construction

The main flow of the Japanese licensing procedure is shown in *Fig.4*. The Japanese procedure is different from the partical construction permits used in West Germany. Japan uses an one-step license basically.

Following the certification of "Permission of the Construction Plan" by MITI, for a commercial reactor, or the certification of "Permission of the Design and Construction Method" by STA, for a research of development reactor, the reactor owner can start construction and preceed through to completion. However, in actual practice, there are several tens of other licenses and approvals which must be obtained between the planning stage and the start of commercial operation.

2. Safeguards

Research, development and utilization of nuclear energy in Japan are carried out only for peaceful purposes according to the provisions of the Atomic Energy Basic Act promulgated on December 9, 1955. Further, Japan has concluded Nuclear Energy Cooperation Agreements bilaterally with the United States of America, United Kingdom, Canada, Australia and France. In fulfillment of the above agreements, Japan ratified the Treaty on the Non-proliferation of Nuclear Weapons (NPT) on June 8, 1976. According to the provisions of Article III, 1 and 4 of the NPT, the Safeguards Agreement between the Government of Japan and the IAEA was concluded (signed on March 4, 1977, and became effective on December 2, 1977).

Responsible organizations for safeguards implementation in Japan are shown in *Fig.5*. Under the law and relevant regulations, the Science and Technology Agency (STA) is responsible for implementation of safeguards in Japan. Inspectors of the Safeguards Division carry out inspection activities by themselves or in the presence of IAEA inspectors. The IAEA shall implement its routine inspection activities through the observation of the inspection activities carried out by the Government of Japan. The Nuclear Material Control Center (NMCC) of Japan was established in April 1972, NMCC supports Governmental activities in the field of non-proliferation, especially, safeguards. Their roles are:

- Treatment of information of national accountancy (as a designated organization by the Japanese Government),
- analysis of samples taken by national inspectors and
- calibration and adjustment of inspection instruments.

1,038 man-days of IAEA effort were devoted to inspection activities in 1985. A half of them was for the Tokai Reprocessing Plant (TRP), where a continuous inspection was carried out. The quantity of the IAEA inspection activities has increased by approximately 20% every year for the past 6 years. The IAEA's inspection activities for the world were 7,700 man-days in 1985, and about 13% were for the PNC facilities. The expenses devoted by PNC for the safeguards activities were about two billion yen, that is 13 million dollars (at the 1986 rate of exchange). A quarter of the expenses was for the personnel. Two billion yen for the safeguards correspond to 2% of the non-construction PNC budget. This amount is believed sufficient to devote for safeguards. The manpower needed for the safeguards activities in all PNC facilities was 15,970 man-days (Nov.1984-Oct.1985). Supposing 250 workdays per year, that corresponds to an average of 65 persons work of full time on safeguards. In addition to that, 15 people worked for safeguards in the safeguards office at PNC head quarters. It is said that 80 persons in total worked exclusively for the safeguards. This is also believed suf-

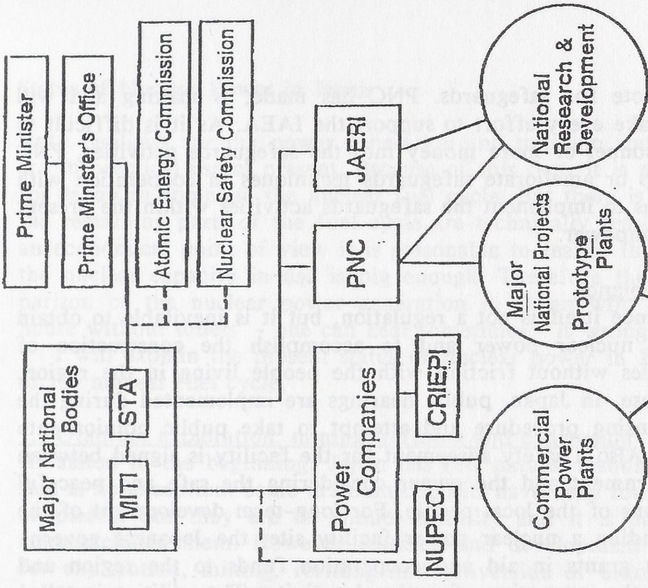

Fig. 3: Nuclear Industry Chart in Japan

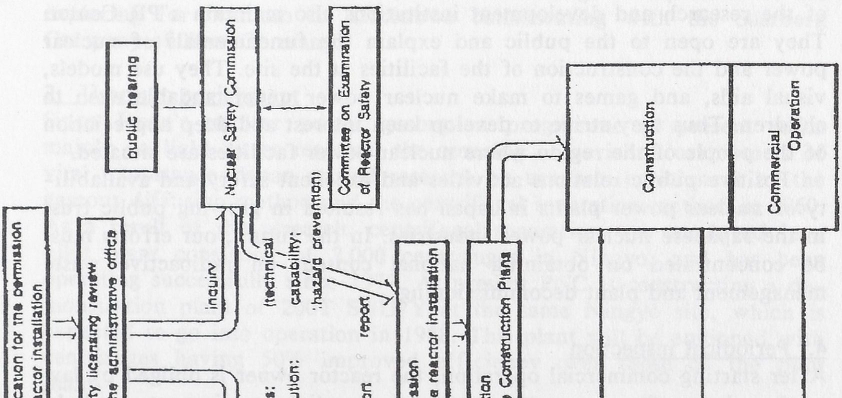

Fig. 4: Licensing Proceedure in Japan

ficient to devote for safeguards. PNC has made, is making and will continue to make every effort to support the IAEA. As it is difficult to put more personnel or more money into the safeguards activities, PNC should develop or ameliorate safeguards techniques in cooperation with the IAEA so as to implement the safeguards activities within the present budget and manpower.

3. Public acceptance

Public acceptance itself is not a regulation, but it is inevitable to obtain it to achieve nuclear power and to accomplish the construction of nuclear facilities without friction with the people living in the region. For this purpose, in Japan, public hearings are implemented during the course of licensing procedure and attempt to take public opinion into consideration. Also a safety agreement for the facility is signed between the local government and the owner considering the safe and peaceful living conditions of the local people. For long-term development of the region surrounding a nuclear power facility site, the Japanese government provides grants in aid and cooperation funds to the region and contributes to the promotion of regional activity. The utilities install a public-relations center (PR Center) at each power station site and most of the research and development institutions also maintain a PR Center. They are open to the public and explain the fundamentals of nuclear power and the construction of the facilities at the site. They use models, visual aids, and games to make nuclear power understandable even to children. Thus they strive to develop keen interest and deep appreciation of the people of the region where nuclear power facilities are situated.

Positive public relations activities and excellent safety and availability of nuclear power plants in Japan has resulted in growing public trust in the Japanese nuclear power industries. In the future, our efforts must be concentrated on obtaining national consent on radioactive waste management and plant decommissioning.

4. Periodical inspection

After starting commercial operation, the reactor owner is obliged by law to shut down after every 13 months of operation and inspect regularly the equipment and piping in general and in detail. For this inspection several months' shutdown of the plant is needed and therefore the availability factor of nuclear power generation in Japan can hardly improve over 70%. Therefore, our electric utilities are endeavouring to shorten the duration of the inspection to less than two months. We believe that this periodical thorough plant inspection plays an important part in the steady and safe operation of Japanese nuclear power plants.

Status of Nuclear Power in Japan

Only facilities for the power generation and uranium fuel manufacture are in practical use at present. Because of this fact, it is most important for Japan to complete the nuclear fuel cycle. But there is no doubt that the remaining parts of the fuel cycle are technically feasible, and from an economical point of view it is reasonable to realize these parts when the nuclear capacity in use is big enough. Therefore the critical comparison of the nuclear power generation in Japan with an "apartment house without toilets" - one can hear sometimes - is wrong.

I will explain the present status of nuclear power in Japan in stages of the nuclear fuel cycle.

1. Uranium exploration, mining, refining and conversion

As stated in the beginning, Japan has few natural resources, and uranium is no exception. Some uranium deposits have been found in a couple of places, but they are in minute quantity and it is not practical to commercialize them. However research and development of techniques for exploration, mining, refining and conversion of uranium are being implemented at the Ningyo Toge Works. Japan is also cooperating in uranium exploration world-wide, as shown in *Fig.6*. At present we are exploring for uranium in Zimbabwe collaborating with the Saarberg Company of West Germany.

2. Uranium enrichment

Since Japan's nuclear power generation programme at present relies mainly on light water reactors, the securing of enriched uranium is of vital importance. Japan started research on uranium enrichment by the gaseous diffusion method and the centrifugal separation method in 1960. As a result of the research, centrifugal separation was employed in a pilot plant consisting of 7.000 centrifuges in Ningyo, and has been operating successfully since 1977. At present PNC is constructing a demonstration plant of 200T SWU/Y at the same Ningyo site, which is expected to go into operation in 1988. This plant will be equipped with centrifuges having 50% improved efficiency over those of the pilot plant.

To realize a sharp reduction of enrichment cost, we are now developing a centrifuge which utilizes carbon fiber reinforced plastics (CFRP).

3. Fuel fabrication

Fuel manufacture and assembly for light water reactors, that is, enriched uranium fuel manufacture and assembly are made on a commercial basis by private industries in Japan. The plutonium fuel manufacture and assembly is undertaken by the research and development company PNC at "Tokai", from the point of view of non-proliferation, and since the required quantity is very small. Because the plutonium is used as oxide and mixed with uranium oxide this fuel is called mixed oxide fuel or shortly MOX fuel. The MOX fuel subassemblies developed and produced in Japan have proven their high quality.

At Tokai at present, a new plutonium fuel manufacturing facility is under construction for producing both FBR (fast breeder reactor) and ATR (advanced thermal reactor) MOX fuel. The 5 ton MOX/Y FBR fuel plant will be completed in 1988 and the 40 ton MOX/Y ATR fuel plant will be completed by 1991. These two plants are automated and are the most modern in the world.

Considering the situation in Germany where ALKEM right now still has an advantage and a development lead with respect to MOX fuel element production we are convinced to close this gap in a few years.

4. Reactors for power generation

a) Light water reactor (LWR)

In the early stages, i.e. the latter half of the 1960s, commercial LWRs were imported mainly from General Electric and Westinghouse of the United States and have been in service since 1975. Thereafter, nuclear power generation increased. In 1985, 32 nuclear units generated a total capacity of 24,500 MW, which is 26.3% of all electricity generation in Japan. Remarkable improvement of Japanese LWR nuclear power generation draws the world's attention. Especially, shortening of the construction times and improvement of the availability factor are worthy of special attention. Results of availability improvement are shown in *Fig.7*. The BWR plants suffered SCC problems during the period 1975 to 1977, and PWR plants suffered from the TMI accident in 1979. These circumstances caused the availability factor to drift below 60% between 1975 and 1979, but after 1980, intense effort by Japanese industry brought about a significant improvement. As shown in *Fig.7*, availability has recently improved to a level above 70%. *Fig.8* shows the numerical record of forced outages and scram incidents per unit, which was only 0.6/unit in 1985.

The reason why the availability factor in Japan remains at approximately 70% and will not increase without difficulty, is that by law, each reactor unit must be inspected every thirteen months. Nowadays, all the electric power companies in Japan are trying to reduce the duration of the inspection period to 2 months, whereas 3 to 4 months was needed in the past.

Since, firstly, the availability factor of LWR has steadily increased, secondly, stable operation has been successfully accomplished, thirdly, data based on the results of annual inspections of each unit has been accumulated, the Ministry of International Trade and Industry (MITI) of Japan considers that enough latitude exists to extend the interval between annual inspections and take this ex-

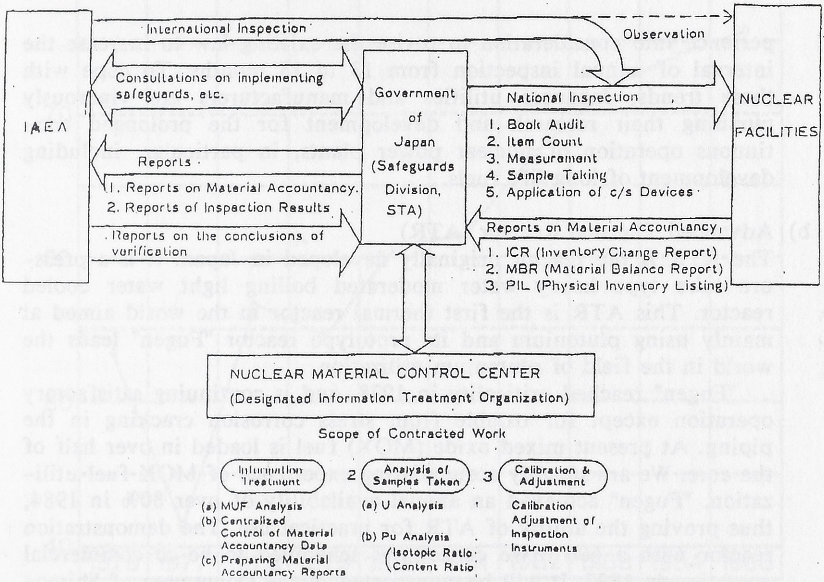

Fig. 5: Safeguards System in Japan

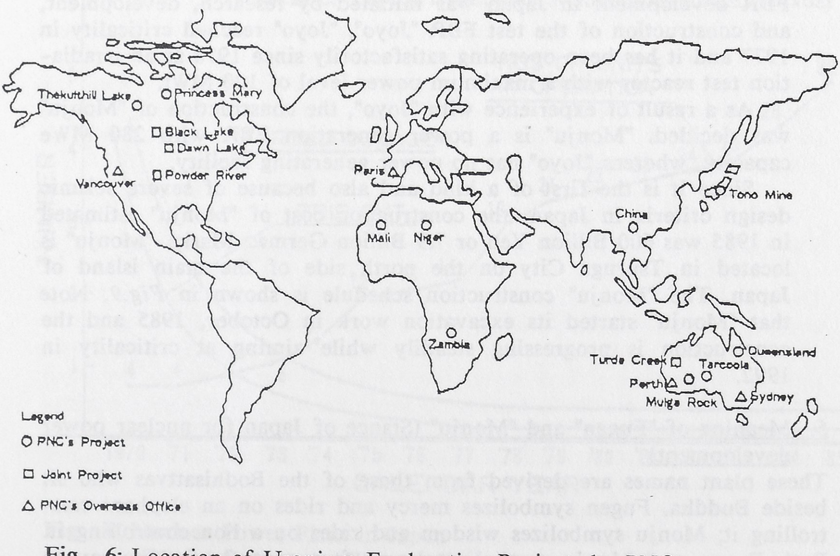

Fig. 6: Location of Uranium Exploration Projects by PNC

perience into consideration to revise the existing law to increase the interval of annual inspection from 13 to 18 months. To cope with these trends, Japanese utilities and manufacturers are vigorously pursuing their research and development for the prolonged continuous operation of nuclear power plants, in particular, including development of long life fuels.

b) Advanced Thermal Reactor (ATR)
The ATR is the reactor originally developed in Japan. It is a pressure tube type heavy water moderated boiling light water cooled reactor. This ATR is the first thermal reactor in the world aimed at mainly using plutonium and its prototype reactor "Fugen" leads the world in the field of plutonium utilization.

"Fugen" reached criticality in 1978, and is continuing satisfactory operation except for trouble from stress corrosion cracking in the piping. At present mixed oxide (MOX) fuel is loaded in over half of the core. We are steadily accumulating experience of MOX fuel utilization. "Fugen" achieved an annual availability of over 80% in 1984, thus proving the ability of ATR for practical use. The demonstration reactor with a 606 MWe capacity is scheduled to be in commercial operation in 1997. It will be constructed in the Ooma area of Shimokita Peninsula which is at the north end of the main island of Japan.

c) Fast Breeder Reactor (FBR)
FBR development in Japan was initiated by research, development, and construction of the test FBR "Joyo". "Joyo" reached criticality in 1977 and it has been operating satisfactorily since 1978 as an irradiation test reactor with a maximum power level of 100 MWt.

As a result of experience with "Joyo", the construction of "Monju" was decided. "Monju" is a power generation FBR with 280 MWe capacity, whereas "Joyo" has no power generating facility.

Since it is the first of a kind and also because of severe seismic design criteria in Japan, the construction cost of "Monju" estimated in 1985 was 600 Billion Yen or 7.9 Billion German Marks. "Monju" is located in Tsuruga City on the north side of the main island of Japan. The "Monju" construction schedule is shown in *Fig.9*. Note that "Monju" started its excavation work in October, 1985 and the construction is progressing steadily while aiming at criticality in 1992.

5. Meaning of "Fugen" and "Monju" (Stance of Japan for nuclear power development)

These plant names are derived from those of the Bodhisattvas who sit beside Buddha. Fugen symbolizes mercy and rides on an elephant controlling it; Monju symbolizes wisdom and rides on a lion controlling it. Both Fugen and Monju symbolize the perfect control of these savage

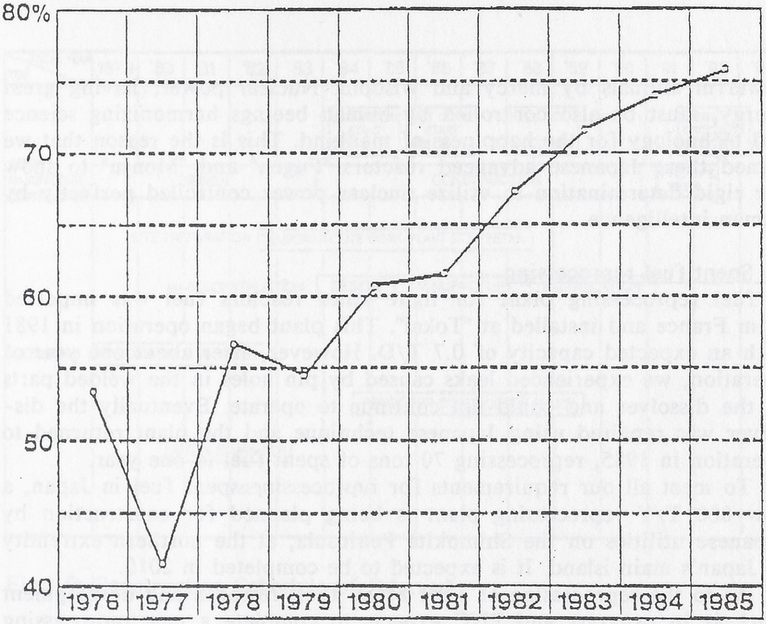

Fig. 7: Plant Operation Capacity Factor in Japan

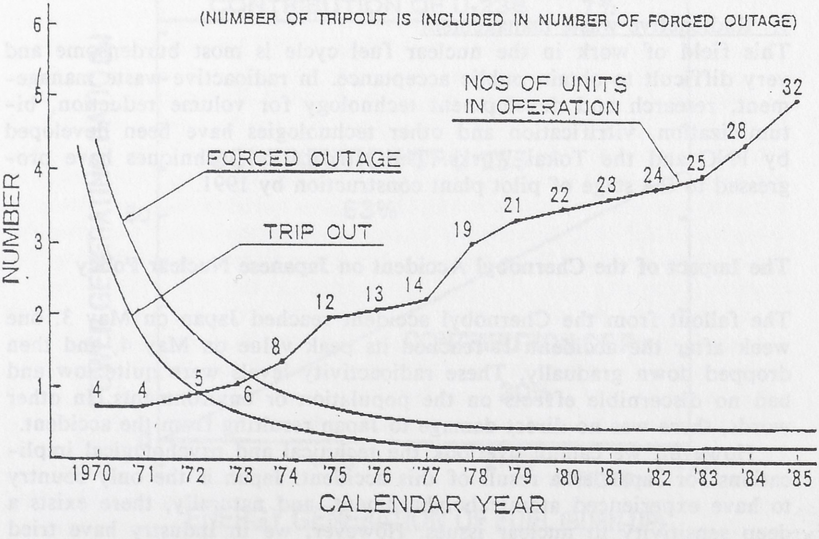

Fig. 8: Nuclear Power Plant in Japan –
Forced Outage and Tripout/Unit/Year

powerful animals by mercy and wisdom. Nuclear power, having great energy, must be also controlled by human beeings harmonizing science and technology for the happiness of mankind. This is the reason that we named these Japanese advanced reactors "Fugen" and "Monju" to show our rigid determination to utilize nuclear power controlled perfectly by human intelligence.

6. Spent fuel reprocessing

A fuel reprocessing plant for light water reactors fuel was imported from France and installed at "Tokai". This plant began operation in 1981 with an expected capacity of 0.7 T/D. However, after about one year of operation, we experienced leaks caused by pin holes in the welded parts of the dissolver and could not continue to operate. Eventually the dissolver was repaired using Japanese technique and the plant returned to operation in 1985, reprocessing 70 tons of spent fuel in one year.

To meet all our requirements for reprocessing spent fuel in Japan, a new 800 T/Y reprocessing plant is being planned for construction by Japanese utilities on the Shimokita Peninsula, at the northern extremity of Japan's main island. It is expected to be completed in 2010.

As to the reprocessing of FBR MOX fuel, research and development work is in progress and PNC expects to complete a new reprocessing facility by 1995 with a capacity of 15 T/Y relying on experiences with the Tokai-Plant and our development.

7. Radioactive waste management

This field of work in the nuclear fuel cycle is most burdensome and very difficult to obtain public acceptance. In radioactive waste management, research and development technology for volume reduction, bituminization, vitrification and other technologies have been developed by PNC and the Tokai Works. The vitrification techniques have progressed to the stage of pilot plant construction by 1991.

The Impact of the Chernobyl Accident on Japanese Nuclear Policy

The fallout from the Chernobyl accident reached Japan on May 3, one week after the accident. It reached its peak value on May 4, and then dropped down gradually. These radioactivity levels were quite low and had no discernible effects on the population or environments. In other words, there was no direct damage to Japan resulting from the accident.

However, we cannot overlook the technical and psychological implications for Japan as a result of this accident. Japan is the only country to have experienced atomic bombardment, and naturally, there exists a deep sensitivity to nuclear issues. However, we in industry have tried over the past 30 years to encourage the public to accept the aspect of nuclear power being used for peaceful purposes and deepen their re-

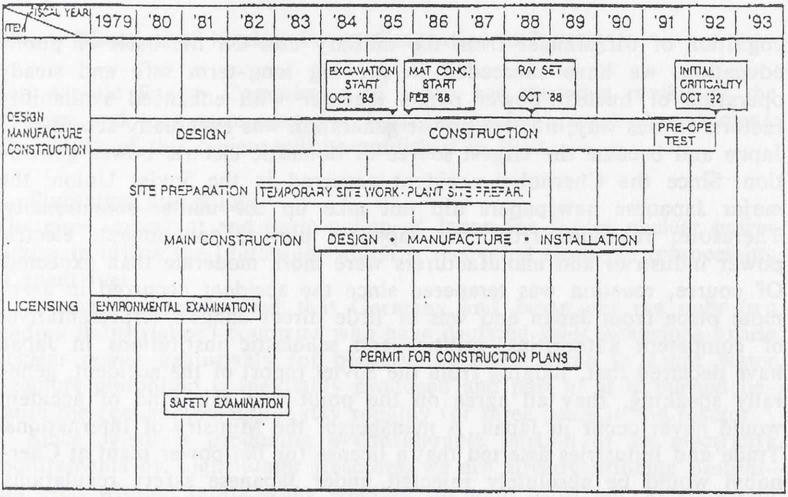

Fig. 9: Construction Schedule of "Monju"

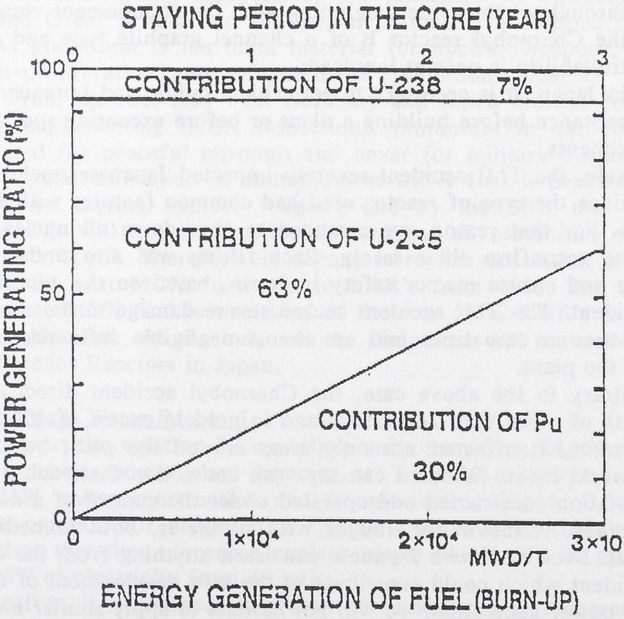

Fig. 10: Generation Energy Source of LWR

cognition of differences from the military use. On the basis of public education, we have succeeded in proving long-term safe and steady operation of nuclear power plants together with enhanced availability factors. In this way, nuclear power generation was eventually accepted in Japan and became the largest source of domestic electric power generation. Since the Chernobyl accident occurred in the Soviet Union, the major Japanese newspapers did not take up the matter sensationally. Therefore, reactions from the Japanese public, government, electric power industries and manufacturers were more moderate than expected. Of course, reaction was tempered since the accident occurred in a remote place from Japan and was of little direct danger. Representatives of competent authorities, utilities and scholastic institutions in Japan have declared that, judging from the Soviet report of the accident, generally speaking, they all agree on the point that this kind of accident would never occur in Japan. A manager of the Ministry of International Trade and Industries asserted that a license for the power plant at Chernobyl would be absolutely rejected under Japanese safety regulations. Essential differences between Chernobyl and the Japanese style of nuclear power plants as pointed out by Japanese experts concerned are:

- Japanese plants have comprehensive redundant protection throughout the cycle, beginning with the containment vessel;
- the Chernobyl reactor is of a channel graphite type and its controllability is poor at low load;
- in Japan, it is necessary to get critical public and bureaucratic acceptance before building a plant or before executing special experiments.

Conversely, the TMI accident severely impacted Japanese nuclear power plants since the type of reactor used had common features with Japanese reactors. For that reason, we arranged to shut down all nuclear power plants to reconfirm their safety. Back-fitting was also undertaken to enhance and ensure reactor safety in Japan, based on the experience of the accident. The TMI accident caused severe damage to the reactor but there were no casualities and an almost negligible influence was felt outside the plant.

Contrary to the above case, the Chernobyl accident directly caused the death of more than 28 persons and injured in excess of 200 persons. Furthermore, it affected not only areas around the plant but also the whole world by its fallout. I can say with conviction that such a nuclear power station constructed and operated under the control of a dictatorial bureaucracy, is inevitably fraught with problems, both immediate and potential. Even so, if we Japanese can learn anything from the Chernobyl accident which could contribute to the safe development of our own nuclear power generation, we will not hesitate to apply similar measures.

Future Direction of Nuclear Power Generation in Japan

The Atomic Energy Commission of Japan has started a review of the medium and long-term plan for Japanese nuclear power development. The results of this review will be published in 1987.

1. Plutonium utilization

The most important and basic policy of Japan for future nuclear power is how to utilize the plutonium which is recovered from the reprocessing of spent fuel.

It must be emphasized that Germany and Japan are the only two leading industrialized countries who have declared their intensions to use nuclear power exclusively for peaceful purposes. Even in Light Water Reactors plutonium is inevitably produced and part of it is burned because the fuel subassemblies stay roughly for three years in the reactor.

Since Japan is producing a considerable portion of its electricity requirements by Light Water Reactors, we are already utilizing plutonium even without reprocessing whether we want to or not, as shown in *Fig.10*. In Japan, spent fuels are reprocessed with the intention to utilize the plutonium which has been recovered by reprocessing. About 70 T/Y of spent fuel are being reprocessed, the remainder is reprocessed in France and Great Britain and the gained plutonium is shipped back to Japan. As plutonium is the main material for nuclear weapons, therefore non-proliferation and safeguards of plutonium must be doubly assured. From the fact that West Germany and Japan are the countries perfectly implementing IAEA inspections, plutonium in our countries will be used for peaceful purposes and never for military purposes. At present, regular utilization of plutonium as MOX fuel is performed by the advanced thermal reactor "Fugen", and by the FBR test reactor "Joyo". But it will not be possible to consume all plutonium only by "Fugen" and "Joyo". Therefore, in Japan, to realize utilization of MOX fuel, we will start MOX fuel tests in LWR's from 1986. The utilities expect to use MOX fuel in one third of the core of 12 LWR's as shown in *Fig.11*. However, on the long run the plutonium will be used mainly in Fast Breeder Reactors in Japan.

2. LWR (Light Water Reactor)

In addition to the existing 32 operating units providing 24,500 MW of operating nuclear power plant capacity, we have 10 units amounting to 10,000 MW under construction and 6 units amounting to 6,300 MW under preparation for construction. These units will be completed by 1995 and at that time, Japanese nuclear power plants will be providing 40,000 MW of electricity from 48 units.

Thereafter, it is planned, in present circumstances, to construct each year nuclear units comprising 1,500-2,500 MW. Among these units, there will be reactors having improved uranium utilization efficiency at less cost, at this cost including improved light water reactors and advanced thermal reactors.

3. ATR (Advanced Thermal Reactor)

For ATR, the demonstration plant "Ooma" of 606 MWe, which is the follower of the prototype "Fugen", is expected to start commercial operation by 1997. After "Ooma", it is planned to construct appropriate numbers of ATR units to keep the plutonium balance until the 2020s when the FBR (Fast Breeder Reactor) is expected to be commercialized.

4. FBR (Fast Breeder Reactor)

In FBR, the prototype "Monju" suffered considerable delay from its original plan. However, the schedule has been fixed and the construction is proceeding on schedule aiming at reaching criticality by 1992. Because of the low current price of uranium, the slump in oil prices and the sudden rise of the value of the Yen, the energy crisis has notably relaxed in Japan. This situation could last for some time. In these circumstances, the Fast Breeder Reactor commercial realization with a considerable number of Fast Breeder Reactors will probably occur around 2030. But to cause no doubts it must be said that the corresponding development continues steadily with high efforts. One or two demonstration plants will be built by 2020, when commercialization of FBR is expected. We must establish FBR technology and cost competitiveness with the LWR.

5. HTR (High Temperature Reactor)

High Temperature Reactor can supply high temperature heat of 1,000 C, therefore the pursuation of its research and development is quite significant in the field of utilization of nuclear power other than electricity generation. A report regarding the way to pursuade the research and development of High Temperature Reactor in Japan was submitted to the Atomic Energy Commission from the Technical Investigation Committee of High Temperature Reactor in August 1986, that is, for the first step, a test reactor should be constructed as soon as possible which will have 30 MWt output, 800 C outlet temperature and ability to irradiate materials.

In Germany, a pilot plant of High Temperature Reactor of 300 MWe is already in operation. Germany is far ahead of Japan in High Temperature Reactor technology. Therefore, Japan has to ask Germany for guidance in this field of technology. In this sense Japan's policy is to advance the international cooperation positively with Germany and United States in this field.

6. Nuclear fuel cycle

Following the described development work, Japanese utilities have decided to construct three nuclear facilities, for enrichment, reprocessing and low-level waste management, on the Shimokita Peninsula. These facilities will be completed by 2010. Then, at that time, Japan's fuel cycle will be closed.

For the vitrification of high level liquid waste, Japan decided to develop the same type of method as West Germany, the Liquid-Fed Ceramic Melter (LFCM). It is expected the pilot plant will be completed in 1991. To promote the research and development of high-level waste management, it is planned to establish a storage technology center in Hokkaido (Japan).

7. <u>International cooperation</u>

For Japan, it is inevitable to promote the nuclear power generation with utmost efforts, establish the fuel cycle and commercialize the FBR for the achievement of Japan's ultimate goal, that is, the establishment of self-sufficiency and security of energy.

Of course, in order to achieve the above goal, it is also inevitable for Japan to cooperate internationally. This is neccessary for accelerating the speed of development by sharing accumulated experiences.

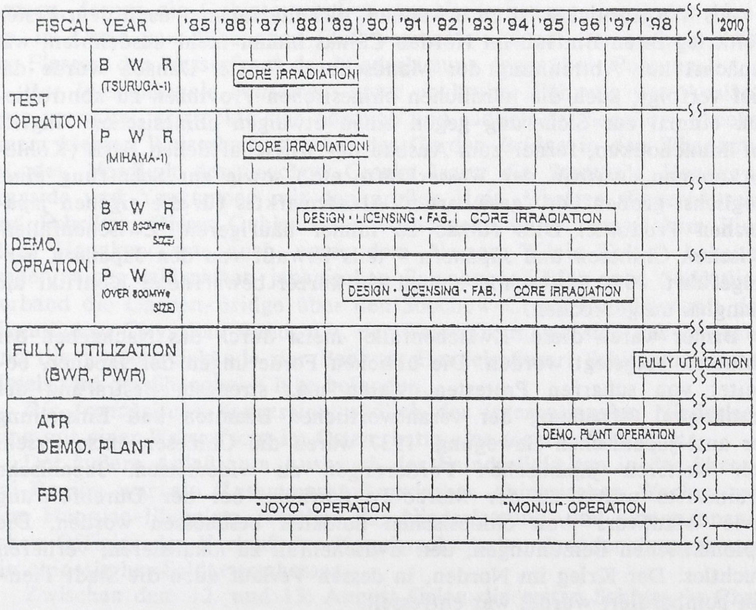

Fig. 11: Plutonium Utilization in Japan