the door to new worlds

Tasaburo Yamada, a Commissioner of the Japan Atomic Energy Commission, described in a scientific lecture to delegates to the Fourteenth General Conference the growing contribution which atomic energy is making toward meeting the needs of his country. A shortened version of his address is published here.

Mr. Yamada began by stating the obvious: that, as he said, "the development and utilization of atomic energy will open new worlds to man." Radiation techniques were being used increasingly for a number of purposes, and the development of power generation using nuclear energy was continuing in advanced and in developing countries.

"Furthermore, not only are such applications as nuclear merchant ships, radiochemistry, irradiation of foods and so on under way, but atomic power is about to have new applications in the desalination of sea water, iron and steel production, and the chemical industry," he continued. In all this work, it was necessary to set long-range objectives, based on estimates of developments in the economy and society, to make long-range programmes for the education and training of scientific personnel and the technological developments necessary to achieve the objectives — and, as the programme developed, to modify them to meet changes in conditions both at home and abroad.

Commissioner Yamada, speaking at the Fourteenth Session of the General Conference.

Photo: IAEA/Preuschl

Japan started work in earnest on the development of atomic energy in the mid-1950s, when the Atomic Energy Basic Law was established to promote the development and use of atomic energy for peaceful uses only. An Atomic Energy Commission was set up to carry out national policy. Accordingly, the first long-range programme was prepared in 1961; it was revised in 1967 to the form in which it exists today.

Mr. Yamada's theme was "integrated atomic power programmes," but, as he pointed out, every country has different political, economic, technological and geographical conditions. Naturally, each country develops atomic energy with emphasis on different points. "But it is also true that we are facing many common problems in the course of the development of atomic energy," he said. "From this point of view, I hope my lecture will be somewhat useful..."

The revised programme now set for Japan lays down objectives for the use of nuclear power and its development in years to come, and long-range plans accordingly. The government's budget is drawn up with this programme in mind. "But it also serves as a guidepost to private industry, academic circles and the nation as a whole," said Mr. Yamada. "Private industry is voluntarily pushing forward industrialization of atomic energy in line with this long-range programme, and the government takes measures to support it in its efforts."

Revising the plans

Mr. Yamada pointed out that in the past decade Japan has attained an economic growth rate averaging about 12 per cent a year. Only a stable and cheap supply of energy could sustain this economic activity. Energy consumption in Japan showed a similar rate of increase — 11.6 per cent, for example, from 1955 to 1967 each year on average.

"The gross energy demand forecast for our country, made in 1967 when the current long-range programme for the development and utilization of atomic energy was established, indicated that it would reach 3 400 trillion Kilocalories in 1975 and 5 980 trillion Kcal in 1985," he said. "However, according to the most recent forecast, it is considered

that it will be 4640 trillion Kcal in 1975, an increase of 36 per cent, and 9980 to 10 940 trillion Kcal in 1985, an increase of 67 to 83 per cent.

"Due to such increases in the estimated gross energy demand, the possibilities for atomic energy are increasing tremendously. In the present long-range programme atomic power installations in 1975 are indicated in capacity as 6 000 MW and in 1985 as 30 000 — 40 000 MW in capacity, but capacity is now expected to increase at a significantly greater rate, reaching 8 660 MW in 1975 and 60 000 MW in 1985. It is assumed in the light of this new estimate that atomic energy will account for 2 per cent of the actual gross energy consumption in 1975, and for about 10 per cent in 1985, although it took only 0.1 per cent in 1968.

"Furthermore, as to the percentage of our total nuclear power production, it will account for 8.3 per cent in 1975 and 33—36 per cent in 1985, while it was only 0.3 per cent in 1969."

Just as it must for petroleum, Japan must import most of its supplies of nuclear fuel from abroad. "But there are advantages relating to inventories in and out of pile, and ease of transportation and storage when compared with petroleum," he pointed out. "And more effective utilization can be expected with the development of advanced types of power reactors, especially the fast breeder reactor which converts Uranium-238 contained in most uranium sources into plutonium, another source material of nuclear fuel. Atomic energy is considered to be a semi-domestic energy source. In addition, as nuclear power generation becomes more economical than conventional power generation with the progress of research and development, its development will be pushed ever more."

Mr. Yamada referred to the growing public concern, world-wide, about the pollution of the air man breathes which may be caused by conventional power stations, among other sources. "I am sure," he affirmed, "that the introduction of nuclear power stations will be a most effective measure for the prevention of air pollution."

So far, he recalled, the development of atomic energy had been studied from the point of view of power generation. But as progress in practical use increased, and the economic advantages to be gained from the use of atomic energy became better understood, its use in industries consuming large amounts of energy had also been studied to determine profitability; demand for its application to industrial processes was thus increasing.

"The forecast for energy requirements does not take into consideration the effect of technical innovations in the future," Mr. Yamada pointed out. "For this, the percentage of the energy supply accounted for by atomic energy will have to be increased rapidly.

"The large-scale introduction of atomic energy into the power generation system and its utilization in other fields have reached a new stage. As a result, it is becoming more essential in the development and utilization of atomic energy to establish the fuel cycle to make possible increased atomic power generation, and to expedite research and development of its practical use in new fields. Now, I am of the opinion that the long-range programme for development and utilization should be revised from fresh points of view, considering projections for energy

demand greater than those assumed previously, present aspects of progress in nuclear power generation, and the demand for it in new fields."

The present, the future

There are already in Japan the Tokai power station, of the Magnox type with an output of 166 MW, which came into operation in 1967; and the Tsuruga power station, of the BWR type with an output of 331 MW, which came into operation on schedule in March this year. Mr. Yamada said it was expected that the Fukushima power station, also of BWR type with an output of 460 MW, and the Mihama power station of PWR type with an output of 340 MW, would come into operation on schedule late this year. Five LWR power stations, with a total output of 3 350 MW, were under construction.

With the expected increase in nuclear power generation — up to 60 000 MW in 1985 — "the amount of natural uranium needed and the separation work required for enriched uranium is tremendous," he said. "Therefore, putting advanced thermal converters and fast breeder reactors into practical use is considered particularly desirable and consequently their development is being promoted as a national project." It was planned to bring fast breeders into use in the latter half of the 1980s on present plans. Development of a thermal reactor of heavy water moderated, boiling water-cooled natural uranium fuelled type, with plutonium generated recycled — which it was considered possible to develop quickly and was expected to make more efficient use of nuclear fuel, thus reducing the national requirement for enriched uranium — was under way. The target was to bring this into operation in the latter half of the 1970s.

By the introduction of these two types of reactor to the power generation system, it was expected that cumulative natural uranium requirements of 450 000 tons for nuclear power generation up to the year 2000 using light water reactors alone would be capable of reduction: by 20 to 40 per cent by the introduction of the advanced converter reactor only, by 30 per cent by introducing the fast breeder reactor only, and by 40 to 50 per cent by using both. The effect of the use of the advanced converter reactor on uranium requirements was greater up to about the year 2000, but the effect of the use of the fast breeder would be greater after that year. It was expected that by using such advanced types of reactors the amount of separative work required for uranium enrichment would be reduced as much as the natural uranium requirements.

The problem of supply

Japan would need about 18 000 short tons of natural uranium by 1975, and as much as 116 000 short tons by 1985. Against this, uranium ore reserves found in Japan so far were just 7 000 short tons (calculated as uranium). Thus, the problem of how to secure the necessary quantities of uranium was very important. To solve it, long-term procurement contracts, short-term procurement, and prospecting were combined to

assure stable and long-term overseas uranium supplies. Private power utility companies had already secured about 32 000 short tons under long-term procurement contracts, and about 2 000 short tons under short-term procurement contracts; and prospecting in foreign countries was under way in cooperation with foreign enterprises. But much more uranium would have to be assured.

Nevertheless, "considering the remarkable increase in demand for enriched uranium in the future, it is not desirable to depend on foreign countries alone for supply in many years to come, from the standpoint of stabilizing the supply," Mr. Yamada continued. "It is necessary to push forward the research and development of uranium enrichment along with the development of advanced thermal reactors and fast breeder reactors which do not require enriched uranium."

Mr. Yamada pointed out that enrichment technology was still classified, although enrichment using the gaseous diffusion process had been carried out in a number of countries. "In 1969 we decided to carry out research on enrichment using a Specified Integrated Research Programme for Atomic Energy," he said, "studying both the gaseous diffusion process and the centrifuge process, and to clarify various problems in technology within the next one or two years. When uranium enrichment is carried out on an industrial scale in the future a matter for consideration will be whether the plant scale should be limited, to cover only a part of the domestic needs for enriched uranium, or enough to cover all of them, or whether it is appropriate to consider the possibilities of making the enrichment service available to foreign countries."

Solving the problems of wastes

A second element in the fuel cycle which Japan has considered important for some years is the chemical reprocessing of spent fuel, for which a plant is to be built "as necessary to keep pace with the increasing use of atomic energy. The building of No. 1 plant with an annual throughput of 210 tons is to be commenced this year by the Power Reactor and Nuclear Fuel Development Corporation, with the target of commencing operation around 1973," he said. According to the projections for the development of atomic energy mentioned previously, the amount of spent fuel will reach 660 tons by 1980 and 1500 tons by 1985. This implies that it will be necessary to build No. 2 plant shortly after No. 1 is completed...

"On account of Japan's small land area and dense population, environmental problems are of first importance in the consideration of the reprocessing process for spent fuel. The need for carrying out research and development of the dry process for the purpose of reducing the amount of liquid waste is understood."

Japan, like all countries with developing nuclear programmes, faces the problem of disposing safely of waste. Mr. Yamada described the magnitude of his country's problem. "Calculated on the basis of development prospects for nuclear power generation in Japan, low and middle level waste both of liquid and solid from nuclear power stations in 1980 will amount to 5 000 cubic metres in quantity, and 28 kilocuries in radioactivity," he said. "The radioactivity from the reprocessing plant

will amount to 3000 cubic metres of liquid and solid wastes of middle level, at one kilocurie, and 700 cubic metres of high and very high level waste at 270 000 kilocuries.

"It is a matter of great importance to decide how to treat and dispose of such a vast volume of radioactive waste. We have started the study of the problem of the handling and disposal of waste, and will continue research and development on techniques to solve these problems."

He recalled that disposal of low and intermediate level wastes deep in the ocean was to be discussed internationally in connection with the preservation of the marine environment, and with the development and use of the oceans in future. For the long-term storage of wastes of high activity it was necessary to set up a satisfactory system for safe treatment and storage for more than a thousand years.

Promoting domestic industry

"Our technology for the construction of nuclear power stations is far behind that of countries such as the USA and the United Kingdom, as we started the development and utilization of atomic energy later than them," Mr. Yamada admitted. "Therefore, while private enterprises are carrying out research and development for power reactors by themselves as well as introducing manufacturing technology from abroad to accelerate their domestic production, our government has to assist their efforts... There are five nuclear industry groups in our country, each consisting of nuclear fuel manufacturers and instrument manufacturers, manufacturers of materials, business firms and banks, and each having electrical machinery manufacturers as its nucleus. The manufacturers of electric products or of nuclear fuel are introducing the necessary technology from abroad, and are co-operating on research and development, as well as coordinating their activities to promote the nuclear industry in Japan.

"We have taken some measures not only in connection with the financial and tax system, relating to the activities of private enterprises for the purpose of fostering a sound nuclear industry, but also such as access to the results of research done at governmental institutes for research, all for the purpose of improving the technical foundation of private enterprises."

He pointed out that technically advanced countries such as the USA and UK have conducted a tremendous amount of research and development concerning the use of nuclear energy for military purposes, and had been able to use some of the results of this work for peaceful purposes. "Naturally, we are not in a position to expect such spin off. As it is, the system for manufacturing nuclear power reactors domestically has been built up by the efforts of private enterprise plus the government's incentive measures."

At first, the prime contractor had always been an overseas manufacturer, and Japanese manufacturers had been sub-contractors. Now, three domestic manufacturers were able to act as prime contractors for light-water reactors; and in some cases the percentage of locally-produced machinery used in power reactor installations was as high as 90 per cent.

A nuclear fuel fabrication plant had been completed this year as a joint venture between foreign and private, Japanese enterprises. And, as a result of the introduction of foreign technology, two fuel fabrication

plants were being built. "Thus, the system of manufacturing fuel domestically is being built up... Our nuclear industry is now able to produce most of the components of a power reactor domestically, but is still dependent on foreign devices for some kinds of component. On the other hand, Japan is in fact in a position to export components, particularly pressure vessels. We are now considering ways to compete satisfactorily with nuclear industries in such countries as the USA and UK, which have much experience in the construction of nuclear power stations, and at the same time ways to further develop export industry."

Siting and Safety

"Our government has stated in the long-range programme that it will promote the setting up of safety standards, research on safety, surveys to obtain sites for nuclear power stations and the implementation of reasonable regulations for the purpose of taking adequate measures to ensure safety at nuclear power facilities," said Mr. Yamada. Guiding principles had been established for the evaluation of sites for nuclear reactors of not less than 10 MWth, and for consideration of the safety aspects of design for nuclear facilities.

On the basis of these guiding principles, "nuclear reactors in our country have been located in remote places far from the centres of the electricity market and along the seashore, favoured with firm and strong ground, as our country is subject to earthquakes.[1)] Estimates for the site area of nuclear power stations of a total of 60 000 MW to be built by 1985 indicate that about 42 square kilometres will be required. To select such large site areas in our country, with its small land area and dense population where the seashore and coastal sea are highly developed and utilized, is becoming a difficult problem. In addition to such difficulties, due to natural conditions, there are social conditions such as the uneasiness felt by the Japanese people about anything connected with atomic energy and the objections of people engaged in fishing due to the fear of losing fishing grounds due to the effect of waste heat rejection and radioactivity from nuclear power stations... There is a tendency for many reactors to be concentrated in one place, or one zone, and already there is a plan to build many reactors totalling 8 000 MW in one place.

"Accordingly, it is necessary for us to find more and larger sites suitable for nuclear power stations and also to emphasize the research and development of technology and so on that will make possible the use of offshore and underground sites and the like. Also, freedom in site selection has to be enhanced by improvement of the safety, protection techniques.

Working in harmony

"In an intensively utilized country such as ours the coordination between nuclear facilities and the environment is a matter of special importance. It is essential to prevent inhabitants nearby being exposed

1) An article on some aspects of the evaluation of sites for reactors — in which work in Japan was discussed — appeared in the Bulletin, Vol. 12, No. 4.

to radioactivity. In this respect, it is necessary to maintain scientific standards of safety, and to overcome the over-sensitivity of inhabitants in the district. Radioactivity in the area around power stations is evaluated and discussed with the participation of representatives from those districts, then the results of this investigation are publicized. This procedure is becoming standard practice.

"We have also made detailed investigations of the behaviour of radioactive materials in the sea and their effect on marine life, as well as at the zone in Tokai-mura scheduled for the construction of a reprocessing plant, and are making efforts to ascertain its safety. Furthermore, in our country, where inshore fishery is very important, the necessity for harmonizing waste heat rejection from nuclear power stations with the surroundings is recognised and a project to use it for the cultivation of fish has already been started. In our country, we are conducting research and development in many fields for the purpose of increasing the number of sites, the improvement of safety protection systems and the preservation of the environment, but still consider it necessary to make further efforts. These problems are common to all nuclear nations, varying only in size and depth. Therefore, we consider it desirable to set up an international cooperation system."

Co-operation was a continuing theme in Mr. Yamada's address — and the necessity for individual effort within the international framework. As he put it, "depending only on imported technology in the future may impair the growth of original approaches, and our own technology for the development and utilization of atomic energy from a long-term point of view. Moreover, the development of atomic energy may help to raise the level of science and technology in many fields and to strengthen the industrial base and to help to build a strong, modernized industrial structure. Therefore independent and original development as far as possible is the basic idea for the long-range programme."

This did not exclude international co-operation in research and development. The Japanese long-range programme stated that "we shall endeavour further to intensify our basic research while proceeding with effective research and development, coordinating basic research and applied research in each field. The research and development of atomic energy extends over many fields of science and technology, plays a pioneering role in their development, and has a great influence on industry and the economy, and its promotion requires the investment of large sums for research over a long period. From this point of view, the role played by the government is very great, and the country should invest as much as possible from national funds."

The shape of the plan

Mr. Yamada explained that subjects which were of especially great importance and urgency, that required systematic and energetic national programmes and large sums of money, cooperation between various sectors and long-term research and development, and that promised great benefits for the whole nation when they had been developed, were selected as "Special Atomic Energy Research and Development Projects (national projects)." For such a project, the government specified objec-

tive and period. It was then carried out in the most effective way, with each related organization cooperating by doing the task appropriate to it, by re-arranging the system and carrying out systematic research and development widely, according to an overall plan. At present, Japan was pushing forward national projects such as the FBR and ATR, as well as a project for the construction of the first nuclear ship to be built in that country, with co-operation between government and private enterprise and the introduction of private funds.

As for advanced converter reactors, "we have decided to import from abroad technology at the experimental reactor stage in order to make possible their early practical use, and to start by building a prototype reactor with an electrical output of about 200 MW. Construction will be commenced in this fiscal year, and it is expected to be critical in 1974. As a result of the evaluation of (this) construction project... it was concluded that the cost of power produced by ATR is expected to be equal to or less than that of power produced by the light water reactor, that the selection of ATR instead of the heavy water reactor being developed abroad has been correct, that the development of ATR is of great significance in our efforts to obtain a stable supply of energy, that there are no serious technological difficulties involved in the project for development of nuclear reactors by the Power Reactor and Nuclear Fuel Corporation, and that to push independent development of ATR will help us to become independent of foreign technology.

"As to fast breeder reactor development, it has been decided to start the construction of the experimental reactor, and the construction of a reactor with an initial output of 50 MW thermal (a target output of 100 MW) is proceeding with scheduled criticality at the end of 1973. For the prototype reactor, the conceptual design for about 300 MW is now under way with expected criticality in 1977."

From nuclear-powered ships — to fusion research

Japan was also promoting a project for the building of its first nuclear-powered ship, a special cargo vessel of 8350 tons gross, "for the purpose of preparing for the age of nuclear merchant ships in the future and of accumulating experience of the building and operation of nuclear ships, as Japan is one of the world's leading countries in the field of shipbuilding and marine transportation."

Mr. Yamada told delegates to the General Conference that this first ship had been launched last year. Construction of the hull was now complete, and it was being equipped with a reactor. "We hope the second ship will be built and operated by private enterprise, and the government intends to take adequate measures to assist in the project," he said. "However, since the economics of nuclear ships are uncertain at present, we shall give further consideration to the building of the second ship in the light of the results of research and development of marine reactors, now under way, the performance of the first ship, and the trend in shipping circles both in Japan and abroad, and the progress in the development of marine reactors in foreign ountries. If the nuclear ship is to be used in practice, we have to be sure that it will be permitted entry into ports and enjoy freedom of navigation on terms

substantially the same as those for conventional ships. There are many difficult problems still unsolved, which make it impossible to give such assurances, and we feel that every effort should be made, both nationally and internationally, to solve such problems.

"These national projects, the first big projects for research and development in Japan, are making progress as we solve the various difficulties involved. From these projects we expect not only direct results, but also such indirect advantages as spin-off in technology and experience of the management and operation of projects."

Research subjects from which great benefit could be expected, and development subjects which might further promote research and development related to atomic energy in Japan, were selected as projects for "Specified Integrated Research for Atomic Energy," said Mr. Yamada. These were promoted by governmental research and development organizations co-operating with each other, each with a clearly defined task, in line with a government programme and with government coordination. At present, research was being carried out on uranium enrichment, nuclear fusion, and work to make possible the commercial application of atomic energy for food irradiation.

Work on nuclear fusion had been designated as a project for Specified Integrated Research for Atomic Energy in 1968, with a view to achieving controlled nuclear fusion — fusion reactors; and a basic plan for research and development had been prepared. This provided for an initial six-year phase beginning in the 1969 fiscal year, and the main phase, the Torus project. The Japan Atomic Energy Research Institute (JAERI) completed a low-Beta axially symmetric Torus device in 1969, and was now proceeding with the design of a medium-Beta device of the Tokamak type.

The programme, and its future

Mr. Yamada recalled that Japan signed the Treaty on the Non-Proliferation of Nuclear Weapons in February this year. "On the basis of the idea that the procedure for safeguards implemented by the IAEA in accordance with the Treaty should be as simple as possible, research and development on safeguards is being carried on energetically, and we are of the opinion that international cooperation in this area should be increased," he said.

"Furthermore, there are many problems that remain to be solved before the realization of multi-purpose utilization of nuclear energy—such as in steel manufacturing, the chemical industry, the desalination of seawater and integrated air conditioning systems for urban areas, and the nuclearization of industries that use large amounts of energy... We are considering the technical feasibility of a very high temperature gas-cooled reactor which will give coolant temperatures that can be used directly in iron and steel manufacturing, technical problems involved in its development, and prospects for solving them.

"The long-range programme clarifies the roles to be played by the universities, JAERI, PNC, JNSDA, IPCR, NIRS and other national and public research laboratories, as well as requesting private enterprises to carry out industrialization of technology that has reached the stage of

practical use and research and development on its improvement; and also to participate positively in national projects and Specified Integrated Research for Atomic Energy, and to take measures necessary for the establishment and improvement of their own technological base.

"Now that the practical use of nuclear generation on a large scale is probable, and that the demand for the application of atomic processes in industries that consume large amounts of energy by means of high temperature gas-cooled reactors is increasing, not to mention the promotion of power generation and nuclear ships, now is considered to be the best time to revise the present long-range programme, estimating the state of utilization of atomic energy around 1990 and clarifying the important new problems for research and development if the programme is to be achieved, then working out measures to solve such problems in accordance with the programme."