Long-range program on development and utilization of atomic energy.

LONG-RANGE PROGRAM ON DEVELOPMENT AND UTILIZATION OF ATOMIC ENERGY

Atomic Energy Commission
Japan

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Part I Introduction

1. Background of Revision of Long-Range Program

In September of 1956, the year of inauguration of the Atomic Energy Commission, the AEC drew up a long-range basic program for the development and utilization of atomic energy, and clarified the goal and policy on the peaceful uses of atomic energy in Japan. Also, it drew up a long-range program for the development of nuclear power generation in December 1957, and a principle on the development of nuclear fuel in December 1958.

Pushed forward along the line laid down in the aforesaid long-range basic program were the expansion and completion of the research facilities of the Japan Atomic Energy Research Institute, exploitation of uranium mines at Ningyo Pass and others and research on refining of uranium ores by the Atomic Fuel Corporation, establishment of the National Institute of Radiological Sciences and completion of research and medical treatment facilities at the Institute, progress of atomic energy research and development by Governmental research organiza-

tions, subsidies for private enterprises' research and development works related to atomic energy and dispatch of students abroad. Also, the Japan Atomic Power Company's purchase of a Calder Hall improved type atomic power plant was propelled in line with the above-mentioned program for the development of nuclear power generation.

Later, however, it was thought advisable to make future development more reasonable by giving some modifications to the original long-range basic program, particularly the program on nuclear power generation, in consideration of the changes in circumstances for the past few years. The main reasons for this judgment are as follows:

Firstly, as a result of the world-wide development of peaceful uses of atomic energy during the past few years, technical information and data have become remarkably abundant as compared with those some years ago, and it is now possible to obtain information in considerable detail for judgment. Accordingly, it has become possible to forecast more concretely and extensively as to a long-range outlook on development and utilization of atomic energy.

Secondly, a change has taken place in the nuclear fuel situation in the world. A few years ago, nuclear fuel including natural uranium did not necessarily enjoy sufficient international circulation, and the supply of such fuel from overseas received considerable restrictions and were unstable as to quantity. It was considered necessary for Japan, therefore, to place emphasis on domestic resources for the supply of nuclear fuel, which is essential to the development and utilization of atomic energy,

and to proceed with development under as independent a system as possible. Owing to a later increase in the capacity of nuclear fuel supply abroad, however, it is now thought appropriate to adopt a policy taking into consideration both the development of domestic nuclear fuel resources and the import of nuclear fuel from abroad.

Thirdly, with the progress of research and development, the complexity of the technical problems, which must be solved in order to put atomic energy to practical uses, has been brought to the surface gradually. Also as to the fast breeder reactor, which was regarded as an indispendable factor in the case of adoption of a self-supporting system on nuclear fuel cycle, the progress of research and development so far made it clear that there exists a lot of technical difficulties, and, in order to solve these technical problems and achieve practical utilization of fast breeder, it was considered necessary to have a longer period of time for research and development than thought of before.

Fourthly, the recent trend of the world economy considerably improved Japan's balance of payment on the one hand, and remarkably increased the supply capacity of petroleum in the world and also decreased its price on the other. Accordingly, it has become possible for Japan to use petroleum to meet the greater part of the energy demand at home. Furthermore, in connection with the later progress of technique on the conventional type of thermal power generation, the largescale, high-efficiency, oil-burning thermal power plant has come to the fore in economic comparision. This fact is bringing

noteworthy effects on the development of nuclear power generation at present. Fifthly, the scope of utilization of atomic energy is expanding in the field of uses of radioisotopes, and radiation chemistry also is making rapid progress. It has become necessary, therefore, to consider comprehensively the effect on the economic growth of the nation not only in the field of utilization of atomic energy for power generation purposes but in other fields.

In light of the changes in circumstances as mentioned in the foregoing, it is clear that there is a considerable change from the conditions on which the previous long-range program was based. Although there has been no change in the basic principle adopted in the previous program, we think it appropriate to draw up a new long-range program in accordance with the goal and policy which correspond to the new circumstances.

2. Significance of Development and Utilization of Atomic Energy

The previous long-range program, to some extent, referred to the significance of the development and utilization of atomic energy. From the national point of view, however, promotion of peaceful uses of atomic energy is becoming all the more necessary. Undoubtedly, it has become clear gradually that development and utilization of atomic energy economically and technically with safety requires more extensive research and development than thought of at the beginning. This, however, does not justify any under-estimation of the significance of the development of atomic energy. As the history of the development of science and technology shows clearly, many problems which arise at

the early stage of development can be expected to be solved one after another with the progress of research and development. Furthermore, from a long-range point of view, the peaceful uses of atomic energy will give enormous welfare to the human race in the future, that is to say;

(1) As to the utilization of atomic energy as a new energy source, considering that energy is indispensable to industrial development qualitatively as well as quantitatively, it is the most important thing in the economic advance of the nation to secure stable, economical sources of energy on a long-range basis. However, since Japan cannot expect much of domestic supply of the conventional energy sources, such as hydraulic power, coal and petroleum, she will have to rely on imports from abroad to meet the greater part of the increasing energy demand. In this connection, considering the recent situation overseas, it is thought advantageous to rely on petroleum as imported energy source for the time being. However, since there should be limitation to the development of petroleum resources in future, it is necessary to start the development and utilization of atomic energy right now in order to ensure the long-range stability of supplying energy resources. Atomic energy has features entirely different from such fossil fuels as coal and petroleum, in that future realization of thermonuclear fusion will increase the usable energy resources almost unlimitedly, and in that nuclear fission reaction produces much energy from a small quantity of nuclear fuel. In this respect, development of atomic energy is expected to play an important role in adding the varieties of energy sources.

(2) The effects of the utilization of radioisotopes and radiation, which is another facet of the development and utilization of atomic energy, on the industrial development of the nation are extremely extensive and have a wide variety. In some fields, the technique of application of isotopes as tracers or radiation sources to medicine, biology and agricuture has reached the practical stage, and is playing such important role in respective fields that cannot be substituted by any other method. Industrial application of isotopes is developing rapidly into the field of radiation analysis, besides ordinary measurement. In the future, when isotopes come to be utilized extensively in all industrial fields, they will make great contribution to automatoin of the production process and improving the quality of products, with the development of the electronic and other industries. Furthermore, in the chemical industry in particular, utilization of radiation will bring about epoch-making progress in production methods and quality of products, and will probably cultivate new fields of products in the future.

(3) Pushing forward the development of atomic energy will bring about important effects in expanding and strengthening the foundation of Japan's industrial economy in many fields, besides the direct effects as mentioned above. That is to say, if Japan is to realize a sound economic growth and enhance the welfare of the people for the future in spite of her narrow land and big population, epoch-making improvement of the nation's technical skill and improvement of the industrial structure are required at all times. In this respect, it is most significant for Japan to make use by her own hands of the atomic energy which

will play a big role in the technological innovation. An increase in energy supply resulting from practical uses of atomic power, further developments in the shipping and shipbuilding fields brought about by achievement of nuclear powered ships, and the possibility of development of new technology and improvement of the quality of products resulting from the application of radiation, will acquire increasing important position in the industries of the nation, and, coupled with the develoment of other kinds of industries, will promote the improvement of the industrial structure. At the same time, the development of new matirials required for the development and utilization of atomic energy, improvement of the purity of materials, or epoch-making improvement of efficiency of machines and instruments, is related to the progress of science and technology in Japan closely and directly. Establishment of foundation of the atomic industry requires coordination of science and technology ranging over a wide variety of fields. In this sense, development from the industries based upon conventional technical know-hows to the atomic industry is expected to become an important factor contributing to accelerating the change of Japan's industrial structure.

From the afore-said point of view, energetic program of the development and utilization of atomic energy in Japan has a very great significance when considered on a long-term basis. Furthermore, considering that the peaceful use of atomic energy is a new kind of industry somewhat different in nature from other industries, and that Japan was behind other countries in making a start in this field, the Government itself should play a key role in promoting the development and utilization

of atomic energy either directly or indirectly, instead of leaving such development and utilization entirely to private circles. In this respect, the Government has responsibility particually at the initial stage. That is, if Japan's atomic industry is to make sound development by making up the leeway rapidly, it is necessary that enormous money and man power should be spent in promoting research and development and that the Government should push forward development systematically and with responsibility in view of securing nuclear fuel and ensuring nuclear safety. Furthermore, considering the fact that the atomic energy field requires international cooperation and coordination more than any other field, it is clear that there is need for the Government to play a positive role in the atomic energy field.

In the revision of the long-range program this time, therefore, it is necessary to study on an over-all basis all processes from basic research to applied research and practical uses in all fields of development and utilization of atomic energy from a long-range point of view, and to draw up a new program which is worthwhile to be pursued by all the related governmental and private organs cooperating with one another.

3. Principle of the New Long-Range Program

In drawing up a new long-range program on the development and utilization of atomic energy, full consideration is given to the changes in circumstances and the significance of development and utilization as mentioned in the foregoing, and study is conducted from a long-range, over-all point of view by using effectively the latest knowledge, information and experiences

obtained so far. In this way, emphasis is placed on hammering out a policy which is most reasonable and effective for Japan in propelling the peaceful uses of atomic energy.

The program covers 20 years from 1961 to 1980. Of this period, the first ten years are considered as the stage of development, and the second ten years the stage of practical progress. This is from the consideration that the development and utilization of atomic energy in the world will remain at the stage of research and development for the time being, and that the establishment of the economy in the development and utilization of atomic energy will not be realized earlier than 1970 in many aspects. During the first ten years, efforts should be focused on research, development, ore prospecting and other matters aimed at solidifying the groundwork in preparation for future developments. During the first ten years, therefore, programs will be drawn up as concretely as possible. During the second ten years, a forecast will be made on the future progress which is anticipated with the materialization of the development program for the first period.

Therefore, part II, which follows the introductory part of the new long-range program, gives an outlook on long-range development in the fields of atomic power generation, nuclear powered ships, nuclear fuel and utilization of radiation. Part III gives programs on research and develoment extensively in various fields, which should be put into practice primarily during the first ten years. Part IV states the promotion measures required for realizing the research and development programs and long-range targets. The new program comprises

four parts in this way.

The purpose of the adoption of such a composition in the long-range program is to make it clear that the main points of the program are emphasis on energetic efforts in steady research and development in each field and the Government's measures for the promotion of atomic energy development, particularly for ensuring the safety of the nuclear installations and their surrounding areas. Efforts will be made to clarify the course to be followed by Japan in her development of atomic energy by placing more emphasis on measures required for effective implementation of the research and development program, establishment of joint research and project research systems, liaison between various research organizations and closer cooperation. Since materialization of the development and utilization of atomic energy depends upon the future progress of research and development and their achievements, it is considered advisable that an outlook on future development in the present long-range program should be given as much flexibility as possible. Meanwhile, in connection with the expansion of the fields of development and utilization of atomic energy, consideration will be given not only to putting atomic power generation to practical uses but to effecting vital relations between various fields of development and utilization of atomic energy.

The basic principle covering the whole long-range program is as follows:

As for the technology which is considered to have approached the stage of practical uses to some extent as a result of considerable development carried out at home and abroad,

expectations are pinned primarily on research and development in private industries and introduction of foreign technology. As for the big projects which should be newly developed in the future, on the other hand, the Government will take the leadership in such research and development. The Government is expected to play a key role in basic research, although this kind of research will be conducted also by private industries to some extent. Furthermore, with regard to the problems which is considered as essential from the safety point of view, the Government will take measures in assuming the full responsibility.

The Government will make positive efforts to secure supply of nuclear fuel on international basis, particularly the enriched uranium, demand for which is expected to increase in the future. The Government will consider in making the best use of plutonium by attaching importance to the uses and development of plutonium as nuclear fuel. Furthermore, the Government will take into consideration the possibility of production of enriched uranium at home, and push forward research in this field from an early stage.

Part II Long-Range Prospect for Atomic Energy Development and Utilization

1. Nuclear Power Generation:

(1) Significance of Nuclear Power Development

Side by side with the growth and expansion of economy, the electric power demands of our country are on a drastic upward trend year after year. The latest estimates based upon the Doubling National Income Plan indicate that power demands in 1970 and 1980 will be about 2.8 and 5 times as large as those in 1959 respectively, and this would require development of installed capacity on the order of 36,220 MW and 48,190 MW respectively for the first and second ten year periods up to 1980. Due to the gradual exhaustion of adequate economical sites to develop, much can not be expected for additional large capacity of hydro electric power for the future, a greater emphasis will naturally be placed upon development of thermal electric power whose cost is expected to be reduced both by technological inprovement and lowering of fuel costs. While the ratio of thermal power generation to the total electric power generation was 33 percent in 1959, it is estimated that this percentage will rise to 65 in 1970 and further to 78 in 1980.

With respect to fuel requirements to meet such increasing scale of power generation, it is considered that in view of the presently known situation of the nation's resources most of the fuel required will have to be imported from abroad. With

particular regard to petroleum which will be used as fuel for oil burning power stations expected to occupy most part of the thermal power generating capacity to be installed under the above-mentioned Doubling National Income Plan, it is observed that composite ratio of petroleum to all types of energy sources, which was 29.5 percent in 1957, will be increased to 49.6 percent in 1970 and to 62.6 percent in 1980. It is likewise estimated that the ratio of electric power to total energy will rise to 46 percent and 50 percent respectively from 38 percent of 1957.

As seen above, an accelerated trend toward dependence upon import for the energy resources required for electric power generation to meet a rapid increase of power demands in future makes it necessary for the country to develop cheaper sources of energy as well as to diversify the types of energy supply to depend upon not only from the viewpoint of sound foreign exchange policy but also with a view to securing a stable supply of energy resources. This would add greatly to the significance of nuclear power development as one of the major sources of power supply.

It has been estimated that promotion of nuclear power development, for which greater part of plant components and materials will come to be spared for domestic production and supply, will be, in the long run, more advantageous than oil burning power stations upon the light of foreign exchange balance.

A high level of technology and a wide range technical fields involved which is made necessary for nuclear power development will help and develop advanced technology and new industry, leading ultimately to an overall enhancement of the nation's

industrial technology and intensification of the country's industrial structure.

(2) Prospects for Technical Progress of Nuclear Power

In view of the fact that the water-cooled reactors of the United States have been in operation as the full-scale power reactor following graphite moderated gas-cooled reactors of the United Kingdom, it is considered that those reactors to be developed for practical utilization in the first ten-year period will mostly be of these two types.

Improvement of the gas-cooled reactors is being made in the direction of high temperature gas-cooled reactors with slightly enriched uranium fuel and it is hoped that full-scale development of this advanced type will be feasible. With respect to water-cooled reactors, on the other hand, such technical improvement as adoption of nuclear superheating will offer better economies.

Among other types of reactors, practical utilization of organic-cooled reactors will be made possible in the second ten year period in view of the current developmental works pursued in overseas countries on such problems as nuclear proterty of organic materials. Considering economical use of natural uranium in future, heavy water moderated reactors will reach the stage of practical utilization in the second ten year period.

Although a considerable development will be made on such other reactor concepts as breeder in the first ten year period, it would not be before the latter half of the second ten year period that their utilization becomes practical.

(3) Prospects for Economics of Nuclear Power

For most of the thermal power stations to be constructed along with increasing power demand, which, it is expected,

will be oil-burning, the power cost will be considerably reduced due to such factors as lower unit construction cost brought about by growing capacity per installation, improvement of thermal efficiency and reduction of fuel cost. Current estimation indicates that power cost per kilowatt hour will be in the vicinity of 2.40–3.00 yen in an around 1970.

Nuclear power cost, on the other hand, is expected to be reduced to something like 2.40 to 3.00 yen per kilowatt hour which is comparable with the above-mentoned cost for oil-burning thermal power, granted that such special conditions prevailing in Japan as high interest rate and need for aseismatic design would add something to the power cost estimation currently obtainable from research data and operation experiences of power plants abroad. Considering high potentiality of technical progress and improvement in nuclear field, it is further expected that nuclear power generation will become more advantageous economically in future.

(4) Development of Nuclear Power Generation During First Ten Years

a. Construction of Power Reactor No. 1

The graphite-moderated, gas-cooled type power reactor, now under construction by the Japan Atomic Power Company, was designed as the first nuclear power plant of a practical scale in Japan. It is aimed at acquiring construction technique, proppelling home manufacture and training scientists and engineers to help the development of the gas-cooled type power reactors which are expected to be installed in the future.

b. Construction of Power Reactor No. 2

Light water cooling reacter is considered to be suitable as the type of Japan's practical-scale power reactor No. 2.

Practical-scale power reactors of this type have recently started operation in foreign countries, and their economic outlook also has been clarified to some extent. Considering their future prospects and the situations at home and abroad, it is expected that a large number of this type of reactors will be constructed during the second ten-year period. In preparation for future development, therefore, it is advisable to construct this type of reactor with a view to acquiring construction technique, propelling home production and training scientists and engineers, etc.

Since the reactor should be selected carefully, however, preparations for construction will be made by sending out an overseas survey team as early as possible.

c. Construction of No. 3 and Subsequent Power Reactors

Following the afore said Nos. 1 and 2 power reactors, another three power reactors or so are expected to be installed during the first ten-year period, which is a scaffold for development in the second ten-year period.

Selection of such reactors is a problem which requires careful consideration. Selection should be made from among the reactors which would have already been developed abroad and which would have obtained prospects for practical uses to some extent, on the basis of the experiences in power reactors Nos. 1 and 2. Considering these points, the gas-cooled and light water-cooled types will be the major power reactors to be taken up during the first ten-year period.

d. Scale of Development

The scale of nuclear power generation capacities to be developed during the first ten-year period in accordance with the foregoing policy will probably be about 1,000 MW in electric output in-cluding No. 1, No. 2 and subsequent power reactors. Electric power generating enterprisers are expected to cooperate in the construction of these power reactors. At the same time, it is considered necessary for the Government to take appropriate measures in financing and taxation with a view to pushing forward the construction of such power reactors.

(5) Development of Nuclear Power Generation During Second Ten Years

During the second ten-year period, it will be desirable to develop nuclear power generation as far as possible. However, there is naturally a limit to the scale of development of nuclear power generation from technical and economic points of view in the operation of the electric power system, since nuclear power will probably be used primarily to meet the base load for the time being because of the high capital costs involved. The appropriate scale of nuclear power generating capacities to be developed during the said period should be considered as about 30 percent of the thermal power generating capacities to be install-ed during the same period. The scale of development of nuclear power generation, therefore, will be about 6,000 to 8,500MW in electric output.

At the present stage, it is very difficult to forecast the types of the power reactors to be installed during the second ten-year period. Judging from the outlook on development

during the first ten-year period, however gas-cooled type and light water-cooled type will be the major power reactors to be taken up. In addition, several reactors of the types to be developed newly from now on will probably be constructed to some extent.

2. Nuclear Powered Ships

(1) Significance of Nuclear Powerd Ships Development

Along with the growth of national economy, the import amount of iron and non-ferrous ores and mineral fuels including potroleum is expected to increase greatly, and such increase of trade amount will eventually bring about an increased demand for the tonnage of the nation's merchant fleet. The estimates made on the basis of the recently formulated Doubling National Income Plan indicate that the annual increase ratio of the total tonnage and that of oil tankers' tonnage will be 9 percent and 10.6 percent respectively for the first ten-year period and the required tonnage of ocean-going vessels in 1970 will be 13.35 million gross tons. This means that construction of approximately 9.7 million gross tons equivalent of ships will be required during the first ten-year period. The breakdown of this figure shows that the tonnage of newly constructed oil tankers is about 2.6 million gross tons and the remaining part is mostly occupied by ore carriers since the import amount of iron ores, which is currently in the neighborhood of 10 million tons annually, is expected to increase to 30 to 40 million tons in 1970.

Such a trend is expected to continue also in the second ten-year period and it is considered desirable to make an increased effort for the construction of large sized and high speed ships

in order to meet an increasing demand for the transportation. In this connection, nuclear powered ships, having advantage when built in large size and with higher speed, are expected to play an important role in the future.

The shipbuilding industry of Japan, on the other hand, not only plays a major part in the nation's exporting industries but also is ranked considerably high among major shipbuilding countries of the world. To sustain in future such a supremacy currently enjoyed, a constant effort must be made to improve its technology. From this point of view, too, it is considered necessary to develop nuclear powered ships in as early a time as possible and thus to establish its building technology.

(2) Prospect for Technical Progress of Nuclear Powered Ships

Although technical feasibility of application of nuclear power to ship propulsion has already been developed in the advanced countries, it further requires to improve performance of reactor plants, simplify shielding structures as well as to reduce construction and fuel costs, if nuclear powered ships are to be well competitive with conventional ships among the merchant fleets. It is expected that along with technological development on these problems construction technics of nuclear powered ships will greatly be improved during the first ten-year period.

As the size of ships comes to be required to be relatively larger, its speed higher and its cruising distance longer, advantages which nuclear powered ships have in these regards will further be emphasized, and it is expected particularly in the second ten-year period that super large size and super high speed nuclear powered ships will appear which, if not of nuclear

propulsion, would be impossible to construct. Development of merchant submarines, taking full advantage of nuclear propulsion, will become active in future.

(3) Prospect for Economics of Nuclear Powered Ships

The cargo freight cost of the conventional tankers and ore carriers on the major service lines around Japan is currently about 0.25 to 0.35 yen per freight ton/nautical-mile and the corresponding figure for nuclear powered ships is expected to become 0.30 to 0.40 yen in ten year time. Considering that nuclear powered ships will become of larger size with higher speed and with longer cruising distance, nuclear powered ships of these types will, in ten or fifteen years, become comparable with the conventional ships.

(4) Preparatory Measures for Nuclear Powered Ships Development

The peculiar characteristics of nuclear powered ships accompany with it a need to secure high safety and it further requires sound legislative measures on such issues as treatment of radioactive wastes, safety administration system, emergency measures, nuclear hazard indemnity and international regulations on nuclear ship navigation. These problems will have to be solved by the time the nuclear powered ships are constructed and operated.

(5) Development of Nuclear Powered Ships During First Ten Years

As already stated, nuclear powered ships are expected to become comparable economically with conventional ships by around 1975 at the latest. In the first ten-year period, in preparation for development in the second period, an nuclear

powered ship will be built in accordance with appropriate specifications and put to navigation with a view to establishing nuclear powered ship construction technology, acquiring navigation experience and training crew members and technicians.

a. Construction of First Nuclear Powered Ship

With regard to the first nuclear powered ship, prompt decision should be made on the question of who will assume the primary responsibility for the construction of the ship. Careful study will be conducted on the construction of the first nuclear powered ship, so that such a ship will be enough to provide a scaffold for the future development of nuclear powered ships. The first nuclear powered ship will be equipped with a light water-cooled reactor. The target for the completion of the ship is set between 1968 and 1970.

b. Acceleration of Research Related to Development of Nuclear Powered Ships

Research and development will be promoted on the designing technique, radiation shielding structure and improvement of performance of propulsion reactors required in the design and construction of the first nuclear powerd ship and in future development. For this purpose, the power demonstration reactor and the research reactor for radiation shielding, which are expected to be built at the Japan Atomic Energy Research Institute, will be used effectively.

(6) Development of Nuclear Powered Ships During Second Ten Years

In the second ten-year period, a rapid increase in the demand for shipping industry is anticipated corresponding to a

remarkable increase in trade which will result from an economic growth. This will increase the demand for high-speed, large-scale ships with longer navigation ranges, at the same time bringing about improvement of the economy of nuclear powerd ships. In the latter half of the said period, therefore, nuclear powerd ships will probably be able to participate in the merchant fleet in Japan's shipping industry too.

3. Nuclear Fuel

(1) Prospects for Demand and Supply of Nuclear Fuel

Progress of the development of nuclear power generation and nuclear powered ships will probably lead to a further increase in the demand for nuclear fuel. Although a long-range estimation of the demand for nuclear fuel is difficult because it concerns the question of the types of the reactor to be developed in the future and the time of construction, it is anticipated that such demand will amount to about several hundreds tons in 1970, and several thousand tons in 1980, in terms of natural uranium respectively.

If the greater part of the above-mentioned fuel is enriched uranium, the annual demand will amount to several tons even in 1970 in terms of ^{235}U, and a sharp increase is anticipated thereafter.

Judging from the overseas situations, there does not seem to be any problem as to quantity in connction with such an outlook on the demand for nuclear fuel as mentioned above, although Japan cannot but rely on overseas sources of supply for the time being since her domestic resources have not yet been developed sufficiently. Also, the overseas market of uranium

concentrate will probably remain weak for some time to come.

Enriched uranium will be supplied probably from the United States, the International Atomic Energy Agency and others. In this connection, measures will be taken to ensure continuous supply of enriched uranium on a long-term basis.

There does not seem to be any obstacle to supply necessary amount of nuclear fuel during the first ten-year period. Considering the possible increase in demand in the future, however, it is not advisable to rely on overseas sources of supply too heavily. It is therefore necessary to push forward research and development with a view to putting plutonium fuel to practical use in the first half of the second ten-year period, and some of enriched uranium required to be manufactured at home in the later half of the second ten-year period.

(2) Production and Processing of Natural Uranium Fuel

a. Development of Domestic Resources

i) Ore Prospecting

The Geological Survey Institute of the Ministry of International Trade and Industry will continue the rough survey which it has conducted on a nation-wide basis in order to locate domestic uranium deposits comprehensively.

The Atomic Fuel Corporation will proceed with prospecting on the present scale for the time being in the areas where being undertaken by the Corporation at present and where have been found promising as a result of the rough survey conducted by the Geological Survey Institute.

ii) Mining and Refining

The Atomic Fuel Gorporation will start trial mining of the Ningyo Pass mine and the Togo mine areas, in connection with the survey on the scale of reserves, in order to establish uranium mining and refining technology. In that case, the home-produced uranium concentrate will be given refining at the Tokai Refinery with a view to developing integrated technology from the mining of uranium ore to the home production of uranium ingot. The natural uranium produced from domestic ore will be used primarily for testing and research purposes at home.

It is expected that, in the future when the possibility of full-scale development of domestic resources becomes clear, not only the Atomic Fuel Corporation but also private enterprises will take part in developing such resources.

b. Refining and Fabrication

For technical and economic reasons, fuel elements for the Calder Hall type power reactor will be imported from the United Kingdom for the time being. It is expected, however, that home-production of the fuel elements will be started in private enterprises on an industrial basis at a time when economical refining and processing become possible. As for the method of refining, the most advantageous method, both technically and economically, should be adopted. In this connection, consideration will be given to using effectively the technology to be developed by the Atomic Fuel Corporation. Also, at the early stage, British technology will be introduced for the fabrication of fuel elements for the Calder Hall type power reactor.

As for the fuel for testing and research reactors, private enterprises also will make efforts for early realization of home

production of fuel elements under the cooperation of the Japan Atomic Energy Research Institute and the Atomic Fuel Corporation. Furthermore, research will be propelled for the improvement of fuel elements performance.

(3) Processing of Enriched Uranium

a. Processing

Fuel for light water-cooled power reactors will probably be imported from the United States for the time being. It is expected, however, that the home production of such fuel will be carried out by private enterprises when the time comes that economical processing at home becomes possible. If necessary, furthermore, introduction of overseas technology will be considered. Since the demand for fuel for testing and research reactors is expected to reach a considerable amount even in the first ten-year period, it is hoped that processing for such fuel will be started by private enterprises as early as possible.

b. Uranium Enrichment

In order to meet an increase in the demand for enriched uranium in the future, and in order to secure a wide variety of enriched uranium supply sources, research and development concerning uranium enrichment will be pushed forward under the leaderships of the Japan Atomic Energy Research Institute and the Atomic Fuel Corporation, with the aim of realizing the home production of enriched uranium to some extent, if necessary, in the latter half of the second ten-year period. Meanwhile, in the case of need for carrying on uranium enrichment undlrtakings in the future, it is considered appropriate to have the Atomic Fuel Corporation undertake the job.

(4) Spent Fuel and Its Re-Processing

Spent fuel will be disposed of in accordance with international agreements. In the future, when the scale of atomic power generation has increased, it may be necessary for Japan to make the re-processing of spent fuel possible at home.

From this point of view, research on re-processing technolgy should be conducted jointly by the Japan Atomic Energy Research Institute and the Atomic Fuel Corporation. Furthermore, for the purpose of building up re-processing technology and training the scientists and engineers, a re-processing pilot plant, capable of treating both natural uranium fuel and slightly enriched uranium, fuel, will be installed at the Atomic Fuel Corporation.

Meanwhile, in the future, the re-processing of spent fuel in full scale, if necessany, will be handled by the Atomic Fuel Corporation.

(5) Prospects for Use of Plutonium

In the first and second periods, progress of nuclear power generation program will presumably result in production of a considerable quantity of plutonium as a by-product.

Plutonium as reactor fuel may most effectively be used in fast breeder reactor. This, however, will involve many technical difficulties, and even in foreign countries, practical use in this line is not expected to be realized earlier than by the middle of the second ten-year period. Therefore, research must be carried out on the use of plutonium as a substitute for enriched uranium in conversion reactors. It is also expected in the future that technology concerning the plutonium-using fast

breeder reactor will be developed satisfactory, and that a reasonable fuel cycle will be established in Japan.

4. Radiation Utilization

4.1 Utilization of Radioisotopes

(1) Prospect for Utilization of Radioisotopes

Development of new radioactive nuclides, exploitation of new utilization technics and progress in tracer technology will further widen the scope of radioisotope utilization in Japan and it is expected that a great stride will be made in full-scale and widespread utilization for practical purposes.

Radioisotopes are utilized in universities, national and regional research institutions and in private industry in such fields as basic sciences, medical science, biology, agriculture and different sectors of industry, contributing greatly to the progress of basic sciences, growth of industry and betterment of national welfare. In the field of basic sciences, radioisotopes utilization has widen the scope of researches through application to physiology, bio-chemistry, geo-physics and archaeology, etc. In the medical field it serves improvement of people's health and welfare through application to diagnosis and treatment of different diseases. In the biological and agricultural fields, radioisotopes utilization for plant breeding and improvement of breed, protection of useful animals and plants, quality improvement of agricultural and fishery products are expected to become still prevalent. In industry, application to process control and quality control in such basic industries as iron & steel and non-ferrous metal industries, quality improvement and development of new products in chemical industry, as well as to civil engineering

and construction works has marked steady progress and it is expected that these applications will greatly contribute to the advance of industrial technology of our country.

(2) Prospect for Demand of Radioisotopes

Along with a widespread use of radoisotopes, number of places to use radioisotopes, the amount used, number of nuclides applied and unit amount used will be greatly increased.

Those nuclides with the largest demand at present are ^{60}Co used as radiation source and ^{32}P and ^{131}I used for tracer purpose. Demand for them is on an upward trend, and used amount of ^{60}Co has been increasing by 8 to 20 percent per year, ^{32}P and ^{131}I by 3 to 4 and 3 to 6 percent resepectively. Provided that these rates are to continue, the annual amount used in 1970 will be 100,000-200,000 curies for ^{69}Co, 40,000 to 45,000 milicuries for ^{32}P and 70,000-80,000 milicures for ^{131}I.

^{3}H, ^{14}C and ^{24}Na used for medical and biological purposes as well as ^{35}S used for researches in different sectors of industry and ^{137}Gs used as radiation sources are some of those nuclides, which, in spite of their relatively small amount of use, are expected to be greatly developed in future.

Demand for labelled compounds amounting to more than a hundred in their kinds will increasingly become larger for use in basic and applied studies of many fields. Such new labelled compounds as ^{58}Co, ^{59}Fe and ^{110}Ag used for studies on metallurgical technics are some of those whose future development is much expected of.

(3) Prospect for Radioisotopes Production

Although we have to depend upon import for the present

day demands of radioisotopes, production of radioisotopes to secure stable supply for an increasing requirement expected in future will be made along with the construction of reactors mainly in the Japan Atomic Energy Research Institute. For those six radioisotopes including ^{24}Na, ^{32}P, ^{35}S, ^{42}K, ^{131}I and ^{198}Au, production should immediately be started so that, in the latter half of the first ten-year period, domestic production may be able to meet major part of demands for these radioisotopes. For ^{3}H and ^{14}C as well as for such short-life radioisotopes as ^{51}Cr, ^{56}Mn, ^{58}Co, ^{64}Cu, ^{76}As and ^{82}Br, production will gradually be started in the latter half of the first ten-year period.

^{60}Co will be produced making use of large output power reactors in the second ten-year period, and consideration shall be given for such radioisotopes as ^{90}Sr and ^{137}Cs so that they shall be produced in relation with re-processing of spent fuels.

4.2 Radiation Chemistry

(1) Significance of Development of Radiation Chemistry

Research and development of radiation chemistry is actively conducted in overseas countries, too, and it is expected that outcome of these studies will infiltrate into different fields in the near future. Particularly important will be the influence of such outcome over a wide sphere of industries including textiles, rubber, synthetic resins and many other sectors of chemical industry.

Progress and development of radiation chemistry, in spite of its relatively new appearence in the realm of modern sciences, are expected to be greatly fostered with the background of

considerable high standard already attained in our country's chemical industry, and with the adequate promotion measures in such relatively backward fields compared with advanced countries as basic research, radiation engineering, and development of radiation sources, it will not be very far beyond before Japan could keep up with those advanced countries in this field.

In this connection, it is considered that promotion of development of radiation chemistry in Japan will not only help promote new technology and industry at large but also intensity the country's industrial structure.

(2) Prospect for Progress of Radiation Chemistry

There is no room for any doubt as to a big potentiality and feasibility of radiation utilization to prove as important a role in chemical industry as heat, pressure and catalysts. Development of new products and reduction of production cost through use of radiation chemistry are some of their features. Applications presently considered very promising may include ion polymerization of formaldehyde, graft polymerization of cellulose fibers, oxidization of benzene and synthesis of nitric acid by fixation of atmospheric nitrogen.

Although these application will have to depend upon further developmental works in future, a pilot plant scale experiments through use of large sources as well as reduction of irradiation cost will promote greatly an early maturity of them in the first ten-year period.

(3) Development of Radiation Chemistry

It is considered to establish a central research organization for a powerful promotion of researches in radiation chemistry

within the framework of the Japan Atomic Energy Research Institute. With the future expansion of the organization's activities, its set-ups and functions will be reinforced.

In this organization will be installed such large unit equipments that could not be constructed by private industries from financial viewpoints. Major role of this organization will be pilot plant scale experiments, research and development of sources of cheaper irradiation cost and basic research works which require use of large unit equipments and facilities.

In running this organization and its facilities, a careful attention shall be givn so that interests and desire of private industries be fully reflected and these equipments be placed for a smooth common use so as to attain the original aims and purposes of establishing such an organization.

Part III Program for Research and Development

1. General Principle

(1) How to Propel Research and Development

In order to carry on effectively the development and utilization of atomic energy in Japan on the basis of the long-range outlook, it is necessary to push forward the required research and development energetically and to have such achievements reflected in the aspect of development and utilization immediately. For this purpose, universities, governmental and provincial testing and research organs and private enterprises should keep close contact with one another in propelling research and development. Furthermore, international cooperation should become closer and strengthened.

From such a point of view, it is desirable for all research organs in the country to maintain conditions fit for developing their originality through free research activities, and to push forward research and development effectively by closer collaboration and cooperation. Also, it is considered to be especially effective in such a new field as atomic energy to propel research and development energetically by establishing a joint research program and a project research program under which the organs concerned will cooperate with one another in order to achieve specific objectives.

Although research in social science is also necessary for the development and utilization of atomic energy, this program

should refer to the natural science field only.

(2) Foreign Technology and Domestic Technology

Development and utilization of atomic energy requires the development of sciences in extremely extensive fields and high-level technology. Japan has been in possession of some of such sciences and technical know-hows since some time ago. Also, Japan's science and technology has some aspects developed since around 1954 particularly as nuclear science and technology, which warrant considerable expectations, The greater part of science and technology, however, belongs to an entirely unknown field for Japan. In pushing forward research and development in future, therefore, it is considered necessary to promote international exchange in the scientific field as far as possible and also to introduce foreign technology with a view to improving research and development more than ever.

Let us take as an example the light water-cooled type power reactor which is expected to be built in Japan within the coming ten years. So far as individual machines and instruments are concerned, Japan can construct many of them with her own technology. However, in order to complete the function of a power reactor plant as a whole and to ensure safety, techniques and experiences are necessary in the designing, manufacture and construction of a plant as a whole. Furthermore, when Japan plans to construct power reactors with her own technology and research and development to be made in her own way, it is significant enough, considering time efficiency and money efficiency, to introduce foreign technology as a means of

promoting her research and development.

From this point of view, it is considered most advisable in pushing forward research and development under the long-range program to place emphasis on two major points: one is research for the purpose of establishing technological foundation for introducing such techniques as have been developed in foreign countries to a high level and for absorbing them and for the purpose of having foreign technology suit Japan's own conditions in making improvement and development; the other is research which expects development in a little farther future based upon Japan's original ideas.

At the development stage of the first ten-year period, Japan will have to rely upon imported technology in a considerable number of fields. However, with the absorption of the technical know-hows to be introduced in the course of energetically fostering Japan's technology in line with this program from now on, it is expected at the latter stage of the program that Japan will push forward her own research and development on the same footing as advanced foreign countries, obtaining results with high economy and reliability.

(3) Project Research

In order to promote effectively such extensive development and utilization of atomic energy as mentioned above and to achieve the objectives as early as possible, it is necessary to clarify the root points by grasping in detail the present state of research and to try to solve various technical and economic problems under integral plans in respective fields. As to basic research, in which the strengthening of mutual cooperation is

of course necessary as the basis of development, full consideration should be given to special relations leading to applied research aimed at specific items of development. The basic research field will become wider in future, and it is considered to be difficult to give some directional and systematic natures to basic research. It is expected, however, that the adoption of the project system, in which both fundamental and applied sciences are integrated toward a specific development target will clarify the emphasis in the development and rapidly increase the speed of development.

In pushing forward the research program for the development and utilization of atomic energy from such a point of view, consideration is given to taking up specific items, defined as project research, which are considered to be most effective and important at the present time as a means of stepping up equal interchange and cooperation with foreign countries in nuclear science and technology, besides making up for the backwardness of Japan in the peaceful uses of atomic energy and developing the nation's own technology, and focusing the national efforts on the said project on a priority basis.

There may be problems as to what should be designated as project research. Anyway, in view of the real purpose of this system, it is not desirable to increase the number of such research items indiscreetly, and the variety of research items should be narrowed down to the items which are best fit from an over-all, long-range point of view. It is decided, therefore, to pick up the research which will be developed with fostering Japan's own technology from a somewhat long-range point of

view, and the research which should be developed urgently as a national policy, excluding the problems which are expected to be solved comparatively easily by the technical know-hows to be imported from abroad in the near future. At first, research and development of the semi-homogeneous reactor is taken up as falling under the former category, and research and development of plutonium fuel under the latter category.

(4) Research for Ensuring Safety

What is most important in smooth promotion of the development and utilization of atomic energy is the ensuring of safety of atomic energy facilities. In drawing up a research and development program, therefore, not only research on the mechanical designs required for ensuring safety, but also survey, research and development concerning problems related to nuclear fuel, shield, instrumentation and control devices, accident analysis and aseismatic strength, and also the problems indirectly related to safety measures, should be planned on a priority basis. Needless to say, installing of atomic energy facilities should pass thorough safety examinations under the Reactor Control Law and other regulations. Also there is a regulation calling for complete measures such as a Governmental inspection system on nuclear fuel. These measures, after all, should be propelled with firm confidence, based on thoroughgoing surveys and research. Research for ensuring safety covers research and development in various fields. In this sense, it is necessary that the Government and private circles should cooperate in pushing forward the safety project by emphasizing its importance in nature.

(5) International Cooperative Research

In propelling research and development, it is necessary to promote joint research, in which the research organs interested in the same research subject cooperate with one another and take over their portions of work, in parallel with the project research. For this purpose, the research organs in the country should maintain close liaison among them through academic societies and at other opportunities and exchange research information effectively. Furthermore, cooperation with overseas research organs should also be developed positively. In particular, in such a new and extensive field as atomic energy, research and development require much money, facility and manpower, and it is not easy for a single country to take care of these matters single-handedly. Consideration should be given, therefore, to such an idea that research organs in various countries make contributions in their respective fields of specialities, like the case of joint research at home, so that research achievements will be made on an international scale.

From such a point of view, the afore-said project research is expected to become an effective stronghold by which Japan will be able to play a positive role on the arena of international cooperation.

Development of such international cooperative research requires deepened contact with various countries and the international organs concerned. Therefore, inter-governmental cooperation under the existing bilateral agreements and through the International Atomic Energy Agency will be stepped up further, and, it necessary, new relations of cooperation will

be opened with regional organs, such as the European Nuclear Energy Agency or EURATOM, considering the expansion of bilateral agreements with other countries, with a view to Strengthening the exchange of information for the development of atomic energy technology. Further, promotion of joint research with these organs will be considered.

(6) Role to be Played by Each Research Organ

In Japan, which is at a initial stage in development, it goes without saying that effective promotion of research and development require cooperation of various fields. At the same time, it is necessary that the development program should be put into practice centering around the researches corresponding to the feature of each research organ.

However, since the development and study of atomic energy cover an extremely wide range, and since the accumulation of sizable data and experiences is required at the initial stage in development, too rigid allotment of work may impede firm relations in research and cause a delay in development. The roles to be played by respective research organs on a priority basis are shown below. In the process of research and development, however, it is natural that there may be overlapping in basic research or in the extended part of research.

a. Universities

Although it goes without saying that importance should be attached to basic research in connection with the development of atomic energy, expectation should be held on research at universities with regard to research in such basic sciences

as nuclear physics, solid state physics and elementary particle theory. Also, as for basic research in such applied sciences as reactor physics, nuclear engineering and nuclear design, much is expected of research at universities. Above all, if Japan's own research is to be developed so that she can equally match foreign countries in the field of nuclear science and technology, it is important to make efforts to materialize effectively the progress from basic science to applied science. From this point of view, it is necessary to consider effecting closer joint research or cooperation between universities and the Japan Atomic Energy Research Institute, which cooperation has not necessarily been satisfactory so far.

As to the training of scientists and engineers, which is indispensable to research and development of atomic energy, almost everything should be sought from university education. In this respect, it is expected that the persons concerned in the Ministry, of Education universities, Atomic Energy Commission and others will maintain close liaison and give effective education.

b. Japan Atomic Energy Research Institute

Among the roles to be played by the Japan Atomic Energy Research Institute as set forth in the Japan Atomic Energy Research Institute Law, especially important are research in the basic science field which should be conducted in parallel with basic research at universities, and basic research which is based on the basic studies conducted by universities or the Institute itself and which will link such basic studies with

applied research having a development target. In other words, the Institute will play the role of a bridge between basic research and practical uses of the results by conducting research in basic science and applied science together with universities, linking such research with the research on applied science to be conducted by the Institute itself, developing such research further into applied research (engineering research) or industrialization testing research (research on putting to practical uses), and eventually contributing to the improvement of Japan's atomic industrial technology.

Thirdly, the Institute conducts applied research which is deemed important for future development, or research required under the basic program on the development of atomic energy, such as research on semi-homogeneous reactors and research on plutonium fuel.

Fourthly, the Institute becomes the center of research and development in the projects, which requires special facilities such as reactors, accelerators and large scale electronic computers, and also cooperates extensively in research at universities, National and regional testing and research organs and private enterprises using these facilities. The Institute will make other research facilities, too, open to use by various circles. In addition, it is important for the Institute to educate scientists and engineers concerned with atomic energy and to give them necessary training.

In order te play the above-mentioned roles, the Institute should give full consideration to the setup for cooperation with private enterprises, and also give consideration to making

closer relation with research at universities and Governmental testing and research organs as mentioned above. Necessary for this purpose are to strengthen the system for the effective operation of the research facilities to be installed at the Institute, to establish a system for the Institute to entrust universities and private research organs with promoting research, and to try to realize a system which can secure the cooperation of university professors or private researchers.

c. Atomic Fuel Corporation

The roles to be played by the Atomic Fuel Corporation are as set forth in the Atomic Fuel Corppration Law. As to preliminary refining and final refining, research will be continued on improvement of the conventional technique. Besides, during the first ten years the Corporation will play an important role in the establishment of fuel element inspection technique, research on re-processing technology, and research on uranium enrichment by the centrifugal separation method. As to research on uranium enrichment, in particular, consideration will be given to stepping up research at the Japan Atomic Energy Research Institute and the Atomic Fuel Corporation gradually with the cooperation of other organs concerned, since it is expected that in the 1970's necessity may arise for carrying out uranium enrichment at home, although such a possibility depends upon a future trend on fuel supply.

In view of the importance of using plutonium effectively as reactor fuel, a system for joint research on plutonium fuel will be established between the Japan Atomic Energy Research Institute and the Atomic Fuel Corporation, and research and

development will be propelled energetically with these organs as the center.

d. National Institute of Radiological Sciences

Research and development by the National Institute of Radiological Sciences, besides propelling general basic research on radiology, has the aspect of using radiation for diagnosis and medical treatment and the aspect of medical treatment on radiation hazards. In addition, the Institute educates and trains the persons required for the prevention of radiation hazards. Since these projects have a great significance in normal and sound development of peaceful uses of atomic energy in Japan, measures should be taken so that research achievements will be reflected duely in the aspect of the development and utilization of atomic energy.

e. Governmental and Public Testing and Research Organs

Governmental and provincial testing and research organs will conduct research and development in the fields in which they can display their respective specialities and local colors. There may be some overlappings of research items in this case. Anyway, further efforts should be made for closer contact and cooperation among various organs and between such organs and the Japan Atomic Energy Research Instititute.

f. Research and Development in Private Circles

In the development of atomic energy technology to the practical stage, private enterprises should play a very important role in applied research and industrialization tests and research. Although the greater part of efforts in the atomic energy field will have to be directed toward the digestion

of technology introduced from abroad and toward the improvement and development of technology based upon such introduction, efforts should at the same time be given to fostering domestic technology, and future development should be expected through a growth of originality. In this connection, as to the research which requires large-scale and expensive research facilities, measures will be taken so that the facilities to be installed at the Japan Atomic Energy Research Institute will be used effectively. Particularly, in the projects which need fostering by the Government at the development stage in connection with the long-range program, private research and development will be promoted through disbursement of research funds and subsidies.

(7) Main Points in Research and Development Program

a. Basic Research

i) Basic research in science should be aimed at fostering the foundation of science and technology on a comprehensive basis and strengthening such a foundation. On the other hand, the basic research which leads to practical application should proceed toward the development goal while improving the basic technical level for the development of atomic energy. Improvement and strengthening of such basic research are important for the sound development of uses of atomic energy.

ii) The research facilities for basic research will become larger in scale and higher in quality with the progress of research methods. Therefore, such research facilities should be installed in competent departments of universities, Govermental research organs and similar testing and research organs, and

measures should be taken to have such facilities used widely by the researchers concerned.

iii) In propelling basic research, exchange of information and interchange of research achievements will be stepped up on an international basis, besides effecting closer liaison among domestic research organs.

b. Research and Development of Power Reactors

i) At the present stage of development of power reactors, Japan cannot yet finalize the selection of most effective reactor type. Therefore, research and development should be conducted effectively and in a flexible manner, with due consideration to future progress of development.

ii) Development of the gas-cooled reactor and the light water-cooled reactor, which are at the practical stage abroad at present, will be done primarily by private enterprises by introducing foreign technology, with the Japan Atomic Energy Research Institute cooperating in research for improvement.

iii) Development of the semi-homogeneous reactor will be propelled strongly as project research under the leadership of the Japan Atomic Energy Research Institute, with private enterprises cooperating.

iv) In order to establish a nuclear fuel cycle for the future, the Japan Atomic Energy Research Institute will propel research and development of the fast breeder reactor and others.

c. Research and Development of Reactors, Related Equipments and Materials During First Ten Years

i) In order to propel basic research on the design of reactors and code computation, it is necessary to install a big electronic computer at the Japan Atomic Energy Research Institute. In this connection, it is desirable to set up a design code center.

ii) As to research and development of the light water-cooled reactor, JPDR will be used to the fullest extent in research on reactor kinetics and nuclear superheating.

iii) In the research and development of the gas-cooled reactor, emphasis will be placed on the adoption of higher pressure and higher temperature for the reactor performance.

iv) In case of need, the Government will take appropriate subsidizing measures toward research and development conducted by private enterprises.

v) A material and engineering test reactor will be installed at the Japan Atomic Energy Research Institute for the development of fuel and material, and measures will be taken to have the said reactor used jointly and effectively by related organs.

vi) In order to propel research and education at universities, it is desirable to further improve the critical experimental facilities and research reactors.

d. Research and Development of Nuclear Fuel

i) Research on refining will be conducted by the Atomic Fuel Corporation and private enterprises.

ii) Research on the fabrication of reactor fuel, which is approaching the stage of practical use, will be conducted primarily by private enterprises. If necessary in that case,

introduction of foreign technology will be expected.

iii) Research on inspection technique of fuel will be conducted by the Atomic Fuel Corporation.

iv) Research on uranium enrichment will be conducted by the Japan Atomic Energy Research Institute and the Atomic Fuel Corporation.

v) Research and development of re-processing will be propelled as joint research by the Japan Atomic Energy Research Institute and the Atomic Fuel Corporation.

vi) Research on the fuel for the semi-homogeneous reactor and on the re-processing of such fuel will be conducted by the Japan Atomic Energy Research Institute.

vii) Research on plutonium fuel will be propelled strongly by setting up a special research and development system jointly with the Atomic Fuel Corporation and the Japan Atomic Energy Research Institute.

viii) Research on thorium fuel will be conducted by the Japan Atomic Energy Research Institute, Governmental testing and research organs and private enterprises in connection with the thermal breeder reactor study.

e. Research and Development of Nuclear Powered Ships

i) The target for the start of navigation of the first nuclear powered ship is set at 1968 - 1970. Construction of the first nuclear powered ship should be the effective means of propelling home production for the future demand of nuclear powered spips.

ii) As to the hulls of nuclear powered ships research and development will be propelled as quickly as possible in consideration of the possibility of demand for the ships from abroad.

iii) The light water-cooled type is considered as the reactor for the propulsion of the first nuclear powered ship. Although the related technology will be introduced from abroad, research for enabling home production will be conducted as far as possible.

iv) Considering the possibility of development in the future, survey and research on nuclear powered sumbarine merchant ships will be propelled.

v) For the primary purpose of conducting research on shielding for the development of nuclear powered ships, a swimming pool type research reactor will be installed at the Japan Atomic Energy Research Institute, and will be used jointly and effectively by the organs concerned.

f. Research on Nuclear Fusion

i) For the time being, emphasis in research on nuclear fusion will be placed on deepening the understanding of high-temperature plasma phenomena and building the technical foundation for plasma experiments.

ii) As to physical solution to high-temperature plasma, research achievements at the Plasma Institute will be expected.

iii) Experiments and research on high-temperature plasma will be propelled, as before, by various testing and research organs.

iv) In the future, in case large-scale experiments become necessary in view of the results of research at home and abroad, such experiments will be taken up as project research, and the research scale will be expanded with construction of experiment facilities on a considerable scale.

v) Survey and research on the MHD power generating method will be carried out under the leadership of the Japan Atomic Energy Research Institute in connection with high-temperature plasma engineering.

g. Research and Development of Uses of Isotopes

i) Efforts will be made, as before, to promote the utilization of isotopes and radiation in the fields of agriculture, biology, medicine and industry.

ii) Particularly, considering that there is much room for industrial uses, further efforts will be made to promote utilization in this field.

iii) Since a further increase is expected in the demand for isotopes, research on the home production of isotopes will be carried out with emphasis on reducing the production cost.

iv) In the first period under the program, consideration will be given to installing a medical reactor at the National Institute of Radiological Sciences.

h. Research and Development of Radiation Chemistry

i) Since radiation chemistry is a new field which promises big development in the future, research and development will be stepped up extensively and positively. Basic research will be conducted by universities, Governmental and public testing and research organs. In addition, efforts will be made to foster basic research at private testing and research organs.

ii) In order to propel intermediate-scale tests in radiation chemistry and development of radiation engineering energetically, consideration will be given to setting up a central

research organization at the Japan Atomic Energy Research Institute as early as possible.

iii) The central research organization, equipped with a large-scale irradiating source, will be utilized jointly and effectively with related organs, especially with private research organs. In the future, consideration will also be given to installing a chemical reactor.

i. Research for Prevention of Radiation Hazards

i) Since the prevention of radiation hazards is a new field of study and is an important problem, research will be carried out positively by the National Institute of Radiological Sciences with the cooperation of universities and, Governmental testing and research organs.

ii) The subjects to be taken up for research at present are biolgical effects of radiation, research on environmental contamination and permissible dose limit, research concerning prevention, diagnosis and medical treatment, and accident countermeasures.

j. Research on Reactor Safety Measures

i) Research on reactor safety measures will be propelled energetically under the cooperation of the Japan Atomic Energy Research Institute, Governmental testing and research organs, universities and private enterprises.

ii) In view of the conditions peculiar to Japan, research on aseismatic construction will be taken up on a priority basis, besides research concerning safety design, shielding, instrumentation and control and safety devices.

iii) Research on the safety measures of nuclear powered

ships, corresponding to the peculiarities of such ships, will be conducted by the organs concerned in parallel with the above-mentioned research.

k. Research on Waste Disposal

i) Development of the utilization of isotopes and other fields of atomic energy in the future will lead to an increase in the quantity of the waste discharged. Therefore, an organ for waste disposal will be set up at an appropriate time. Also, the Japan Atomic Energy Research Institute, Governmental testing and research organs and some private enterprises will engage research on waste disposal.

ii) Research on waste disposal will be conducted as to liquid, gaseous and solid state wastes. Furthermore, in preparation for the future, positive research will be conducted on the disposal of waste into the ocean.

2. Basic Research

(1) Necessity of Basic Research and Its Scope

The scope of research concerning the development and utilization of atomic energy is very large, including over-all surveys and research at the Atomic Energy Commission, basic research in the fields of basic science and applied science at universities, the Japan Atomic Energy Research Institute and Governmental testing and research organs, and the testing and research for practical uses of atomic energy now being pushed forward primarily by private enterprises. As to the development of reactors, university research in basic science, such as elementary particle theory and nuclear physics, constitutes

an extensive foundation, and basic research in applied science, such as reactor physics, becomes the foundation for the development toward practical improvements of reactors. Construction of reactors can be started only when the stage of tests for industrialization and practical uses is reached by way of the stages of applied research for nuclear design or reactor design. The basic research in the fields of basic science and applied science, which constitutes the under-current of the development and research on atomic energy, is not of such a nature that may receive restrictions on the direction of research or that may be criticized about the basis of planning, but is of such a nature as will improve latent ability on an extensive basis. On the other hand, the basic research, which should serve effectively and directly for the development and utilization of atomic energy developing from basic research as science, that is, basic research for specific purposes such as the development of reactors, will automatically have its scope defined and have clear targets.

(2) Roles to be Played by Universities, Japan Atomic Energy Research Institute and Other Research Organs

Although basic research as science and basic research on the development of atomic energy differ from each other in respect of direction and system, consideration should be given to effecting better relations between them so far as basic research on the development of atomic energy makes progress with basic research in science as the foundation. Also, in order to effectively achieve the ultimate goal of development and utilization of atomic energy, conisideration should at the

same time be given to the division of role in research and development. As for basic research as a whole, the matters not directly related to specific development objects should be taken charge of by universities, while basic research for development toward concrete targets set up for the future application should be conducted primarily by the Japan Atomic Energy Research Institute and Governmental testing and research organs, with the cooperation of private enterprises, as is clear in view of the characters of the respective research organs. There is no rigid boundary between basic research as science and basic research for development, and it is only natural that division of research field into these two should be made in a sufficiently flexible way. For closer liaison between these research organs, it is necessary to prepare opportunities for effective discussions so that all research organs concerned will be able to participate in easily.

(3) Scope and Facilities of Basic Research

Since the purpose of basic research is considered to lie in proceeding toward the development target while improving the latent technical level for the development of atomic energy, and since basic research as science calls for enough flexibility, it is expected that the specific importance of basic research will increase all the more in the course of the development of atomic energy for the coming ten to twenty years.

At the same time, it is anticipated that facilities for basic research will become larger in scale and higher in quality with the progress of the research techniques resulting in a gradual increase in research expenses. In the theoretical fields of

nuclear physics and reactor design, for instance, high-speed, big-capacity electronic computers are becoming indispensable in view of the existence of a stack of problems which cannot be solved by medium-size electronic computers because of the increasing complexity of conditions. Also, for the propulsion of basic research in nuclear physics and elementary particle theory, installing of large accelerators should be considered with joint uses in mind. In addition, special, large-scale facilities are expected to be desired in the fields of solid state physics, chemistry and biology, too.

It is to be desired that these facilities will be installed at competent departments of universities, Govermental testing and research organs and similar public research organs, that measures will be taken to make these facilities open to use by the researchers concerned on an extensive basis, and that an appropriate steering organ will be set up in order to have these facilities used effectively. It is also necessary to improve the joint research setup for the research organs concenrned in connection with the joint use of these facilities.

(4) Need of International Exchange of Information

In propelling basic research, needless to say, it is necessary to effect close liaison between the domestic research organs as mentioned above, and to maintain cooperation between research organs and industrial circles in the course of basic research and applied research. Furthermore, consideration should at the same time be given to exchange of information and research achievements with foreign countries. In the extensive field involved in basic research as science or in the

basic research in which the development target is clarified, it deserves consideration to push forward new kind of development on the basis of conceptions with originality. At the same time, in order to carry out research and development effectively, it is considered to be highly effective means to have as many opportunities as possible for international research and discussion and to propel joint research projects. Since the trends in the nations, which are advanced in the atomic energy field, show the progress of joint research and development, particularly basic research on an international basis, consideration should be given to promoting the exchange of information with foreign countries and further to conducting joint research on an international basis. As part of exchange of research achievements with foreign countries, it is desired for Japan to participate positively in science panel discussions and to become the host nation to sponsor international conferences.

3. Research and Development of Reactors

(1) Evaluations of Various Kinds of Power Reactors, and Research and Development Policy

In view of the latest trends at home and abroad, it is anticipated to be around 1970 that the use of atomic energy for power generating purposes will become economical. During the first ten years, which mean the stage of development, therefore, the development of electric power generating reactors and other reactors will be propelled energetically with a target set on the home production of power reactors. Selection of the reactors to be developed in Japan should be made carefully in consideration of development in foreign countries during the

coming ten years. Emphasis in the development of reactors in Japan, however, will be placed on the light water-cooled, gas-cooled and semi-homogeneous reactors, because the development of light water-cooled and gas-cooled reactors has progressed considerably in various foreign countries, and because there is a favorable prospect for the development of the semi-homogeneous reactor, on which research is being propelled primarily by the Japan Atomic Energy Research Institute.

Furthermore, it is advisable to make efforts to carry on research concerning the organic-cooled reactor, heavy water-moderated reactor, fast breeder reactor and aqueous homogeneous reactor, which hold out prospects for future development.

a. Light Water-Cooled Reactor

Light water-cooled reactors have been developed since earlier days primarily in the United States, and considerable achievements have been recorded through their operations. The cost of construction of such reactors is expected to be reduced by permitting bulk boiling inside the reactor and also by increasing the reactor size in the case of the pressurized water type reactor, and by increasing the vapor content in the reactor core and by realizing a single cycle in the case of the boiling water type reactor. In this way, such reactors are expected to become payable around 1970.

In Japan, development of this type of reactor is under way, and it is expected that considerable number of the power reactors constructed in the near future will be of this type. Research

and development will be propelled, therefore, so that power reactors of practical scales will possibly be constructed primarily by the hands of domestic makers early in the 1970's. Introduction of foreign technology also is considered necessary for the establishment of the technical level required for the construction of this type of reactors. In order to foster technology for the construction of such reactors, however, further fostering measures should be taken on a priority basis.

Development of light water-cooled reactors requires research on an increase in in-pile output density, reasonable designs of containers, cooling system and safety devices, adoption of the nuclear superheat system, reduction of expenses for fabrication of fuel and increase in burnup aimed at improving the economy. Although such research should be propelled primarily by private enterprises, research on basic problems in nuclear physics and reactor design and various kinds of experimental research using JPDR should properly be conducted under the leadership of the Japan Atomic Energy Research Institute with private enterprises participating. With regard to JPDR, consideration will be given to conducting research on the nuclear superheat system at the latter half of the development stage depending upon future development.

b. Gas-Cooled Reactor

The gas-cooled reactor, when using natural uranium, affords only a small degree of freedom in designing, and can not satisfactorily meet the economic demand for higher operational temperature and smaller reactor size. However, improvement is possible to some extent by adopting hollow

fuel elements, which increase surface area ratio, or by increasing operational pressure. High economy is obtained also by the adoption of slightly enriched fuel, which increases the degree of freedom in designing thereby increasing operational temperature and minimizing reactor size. Also, it deserves consideration to increase operational temperature further by using graphite as the canning material.

Considering such a situation, as it is expected possible to put this kind of improved type high temperature gas-cooled reactors to practical use in the second ten-year period, it is necessary for Japan, too, to push forward development and research on this type of reactors. During the first ten years, research will be propelled on such basic problems as the treatment of fuel, fuel canning material and graphite and structure of reactor core.

c. Semi-Homogeneous Reactor

Considering the recent trend abroad, there is the possibility of the semi-homogeneous reactor being put to practical use in the latter half of the period covered by this program, that is, in the 1970's, and becoming an excellent power reactor. This reactor has also the advantage that it can use thorium as the fuel. Therefore, it is believed that the Japan Atomic Energy Research Institute and other organs concerned should concentrate their technical knowhow and efforts upon research and development of this reactor. For this purpose, research on this reactor will be propelled energetically as project research centering around the Japan Atomic Energy Research Institute. At first, the Japan Atomic Energy Research Institute consi-

dered the high temperature gas-cooled reactor alone in this field. As a result of the survey and research conducted so far, however, it has come to be believed that the idea of bismuth cooling, which has not yet been taken up abroad, is promising. During the first half at the development stage, therefore, considerable emphasis will be placed also on the development of the bismuth-cooled reactor. That is, efforts will be exerted for the development of bismuth technology and fuel for the semi-homogeneous reactor, and for solving various technical problems thereby ascertaining the evaluation on the feasibility as power reactor. If the said reactor is found promising as a result of such study, construction of an experimental reactor will be considered in the latter half at the development stage, and development will be pushed forward energetically. Furthermore, if necessary, development of the power demonstration reactor will be taken up for consideration.

d. Organic-Cooled Reactor

Although the organic-cooled reactor today still involves a lot of uncertain factors, it is considered promising in the future as a reactor for power generation and ship propulsion purposes in view of the characteristics of organic materials. In Japan, corresponding to the progress of development abroad, the Japan Atomic Energy Research Institute and private enterprises will propel basic research on heat transmission, organic materials and other matters.

e. Heavy Water-Moderated Reactor

Development of the heavy water reactor is slow because of the expensiveness of heavy water. This type of reactor,

however, can use natural uranium, and also has the possibility of nuclear superheating with vapor used as the coolant. Research on this type of reactor will be conducted primarily by the Japan Atomic Energy Research Institute by means of JRR-2 and JRR-3, with reference to the state of development overseas.

f. Fast Breeder Reactor

Although the fast breeder reactor has been developed since early days, it involves technically difficult problems because it aims at breeding, and the stage of practical use of this type of reactor is still remote in the future. Although the ideal form of this type of reactor is the plutonium fuel-led reactor, plutonium technique has not yet been established firmly. As for the reactor of this type, it is difficult to realize both breeding and economy in a design. The use of ceramic fuel or cermet fuel, however, gives doubling time of ten years or so and increases burnup, thereby holding out the possibility of excellent economy. In the first half of the development stage, therefore, research will be propelled on the techniques for handling, treating and processing plutonium fuel, sodium technique and thermal characteristics of fuel elements. In the second half of the development stage, construction of an experimental reactor will be considered depending upon the progress of research and development.

g. Aqueous Homogeneous Reactor

Whether or not the aqueous homogeneous reactor is promising for the future is unknown yet. When the problem of natural resources is considered, however, this reactor has an

advantage in respect of effective use of thorium. Basic research, therefore, will be continued for the time being.

(2) Research and Development of Power Reactors, Related Equipments and Materials During First Ten Years

a. Reactor Design

i) Research on Reactor Physics

Research on reactor physics leaves much room for rapid development in future. In the field of theoretical research, it is necessary to push forward positively the theoretical analysis of the nuclear-physical properties of reactors and various phenomena, and to make comparisons with experimental data. For this purpose, accumulation of experimental results obtained from the critical experimental facilities and others is considered to be indispensable to the promotion of research.

As for digital solutions for reactor theories, codes with medium-scale electronic computers are being developed at the Japan Atomic Energy Research Institute and private enterprises. Installing of large computers, however, is necessary in order to conduct calculations on criticality, burnup and shielding more properly taking two dimensions into consideration. For this purpose, it is advisable to install a big computer at the Japan Atomic Energy Research Institute promptly for the development of codes, and to conduct joint development on a systematic basis by making such a computer open to pubilic uses. Also, it is expected that several sets of big computers will be installed at universities and private enterprises toward the middle of the first ten-year period.

Since Japan is backward in experimental research, installing

of sub-critical and critical experimental facilities will be accelerated. At the same time, it is necessary to accumulate experimental data and to develop new experiment and measuring methods promptly. Various kinds of experimental facilities, from those for education and training purposes to those permitting measurement at high temperatures and a pressurized state, are required for this purpose. About 20 such facilities are expected to be installed at universities, Japan Atomic Energy Research Institute and private enterprises at the first half stage.

ii) Research on Thermal Design of Reactor

Thermal design of reactors has a special importance, since reactors are under severe conditions as compared with conventional plants. In Japan, various kinds of experiments are being conducted by installing heat-transfer experiment loops at the Japan Atomic Energy Research Institute and private enterprises. In future, it is necessary to continue such research and to make efforts to obtain universal results on the basis of the outcome of the experiments conducted with JPDR.

Considered as the important subjects of research are theoretical analysis of phenomena concerning heat-transfer and flow, such as burn-out, pressure loss and flow pattern; research on the distribution of void creations, burn-out of fuel elements, distribution and vibration of flow in two-phase flow, pressure loss, sub-cooling, local boiling and bulk boiling with high-temperature experiment loops; research on changes in viscosity and heat-transfer coefficient, decomposition and polymerization of organic materials due to heat and radiation,

and transition temperature by organic material experiment loops; research on relations between the heat-transfer coefficient, fluid resistance and temperature by high-temperature, high-pressure gas experiment loops; and research on the effect of void on reactivity, boiling or burn-out under radiation and change with a lapse of time in the heat-transfer coefficient of fuel rods by JPDR.

Since research on such matters is extensive and requires a lot of data, it is advisable for the Japan Atomic Energy Research Institute and private enterprises to maintain close cooperation with each other.

b. Control of Reactor and Reactor Kinetics

Research on the control and reactor kinetics should be promoted, because this problem is related to the safety of reactors. Particularly, with emphasis on the analysis of experiment data, which have so far been insufficient and on the development of new research methods, development and research should be conducted under cooperation between the Japan Atomic Energy Research Institute and private enterprises on theoretical development based on theoretical studies on reactor kinetics in general and experiment results; analysis into thermal and hydrodynamic problems and digital calculation of the limit to power density related to the boiling phenomenon; optimum design on reactor kinetics and control; control computers handling many information data; and develoment of computing control systems for reactors.

c. Research and Development for Improvement of Power Reactors

For the improvement and development of power reactors in the future, it is necesary to take up research, in the first ten-year period, on theoretical and experimental results to clarify the relations between the number of regions in the reactor core, method of replacing fuel and burnup of fuel; on reactor core containing burnable poison; on design of plant in connection with adoption of superheated steam; on method of control of the nuclear superheat reactor; and on the thermal properties of the hollow type fuel rod. Meanwhile, in connection with the trend in development in various countries, consideration will be given to conducting research concerning the thermal characterics of the nuclear superheat reactor by installing a nuclear super-heat in-pile loop on JPDR in the latter half of the development stage.

d. Fuel

Research and development of fuel will be propelled early in the first ten-year period, with emphasis on the completion of the technology which has been developed since earlier days and on the improvement of such technology. At the same time, basic research will be started on the development of various new kinds of fuel in consideration of future progress of power reactors. In the latter part of the development stage, production of the fuel so far developed and research on the practical use of new types of fuel will be propelled in parallel with each other.

With regard to home production of fuel for the Calder Hall improved type power reactor, introduction of foreign technology will be considered, and at the same time the development

of fuel alloy or improved alloy will be pushed forward step by step. Research in this field will be conducted primarily by private enterprises, with various other research organizations cooperating.

Introduction of foreign technology will be considered on the fuel for light water-cooled reactors, too. Private enterprises are expected to develop reserch on mass production of uranium dioxide pellets autonomously. Also, research will be continued on new fabrication processes to lower production cost, such as the extrusion method and swaging method.

Furthermore, in connection with an outlook on the future development of power reactors, consideration will be given to propelling research on new fuel, such as uranium carbide and other ceramic fuel, cermet fuel, uranium dioxide-thorium dioxide fuel or uranium carbide-thorium carbide fuel, positively from around the middle of the first ten-year period.

As to technology for the canning of ceramic fuel and assembling into fuel elements, autonomous development by private enterprises is expected.

e. Material

As for the materials which have already been developed, emphasis will be placed on completing such technology, and research on mass production will be conducted after the middle of the first ten-year period. Also, positive research will be conducted on the development of new materials.

Research will also be conducted, on a priority basis, on final confirmation of material quality by irradiation test, and on the establishment of processing, welding and inspecting

methods in the use of materials in structures.

i) Moderator, Reflector, Coolant

Private enterprises already have almost completed technique for the production of several tons of heavy water a year. In case a larger amount of heavy water is required in view of the future progress of heavy water reactors and an outlook on demand for heavy water, consideration will be given to having private enterpises gradually conduct testing and research for industrialization fit for mass production, starting sometime in the latter part of the development stage.

High-purity, high-density graphite to be used as the moderator and the reflector has been studied primarily by private enterprises to the extent of establishing production technique. As to the development of the impermeable graphite material which may be used in future power reactors, private enterprises are expected to make efforts in parallel with the development of such reactors.

As to organic materials, in-pile and out-pile tests will be conducted by the latter half of the development stage, and research on the refining of such material and research and development of new kinds of organic materials will be conducted primarily by the Japan Atomic Energy Research Institute.

ii) Canning Material

As to fuel canning materials, research and development have been propelled on magnesium and its alloy, stainless steel, zirconium and its alloy, etc., with considerable achievements. On putting such materials to practical uses, however, there are some problems remaining unsolved, such as the

fabrication process with high dimensional accuracy, the effect of wall thickness allowance on nuclear property, method of inspection for defects and in-pile irradiation tests. Although research in these fields should be conducted by private enterprises autonomously, the Japan Atomic Energy Resaerch Institute, Governmental testing and research organs and private enterprises should maintain close liaison in research and development as to corrosion tests and irradiation tests so that home production will be realized as early as possible.

Research on the refining, shaping and fabrication of beryllia and on the refining and fabrication of beryllium is taking place to some extent. In the firste ten-year period, research will be conducted on the method of economical production and fabrication of beryllium step by step in consideration of development overseas.

Also, researh on improvement and processing will be conducted on new canning material composed of ferro-aluminum alloy or ferro-alluminum alloy plus several other elements, and efforts will be stepped up gradually to put such material to practical use.

iii) Structural Material

Although stainless steel is excellent in respect of strength and resistance against corrosion, it has such a defect that the cobalt contained therein assumes inductive radioactivity. It therefore deserves consideration to use carbon steel or low-percentage alloy steel, which has little inductive radioactivity, in place of stainless steel. Accordingly, it is necessary to study the treatment of products resulting from the corrosion of

carbon steel and the annealing to be made following welding.

Research on the irradiation characteristics of structural materials, such as stainless steel and carbon steel, to be used to surround the reactor core, should desirably be conducted primarily by the Japan Atomic Energy Research Institute so as to accumulate sufficient data.

Stainless-clad steel plates have been trial-manufactured in Japan, too. Research will be conducted in future on how to give uniformity and machinability. As to spot welding technique, research has been conducted with considerably favorable results. As to actual construction, however, techniques should be developed on designing construction method and inspection method.

iv) Controlling Material

Research on the smelting of boron steel, boron stainless steel, hafnium and other materials used for controlling is being conducted in Japan, too. In future, it is expected that research and development of fabrication technique on such material will be conducted primarily by private enterprises.

Meanwhile, rare earth controlling materials have recently come to attract attention. Consideration will also be given to the development of technique on such materials.

f. Related Equipments

As to various kihds of equipments used in reactors, research has so far been conducted by private enterprises, and the Government also has been making efforts for the promotion of such industry by taking subsidizing measures. For the time being, emphasis in this field will be placed on

light water-cooled reactors and gas-cooled reactors.

Primarily by private enterprises, research and development will be propelled on the designing and manufacture of pressure vessels, circulation pumps, valves, heat exchangers, steam separators, control rod driving devices and control and safety circuits.

(3) Semi-Homogeneous Reactor

a. Research on Designing

Conceptional designs will be made on experimental reactors, prototype reactors and power reactors always on the basis of the latest experiment data and survey results, and efforts will be continued to approach completion.

Full-scale nuclear designs, thermal designs and structural designs will be made on experimental reactors by studying various kinds of reactor constants by the semi-homogeneous critical experimental facility and by collecting, by loop experiments on heat-transfer and other methods, various data required for designing. It is necessary, for this purpose, to install a large computer at the Japan Atomic Energy Research Institute as early as possible.

b. Fuel

Choice between uranium dioxide-graphite fuel and uranium carbide-graphite fuel as the fuel for semi-homogeneous reactors should be made depending upon the maximum temperature adopted in nuclear design, and these two kinds of fuel will be studied in parallel for the time being. Special importance should be attached to the development of uranium carbide fuel, since this kind of fuel can be used in other types of reactors,

too and since it will possibly be used as the fuel for high-temperature reactors. Research will also be conducted on the fuel for the blanket part, such as thorium carbide.

In order to study the behavior of nuclear fission products and changes in the physical and chemical properties of fuel at high temperature and high neutron flux, experiments with high-temperature, normal-pressure gas loops and high-temperature, high-pressure gas loops will be conducted. In addition, problems in the continuous removal of gaseous nuclear fission products will be solved.

One of the advantages of uranium dioxide-graphite fuel is that it can be given physical or simple chemical re-processing. Therefore, further research will be conducted to ascertain such a possibility and to develop the re-processing method best fit for the fuel for semi-homogeneous reactors.

c. Material

As to bismuth, impurities of home-produced bismuth will be examined, and industrial research for the improvement of its purity will be promoted. Techniques for the melting, solidifying, re-melting, injection and discharge of a large quantity of bismuth will be acquired. Also, tests on co-existence as to the bismuth of pumps and valves will be conducted. As the formation of ^{210}Po from bismuth presents many problems, the behavior of Po will be clarified through in-pile capsule tests and others, and research will be conducted on its removal.

The iron-steel material which can be used with bismuth at psesent is considered to be low-chrome steel and low carbon steel. Primarily as to such a kind of materials, research and

development will be conducted on materials which have better resistance against corrosion, mechanical strength and meld-ability.

As non-ferrous materials, beryllium, molibdenum and tantalum have excellent properties. Since these materials are very expensive, however, it is necessary to develop the methods for the canning of steel surface and plating.

Graphite is highly stable with bismuth. The biggest problem to be solved in the use of graphite, however, is penetration of bismuth into graphite and the property of graphite at high temperatures. Therefore, the absorption of bismuth into graphite and the reaction of bismuth-graphite under irradiation will be studied by means of bismuth uptake apparatuses, in-pile capsule testing facilities, etc., together with the develop-ment and research on excellent impermeable graphite. Further-more, with regard to the graphite canning of steel surface, research and development will be propelled concerning mechanical strength and thermal strength.

Research will also be promoted on reaction between graphite and gas, which is an important problem in the case of gas-cooling. There is the idea of conducting the control of this type of reactor by liquid cadmium. In order to study such possibility, research and development will be conducted on the metal which is corrosion-proof with cadmium and bismuth.

d. Over-All Engineering Tests

An over-all engineering test facility, simulating the experimenal reactor, will be completed toward the middle of the first ten-year priod. With this facility, engineering

research on the core structure of experimental reactor, over-all research on the flow and heat transmission of coolant, and various kinds of over-all engineering experiments will be conducted in parallel with comparison with the results of the experiments so far conducted on a small scale. In this way, the performance characteristics of semi-homogeneous reactor will be studied in the engineering field, and necessary data for the construction of experimental reactors will be collected.

e. Construction of Experimental Reactors

If possibility of excellent power reactors is recognized as a result of the research conducted in the first half of the development stage, experimental reactor will be constructed in the second half of the same stage so as to push forward development energetically. If it is found, as a result of the research conducted in the first half of the development stage, that bismuth is not necessarily fit as the coolant, development of high-temperature gas-cooled reactors alone will be propelled.

f. Development Setup

Research and development of semi-homogeneous reactors have so far been conducted by the Japan Atomic Energy Research Institute. In future, however, a system for effective cooperation between the Institite, related research organs and private enterprises should be established so that research and development in this field will be pushed forward as one of the projects in the development of atomic energy in this country.

(4) Breeder Reactor

a. Fast Breeder Reactor

Fast breeder reactors are being developed with considerable

emphasis on foreign countries. In Japan, research should be conducted in this field, primarily by the Japan Atomic Energy Research Institute, aiming at a final, ideal type. In this connection, technical information overseas will be digested sufficiently, and technical development will be propelled by giving priority to such technique as can be developed in Japan and to the technique requiring experimental research in the parts related directly to safety and other matters. As for the type to be adopted in the future, it is advisable to aim at a ceramic or cermet fuel reactor using plutonium. In line with the aforesaid principle, future research and development will be propelled as follows:

i) Sodium Technique

Major problems on sodium are reaction with the air or water, and corrosion in sodium. On these problems, research with test loops are already under way at private enterprises. In the future, research will be conducted on corrosion and heat-transfer characteristics due to sodium cooling by installing an in-pile loop utilizing the research reactor of the Japan Atomic Energy Research Institute. At the same time, development of machines and instruments related to sodium-cooling will be developed, aiming at home-production in the future.

ii) Plutonium Technique

Handling of plutonium is difficult because it is toxic and radioactive. Therefore, it is necessary to get used to handling plutonium while studying the method of fabrication. Furthermore, research on the thermal properties of ceramic or cermit of plutonium and their irradiation tests will be conducted.

iii) Reactor Physics and Control

In the fast breeder reactor, clarifying of nuclear constant has a special importance for ensuring the safety of the reactor and making an optimum design for the reactor core. Therefore, a critical experimental facility, whose fast region is sub-critical and in which some thermal neutrons are mixed, will be installed at the Japan Atomic Energy Research Institute for the purpose of clarifying nuclear cross section and delaied neutron ratio and conducting research on the control of the fast reactor.

iv) Construction of Experimental Reactors

On the basis of the results of the aforesaid research, and adopting technical information overseas, small-scale experimental reactors will be constructed in the latter half of the first ten-year period or in the first half of the second ten-year period for the purpose of conducting research related primarily to safety and also engineering research for practical-scale reactors.

b. Aqueous Homogeneous Reactor

In foreign countries, research and development of aqueous homogeneous reactors have been conducted for a considerable length of time. However, the stage of practical use is still remote because of difficult problems as to fuel solution, slurry, etc. Right now, therefore, Japan will not conduct research anticipating power reactors, but will propel research primarily on basic matters by means of the critical experimental facility of the Japan Atomic Energy Research Institute. While going this way, machines and instruments for practical reactors will

be developed depending upon development overseas. In line with the aforesaid principle, research and development will be conducted in future as follows:

i) Reactor Physics

In the field of basic research on the aqueous homogeneous reactor, research will be conducted on neutron economy, breeding ratio and long-range variation in burnup as well as solution of nuclear constant by the critical experimental facility.

ii) Fuel Solution

Research will be conducted on the stability and corrosion of aqueous solution of uranyl sulfate, as the reactor core fuel, at high temperatures and pressures.

iii) Slurry

Research will be conducted on technique to create uniform suspension of oxidized thorium slurry as the blanket fertile material, and on the stability, corrosion and erosion of slurry at high temperatures, under high pressure and in radiation.

iv) Construction of Experimental Reactor

When the breder reactor is found promising as a power reactor in view of the results of the aforesaid research and overseas development, consideration will be given to constructing a small-scale experimenal reactor.

(5) Installing of Reactors for Testing and Research

a. Shield Research Reactor

As to the probabilities of various kinds of reactions between radiation and shielding and structural material, which are a factor necessary in the design of shielding structure,

and as to radiation sources, there are many unknown fields, and actual designs are covered by big safety factors. Altough the adoption of such safety factors does not become a problem in the shielding for the existing research reactors and electric power generating reactors, basic research aimed at obtaining data for shield designs and experimental research by lifesize models have great significance, economically too, in the development of reactors whose volume and weight should be minimized, such as ship propulsion reactors.

In order to step up basic research concerning the shielding, which has so far been the weak point in the development of atomic energy, from such a point of view, shield research facilities, with a swimming pool type reactor as their main part, will be installed at the Japan Atomic Energy Research Institute promptly, with which to conduct over-all research concerning the shielding of reactors. With regard to the operation of the facilities, measures will be taken so that they will be used jointly with other organs concerned.

b. Material and Engineering Test Reactor

There are differences in material testing facilities depending upon whether they are for irradiation tests on a comparatively small scale or for large-scale engineering tests. So far as engineering test are concerned, it is desirable to have such facilitles as will realize conditions close to the actual operational conditions of reactors in respect of pressure, temperature, flow rate, neutron flux, heat flux and shape.

In this respect the use of a practical reactor in material tests can be considered. To conduct research effectively,

however, it is advisable to install a material and engineering test reactor for the exclusive purpose. Therefore, prompt investigations will be made on reactor type, scale and method of steering, so that such a reactor will be installed at the Japan Atomic Energy Research Institute as early as possible at the develpment stage.

c. Chemical Reactor

With regard to the chemical reactor aimed at using the radiation and thermal energy produced in the reactor directly in a chemical process, investigations and necessary basic research will be conducted primarily by the Japan Atomic Energy Research Institute, and construction will be started when an outlook on practical uses becomes definite.

d. Medical Reactor

For the purpose of conducting research on neutron treatment on tumor, biological effects of neutrons and also radiation hazards, prompt surveys and research will be conducted primarily by the National Institute of Radiological Sciences on the method of uses of a medical reactors and on a program on the uses of such reactor, and consideration will be given to the installing of the reactor with the cooperation of the Japan Atomic Energy Research Institute.

(6) Research and Development Program of Reactors

In the development and utilization of reactors, the course to be followed should be clarified in connection with construction of research reactors and material and engineering test reactor as research facilities and in relation to the developmet of various kinds of power reactors which will possibly be put to

practical uses in the future.

Research and development of atomic energy as a whole, when looked upon from the aforesaid point of view, will probably be as shown in the table of program attached. (See 110 page)

Since it is impossible to give a correct forecast on the development of atomic energy technology for the coming 20 long years, the program for the latter half in the 20-year pogram cannot but be something like a general prediction. In spite of such a situation, construction of reactors in the future was included in this program so as to clarify the course to be followed in the development and research on nuclear reactors.

As for testing and research reactors, in addition to JRR-1 and JRR-2, the year 1961 will see the completion of JRR-3, followed by the construction of a shield research reactor. Also, construction of a material and engineering test reactor will be started so that it will be started up in 1965 or 1966.

Power reactors will be constructed in accordance with what was envisaged in Part 2 of this program. JPDR now under construction at the Japan Atomic Energy Research Institute, which is expected to be completed in 1963, will be used for research on the reactor kinetics of light water cooled reactors and for research and development required in future improvement. Furthermore, JPDR, like the aforesaid shield research reactor, will contribute to the development of nuclear powered ships in Japan. In the future, consideration will be given to using JPDR also for research on nuclear superheating corresponding to the progress of light water-cooled reactor

technology.

Such power reactors as will possibly be put to practical use in the second ten-year period will be studied and developed primarily by the Japan Atomic Energy Research Institute. That is, an experimental reactor for a semi-homogeneous reactor will be constructed in the latter half of the first ten-year period. If excellency of bismuth cooling is recognized as a result of operation and study of the said reactor, consideration will be given to developing the reactor to a practical-scale power reactor in the latter half of the second ten-year period through a stage of a prototype for bismuth cooling.

At the same time, if possible, in the light of the progress of development of high-temperature gas-cooled reactors overseas, consideration will be given to developing high-temperature gas-cooled reactor by acquiring foreign technology through international cooperation. In this connection, it is expected that development will be made to the stage of practical-scale prototype reactors by the middle of the 1970's.

As for the aqueous homogeneous reactor, construction of a small-scale experiment reactor in the latter half of the first ten-year period will be considered. Whether or not this kind of reactor should be developed to a power demonstration reactor in the future will be decided after the characteristics and efficiency of the experiment reactor are clarified.

Furthermore, as it is expected that a fast breeder reactor using plutonium will be put to practical use in the second ten-year period, research and development will be propelled with the aim of constructing an experimental reactor by the end of

the 1960's. If the possibility increases of using plutonium as the fuel for the thermal neutron power reactor, construction of a plutonium re-cycle experimental thermal reactor will be considered in the latter half of the 1960's. In that case, consideration will be given to conducting joint research with foreign countries, or international organizations, if possible. If the possibility is slim of the use of plutonium as the fuel for power reactors, and if there is favorable development of high-level utilization of natural uranium by natural uranium-heavy water type reactors, then the development of natural uranium-heavy water-moderated reactors will be taken up positively, and consideration will be given to construction of an experimental reactor.

4. Research and Development of Nuclear Fuel

Technique for the manufacture and processing of nuclear fuel has much room for improvement as to burn-up, thermal efficiency and methods of manufacture and processing. Furthermore, since atomic reactors in themselves are at the stage of development, it is anticipated that demands for new types of fuel element will arise gradually. Research on nuclear fuel, therefore, should be conducted, maintiaining close relation with the development of reactors.

The progress of atomic power generation is expected to produce a considerable quantity of plutonium. Whether or not such plutonium can be put to practical use in reactors effectively will influence the future of atomic power generation greatly. Therefore, development of plutonium fuel should be promoted as an item of joint research by the Atomic Fuel

Corporation and the Japan Atomic Energy Research Institute. Furthermore, efforts will be made for the establishment of an independent fuel cycle at home by simultaneously propelling the development of techniques concerning the re-processing of spent fuel and re-use of depleted uranium.

Also, research concerning uranium enrichment would be carried out to prepare for a future increase in the demand for enriched uranium and also to increase the varieties in the sources of fuel supply.

(1) Refining

The Atomic Fuel Corporation is conducting tests for production on the milling and refining of uranium. Research will also be conducted for the improvement of refining technique, such as the simplifying of refining process, and improvement of equipment. Uranium metal, required for the tests and research to be conducted for the time being, will be produced by such equipment. In addition, research will be conducted on the refining method fit for the treatment of low grade ore.

At the same time, research on refining technology will be propelled in private enterprises, too. In the future, in the home production of fuel for natural uranium type power reactors, studies will be made on the respective techniques developed by the Atomic Fuel Corporation and private enterprises as well, and the most advantageous method will be adopted from technical and economic points of view.

(2) Conversion of Uranium Hexafluoride into Uranium

Dioxide or Metallic Uranium

As to the conversion of enriched uranium hexafluoride into uranium dioxide or metallic uranium, overseas sources will be relied upon for the time being. However, technique for the treatment of enriched uranium hexafluoride will be developed promptly, so that such conversion will be made at home depending upon its economics in case the processing of enriched uranium fuel is conducted domestically in the future. It is expected that technology in this field will be developed primarily by private enterprises in connection with processing. In this case, consideration will be given to the importation of foreign technology, if necessary.

(3) Processing

With regard to the fuel for JRR-3 reactor, the Japan Atomic Energy Research Institute will conduct research on natural uranium alloy fuel, its processing, canning material and canning method with a view to improving the efficiency of fuel rerformance. Private enterprises will cooperate with the Japan Atomic Energy Research Institute in this field.

As to fuel for power reactors, efforts will be made to accumulate technical achievements in preparation for future development. Furthermore, since there is much room for the improvement of nuclear fuel processing technique, private enterprises are expected to develop their research concerning the development of new alloy fuel, and the swaging and extraction processing of ceramic fuel.

At the same time, the Japan Atomic Energy Research Institute will carry out general basic research concerning the

processing of nuclear fuel and research for the development of fuel of new types.

(4) Inspection of Nuclear Fuel and Irradiation Test

Nuclear fuel inspection technique has a special importance in connection with reactor safety. Therefore, research concerning non-destructive inspection and destructive inspection will be propelled with a view to developing the formula of aplication of such inspection methods to various kinds of nuclear fuel, and establishing inspection standards. This research will be carried out energetically primarily by the Atomic Fuel Corporation with the collaboration of private enterprises cooperating.

Also, since irradiation tests in reactors are indispensable to the development of nuclear fuel, measures will be taken so that the testing and research reactors of the Japan Atomic Energy Research Institute will be used effectively. Furthermore, a material testing and engineering reactor will be installed in the latter half of the first ten-year period so as to propel the development of nuclear fuel.

(5) Uranium Enrichment

In preparation for meeting the demand for enriched uranium in the future, and in order to increase varieties in its source of supply, research and development of uranium enrichment will be propelled so that enriched uranium would be produced at home to some extent in the latter half of the second ten-year period.

For this purpose, general basic research concerning uranium enrichment will be conducted primarily by the Japan Atomic Energy Research Institute. At the same time, research

and development of the centrifugal separation method, which have already started, will be propelled primarily by the Atomic Fuel Corporation with the collaboration of other related organizations. Meanwhile, consideration will be given to having the Atomic Fuel Corporation undertake uranium enrichment in the future.

(6) Re-Processing

Considering the fuel inventory, expenses for the transportation of spent fuel and realization of a fuel cycle in atomic power generation in the future, Japan should promptly establish a formula for the reprocessing of spent fuel. From this point of view, a pilot plant for production tests on reprocessing will be constructed by the Atomic Fuel Corporation so that it will be completed in the latter half of the first ten-year period. In order to obtain basic data for the construction of such a pilot plant, the Atomic Fuel Corporation and the Japan Atomic Energy Research Institute will cooperate in conducting engineering tests and research on the solvent extraction method using hot cave to be installed at the Japan Atomic Energy Research Institute. The Japan Atomic Energy Research Institute will also conduct, in parallel with the developmentsof the semi-homogeneous, aqueous homogeneous and fast breeder reactors, basic research concerning the mechanical separation method, fluoride fractional distillation method and dry metallurgical method for the reprocessing, of the spent fuel in the said reactors. Depending upon the progress of basic research, engineering research will be conducted by means of the hot cave.

(7) Depleted Uranium

It is anticipated that in the future a considerable quantity of depleted uranium will be produced by the reprocessing of spent fuel. Development of technology for the re-use of such depleted uranium is indispensable to the establishment of a fuel cycle. Conceivable as the methods of re-use are for the blanket in the breeder reactor, use after giving re-enrichment or plutonium-mixing, and use after adjustment into uranium of the prescribed degree of enrichment by mixing with uranium of higher or lower enrichment. Research will be propelled, primarily by the Atomic Fuel Corporation. to clarify the technical possibilities of such re-using methods and to establish the most economical formula of re-use.

(8) Plutonium

Development of plutonium fuel will be the basis for fuel cycles, so the Atomic Fuel Corporation and the Japan Atomic Energy Research Institute will propel it strongly as their joint research project. The goal of such efforts is set at starting the use of plutonium in the thermal reactor in the first half of the second ten-year period, and in the fast breeder reactor in the latter half of the second ten-year period. In this case, the Japan Atomic Energy Resarch Institute will primarily take charge of physical and chemical basic research, reactor physics and reactor design, while the Atomic Fuel Corporation will primarily take care of plutonium metallurgy, processing technology, small scale manufacture of fuel for testing and production.

Nuclear property of plutonium and its property as solid state have not yet been clarified fully. Great care is required

in handling plutonium, since it is alpha ray radiating material, and since it has severe toxicity. It has also such properties that it has five transformation points as metal, that its melting point is low, and that it is not stable when exposed to radiation. At an early stage of development, therefore, analysis of plutonium and physical as well as metallurgical basic research will be conducted in parallel with training in the technique for handling plutonium and education of researchers, so that processing metallurgical study will be conducted on this basis. Furthermore, efforts will be made to promote development by installing equipment for the small-scale manufacture of plutonium fuel, and the plutonium fuel necessary for criticality experiment and other apparatuses will be supplied.

In parallel with the afore-mentioned, plutonium fuel irradiation tests will be conducted by means of the already installed reactors and the material testing and engineering reactor. On the basis of the achievements obtained from such tests and experiments, consideration will be given to using plutonium fuel in already installed reactors one after another, and putting plutonium fuel to practical use in thermal reactors.

(9) Thorium

The Japan Atomic Energy Research Institute, with the cooperation of private enterprises, is conducting research concerning thorium oxide as the fuel for the semi-homogeneous thermal breeder reactor and the aqueous homogeneous thermal breeder reactor. Furthermore, in the future, research will be conducted on the manufacture and processing of metallic thorium.

Meanwhile, private enterprises are expected to conduct research concerning the refining of thorium.

5. Research and Development of Nuclear Powered Ships

During the first ten years the domestic technique will be improved through introduction of technical know-how from abroad with regard to a light water-cooled reactor, and at the same time a first nuclear pawered ship will be built and put in service as the most effective means to push forward the research and development for the deomestic production of such ships. Methods for constructing the first nuclear powered ship will be decided upon after necessary design research has been conducted. The technique of constructing such ships will be acquired while confirming the results of the design research through experiments as far as possible in the courses of designing and construction. At the same time, technical and economic problems for practical application will be clarified. After the completion of the first nuclear powered ship, operation tests will be made in order to examine the adequacy of the design standard, to compare the computation for designing with the accuracy resulting from experiments, to study errors in manufacture, and to conduct analysis on economy. Then efforts will be made for the development of more economical reactor cores in consideration of the results of the foregoing tests. Studies will also be made on the adoption of organic cooled reactor, gas cooled reactor and nuclear superheating system of water cooled reactor and also on an atomic merchant submarine which is most characteristic of atomic energy.

(1) Design Study

a) Establishment of Design Standard

Since 1956, studies have been made in Japan on the effect exerted on the reactor by external force caused by the movement of a ship, on the dynamic characteristics of a propulsion reactor required from the change in the ship's load, on a ship's vibration causing resonance to the atomic power plant, on a ship's structure around the reactor, and on the control system for the reactor. Design standards for an nuclear powered ship and for its propelling device will be set up through analysis of the results of the foregoing studies and through further studies if necessary. These standards will concern the acceleration of external force exerted on the reactor system by the movement of a ship, frequency and extent of vibration affecting the reactor system, extent of change in the load, particulars of the auxiliary power equipment, the scram system, details of the container, intensity of the hull against collision, stability in case of damage, and waste disposal.

b) Design Study on Hull, Engine and Equipment

On the basis of the design standards mentioned above, design studies for the technical and economic evaluation will be conducted. The design study concerning the hull will include the basic designing meeting the best conditions for an nuclear powered ship's use, speed, output, cruising range, and safety; and the detailed designing of nuclear power plant, propelling device, auxiliary machines, living quarters, reactor protecting structure, etc.

In design study concerning the engine, importance will be

attached to design of the saturation steam turbine and the auxiliary power equipment, and especially studies on the corrosion of turbine blade and the method of separating hygroscopic moisture will be made.

Studies on equipment will range over waste disposal device, fuel exchange equipment, radiation monitoring device, and other special equipment.

c) Design Study on Nuclear Power Plant

With regard to the problems on the designing and manufacture of individual equipments and facilities, as far as possible, and the design study will be carried out mainly on the power plant system for a light water cooled reactor. That is, the thorough analysis will be made on the following items: the unification between the pressurizer and the reactor container in the pressurized water reactor and between the steam drum and the reactor container in the boiling water reactor; comparison between direct cycle system and indirect cycle system; the relation between method of the cooling and necessary pumping power in the forced circulation system; the relation between flow of coolant and vertical acceleration in the natural circulation system; the relation between adoption of mechanical seal and complication of the power plant; the life of core and the method of controlling for excessive reactivity in the initial stage; choice of materials required; capacity of purification system; and the weight of shielding.

(2) Research Related to the Construction of the First Nuclear Powered Ships

The construction of the first nuclear powered ship will be

started after the specification has been decided as a result of the design study. To make the design accurate, it should be confirmed by experiments as far as possible by making effective use of the JPDR, shielding test reactor and the critical experiment device, and points in question for the development in the future will be made clear while making sure the basic data used for the designing and the accuracy of computation. Experiments regarded as necessary in this case range over on the distribution of output using the critical assemply device, measurement of the excessive reactivity at the intinial stage and the value of the control rod, hydrodynamic experiment on the reactcr core cooling system, the change in distribution of void and inflow at rolling and pitching of the ship, control rod driving test, vibration test of modeled equipments and facilities of primary circuit, and full scale irradiation test of the shielding.

Through the construction of a hull and the installation of machines and apparatuses, experiences will be gained on the construction process, assemby of the container, method of shield construction, order and arrangement of machines and apparatuses to be installed, fuel loading and unloading equipment, and method of inspection and tests.

After the completion of the first nuclear powered ship, the performance estimated as the result of designing will be compared with the actual performance of the ship through various tests including actual navigation, and through this comparison will be scrutinized the adequacy of the standards used for designing, the comparison between computation and

experiments, and errors in manufacture. At the same time, reactor cores for replacement will be improved.

(3) Study of Shielding

The method of computation for the reactor shielding has been developed to some extent, but there is still a wide range of undeveloped fields, and as a matter of fact actual shield designing is covered by a big safety factor. The existing reactors on land have few disadvantages because of this big safety factor, but in the case of nuclear powered ship an increase in the weight of the shielding directly affects its performance because it causes a decrease in load. The weight of the shielding comprises more than 50 percent of the total weight of the engines-almost equal to the weight of the fuel load for them. Therefore, decreasing the weight of shielding through development of the shielding technology is an important factor to improve the performance of a nuclar powered ship. In the Japan Atomic Energy Research Institue will be promptly established facilities for studies on basic matters such as the measurement of physical constants of various shielding materials with regard to irradiation, on the secondary shielding with consideration given even to the diffusion of radiation in the air, and on the test of a full-size model at three dimension shielding

The aforesaid facilities will be used mainly for experiments and studies on the penetration decrement of radiation through shieldings for the measurement of the physical effects of radiation, for the engineering experiments of the secondary shieldings in the water and in the air, and for experiments and studies on the heat generation of shielding and the activa-

tion of coolants.

(4) Development of New Type Powered Nuclear Ships

a) Development of propulsion reactors

Two ways are now conceivable for the improvement of atomic power plants for ships. One way is to curtail the expenses for reactors, which are a heavy burden to the realization of economic nuclear powered ships, and the other to improve the efficiency of the plants, through development of light-weight, small-size gas cooled reactors with gas turbine plants and aboption of nuclear superheating system in the light water cooled reactor. The former can be developed from a comparatively early date in connection with the construction of the first nuclear powered ship, and the latter will be studied so as to be practically applied in the latter ten-year period.

b) Development of new type nuclear powered ships

Main efforts will be exerted for the present to develop a nuclear powered ship in which the conventional power plant is replaced by atomic power plant. However, the special feature of atomic energy is truly displayed when it is used for very large super-high speed ships and submarines which can not be realized with conventional power plant. Therefore experiments and studies will be further continued on the resistance, dynamic stability, hull structure, and diving navigation method of large-type high-speed marchart submarines.

6. Research on Nuclear Fusion

Research on nuclear fusion reaction includes many unforeseen and unknown problems at the moment, and establishment of long-range research program is rather difficult. For the time

being, however, it is considered effective to push forward the research as described hereinafter by placing emphasis on deepening the understanding of high-temperature plasma phenomena and on building the technical foundation for plasma experiments. That is, theoretical study of plasma physics will be propelled, and at the same time, research on high-temperature plasma experiments will be continued as before at each testing and research organ. As to the Plasma Institute which is under preparation for establishment as a central organ to study plasma science systematically under close relation with the afore-said research, the cooperative measures will be taken positively for the materialization of the Institute and for the perfection of equipments. Furthermore, the trend and the results of development in foreign countries and the results of research in the country may be expected to give concrete perspective for the realization of nuclear fusion reaction in the latter half of the development stage. In this case, the research will be taken up as a project research, and the research scale will be expanded with the construction of experimental facilities on a considerable scale.

As to the direct electric power generation, research will be propelled at the Japan Atomic Energy Research Institute as a research center by taking the development in foreign countries into consideration.

(1) Generating and Heating of High Temperature Plasma, and Analysis of Phenomena

Experimental facilities and measuring instruments at each research organ will be perfected, and measures to accumulate

reliable data will be taken by making experiments on physics, control, heating, generation, inspection and measurement of high temperature plasma. Analysis or theoretical study on plasma phenomena will be propelled, and training of scientists will also be made. Measures to make experiments speedily for the new ideas on heating and keeping the plasma will be taken.

The afore-said research will be conducted as before at the Governmental testing and research organs, the Japan Atomic Energy Research Institute and others in parallel with the research at universities.

Further, research on generation, heating, measurements and others of plasma being developed at the private enterprises such as ion-cyclotron resonance type, scallop type and toroidal discharge type with induction pinch method will be continued, and the measures will be taken to attain results rapidly.

(2) Development of Measuring Technique, Instruments and Materials

Experiments on plasma must be conducted with special measuring methods under special conditions. Development of measuring technique required for the experiments will, therefore, be pushed forward in parallel with the afore-said plasma experiments.

Those technical research subjects which are suitable to be developed by private enterprises will be fostered positively.

7. Research and Development of Uses of Isotopes

(1) Research on Production of Isotopes

Research on production of radioisotopes is being conducted

with the Japan Atomic Energy Research Institute as a center. This research will be propelled consecutively. Namely, fundamental study on nuclear reaction, production research using hot-atom effect, research on separation and purification after nuclear reaction, research on short half-life nuclides, research on target materials and so forth will be pushed forward. Furthermore, research on separation and purification of useful nuclides will also be conducted in order to utilize the fission products produced in the process of used fuel reprocessing.

Some of the production research on labelled compounds are completed and small scale production is being conducted partly at the private enterprises. Further, research on production of labelled compound containing ^{14}C, ^{198}Au, ^{3}H, ^{35}S, ^{32}P and others will be pushed forward.

(2) Research on Biological and Agricultural Applications

Research on biological and agricultural applications of radioisotopes is being conducted mainly at the universities, Governmental testing and research organs, and will be pushed forward consecutively.

Research on molecular level biology; physiology and metabolism of living matter; biochemistry; pathology; prevention, diagnosis and treatment of animal diseases; soil fertilizer; agricultural medicenes; agricutural constructions; improvement of quality of agricultural, forestry and fishery products; and so forth using various kinds of labelled compounds containing ^{3}H and ^{14}C, and research using many kinds of radioisotopes simultaneously will be pushed forward energetically.

As to the field of biology, research on behavior of nitrogen

and oxygen in the living things is requested. These radio-isotopes, however, have short half-lives making utilization of these isotopes difficult. It is necessary, therefore, to conduct research in this field using stable isotopes such as ^{15}N, ^{18}O and others.

Activation analyses will be applied to the research on ingredients existing in trace amounts in the soil, animals, plants and sea water which has been difficult until today, and research in this field will be promoted.

Research on radiation breeding has been conducted using the gamma ray irradiation rooms and considerable results have been obtained until today. Research in this field should be pushed forward consecutively. On the other hand, irradiation research on plants under the natural circumstances with the radiation field of the Ministry of Agriculture and Forestry as a research center will also be conducted. Furthermore, research on heredity and breeding will be promoted by conducting irradiation study of living things under the controlled circum-stance conditions.

(3) Research on Medical Applications

As to the medical applications, application to basic medicine, diagnosis, treatment and others will, further, be pushed forward, and research using neutrons from the reactors and radiations from the accelerators will be propelled.

Pathological and physiological research as a basic study for diagnosis and treatment of diseases by the utilization of isotopes will be propelled. In parallel with this research, research on utilization of short half-life nuclides such as ^{24}Na, ^{42}K, ^{52}Mn,

^{64}Cu, ^{72}Ga, ^{90}Y, ^{198}Au and others, on utilization of new nuclides such as ^{33}P, ^{132}I, ^{152}Eu and others, and on utilization of various kinds of labelled compounds will also be pushed forward.

Furthermore, utilization of particle accelerators and radioisotope sources for the purpose of treatment of vicious tumor and others will be promoted. Moreover, research on diagnosis and treatment of tumor by irradiating thermal neutrons from outside the living bodies and by producing heavy particle rays having larger biological effects at a disease focus will be conducted.

(4) Research on Industrial Applications

Although industrial utilization of radioisotopes in Japan seems to be considerably behind the United States of America and the European countries, development in this field should be propelled speedily because the utilization in this field affects great influence technically and economically.

Development of industrial utilization of radioisotopes will be pushed forward by placing the emphasis especially on the items described hereinafter.

a. Process Control Using Radioisotopes

Utilization of radioisotopes in the field of automatic process control is not developed yet in Japan, although utilization of isotope-loaded measuring instruments is partly made. Resarch on improvement of accuracy and stability of isotope-loaded measuring instruments for control purpose, on radioisotopes fit for control measurements, on structural parts and on method

of measurements will be promoted in order to propel research on process control. Moreover, research on actual application of automatic process control with some of the typical processes will also be conducted.

b. Process Analysis Using Radioisotopes

It is extremely useful for the chemical and metallic industries to grasp the conditions of flow, diffusion, mixing and others of materials in the processes using the characteristics of radioisotopes. Research on processes and on analyses of reaction, on isotopes fit for process analysis at the actual spot, and on counters will, therefore, be promoted, and uses of isotopes will be pushed forward.

(5) Basic Research

Research on radioisotopes themselves such as disintegration models of radioactive nuclides, purity of isotopes, counting method of low level isotopes, counting method of mixed nuclides, standard sources, scattered radiation and others as a basic research is requested which is common to various fields of uses of isotopes.

In parallel with this research, on the other hand, research on improvement of accuracy and stability of radiation detectors such as improvement of the characteristics of Geiger counters, proportional counters and others, development of counters for extreemely week radiation, and research on heavy particle counting methods by means of semi-conductor counting elements and spark counters will also be conducted.

Althongh the detection of trace amount of inclusion in the matters, study on behavior of trace ingredients and others have

been difficult in many points applying conventional technique of analysis, the activation analysis will become prominent measures to overcome these difficulties. Research on activation analysis utilizing neutron generators, therefore, will also be carried out.

Development and utilization in various other fields, namely research on analytical chemistry and reaction mechanism, research on bioohemistry such as photosynthesis, development of uses of gaseous isotopes such as ^{3}H, ^{85}Kr and others to various fields, utilization in social science and geophysics such as dating in archaeology, utilization in geology such as measurement of geological age, survey on water flow, survey on movement of sandy and muddy deposit, and survey on underground resources will be propelled.

8. Research and Development of Radiation Chemistry

Situation of researach and development of radiation chemistry in Japan is considerably behind the United states of America and the European countries especially in the fields of basic research, development of reaction processes, research on radiation engineering and in development of radiation sources. It is necessary, therefore, to push forward the research and development in these fields. Furthermore, special division on radiation chemistry will be established to conduct intermediate-scale testing and research aiming at future industrialization. The large-scale facilities which are difficult from the economic point of view for the private circles to install will be installed, and intermediate-scale tests on promising items of radiation chemistry, research and development of low irradiation cost

radiation sources, and basic research requiring the uses of large-scale facilities will be conducted at this division.

(1) Basic Research

Life measurement and property study of primary products such as ions, free radicals, excited molecules and others, study on mechanism of radiation action using tracer technology, study on the effects of difference in types of radiations, in energy and in radiation doses, study on action of additions, and study on effects of external conditions such as temperature, pressure and magnetic field, all of which are the basic field of radiation chemistry, will be propelled for the purpose of making clear the reaction mechanisms in radiation chemistry.

(2) Research on Reaction Processes

As to the reaction of orgainc high polymer which forms a part of development of reaction processes in radiation chemistry, emphasis will be placed on ionization polymerization of formaldehyde, radical polymerization of vinyl chloride and others, graft polymerization of cellulose fibre, and linkage of rubber, polyethelene, polyester, organic semiconductor and others.

As to the reaction of organic low molecules, production of organic acid from paraffin hydrocarbon, production of phenol from benzene and production of acetylene from methanol, in parallel with research on telomerization, polymerization of acetylene and others under pressurized c ndition, and reaction of additon will be promoted.

As to the inorganic reaction processes, research on activation of catalyzer for ammonium synthesis and methanol

synthesis, synthesis of nitric acid from atmospheric nitrogen and others will be conducted. Furthermore, research on improvement of property of mixed oxide catalyzer by irradiating radiation will also be carried out.

Research on food reservation by sterilization and disinfection, on food reservation by inhibition of sprouting, and on disinfection process of injection, medicine and others will also be conducted.

(3) Research on Radiation Engineering

Development of reaction apparatus, irradiation technique, research on anti-radiation materials, research on measurement and on its automation will be propelled energetically in order to promote the industrialization of radiation chemistry in Japan.

(4) Development of Radiation Sources

As to the industrialization of radiation chemistry in Japan, research and development of radiation sources from the point of irradiation cost, stability and safety will be promoted since the development of radiation sources fit for the industrialization economically and technically is one of the most important factors.

Research on method of producing ^{60}Co by using cobalt target as a part of reactor control system will be conducted for the purpose of reducing the irradiation cost of large quantity ^{60}Co source. For the purpose of developing large output accelerators fit for industrial uses, research on stability, development of accelerating tubes, stablization of current and energy, improvement of quality of parts and others will be pushed

forward.

Loop experiments using the existing JRR-2, JRR-3 and others will be conducted for the time being for the purpose of developing the chemical reactor. Furthermore, research on radiation contamination, shielding, safety, technique of uniform irradiation, heat removal and others will be carried out for the purposes of utilizing spent fuel, high level waste liquid and fission products as radiation sources. Research on separation and utilization of gamma sources such as ^{137}Cs and others, and of beta sources such as ^{90}Sr and others will also be promoted,

9. Research for Prevention of Radiation Hazards

As to research for prevention of radiation hazards, the following subjects will be conducted at the National Institute of Radiological Sciences as a center, with the cooperation of the universities, the Governmental testing and research organs and the Japan Atomic Energy Research Institute in order to carry on research effectively.

Research on nentron hazards will be conducted by using medical reactor in parallel with research on its medical application.

(1) Basic Research on Radiation Hazards

Priority will be given to research on mutual reaction between radiation and living body, determination and measuring method of absorbed dose, action of radiation to cell and tissue, general effects of radiation to living body, development of radiation hazards in human body, occurence of mutation by radiation, and neutron hazards since basic research on radiation

hazards form the basis for the determination of permissible dose.

(2) Research on Environmental Contamination

Survey and study on exposure dose from natural environment will be conducted. Radiation contamination of environment will be foreseen to increase with the utilization and development of atomic energy. Research on circulation of radioactive substances in the natural world, on somatic effect of radiation in atomic energy professional environment, and on contamination of environment and human bodies by radioactive substances will be conducted, therefore, as research on radiation hazards in professional environment of atomic energy industry.

(3) Research on Permissible Dose

Research on permissible dose is one of the most important subjects in the field of research on prevention of radiation hazards since basic data on apportionment of genetic dose in connection with atomic energy professional environment will be given.

Although the value of permissible dose is given tentatively by the ICRP recommendation and others, the value is cut down in every recommendation, and living conditions and constitution considered is applicable mainly to the western people. Research on important factors forming the basis for the determination of permissible dose, on genetic significant dose, and on relation between permissible dose and the characteristics of the Japanese living conditions will, therefore, be conducted by taking the various factors shown in the

recommendation and living conditions of the Japanese into consideration.

(4) Research on Prevention, Diagnosis and Treatment

Research on diagnosis and treatment of hazards of radiation exposed people and on preventive medicine for radiation hazards will be pushed forward since these are considered to be important problems for the future development of atomic energy.

(5) Research on Accident Countermeasures

Although safety of facilities is taken into consideration to the fullest extent when the atomic energy facilities are to be installed, research on limit dose, measurement and analysis of main cause of an accident, emergency measures for the exposed people, and decontamination at an energency will further be conducted.

10. Research on Safety of Atomic Energy Facilities

It is necessary to secure the safety for the propulsion of development of atomic energy facilities. Prediction of hazards and damages caused by the accidents by assuming the accidents of atomic energy facilities, and research on counter-measures to prevent accidents will, therefore, be propelled energetically at the Japan Atomic Energy Research Institute as a center, with the Governmental testing and research organs, universities and private enterprises participating.

(1) Research on Safety Design

Atomic energy facilities are completely different from the conventional facilities in materials, structures and others since they handle radiations. The perfection of the safety design

will, therefor, be made more perfect by conducting research on theoretical calculations and on model experiments in order to establish safety standards of the facilities.

(2) Research on Shielding

As to theoretical research, development of calculation methods by applying typical theoretical equations or statistical theories, in parallel with study on computing code, shielding calculation of reactor main, and calculation of radiation accumulation in the reactor core will be pushed forward. Experimentally, on the other hand, measurements of various constants using reactors will be conducted, The accurate basic data on shielding design will be obtained in this way, and the results will be checked with the theoretical calculations in order to improve reliability of the theories.

(3) Research on Instrumentation, Control and Safety Devices

Research and development of various measuring instruments, safety devices and others having higher reliability and accuracy will be pushed forward. In parallel with these researchs, control methods which are free from danger in case of miss function or miss operation will be established.

(4) Research on Hazard Analysis

It is necessary to analyze the change of pressure, temperature, neutron flux, core output and others of the systems in transient state in case of loss of coolant pumping power in the reactor. Furthermore, research to find out analytical equations and their numerical solutions clarifying the behavior of fuel, coolant and fission products on the occasion of melting of

reactor core by loss of coolant caused by the damage of primary loop will be conducted for various types of reactors. Research on optimum design of containers in relation to the afore-said research will also be carried out. Moreover, necessary research on hazard analysis of reprocessing facilities and others will be promoted.

(5) Research on Release and Diffusion of Radioactive Substances in the Accidents

Although there are little examples in foreign countries and it is a difficult problem, research on release and diffusion of radioactive substances in Japan will be pushed forward by applying systematical theories and experiments. Especially, it is important to clarify the radiation leacage and its distribution, species and amount of radioactive substances released, and conditions of movement of radioactive substances to the surrounding area according to the weather conditions in case of accidents.

Advanced data treating technique will be developed in order to find out the anticipated weather conditions adequately using the past records. As to the diffusion of radioactive substances, theoretical equations to be applied will be inquired, and effects of locality will be clarified after carrying out experiments systematically.

(6) Research on Fuel Failure

There are many unknown factors as to fuel failures such as the growth of pin-holes when pin-holes are generated in the fuel sheaths, mechanism of fission product release from the pin-holes and relation between the extent of fuel failure and

the radiation level. Research on these fuel failures will be conducted hereafter and the data will be accumulated.

As to the fuel failure detecting equipment, research on highly reliable detecting methods to detect the location of fuel failure during the reactor operation will be propelled, in parallel with the research on sampling methods, since research on these subjects is especially difficult in case of light water-cooled reactors.

As to fuel failure detecting, on the other hand, it is necessary to investigate if the detection for each channel is required or not in relation to the behavior of fission products.

(7) Research on Aseismatic Strength

Since Japan is a country subject to frequent earthquakes, aseismatic strength will, especially, be the big problem from the standpoint of safety. Research on vibration test, aseismatic strength test and others using real objects or models will be conducted, therefore, in order to establish the aseismatic design standards of various structures and equipments.

Furthermore, research on development of measuring technique of vibration behavior and resonance phenomena of various equipments in the earthquakes will be propelled, and aseismatic testing technique of the structures will be established.

(8) Miscellaneous Research

Other research on definite problems such as the setting and selection of levels in various safety systems will be necessary. Research on development of inspection technique such as strength test, leakage test, non-destructive inspection and so

forth, and research on establishment of inspection criteria will be propelled urgently.

11. Research on Radioactive Waste Disposal

Release of large quantity of radioactive wastes from refining, fabrication and reprocessing of nuclear fuel, and from use of radioisotopes will be expected with the progress of development and utilization of atomic energy. Although most of the wastes are from the use of radioisotopes and extremely small quantity of wastes are disposed at the moment, an organ for waste disposal will be established to prepare for the future increase of radoiactive wastes in order to realize unification of disposing business of these wastes. Research on radioactive waste disposal will be conducted and developed by the Japan Atomic Energy Research Institute, Governmental testing and research organs and a part of the private enterprises.

(1) Research on Disposal of Liquid Waste

Research on disposal of liquid waste such as dry up by vaporization, precipitation by flocculation and ion exchange is almost completed, and is being utilized at the moment. Research on the equipments of high efficiency and high rate of decontamination will, further, be promoted, and research on fluidized bed calcination for the purpose of disposal of high level liquid waste will also be conducted. Moreover, research on disposal by glass solidification and by biological methods such as active sludge method will also be carrid out.

(2) Research on Disposal of Gaseous Waste

Research on disposal of radioactive aerosol is being carried out by applying steam ejector method and aggregation method.

This research will be developed further, and research on disposal by vibration method and by dust impact method will be promoted. Research on filters will also be conducted in connection with disposal of aerosol.

As to research on disposal of gaseous radioactive waste, disposel of inert gases such as xenon and krypton released from reactors and reprocessing plants will energetically be carried out since research in this field is undeveloped.

(3) Research on Disposal of Solid Waste

As to solid waste, research on disposal of inflammable waste by incinerator will be conducted. As to noninflammable waste, on the other hand, research on compressing and crushing equipments in order to cut down disposing costs, and research on safety of these equipments will be carried out.

Moreover, research on solidification processes for the purposes of disposing the sludge yielded from disposal of liquid waste and disposing the ion exchange resin saturated with high liquid waste will be conducted, in parallel with the research on washing of contaminated matters by cleanser, and on decontamination process of contaminated equipments.

As to disposal of animals, research on incinerators for the disposal of animals, and on dry up processes and putrefaction processes will be conducted.

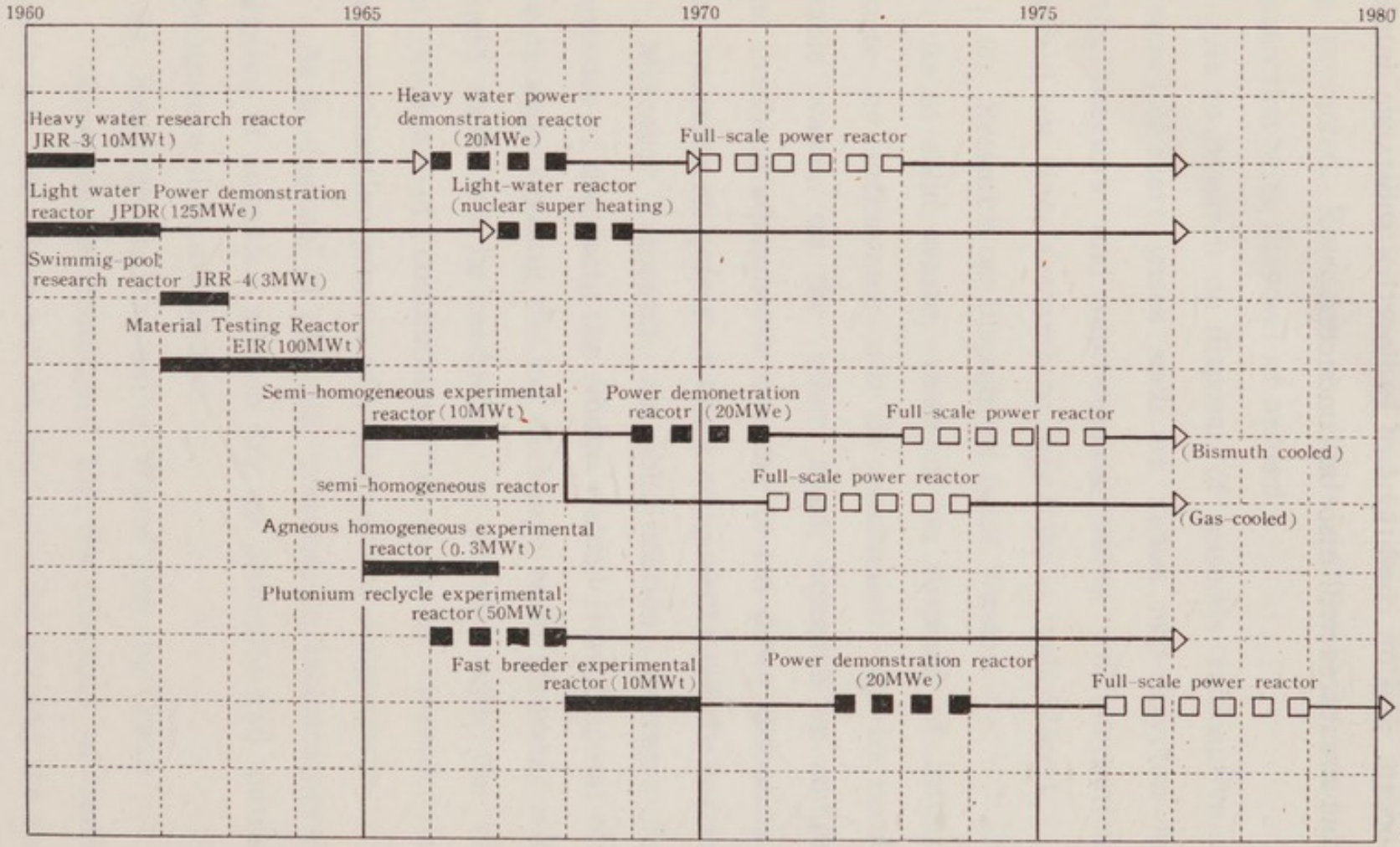
(4) Research on Disposal of Waste into the Ocean

Research on containers for the disposal of radioactive waste into the ocean will be conducted by placing the emphasis on submergible pressure limit and on prevention of putrefaction.

Moreover, research on flow rate of abyssal current, circu-

lation of abyssal water and diffusion in connection with disposal to the ocean, and on conditions of radioactive substance intake of marine creatures will also be conducted.

Program on Research and Development of Reactors



Note; (1) ■■■■ Definite or almost definite projects

(2) ■ ■ ■ Possible projects

(3) □ □ □ Projects more indefinite than

Part IV Measures for Promotion of Development and Utilization of Atomic Energy

1. General Principle

Progress in the development and utilization of atomic energy is considered to have very important, far-reaching effects on Japan' economic development in the future. However, since Japan is far behind some foreign countries in this field, it is necessary for all related organs, governmental or private, to closely cooperate with one another in order to make the progress effective.

Especially the Government must assume great responsibilities for the development and utilization of atomic energy, because this field of undertaking, unlike other fields, has a rather peculiar character and also because it is a new field still involving many undeveloped spheres. In other words, the Government is responsible for playing a positive role for effective development and at the same time working out all measures to secure safety which is indispensable for the development and utilization of atomic energy.

Measures to be carried out by the Government may be divided into two aspects: the direct and the indirect ones. The direct aspect includes effective financial support, under appropriate plans, for the research and development of atomic energy at universities, the Japan Atomic Energy Research Institute, the Atomic Fuel Corporation, the National Institute of Radiological

Sciences and other national research organs. It also includes positive fostering of private circles in their research on the domestic production of reactors, their related equipments and facilities and fuels by furnishing subsidies and research-contracts on specific items; adoption of adequate aid for the procurement of funds, and extention of necessary assistance in the acquisition of nuclear fuel from abroad, which is still restricted under the international agreements and other means. The indirect aspect comprises enforcement of plans for the adequate training of scientists and engineers needed for the research and development, and establishment of a compensation system to provide against unexpected nuclear occurence. With regard to the aforesaid measures, the Government will take appropriate legal steps as occasions require in accordance with each stage of progress in the development and utilization of atomic energy, in oder to contribute to favorable promotion of such development and utilization.

It is of course proper for private enterprises to make efforts to hasten the practical application of atomic energy. But, at the first stage of the atomic energy development and utilization program it is essential that those circles push ahead their own research and development in preparation for their future development, and at the same time introduce necessary technical know-how from abroad and thus solidify the foundation of atomic industries. For this purpose they must carry out to some extent the designing, manufacture, construction and operation of atomic energy facilities for the purpose of obtaining technical experiences, even though this is not always com-

mercially paying. Such experiences will enable prompt domestic production of atomic energy facilities on the basis of foreign techniques introduced, and in the meantime private enterprises will find mens to make effective use of their original ideas, greatly contributing to the improvement of efficiency and economy at an earlier date. From this point of view it is expected that those who are concerned with atomic industries, whether manufacturers or users, cooperate with one another to produce greater effects.

The aforesaid measures must be hastened and carried out from an overall, long-range viewpoint in such a manner that their defficiencies can be filled up among themselves. However, it is considered appropriate that, in connection with the long-range prospect on the development and utilization of atomic energy and the research and development plans in this prospect, the fore-going measures be divided into six items: 1) installation of research facilities and establishment of joint research systems, 2) training of scientists and engineers, 3) safety measures, 4) aid of private enterprises, 5) securing and effective uses of nuclear fuels, and 6) other important measures.

2. Installation of Research Facilities and Establishment of Cooperative Research System

It is of course necessary to make more effective use of existing research organs and facilities in order to effectively push forward the research and development of atmic energy. In connection with the long-range program, however, it is considered equally necessary to complete new research facilities and set up joint

research systems.

(1) Installation of Research Facilities

In order to expedite the utilization of atomic energy, a great emphasis must be given to the research and development in the first ten years. This research and development will be conducted by private circles as well, but a leading role will have to be played by the research and development in which the Government will make investment directly or indirectly. Research facilities will be newly installed or expanded in consideration of the important effects to be exerted by the results of the research and development in the first ten years upon the atomic energy development and utilization in the latter period or even in later years. Main facilities needed in this case will be installed at the Japan Atomic Energy Research Institute, the Atomic Fuel Corporation, the National Institute of Radiological Sciences, universities, and national research organs.

Facilities to be iustalled at the Japan Atomic Energy Research Institute are a large-scale electronic computer, a large-scale accelerator, research reactors JRR-3 and JRR-4 (for studies on shielding), the JPDR and a material testing and engineering reactor. Also large-scale radiation sources will have to be set up to promote the study on radiation chemistry. It is also necessary to establish facilities for the research and development of plutonium fuel to which importance is attached in the first period. If research and development make progress in the future on the semi-homogeneous reactor and the fast breeder, which are deemed as essential items for the development of power reactors in Japan in the future, it may become necessary

to build an experimental or a demonstration power reactor for that purpose at an appropriate stage. If research on high-temperaure plasma makes progress and basic data are sufficiently obtained on nuclear fusion, establishment of a large type experimental facilities requiring a considerable amount of expenses will become necessary for further studies and development.

Major facilities to be established at the Atomic Fuel Corporation are those for the research and development of re-processing and waste disposal. Also necessary are facilities for the research on processing of ores, refining, uranium enrichment, plutonium and fuel inspection. With regard to the domestic production of nuclear fuels, ore prospecting, mining and refining will be conducted to some extent but they will be carried out on an experiment scale for the time being. Therefore the facilities for those purposes will have much to do with research and development.

Facilities to be set up at the National Institute of Radiological Sciences are those for medical treatment in addition to research facilities directly necessary for the studies on radiological sciences. Establishment of a reactor particularly for medical use is also conceivable in the future.

The construction of a first nuclear powered ship will provide a footing for the development of this kind of ship in the latter period; therefore the Government will make best efforts to secure funds for its construction.

Since the research and development of atomic energy must be pushed forward widely and collectively, it is necessary to expand and complete research facilities in universities and other

Governmental test and research organs in addition to the facilities mentioned above.

It is difficult to concretely estimate Government funds for the completion of those facilities. However, excepting national expendifure concerned with education, the necessary Government funds may be roughly estimated at 180 to 200 billion yen including research expenses for the first ten-year period.

(2) Establishment of Cooperative Research Setup and Joint Use System

For the establishment of a cooperative research setup an organization to which the functions of related research organs are organically connected will be established under the leadership of the Japan Atomic Energy Research Institute in order to vigorously carry out some project studies mentioned above. Also a new steering committee mainly aimed at utilizing large-scale facilities in specific research organs will be established. In other words, an organization like an advisary council comprising the Government and private circles will be created for the development of the Semi-Homogeneous Reactor which is one of the subjects for the project research. In this council will be examined the results of the research and development of the Semi-Homogeneous Reactor in the JAERI and also discussed measures for the development of its effects. At the same time, appropriate contact will be made to seek cooperations of universities, Governmental test and research organs and private research organs.

Concerning the research and development of plutonium fuel, which is another subject for the project research, a joint

research organization comprising the JAERI and the Atomic Fuel Corporation will be established to push the most effective plans for the assignment of their research and the completion of facilities, to consolidate their research efforts through this joint research organization, and thus to develop the practical application of their studies as soon as possible. In operating this organization, measures will be worked out to obtain the cooperations of universities and other research organs.

With regard to other important subjects other than for the project research, mentioned above, efforts will be made to carry out joint research system that will enable the efforts of related research organs to be coordinated most effectively.

In the operation of the research plan calling for the use of large-scale facilities to be established in the JAERI it is necessary to take such measures as will enable researchers under private enterprises to follow effective activities. That is to say, in the use of the reactor for research on shielding and the material testing and engineering reactor, an appropriate research steering committee will be established between the JAERI and related research organs in order to accelerate studies efficiently. This will be the same in the use of facilities for the development of radiation chemistry. Also in the utilization of a reactor for medical use which is considered to be installed in the National Institute of Radiological sciences, the same measure will be taken in an effort to achieve the joint operation of the research equipment.

3. Training of Scientific and Technical Personnel

In order to effectively implement the Long-Range Program,

there must be provided an adequate means of training scientific and technical personnel. At the present initial stage of atomic energy development it is necessary to emphasize the importance of training competent research workers rather than merely to secure a sufficient number of trainees.

(1) Classification of Atomic Scientists and Engineers

From the point of view of the present state and expected future direction of atomic energy development it is coveninet to classify the atomic scientists and engineers into the following categories:

a) Specialized Atomic Scientists and Engineers

To this group belong those who have both sufficiently specialized knowledge and engineering ability in the fields of nuclear physics, nuclear engineering and other such subjects.

b) Scientists and Engineers in the Fields Relates to Atomic Energy

This group is made up of those who possess specialized knowledge and technological ability in such fields as mechanical and electric engineering, physics, chemistry, biology, metallurgy, etc. and also in nuclear science.

c) Scientists and Engineers in Radiation and Related Fields.

Those who have knowledge and engineering ability sufficient to satisfy the requirements for a "Radiation Handling Chief Superviser" and are actually engaged in the use of radiation, radiation chemistry and the related fields of work.

d) Health Physicists.

Although neither the operational nor legal concept of a health physicist has yet been established, it is considered to be a

man who directs safety operations and work control by participating in health protection programs radiation measurement in and out of a work shop, estimating the degree of hazard resulting from such radioactivity, controlling and disposing of radioactive waste, implementing emergency measures, etc.

Professors who teach and engage in research in the fields related to nuclear energy at universities constitute the core of the training program. It is vital for that reason immediately to reinforce faculty staffs of universities and make them really efficient, but, because the details as to the scope and content of such improvement must be affected by the progress of the above-mentioned overall training program as well as the considerations relating to other faculties and research programs of the universities concerned, it will be better that the Ministry of Education and other authorities proceed with formulating a faculty reinforcement plan taking carefully into consideration the progress of the overall atomic energy development and scientifrc and technological development promotion programs.

At the same time it is desirable to launch a program for training a large number of technical workers apart from the group of highly specialized atomic scientists and engineers.

(2) Estimated Number of Necessary Scientists and Engineers

Despite the need to estimate, prior to the formulation of a training program, the approximate number of atomic scientists and engineers that will be required in the future, it is extremely difficult to calculate exactly how many will be demanded. At

the moment, however, a rough estimation, made on the basis of the number of such technical personnel to be required by each of private enterprises, the national research institutions, the Japan Atomic Energy Research Institute, the Atomic Fuel Corporation and other similar organizations, suggests that in 1970 1,200–1,300 nuclear specialists, 4,500–5,300 scientists and engineers in the related fields, 5,000–5,500 radiation scientists and engineers and 300–350 health physicists will be required.

These numbers do not include those in the scientific faculties of universities nor the scientific and technical administrators. According to a survey made toward the end of 1958, the scientists and technicians working at universities occupied 40% of the nation's total and it is expected that they will continue to demand as many in the future.

(3) Education and Training Measures

In order to train and supply the afore-mentioned numbers of scientists and engineers that will be needed in the coming ten years, it will be vital for the authorities and organizations concerned to keep in close touch with each other and build a systematic training machinery.

a) Universities

The role of universities in the education and training of atomic scientists and engineers is very great. In the light of the compelling need to supply the estimated large numbers of atomic energy specialists who will be indispensable for the effective development of peaceful utilization of atomic energy, their mission cannot but be of utmost importance. For that reason the existing faculties and specialized post-graduate

courses in atomic energy and related fields must be reinforced by improvement of their curricula and expansion of research facilities and, furthermore, such faculties or graduate courses, and in some instances both, must be newly created in order to help train a sufficient number of atomic scientists and engineers, specialists in the related fields of science and in radiation utilization.

Even at such universities that have no specialized atomic science faculties nor graduate courses it will be necessary to introduce lectures on the related subjects so that they may also help bring up scientists and engineers in the fields closely related to nuclear sciences.

Universities, whether governmental or private, that are planning training courses for atomic scientists and technicians must be encouraged one way or another to proceed with such programs.

The facilities for research activities to be installed at the universities that have atomic science faculties and/or specialized graduate courses and so play a part in the basic education of future specialists must be adequate and sufficient to meet the requirements of teaching and research to be conducted therein in accordance with their specific research programs. From that point of view it is highly desirable that an educational reactor or a test reactor and a critical or sub-critical assembly be installed in each district or at each important university, while at least such basic facilities that are needed by the students for satisfying the requirements of specialized courses as radiation measuring instruments, irradiation equipment, etc. must be

promptly made available.

These educational and research facilities that have to do with nuclear sciences, however, cost far more than equipment needed in other branches of science not only for their installation but also for the maintenance, operation and experimenting with them. Cooperation and assistance must be sought, therefore, from various qaurters concerned, so that sufficient resources may be placed in the service of substantially advanced educational programs to be undertaken by universities for training of atomic energy specialists, at the same time that some organizational machinery may be set up by which expensive equipment, such as an atomic reactor, can be made commonly available to more than a few universities. Such scheme for the reinforcement and expansion of teaching curricula and research facilities of universities must be carefully worked out, just the new introduction and consolidation of faculties and graduate courses, by the Ministry of Education and other agencies concerned.

b) Reactor Training School of the Japan Atomic Energy Research Institute

The primary function of the Reactor Training School is to re-educate or provide more advanced training for those university graduates who continue to be engaged in occupations related to atomic energy and, for that reason, it must play an important role in the atomic scientist education and training programs even after the university facilities are made more satisfactory than at the present time.

The School needs to expand its accomodation capacity, its curricula, research facilities etc. in accordance with the progress

of reactor installation and other development schemes of the Institute. Particularly important it will be for its advanced training course to conduct training programs under research themes that are possible only with the help of such facilities as the Institute can offer, so that concentrated efforts may be made toward fostering specialized nuclear scientists and engineers.

In formulating the curricula of the School attention must be paid to the specific need for certain kinds of knowledge and technical information that will be immediately useful to the actual implementation of the existing atomic energy development plan. At the same time, measures must be worked out to enable also foreign students to be enrolled at the School.

The content and scope of the reactor operation training course, which aims to foster future reactor operators, must be determined by the approximate demand for this group of engineers in the future and in some instances training in power reactor operation, for example, may be necessary.

c) The Radioisotope Training School of the Japan Atomic Energy Research Institute

The Radioisotope School will further expand and make more satisfactory its teaching and training courses as well as its research facilities in the radiation and related fields. In particular, in close connection with the elementary engineering courses that are given by universities it will offer training facilities and services in more advanced and specialized courses for elevating the level of knowledge and engineering skill of radioisotope engineers.

It will continue to accept foreign students also.

d) The Training Division of the National Institute for Radiological Sciences

The curricula and scope of the training courses to be offered by the Training Division of the National Institute for Radiological Sciences, which aims to bring up radiation safety supervisers, will be determined in the light of the legal provisions relating to the specification of their tasks.

The Short-Term Training Course that has already been established shall be expanded to accomodate for an increased number of students and the level of training curricula advanced in order that it may effectively meet the ever-increasing demand for radiation safety control supervisers by providing educational facilities for those who are engaged in safety operations on the spot.

Even after specialized graduate courses specifically aimed at the education of radiation safety supervisers are set up within universities sometime in the future the Training Division of the National Institute for Radiological Sciences shall continue to play an important role as a school of advanced field study and practical training for the graduates of such university courses who remain in this field of occupation.

e) Other Training Institutions

Apart from the above-mentioned training schools or courses of atomic energy research organizations, various governmental or private institutions, such as the Institute of Public Health, the Navigation Training Institute, etc., must provide adequate training facilities and services in order to catch up with the progress of the progress of the development of atomic energy

utilization and help disseminate authentic information and knowledge.

f) Study Abroad

For the effective learning and digestion of foreign technological knowhow relating to atomic energy a better use must be made of the student exchange program. In other words, at the same time that domestic training institutions are gradually made more capable of accepting a large number of students for training, it will be necessary to continue to send out abroad those who work in each specialized field with a view to importing continuously the ever-growing technological knowhow being developed in the more advanced nations.

To determine the optimum number of the students to be sent abroad, the present phase of the country's atomic energy development plan and the actual situation of the training institutions available in the country must be carefully examined, so that the program may prove sufficiently flexible. At the same time, the increase in number and progress in specialization of atomic scientists and engineers that will be demanded in the coming years will call for an increase in the number of such students. It will be necessary, for that reason, to utilize not only the atomic science student exchange scholarship program, for which the applicants must be recommended by the Atomic Energy Burean of the Science and Technics Agency, but also the fellowships offered by the International Atomic Energy Agency, the Fund for Peaceful Atomic Development as well as various aid programs sponsored by foreign governments.

g) Exchange of Researchers

The exchange of researchers both within the country and with other nations is vital for effective promotion of the development plan as well as for strengthening the ties between able researchers from different countries.

As to the domestic exchange program, a system of researcher exchange between the Japan Atomic Energy Research Institute and other research organizations and that of travelling researchers can be established, taking into consideration the development of various training institutions.

Concerning the exchange of researchers with other nations of the world, the government shall not only aid privately sponsored programs but, if necessary, will positively encourage the participation of Japanese researchers in international joint research projects.

4. Safety Measures

The promotion of atomic energy development demands not only the above-mentioned direct or indirect aid measures but also reliable safety devices to create the environmental basis for the effective use of atomic energy.

These subjects include the assurance of safety of various nuclear facilities, and the safety design and control system of reactors in particular, perfect hazard prevention measures, disposal of waste, etc. Although the cooperation of private industry is needed for these subjects, the government has the primary responsibility to look to it that most adequate measures are implemented to satisfy these requirements.

(1) Safety Assurance of Nuclear Facilities

Despite the increased safety reliability of atomic reactors

which has been brought about by the development of new mechanical devices and materials, Law for Control of Nuclear Reactor, etc. has been early legislated in Japan which require installation of a reactor to be authorized after a strict prior examination. For that purpose the Japan Atomic Energy Commission has set up Reactor Safety Examination Committee within its framework in charge of safety inspection and examination, while other Ministries of government have also expanded their examination function relating to the subject matters that fall in their jurisdiction: it will be necessary for the AEC's Safety Examination Committee to be reconstituted into an independent permanent committee distinct from other committees so that its functions may be strengthened. Marine reactors and reprocessing facilities must also be placed under the safety examination of these organizations. Together with such consolidation of the examination and control organs it will be necessary to establish the safety standards for power reactors, nuclear powered ships and other facilities. The Radiation Council, the Safety Standards Committee of the Atomic Energy Commission and other governmental organs concerned must study this problem, using the international standards for reference.

In view of the fact that reactors loaded on nuclear ship are different from those based on land in that it is navigated on the waters and quite probably enters ports where the general public may assemble, the entry of ships must be limited to designated ports, their reception conducted according to specified procedures worked out against any possible incident, so that the general public in the neighborhood, the port facilities

and other ships calling at these ports may be effectively protected and contamination of the water and water resources prevented.

(2) Inspection of Fuel Elements

The Law for Control of Nucler Reactors, etc. provides for measures to be applied to the safety control of nuclear fuel materials, but establishment of a governmental examination system in conformity with the international practice is needed in order to make it more effective.

The development of fuel element examination techniques can be undertaken mainly by the Atomic Fuel Corporation, which can place its experience and technological resources at the service of the state examination system and so help set up relaible examination methods and standars.

(3) Radiation Hazard Prevention

As the use of radioisotopes and radiation becomes more prevalent, the number of workshops dealing in them will progressively increase. Already the Radiation Hazard Prevention Law, the Medical Treatment Law and the Pharmaceuticals Law stipulate that such institutions may not deal in radioisotopes unless there sre sufficient evidences that complete safety is insured. Even after the operations are started on duely granted authorization, they must be periodically inspected by an official examiner. These existing examination and inspections systems, however, must be further improved in their actual application and more effective means of preventing radiation hazards must be discovered by the National Institute for Radiological Sciences and other institutions to meet the future emergencies.

(4) Disposal of Radioactive Waste

At present measures are taken for the recovery and storage of radioactive waste resulting from the use of isotopes, but the expected increase in volume of waste to be disposed that will naturally accompany with it a wider propagation of isotopes in future will demand much more than just recovery and storage. Furthermore, when the research and power reactors multiply and the reprocessing of spent fuel gets under way in the country, a large quantity of highly radioactive waste will be produced, a part of which can no doubt be used again through proper reprocessing but a greater part must be so disposed that no harmful effects shall accrue from the dangerous waste.

Such part of radioactive waste as individual institutes and workshops cannot dispose in a satisfactory manner must be passed over to a public organization which will find a proper way of its disposal in conformity with the international practice.

5. Fostering of Atomic Industries

It may be necessary that the Government push ahead with research and development with its own investment and at the same time urge private enterprises to develop and utilize atomic energy upon their own originality and responsibility. To foster the atomic industries of Japan during the first ten years will be to give them experiences in their own fields, and this is considered to be effective to bring about rapid expansion in the latter period. Measures to be taken by the Government to foster atomic industries are as follows:

(1) Low-Interest Loan and Special Tax Measures

Nuclear power generation is a new industry and is charac-

terized by high construction expenses and low fuel cost. Consequently, the construction of 1,000 MW nuclear power plants in the first ten years will need much more fund than that of oil-burning power plants. So the Government will have to consider securing of long-term and low-interest funds both either from domestic resources or from overseas financial organs.

It is also necessary for the Government to give favorable consideration to private enterprises not only on research expenses but also on taxation, in order to bring up the Japanese atomic industries which are but at the first stage of their development.

(2) Subsidy for Domestic Technology

In pushing research and development forward it is considered essential to solidify the basis of Japan's atomic industry as soon as possible through the introduction of technical know-how from abroad, to push through improvements on the technical basis thus established, and, on the other hand, to carry on studies on the basis of Japan's originality. For the achievement of these objectives, much expectation is placed in the sound development not only of Governmental test and research organs but of private organs as well.

Therefore, in addition to accelerating the domestic production of nuclear equipments and facilities, Japan's originality and idea must be used and developed effectively in the future. For this purpose, the technical levels of Japan's private circles must be developed on a priority basis so that they may reach the same level as those in advanced foreign countries by the time about the middle of this atomic energy development program. During the first ten years, it is necessary to develop superior

technniques of private circles through the Government aids such as subsidies and research contracts. Such measures must be taken more positively for researches which conform to the development program.

6. Securing of Nuclear Fuel and its Effective Uses

Securing of nuclear fuel for reactors is the most important problem for the sound development and utilization of atomic energy in Japan. Part of the fuel required can be supplied in Japan, but the greater part of it must be purchased from abroad under present situation. There are many countries capable of supplying natural uranium, but Japan have to depend upon the United States and the International Atomic Energy Agency for the supply of enriched uranium. Since the Government itself purchases enriched uranium and leases it to private circles, according to the present regulation it must, in constructing nuclear power plants and other facilities, take measures which will enable nuclear fuels to be supplied smoothly for a long time, through the conclusion of agreements necessary for long-term supply of fuel with foreign countries and the international organ.

Although the number of supply sources of fuel are considered to increase in the future, studies on uranium enrichment will also be carried out in Japan.

At present the credit of spent fuel and plutonium is taken into account in estimating the cost for nuclear power generation. Whether or not they have any economic value, therefore, will have great effects on the economy of nuclear power generation. The Government will have the Japan Atomic Energy Research Institute and the Atomic Fuel Corporation assume leadership in

the research and development of uses of plutonium and depleted uranium.

Thus a consistent setup for nuclear fuel will be established through the securing of supply sources, manufacture of fuel elements, re-processing of spent fuel, and effective uses of plutonium and depleted uranium as a fuel.

7. Other Important Measures

(1) Betterment of Environmental Conditions for Atomic Installations

As large-scale atomic installations are expected to increase in number in the future with the progress of research and development on atomic energy, it is necessary to choose proper location for such installations and at the same time place the surrounding areas in proper condition. Measures to be taken for this purpose are to place nuclear facilities for the completion of environment in proper positions, to have owners or enterprisers of atomic installations take proper steps for the radiation monitoring system, and to formulate a monitoring plan to be carried out by the owners, regional public entities and the Government.

(2) Preparation of Emergency Counter-Measures

Various safety measures mentioned above may be enough to secure the safety of reactor facilities, but measures to prevent unexpected accidents and also those concerning cooperative organizations for the prevention must be studied and formulated, and related laws and regulations must be completed if necessary.

(3) Establishment of Nuclear Damage Indemnity System

It is necessary to establish a nuclear damage indemnity system aimed at protecting third persons from nuclear damage in case of accident and also at contributing to the sound development of atomic enterprises. The Government is now working out measures for this purpose.

Since arrangements for the nuclear damage indemnity system must be made on an international scale, positive cooperation will be made by the Government in the acceleration of this system through the International Atomic Energy Agency. Sufficient measures will also be taken for the compensation for the damage caused to employees.

(4) Survey on Radioactivity in Environments

The level of radioactivity has heretofore been generally surveyed across the nation, but the investigation has been mainly directed to the fallout resulting from the atomic and hydrogen bombs tests. The recording of fallout will be the same as heretofore so long as the world situation does not change remarkably, but priority will be given hereafter to analysis of nuclear species in order to investigate the radioactivity level in environments in connection with the peaceful uses of atomic energy.

a) In accordance with the aforesaid plan, the radioactivity survey network will exert primary efforts to investigate the backgrounds of areas where nuclear installations are likely to be established in the future and harbors which nuclear powerd ships are likely to enter.

b) Investigation of uranium mines and their surrounding areas will be strengthened and various measurements will be conducted

regularly with regard to the weather and other phenomena in thses areas.

c) As a general, basic investigation to prepare for the disposal of radioactive waste into the sea, continuous survey will be made of the current of the waters around Japan, the waters on the surface and in the depth, the bottom conditions of the deep sea and living things in the waters.

d) In the case where nuclear installations are on the seashore, and when radioactive waste has been thrown away, monitoring will be conducted regularly against the sea waters near-by, deposits at the bottom of the sea, and living things in the sea.

The problems of fallout and the disposal of radioactive waste into the sea are something international; therefore cooperation will be made with other countries in investigating ^{14}C and the radioactivity level of foods concerning rice-eating nations in the Far East and Southeast Asian areas. At the same time, investigation and research on the radioactivity level at sea will be conducted in close contact with the IAEA, and measures will be sought to make investigations on an international level if necessary.

(5) International Exchanges of Information

Although the research, development and utilization of atomic energy in Japan have made progress during the past several years, they are still far behind those in other advanced nations. Therefore, it will play an important role for the acceleration of the development plan to attain smooth exchanges of information with such countries as well as among atomic energy

research organs in Japan.

International exchanges of information concerning atomic energy are very active at present, and Japan also shares the benefit of these exchanges. Up to the present, however, importance has been attached to the acquisition of information from abroad and efforts to furnish Japan's research results to other countries have been rather insufficient. We must hereafter positively furnish other countries with her information even for the purpose of obtaining important information from abroad on exchange basis. For this purpose, the Government will have related organs maintain close contact with one another and give necessary aid in pushing this kind of business as through the Japan Science and Technology Information Center, etc.

(6) Measures for Improving Public Relations in Atomic Energy Activity

For the development of new technology like that of atomic energy, it is necessary for the people in general to foster this technology with their true knowledges on it. In this sense, vigorous and thorough going diffusion of proper knowledges of atomic energy is a very important task to push ahead with the development and utilization program. This activity is now being followed by the Government and private organs concerned, but activities to be pursued by the Government hereafter will be made more vigorous and positive and those to be followed by private organs must be given proper aid.

Concrete ways to diffuse knowledges of atomic energy are as follows: teaching materials for junior and senior high school pupils should include as many items concerning atomic energy

as possible; contents of necessary publications issued by each organization shall be made substantial with adequate materials furnished by the Government, the JAERI, the Atomic Fuel Corporation, and the National Institute of Radiological Sciences; and aid will be given to the production of films and slides, and exhibitions and lectures to improve public as a whole.

Since these activities are diversified, efforts must be exerted to make them most effective by taking measures for the Government and private organs concerned to maintain close connection with one antoher.