International Atomic Energy Agency

PROGRESS IN PEACEFUL APPLICATIONS OF NUCLEAR ENERGY DURING THE YEAR 1966/67

Statements by Member States

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Statements by Member States

This booklet contains the 11 statements on the progress made during the year 1966/67 in peaceful applications of nuclear energy which Governments of Member States had communicated to the Director General by the end of 1967[1].

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1) The suggestion that such statements should be prepared for the information of the Conference was made at its session in 1966 — see document GC(X)/OR.107, para. 127. See also the Director General's note at the beginning of document GC(XI)/INF/97.

A. CANADA

The past year has been one of progress and expansion for the Canadian nuclear power programme. Probably the most significant development was the decision by Canada's largest electric utility company, the Hydro Electric Power Commission of Ontario, to add two 540-MW units to its Pickering nuclear power station, now being built near the City of Toronto. This will double the station's capacity to more than 2000 MW(e) and make it the second largest nuclear power plant under construction in North America. Ontario Hydro's decision, involving an estimated outlay of $256 million, offers further confirmation of the confidence placed in the nuclear power system developed by the Crown company, Atomic Energy of Canada Limited.

Known as CANDU (for Canada Deuterium Uranium), the Canadian system features the use of heavy water as the moderator and natural uranium as fuel, a combination that gives high fuel burnup and low fuel costs. Indeed, estimated fuelling cost for the Pickering reactors is the lowest predicted on the basis of firm fuel orders for any nuclear power station now under construction anywhere. Another feature of the Canadian system is that because of the high burnup it is not necessary to place a value on spent fuel. However, as spent fuel contains plutonium it has potential for future exploitation either on the market or for recycling in CANDU Reactors.

Canada's first nuclear power plant, the 22-MW(e) Nuclear Power Demonstration Station (NPD), is now in its sixth year of successful operation and is continuing to confirm the soundness of the CANDU concept. In 1966 NPD achieved a net capacity factor of 88.2 and in the peak load period of December 1966-February 1967 the factor had a value of 97.9. This performance record is all the more noteworthy in view of the fact that the station is used for engineering development and staff training as well as for demonstration purposes.

Canada's second nuclear plant and the first of commercial size came into operation during the past year. On 15 November 1966, the reactor at the 200-MW(e) Douglas Point Station in Ontario went critical, and on 17 January of this year the first electricity was produced. Meanwhile construction began of the latest in the CANDU family, the 250-MW(e) Gentilly Station on the St. Lawrence River in the Province of Quebec. Gentilly is a departure: it will use heavy water as a moderator and burn natural uranium as fuel but its coolant will be boiling light water instead of heavy water.

Another development in the past year was the conclusion of an agreement between the Governments of India and Canada to build a second 200-MW(e) CANDU unit at the Rajasthan Atomic Power Project in north-west India. The first Rajasthan unit is under construction and is expected to begin operation in 1970. In Pakistan the Canadian General Electric Company Limited is building a 137-MW(e) heavy-water-moderated, natural-uranium-fuelled nuclear power plant. Completion is scheduled for 1970.

Thus there now are in operation or under construction in Canada and abroad six nuclear power stations of Canadian design, comprising ten reactors in all, having a total generating capacity of more than 3000 megawatts and representing an aggregate investment of more than $900 million. The Canadian nuclear industry is keenly interested in participating in the export market of nuclear power reactors and recent organizational developments in industry are expected to enable it to compete even more actively on world markets in the future.

Of major importance to this nuclear power programme is the establishment in Canada of a heavy water industry. Production is about to begin at the heavy water plant at Glace Bay in the Province of Nova Scotia and construction has begun of a second plant, also in Nova Scotia, which is scheduled to come into production in 1969.

The two plants have a total designed capacity of more than 900 tons a year.

Canada is also, of course, a country of increasing importance as a source of nuclear fuel, and the Canadian Government, as well as the Canadian uranium industry, is very interested in promoting the export of uranium, subject to the conclusion of an agreement with the importing country to provide for appropriate verification and control that the uranium will be used for peaceful purposes only. Within this general framework the Canadian Government's policy on uranium export permits forward commitments by Canadian producers to supply reactors which are already in operation, under construction, or committed for construction in other countries for the average anticipated life of each reactor (generally calculated for amortization purposes to be thirty years); the Canadian Government is also prepared to authorize export for periods of up to five years of reasonable quantities of uranium for the accumulation of stocks in the importing country.

B. GERMANY, FEDERAL REPUBLIC OF

Progress Report on the Applications of Nuclear Energy in 1966/67

1. Nuclear energy is reaching full commercial efficiency in the Federal Republic of Germany

German industry is in a position to offer light-water nuclear power stations which are competitive with regard to technical quality and prices.

In the middle of 1967 some German electricity supply companies decided to build two light-water nuclear power stations with a net electrical output of 1240 MW(e). The board of directors of Preussenelektra took the decision to set up a nuclear power station with an electrical output of 600 MW(e) near Würgassen on the Weser; the boards of directors of Nordwestdeutsche Kraftwerke and of Hamburgische Elektrizitätswerke agreed on the joint construction of a nuclear power plant of an electrical output of 640 MW(e) near Stade on the Elbe. Both power stations are to go into operation in 1972.

At the beginning of the seventies the Federal Republic of Germany will thus have at least 11 nuclear power stations and experimental power reactors with a total output of 2150 MW(e). The nuclear power stations at Würgassen and Stade will be financed solely by the electric power industry; they will not receive any government grants.

2. Further increase in the Federal Government's funds for the advancement of nuclear research and development

In 1967, too, the Federal Government will allocate more funds for the advancement of nuclear research and engineering than in the previous year. Such funds amount to a total of about DM 800 million, which is an increase of 20 per cent over the sum of approximately DM 650 million raised in 1966. Another DM 250 million will be made available by the German *Länder*.

About DM 570 million of the Federal funds will come from the budget of the Federal Ministry for Scientific Research.

The total amount of Federal funds, i.e. DM 792 million, will be spent as follows:

37 per cent on international co-operation:

30 per cent on nuclear development outside the nuclear research centres, including the construction and operation of large nuclear experimental facilities;

24 per cent on nuclear research centres other than the large experimental facilities;

7 per cent on nuclear research at universities and at institutes outside the universities; and

2 per cent on radiation protection and nuclear safety.

3. Progress made in the construction and commissioning of further power reactors in the Federal Republic of Germany

The boiling-water reactor of Gundremmingen on the Danube, which is one of the three nuclear power demonstration plants of the light-water type whose construction was started early in or in the middle of the sixties, reached criticality for the first time on 14 August 1966 and its full electric power output of 237 MW(net) on 23 December 1966. By 30 June 1967 the Gundremmingen reactor had fed the public utility grid with approximately 600 million kWh.

Construction work on the other two sites, namely Lingen on the Ems (boiling-water reactor of 160 MW(e) nuclear plus 80 MW(e) by oil-fired super-heater) and Obrigheim am Neckar [pressurized water reactor of 283 MW(e)], progressed according to schedule so that both facilities may be expected to go into operation in 1968.

Subsequent to Gundremmingen and Lingen, the Obrigheim nuclear power station was also granted the status of a joint enterprise of the European Community in the fall of 1966.

In the Federal Republic of Germany there are at present five experimental power reactors — AVR, HDR, KNK, KKN and MZFR — in operation or under construction. The construction work on the superheated-steam reactor (HDR) at Grosswelzheim am Main, on the compact sodium-cooled reactor (KNK) in the Karlsruhe nuclear research centre and on the nuclear power station (KKN) at Niederaichbach on the Isar made good progress. These three facilities will go into operation by 1970 at the latest.

At Jülich the gas-cooled AVR reactor of the high-temperature type, which serves as an experimental reactor and for gaining operational experience with a view to the development of large high-temperature reactors, went critical on 26 August 1966 for the first time. Following an extensive experimental operation at low-power output it is to reach its full electric power output of 15 MW(e) by the end of this year. At the multi-purpose reactor MZFR of the D_2O-moderated-and-cooled type at Karlsruhe, the trial operation agreed upon by contract was terminated in December 1966 and the reactor was taken over by the government operating company.

The installation of the advanced pressurized-water reactor into the bulk carrier "Otto Hahn" at Kiel is nearing completion. A few weeks ago the pressure vessel which will house the reactor core was installed. The zero-power experiment for the "Otto Hahn" is at present being prepared at the Geesthacht reactor station of the GKSS and will presumably be concluded early in 1968.

4. Fast breeder development is nearing industrial exploitation

The fundamental studies on the development of a sodium-cooled and a steam-cooled power breeder reactor that were carried out by the Karlsruhe nuclear research centre under an association contract with the European Community made further progress during the period of time under review. After completion of a reference study and systems analysis for a 1000 MW(e) sodium-cooled fast-breeder nuclear power station a similar study and analysis were concluded for the steam-cooled facility. Both studies constitute the basis for planning and designing fast-breeder prototypes with a 300 MW(e) output by two groups of German industrial firms.

The experimental reactors HDR and KNK will play an important part in testing fuel and breeder elements, as well as major reactor components, especially since the second core to be inserted into the KNK will be a fast one and that of the HDR a fast thermal one.

The Karlsruhe fast zero-power assembly (SNEAK), which went into operation at the Karlsruhe nuclear research centre in December 1966, offers the opportunity to explore experimentally the neutron physics of fast-breeder reactors.

5. Growing efforts by the Federal Republic of Germany in the field of the fuel cycle

While the main emphasis was placed on reactor construction and development in the support given to nuclear engineering over the last years, the foreseeable growth in the number of nuclear power stations and the progressing development work on high-temperature and breeder reactors have focussed attention on the fuel cycle with its components — uranium prospecting and supply, fuel element fabrication, chemical reprocessing of irradiated nuclear fuel, as well as the use and disposal of radioactive wastes.

Although objections raised by national conservancies caused difficulties for quite some time, it has now become possible to continue to a limited extent the underground work for opening the largest German uranium ore deposit so far known, near Menzenschwand in the Black Forest.

A group of German firms concluded a contract with a Canadian enterprise (Brinex) concerning its participation in a uranium prospecting project in Canada. If such prospecting turns out a success the group of firms will also have an interest in the mining of the uranium ore deposits that are discovered.

In the Karlsruhe nuclear research centre good progress was made in the construction of the first German reprocessing plant for irradiated fuel elements which will have a yearly capacity of 35 tons. (fuel elements containing natural uranium and low-enriched uranium).

In the Asse salt mine near Wolfenbüttel in the north-west of Germany radioactive wastes were for the first time given a trial storage by the Gesellschaft für Strahlenforschung mbH. This experiment involved 1722 casks of concrete-fixed low-activity wastes from the Karlsruhe nuclear research centre.

Working groups at German university institutes increased their efforts to develop isotope batteries.

6. 10th anniversaries of the nuclear research centres at Jülich and Karlsruhe

During the period of time under review the two largest German nuclear research centres of Jülich and Karlsruhe celebrated their tenth anniversaries.

Up to the end of 1966, the Federal Government and the *Land* governments had raised about DM 650 million and DM 750 million for investments in and the operational costs of the nuclear research centres at Jülich and Karlsruhe respectively, where about 6000 persons are employed, 1000 of whom are scientists holding university degrees.

The working programmes of the two centres are focussed on projects of reactor development and the relevant fuel cycles, i.e. fast breeder reactors at the Karlsruhe nuclear research centre and high-temperature reactors at the Jülich nuclear research establishment of the *Land* of Nordrhein-Westfalen. Both projects are carried out under an association agreement with the European Community and in co-operation with German nuclear industry. The two centres also engage in basic research, such as the development of a high-intensity proton accelerator in the 40-GeV range at the Karlsruhe nuclear research centre and research projects in solid state physics and plasma physics at the Jülich nuclear research establishment.

7. Number of research and training reactors has been brought up to 27 altogether

On 30 June 1967, 15 research reactors and nine small training reactors were in operation in the Federal Republic of Germany and another three research and training reactors were under construction or were being planned.

The following three specialized research reactors went critical during the period under review:

(a) The TRIGA Mark I, a homogeneous reactor of the German cancer research centre at Heidelberg;

(b) A reactor which is used for burn-up measurements on spherical fuel elements at Jülich; and

(c) The SNEAK facility at Karlsruhe, which is of importance in connection with the neutron physics of fast reactors.

8. Further expansion of basic research institutes in the Federal Republic of Germany

A large number of experiments were carried out at the 6.5-GeV electron synchrotron DESY at Hamburg during the period under review. The fact that the scientific group at DESY received an ever-growing number of invitations from abroad to talk about their experiments reflects the international attention which is paid to these experiments.

At Munich Technical University the institute of radiochemistry and its laboratories and auxiliary installations was brought into full operation, and thus another establishment of basic research in nuclear chemistry was completed in the Federal Republic of Germany.

During the period under review a 2.3-GeV electron synchrotron and a 300 MeV electron linear accelerator were commissioned at Bonn University and Mainz University respectively. Studies on a heavy ion accelerator were continued at Heidelberg University.

9. Progress in biology, medicine and radiation protection

The Gesellschaft für Strahlenforschung mbH at Neuherberg, Munich, is growing into a large centre for research in radiobiology and nuclear medicine.

10. International co-operation

Under an agreement concluded on 16 January 1967 the Federal Republic of Germany and France will jointly build and operate a research institute with a very high flux reactor at Grenoble. The reactor chosen will use D_2O as a moderator and coolant and will be built by industrial firms of the two contracting parties.

During the period under review the laboratories of the European Organization for Nuclear Research (CERN) at Geneva were used by many visiting groups from institutes of German universities and the Max Planck Society as well as the nuclear research centres.

In line with the activities performed within EURATOM, nuclear research centres and industrial firms of the Federal Republic of Germany, Belgium and the Netherlands will closely co-operate in the development of fast-breeder reactors.

C. INDIA

The Progress made by India in the Peaceful Uses of Atomic Energy during the Year 1966/1967

During the year 1966/1967, India has made rapid strides in the peaceful applications of atomic energy. Some of the highlights of these developments are given below.

India's nuclear power programme continued to register satisfactory progress. Work on the 380-MW(e) Tarapur Atomic Power Station is proceeding according to plan. This Station, which is being built with United States assistance, is expected to go into commercial operation by October 1968. Similarly, work on the first 200-MW(e) unit of the Rajasthan Atomic Power Station has progressed according to schedule and the Station is expected to go into operation early in 1970. The construction of the second 200-MW(e) unit of the Rajasthan Station has commenced. This unit is expected to be in operation by the middle of 1972. Both units of the Station are being built with Canadian collaboration and assistance. Preliminary work on the Madras Atomic Power Station which will also produce 400 MW(e) has commenced. With the commissioning of these three nuclear power stations, India will generate more than a million kilowatts of electricity through atomic energy. In all these three stations, power costs will already be lower than what they would have been had power stations using conventional fossil fuels been built at these locations.

In executing these projects, ever-increasing emphasis has been laid on the maximum use of indigenous skills and materials. This can be readily seen from the fact that, whereas for the Tarapur Atomic Power Station about 66% of the cost was in foreign exchange, the corresponding figure for the first unit of the Madras Atomic Power Station will be only 20%.

The extraction of the plutonium which will be used in the second generation of power reactors is an extremely important aspect of India's nuclear power programme. The constructional and operational experience gained with the existing plutonium plant has been made use of in designing a new facility for handling irradiated fuel from nuclear power stations. Development work connected with the design of additional auxiliary facilities for processing the irradiated power reactor fuels and irradiated thorium has also progressed satisfactorily. An experimental station for developing fast breeder reactors will be set up adjacent to the Madras Atomic Power Station.

The extent and scope of the country-wide operations in respect of prospecting for atomic minerals was widened considerably. The Jaduguda Uranium Mill, which is capable of processing 1000 tons of uranium ore per day, is now complete, and the production of uranium concentrates has already commenced on a trial basis. A new mechanized plant to process minerals present in the beach sands of Kerala has been completed. This will produce considerable quantities of ilmenite, monazite, zircon and rutile. The capacity of the rare earth plant will also be expanded in the near future. The construction of a large heavy water plant has been decided upon and work on this plant will commence in the near future. Based on the experience gained in the construction and operation of the Uranium Metal Plant and the Fuel Fabrication Facility at Trombay, a fuel complex is now being set up at Hyderabad. This will consist of a large-capacity uranium metal plant and a fuel fabrication facility capable of meeting the country-wide power-reactor fuel requirements of the immediate future. The production of fuel for the first unit of the Rajasthan Atomic Power Station has already commenced. Considerable progress has also been made on methods of treating high-, medium- and low-level radioactive wastes.

It is expected that by about 1975 India will be in a position to set up single nuclear power units of about 600 MW(e) capacity. Studies recently conducted have indicated that in certain areas of India nuclear power and desalinated water from the sea can be produced at such economical rates that it would be possible to concentrate in these regions electricity-intensive industries for producing materials such as fertilizers, insecticides, caustic soda, chlorine and aluminium. It has been estimated that these very large stations would produce power and desalinated water at costs which are significantly lower than those prevailing at present. This would completely change the economic picture of regions where at present no industrial development is possible because of lack of power and water. In view of the importance of this concept, a special study aimed at assessing the technological and economic implications of such an agro-industrial complex has been undertaken by the Indian Atomic Energy Commission jointly with the United States Atomic Energy Commission. As projects of the type envisaged above would lead to a significant increase in man-power requirements, considerable accent has been laid on specialized training programmes in the field of atomic energy.

Apart from the nuclear power projects and their immediate ancillary facilities, significant progress was registered in a number of other areas. On the basis of processes and techniques developed indigenously at the Bhabha Atomic Research Centre, a large electronics complex is now coming up at Hyderabad. This complex has undertaken commercial-scale production of electronic control systems and computers aimed at satisfying a substantial fraction of the overall requirements of the country.

The Bhabha Atomic Research Centre has continued to develop a number of instruments and processes with a view to increasing to the maximum extent possible the proportion of Indian equipment and techniques used in the field of atomic energy. Developments during the year included:

(a) Production of high-purity materials;
(b) Extraction of rare elements;
(c) Development of special materials for transistor technology;
(d) Production of special alloys;
(e) Successful development of flow-sheets for the exploitation of by-products in uranium ore such as copper, nickel and molybdenum minerals; and
(f) Development of a D.C. plasma gun capable of operating at a power level of 60 kV and producing temperatures ranging between 5000 and 30 000°C.

The Seismic Array Station which was set up at Gouribidnur for conducting studies on underground nuclear tests continued to operate satisfactorily. This array is now being extended to a 20-element array and the necessary instruments for this purpose are being developed. Studies on atmospheric fall-out from nuclear weapon tests were continued, and methods of increased precision have been developed for the detection and estimation of fall-out products. Among the many special-purpose instruments designed and constructed were a 1024-channel pulse-height analyser and a transistorized automatic data-logging system for the meteorological tower at the Tarapur Atomic Power Station site.

The production of isotopes and labelled compounds was considerably expanded and isotopes were exported to a number of countries in Europe, Africa and Asia. The first high-specific-activity cobalt source (of a strength of 1800 curies) to be fabricated at Trombay was installed in a cobalt cancer therapy unit. The country-wide radiation protection programme gained considerable momentum and it now covers nearly 12 000 workers all over the country. This is an index of the growing use of radiation sources throughout the country.

The development of radiation preservation processes for perishables such as fruits, vegetables, fish and milk products was continued. Two pilot-scale cobalt-60 food irradiators have just been installed with Canadian assistance. One is a large package irradiator and the other is a portable one which can handle grains and other free-flowing materials. These irradiators, along with the associated analytical, research and processing facilities, will provide considerable impetus to this programme. Following these initial efforts, a production-scale irradiation facility will be designed for installation and use in one of the grain storage centres in the country.

Yields trials on promising rice and groundnut mutants have established the higher yield capabilities of these mutants. A large-scale project to expand further the use of radiation in agriculture has been jointly proposed by the Indian Council of Agricultural Research and the Indian Department of Atomic Energy. It is hoped that this project will be assisted by funds from the United Nations Development Programme. The Agency has assisted considerably in formulating and crystallizing this project.

Three scientists from Afghanistan received training in the safe handling of radioisotopes and in radiochemical techniques. This was a prelude to the setting up of an isotope dispensing centre at Kabul by scientists of the Bhabha Atomic Research Centre. Two scientists from Saudi Arabia were trained in radiation monitoring techniques. A number of other scientists from abroad came to work in the Bhabha Atomic Research Centre under bilateral arrangements and fellowship programmes.

Work at the Tata Institute of Fundamental Research in various areas such as particle physics, computer development and research, nuclear magnetic resonance, cosmic rays, radioactive dating, radio-astronomy and molecular biology was continued.

At the Saha Institute in Calcutta, a technical physics group has been formed to develop technical know-how and research equipment. In conjunction with other units of the Institute, this group is helping to develop some of the costly and scarce equipment required by research workers. The Department of Atomic Energy continues to provide financial and other forms of assistance to the Saha Institute and a number of other institutions all over the country to promote research and development work in the field of atomic energy.

At the Tata Memorial Centre studies on the body distribution of cancer among Indians have been undertaken and new methods of treatment of cancer of the gullet, cheek and tongue are under investigation. Significant progress has also been made in a project to evaluate the use of phosphorus-32 in the early diagnosis of cancer in the nose and throat.

D. ITALY

Main Features of Nuclear Progress during 1967

Since last October, Italy — and in particular the National Nuclear Energy Commission (CNEN), working closely with the national bodies and industries concerned — has launched the programmes outlined at the tenth regular session of the General Conference [2]. In some cases decisive progress towards carrying them out in full has recently been achieved.

In addition, new activities, under study for some time, during the past few months have reached the execution stage.

The CNEN itself, while not neglecting fundamental research, has concentrated, on both the technical and the financial side, on activities with a major bearing on the industrial applications of nuclear energy. Consequently, this document will deal mainly with the progress made in the CNEN's principal technological programmes.

Its technological research can be sub-divided into two sections, one dealing with reactor development and the other with the nuclear fuel cycle.

A. Reactors

The main programmes under this section can be listed under the following headings: CIRENE, PEC, PPN and ROVI.

CIRENE — CISE [3] (CIse REattore a NEbbia or CISE fog-cooled reactor). On 7 July 1967, the CNEN and l'Ente Nazionale per l'Energia Elettrica (ENEL) signed the agreement for the joint construction of a prototype reactor CIRENE as the first real step towards construction of a power reactor of Italian design. With the CIRENE prototype reactor of 110 MW thermal and approximately 35 MW electric, the CNEN will be entering the promising field of advanced converters.

The programme is based on a new cooling design using water in transition from one phase to another initially conceived by the CISE laboratories in Milan — the nuclear research arm of ENEL — and developed as part of the CNEN's applied research programme.

The CIRENE programme is thus a tripartite CISE-CNEN-ENEL programme in which EURATOM has also shown interest, giving technical collaboration and financial support during the research stage.

The decision to build the prototype brings within reach the possible industrial use of CIRENE-type reactors of Italian design which would contribute during the coming years towards producing that part of the total electricity output assigned to nuclear power stations under ENEL's programmes.

Primarily the CIRENE prototype will be an experimental installation that can be used to carry out tests which would present difficulties elsewhere and to determine whether the results of small-scale experiments can be extrapolated to an industrial installation. Furthermore, operation of CIRENE will provide valuable experience for assessing real construction and operating costs and making any necessary modifications in the design of the prototype in order to optimize the planning and design criteria and to reduce the costs of full-scale installations.

The construction of the prototype will also provide a training-ground for Italian reactor engineers and help in training the specialized staff who will be responsible for the future technological development of CIRENE-type reactors.

Finally this prototype will be the main supporting installation for progressive improvement of this reactor type, particularly as an irradiation facility for the production of new fuel elements and the testing of more advanced concepts that might be incorporated in the design of the type itself (e.g., thorium fuel cycle and nuclear superheat).

The reactor is a pressure tube, heavy-water-moderated, fog-cooled type. It will be built at the Latina nuclear station for completion between now and the end of 1971 in close collaboration with, and with the financial help of ENEL and the Italian industries which are to provide all the components. The electric power produced will be fed into the grid.

Research and experiments on the fuel elements are also in hand, the intention being that the elements should be fabricated in Italy.

The fuel to be used in the prototype will be natural uranium in the form of oxide. A feature

2) See document GC(X)/OR.108, paras. 33 and 34.

3) Centro Informazioni Studi ed Esperienze.

of the design will be a vertical pressure-tube system through which the "fog" (i.e. the water in a state of transition from one phase to another) will circulate for purposes of heat removal. Fuel loading and unloading will take place while the reactor is in operation.

The industrial group designated to install the prototype will not merely carry out the construction work but will take an active part in the work of developing this type for industrial purposes.

PEC (Prova Elementi Combustibile, i.e. Fuel Element Tests). This is a longer-term programme concerned with fast reactors.

Between now and 1975 the percentage growth in electrical energy and power requirements is expected to be between seven and nine per cent per annum and, during the period 1970-1975, new nuclear power stations brought into operation will, it is estimated, have an overall capacity of 3000 MW(e). This means that from 1975 Italy will be producing plutonium at the rate of several hundred kilograms a year. Without extending forecasts to the period 1980-1990, when it is generally considered that fast reactors will become truly competitive with the present generation of thermal reactors, it is quite apparent that Italy too is giving attention to the matter of using the plutonium produced and that from now onwards it will be concerned with developing fast reactors (using plutonium fuel), whilst continuing at the same time (for some while at least) to study the possibilities of profitable reprocessing and utilization of the plutonium produced in water-cooled reactors.

The CNEN is investigating these problems by an extensive programme of basic research. In other words, it intends to have prepared industry and to be ready itself for the advent of this type of reactor. The result is then a generalized programme which, for the present, is not aimed at building an actual power station or a prototype reactor but at making a thorough study of fuels for fast reactors and of the basic components of sodium-cooled reactors.

One of the two main installations planned under the fast reactor programme is the CNEN's PEC project. The other is to be an experimental plant of about 50 MW capacity for intermediate exchangers and sodium vapour generators.

The PEC, which is planned for completion by the end of 1971, is a fast reactor cooled by liquid sodium, of initial capacity 80 MW(th), which can reach a maximum output of 140 MW(th). The core is divided into two seed areas: the experimental region and the normal working region.

With this reactor it will be possible to carry out trials under stationary as well as transient operating conditions, and on the experimental level to bring about fusion of some of the rods in the experimental region. The reactor will operate with a core of "ventilated"-type elements.

The PEC will thus be the basic tool for perfecting design of fuel elements for fast reactors of the future.

PPN — (Marine Propulsion Programme). The CNEN has for a long time been interested in nuclear ship propulsion — a most important application of nuclear energy. The reasons for this interest are both numerous and extremely valid at the present time: the growing importance attached to the commercial aspects of nuclear ship propulsion in various countries; the efforts being made by countries with special shipbuilding interests; the excellent economic prospects which nuclear propulsion appears to offer after 1970, with the advent of larger and faster ships; the importance of shipbuilding within the national economy; the grounding received by technical personnel as a result of studies carried out in recent years.

With its first five-year plan the CNEN assumed the role of a promoter of studies and experiments. As from 1961 it played a direct part in the programme of project studies undertaken by Fiat and Ansaldo with the financial participation of EURATOM.

In recent years the CNEN has decided that it is essential to assign to marine propulsion an important place in its programmes and has resolved to take more decisive action with clear, precise aims.

In this spirit, the CNEN convened an expert committee comprising representatives and technical specialists from all interested sectors — shipbuilders and the representatives of the relevant departments and institutions. The recommendations of this committee brought out clearly the need for practical steps towards the construction of an Italian nuclear ship. It was equally clear that economic difficulties would hinder the rapid realization of such a project; neither industry in general, nor the shipyards, nor the other interested parties (with the exception of the CNEN, which could not, however, assume the entire financial burden) were able to guarantee the funds necessary for an enterprise which was obviously not an economic proposition. In fact, the construction of a nuclear ship can at present be regarded only as an extremely useful technological experiment.

Only at the end of 1966 were the above difficulties overcome by means of an agreement between the CNEN and the Navy on the building of a nuclear-powered logistic support ship.

The participation of the Navy is due solely to the fact that it is the only national institution with the organization and financial structure necessary for the realization of this project, which is of a completely non-military nature and therefore not subject to special security arrangements.

It was decided that the first project in this field should be an experiment on a nation-wide scale, on which could be focussed the efforts of the public and private institutions which were already engaged in this sector or which wished to enter the field.

The agreement provides for the construction and operation of a nuclear-powered merchant vessel. The programmes also makes extensive provision for research with respect both to the design of the reactor and to improving the performance of the power plant.

The ship will be equipped with an 80-MW(th) experimental reactor, moderated and cooled by pressurized water. This reactor type has been selected on the basis of a thorough analysis by a study group which, after several years of study, determined the most promising reactor characteristics for marine propulsion from both the economic and the safety points of view. Careful examination of domestic costs and construction facilities has shown that it will be possible to manufacture about 90 % of the nuclear plant components in Italy.

The ship, which will have a capacity of 18 000 tons, is to be a logistic support vessel, with features designed to make it an ideal means of acquiring technical and scientific experience in the nuclear sector. It will also be the best available means of training qualified personnel.

The Navy will undertake the construction and operation of the ship, while the CNEN will be responsible for all aspects of technical research.

The experience acquired in the design and construction of the reactor section will be particularly valuable, with regard not only to nuclear marine propulsion, but also, and more generally, to the development of industrial nuclear technology.

The PPN is therefore a major experiment on a national scale, in which industry is to play a leading part.

ROVI. Evaluation studies on the possible utilization of organic liquid reactors for generating industrial steam have been concluded. The working group which was set up for this purpose and which included representatives of some of the most important sectors of Italian industry concerned with nuclear energy arrived at the conclusion that, as steam generators for desalting, ROVI reactors have good competitive prospects at powers below 400 MW(th).

In view of the growing interest of developing countries in plants in this power range suitable for producing fresh water, the study group recommended that the CNEN sponsor the construction in Italy of a prototype plant capable of supplying water to a region with scanty water resources, thereby enabling interested sectors of Italian industry to acquire the experience necessary for the development of the reactor type in question.

The CNEN accordingly convened a meeting of the most important sectors of Italian industry with a view to determining possible areas of collaboration.

At this meeting, the sectors of industry represented expressed a unanimous desire to establish a consortium, under the auspices and with the collaboration of the CNEN, with a view to the commercial exploitation of ROVI reactors on both the domestic and, particularly, the international market. Talks aimed at establishing an actual project are still in progress.

B. Fuel cycles

This is the second major field of the CNEN's activities.

Fuel fabrication. Fuel element fabrication, which as we have seen has no less important a bearing on the economics of nuclear power production, is a phase of the fuel cycle which has long engaged the attention of CNEN personnel and its resources. The major part of the work in this field has been conducted by the fuel element fabrication laboratory at Saluggia (Vercelli Province), and partially by other CNEN centres. Here we give under different headings a short list of the elements studied.

Plate-type metal elements for research reactors (of the MTR type). These are highly enriched uranium-base fuel elements of the type used in such Italian reactors as the SORIN (Società Ricerche Impianti Nucleari) reactor at Saluggia and the one at the CAMEN centre at S. Piero a Grado. The CNEN's production experience is drawn from the manufacture of two charges for the Avogrado reactor belonging to the SORIN organization, and of one charge (now being prepared) for the Galileo reactor belonging to CAMEN. The performance of the elements manufactured for SORIN has proved to be superior to specifications.

Rod-type metal elements for gas-cooled reactors. These are elements of natural uranium metal, sheathed in aluminium or magnesium alloys, of the type used in plutonium reactors and in graphite-gas-cooled nuclear power stations of the so-called "English" type. One example of such a power station is the Latina reactor.

Fuels of this type were the first to be developed by the CNEN, and they have been produced as prototypes in small quantities. Before obtaining the finished product two problems must first be solved: the production of nuclear-grade uranium metal (beginning with concentrates of commercial uranium), then the actual fabrication of the element. As far as the production of nuclear-grade uranium metal from concentrates of commercial uranium is concerned, the CNEN has developed and tried out, on a pilot level, an original method of its own for producing samples of remarkable purity.

With regard to the actual fabrication of the element, the CNEN has developed the main processes involved and applied them on an industrial scale. As we know, one of the major drawbacks in utilizing uranium metal as a nuclear fuel is its tendency to buckle in certain specified directions following thermal cycling, i.e. the repeated temperature and activity fluctuations which the reactor is subject to. One means of reducing, if not avoiding, this drawback is by using uranium in alloy with other metals. The CNEN, in collaboration with other research groups (Società Nazionale Metanodotti), is rounding off a study begun in 1961 on the possibility of improving uranium performance under irradiation by adding small quantities of binders (molybdenum, niobium, zirconium). The results obtained on binary alloys are very promising; studies are at present in progress on the prospects offered by ternary alloys.

Ceramic rod elements for water-cooled reactors. These fuel elements are those used in large light-water nuclear power stations (like the ones at Trino, Vercellese and Garigliano), and in certain experimental converter reactors (CIRENE). The fuel material made up of sintered uranium oxide slugs is contained inside rods made either of stainless steel or of special zirconium alloys (zircaloy). The fuels designed for water-cooled power stations using the thorium cycle are identical, except that in the latter case the rods contain mixed sintered uranium and thorium oxides. With the aim of acquiring the relevant know-how, the CNEN has been evaluating the thermodynamic and nuclear parameters for some time and is now in the process of developing a number of computational codes; the results of this work will be checked by major irradiation experiments on samples and prototypes. In this sense we can claim that the CNEN is far on the way to acquiring the know-how for the project. The situation is somewhat different with regard to fabrication. The techniques developed by the CNEN can now be utilized for fabricating, in perfect conformity with the specifications, ceramic rod elements for power stations of the Garigliano and Trino types, and for water-cooled reactors in general.

Intense research and development is going on at the same time in the case of materials and new fabricating techniques. Research is being done on materials such as zirconium alloys or certain stainless steels and on ceramic fuels of a new type. In this respect reference must be made to the technique perfected by CNEN and dubbed "Sol-gel" process, used in the preparation of high-density uranium oxide salts to replace the slugs inside fuel element rods. The sol-gel method is based on a series of chemical operations on colloidal solutions, followed by heat treatment at a moderate temperature. This method has been studied and tested at laboratory level and has been applied to the preparation of ceramic fuel samples of a number of different kinds; uranium, thorium and plutonium oxides (or mixtures thereof), uranium and thorium carbides, and uranium nitrides. The CNEN method is at present being tested in a small-scale installation capable of preparing a few dozen kilograms of material needed for a series of rod-filling trials and for irradiation experiments.

Research into fabrication techniques mostly concerns new possibilities and already known operations, or particular phases of the fabrication process that require development in order to evaluate new materials. This research includes a new method of sintering, special vibration techniques, new soldering and rod-sealing methods, new assembly techniques, new ways of checking cladding and, finally, new analytical and inspection methods.

Fuel reconditioning and recycling

The reprocessing of irradiated fuel is closely connected with its fabrication. The fact that the fissile material contained in a fuel element is not entirely used up in the reactor and that at the same time, as a result of nuclear reactions, new fissile material is formed in the element itself, leads to the problem of how to recover and recycle the uranium and plutonium that is still usable in the fuel discharge from reactors and from nuclear power stations. The CNEN has devoted considerable time and money to acquiring greater knowledge of fuel reconditioning problems on an industrial scale.

EUREX: This is the context in which the EUREX programme has evolved. The programme envisages study of the main technological and chemical problems bound up with installations for reprocessing irradiated fuel so as to obtain by 1971-72 sufficient technological data to design and construct installations on an industrial scale. In connection with this programme a pilot installation is being constructed at Saluggia for the reprocessing of irradiated fuel; construction is at present at an advanced stage, and the plant should enter into service during 1968. The design has been optimized for the treatment of highly enriched uranium fuel of the MTR type, but is sufficiently versatile to allow research on a normal scale into the treatment of natural or 5 %-enriched uranium fuel cladded in aluminium, magnesium, zirconium or stainless steel.

The EUREX installation will have an annual processing capacity of between 25 and 30 tons of 5 %-enriched uranium.

Its aim is to experiment, on a scale such that the results can be extrapolated to a larger installation, both with regard to new chemical extraction techniques and the resistance and reliability of control apparatus, not only for highly enriched fuel but also for natural or slightly enriched uranium fuels such as those which are at present being used in the three major Italian nuclear power stations. The EUREX installation will also provide an effective means of training technicians for work on the reprocessing of irradiated fuel and preparing Italian industry to deal with the problems involved.

PCUT. The CNEN's second installation in the fuel sector will enter service at Rotondella (Matera province) in the next few months. This is the ITREC (Installation for the Reprocessing of Fuel Elements) installation and comes under the PCUT (Uranium-Thorium Cycle) programme. The EUREX and PCUT programmes are complementary in that whereas EUREX is concerned with water-treatment techniques (the initial material being irradiated fuel, and the final product uranium and plutonium purified from fission products, which are stored separately), the ITREC installation covers the whole operation of fuel recycling, which, as we know, sometimes displays (e.g. in uranium-thorium converter reactors, or for plutonium recycling in fast reactors) characteristics that preclude reprocessing on the spot.

In November 1965 the CNEN signed an agreement with the US Atomic Energy Commission to carry out reconditioning and refabrication of uranium-thorium fuel elements from the Elk River (USA) reactor at the ITREC installation. This agreement applies to all the aspects of uranium-thorium fuel recycling.

ITREC should be considered more as a research installation than as a commercial one; the installation in fact will enable us to carry out pilot experiments to obtain data on methods and costs in the fuel cycle, capable of being directly extrapolated to industrial installations. The project is sufficiently versatile in character to allow us to adopt a variety of approaches in our work at the chemical installation, without having to modify the apparatus, and to switch over easily to the handling of fuels significantly different from those used up to now. Finally, mention ought to be made of the special studies at present under way with a view to modifying the plant so that it can be used for the plutonium cycle (in connection with other CNEN projects) or for recycling thorium in heavy-water reactors (CIRENE) and in high-temperature gas reactors.

The plutonium programme

As is known, the joint CNEN-ENEL programme for plutonium includes studies and research for use in evaluating the technical prospects for using the plutonium produced in nuclear power stations as fissile material in thermal and fast reactors. Within the framework of this programme we have already begun the construction of a laboratory at the Casaccia Nuclear Study Centre.

C. Other activities

As mentioned above, the CNEN's principal effort has been concentrated mainly on applied research; at the same time intensive effort has been devoted to fundamental research, which has accounted for 30 % of all CNEN funds. This percentage is mainly made up of research into high-energy nuclear physics carried out at the National Institute for Nuclear Physics (INFN).

Other important research has been conducted into biology, agriculture and geo-mineralogy.

Biological research has dealt mainly with radiation interactions in man as a means of protecting human beings and, more particularly, of repairing damage caused by radiation.

As far as agriculture is concerned research has been principally directed towards using radiation to improve plant genetics and to protect agricultural produce.

The CNEN's programme to facilitate and broaden the distribution of scientific and technical information comprises the publication of reports, bulletins and material in popular form and the organization of congresses, symposia and other meetings.

Finally, mention should be made of COMISOTOP, a study group that meets from time to time to discuss the application of radioisotopes in industry in all its aspects. All interested parties, from the producer industries to the user industries, from carriers to ministerial experts, are represented in COMISOTOP.

Mention should finally be made of two important undertakings begun in recent months. The IRI group has begun a reorganization of all its activities in the nuclear sphere and has set up a number of organizations and companies (Ansaldo Meccanico Nucleare, Progettazioni Meccaniche Nucleari, Società Italiana Impianti), with headquarters at Genoa, to carry out in the field of atomic energy a co-ordinated programme in close collaboration with each other. Of equal interest is the agreement signed in recent months between Fiat, the Breda Company of the EFIM group (Organization for Administering the Financial Resources of the Engineering Industry) and Westinghouse to set up a company for constructing nuclear power stations and for fabricating fuel elements on an industrial basis.

E. JAPAN

Progress in the Peaceful Applications of Nuclear Energy in Japan during the Preceding Year

A. Outline of the Long-Range Programme for the Development and Utilization of Atomic Energy

1. In recent years steady progress has been made in Japan in every field of the peaceful uses of atomic energy, and the outlook for its practical utilization in the future has become much clearer; under these circumstances the Atomic Energy Commission, in order to bring the nuclear policy up-to-date, revised in April 1967 its Long-Range Programme for the Development and Utilization of Atomic Energy which had been formulated by the Commission in 1961.

2. In the new Programme, in the first place, the long-range development plan for nuclear power generation has been revised and the basic philosophy and policy have also been clarified. Special consideration is given to the development of power reactors by designating it as a "national project", and the outline of the development plan for power reactors is set forth below.

3. As for nuclear fuel, the Programme foresees that every effort will be made to secure the necessary nuclear fuel, and an appropriate nuclear fuel cycle is to be set up for the efficient use of the fuel. For this purpose, fuel reprocessing plants are to be constructed, nuclear fuel processing enterprises are to be fostered, and at the same time development of plutonium fuel as well as research on uranium enrichment are to be promoted.

4. In the second place, the Programme takes into account the prospects for the development of nuclear-powered ships. On the basis of the Programme, the construction of the first nuclear-powered ship will be promoted, and research and development of marine propulsion reactors will also be accelerated.

5. In the third place, the utilization of radiation is considered. The practical applications of radiation in medical, agricultural and industrial fields are to be substantially expanded, and particular attention is paid to the promotion of research and development in radiation chemistry and food irradiation.

6. In addition, the Programme refers to nuclear fusion. In view of the need for an overall research and development programme on nuclear fusion, the necessary steps will be started in 1969 to make further progress in this field.

7. As for safety measures, more concrete and reasonable safety standards will be developed, based on the studies of practical applications, to cope with the expanding utilization of atomic energy in new fields. Because of the special dietary habits of the Japanese people, which make them highly dependent on marine products, attention is paid to radioactive waste disposal into the sea, and an overall survey of research on radioactive contamination of the ocean will be promoted. Also, particular interest in the international control of radioactive waste disposal into the sea is expressed.

8. Moreover, the importance of basic studies in the research on, and development of, nuclear energy, including the development of power reactors, is pointed out.

9. In order to provide more trained scientists and engineers, a great effort must be made to expand education in the field of atomic energy in colleges and universities. At present, the number of the scientists and engineers working in this field is estimated to be approximately 10 000, and another 19 000 will be required in ten years' time.

10. And lastly, as to the exchange of information on atomic energy, furtherance of international co-operation is expected along with expansion of information activities.

B. Outline of nuclear power development

11. In relation to the Long-Range Programme mentioned above, a description is given below of the progress that has been made in the development and utilization of atomic energy during the preceding year.

I. Nuclear power generation

12. With the rapid progress in the technology of nuclear power generating plants, which has made them more economic, much interest has been shown in nuclear power generation since it is considered to be the most promising energy source for the future.

13. Two power reactors are now in operation in this country, i.e. the power demonstration reactor, a light-water-cooled, boiling-water reactor of 12 500 kW(e), and the improved Calder Hall-type reactor of 166 000 kW(e). In 1966 the construction of three more light-water-cooled reactors was undertaken by private electric companies. These reactors are expected to be in operation by 1969 or 1970. The total capacity of the nuclear power plants in Japan will be around 1 300 000 kW(e) by 1970.

14. With regard to the three light-water-cooled nuclear power plants under construction, the first is the 322 000-kW(e) boiling-water reactor which

is under construction in the city of Tsuruga, located in the central part of Japan and on the shore of the Sea of Japan. The second is the 340 000 kW(e) pressurized-water reactor which is being built in Mihama, adjoining the above-mentioned city; and the last is the 400 000-kW(e) boiling-water reactor which is under construction on the Pacific coast of the Fukushima Prefecture.

15. In addition to the plants mentioned above, the construction of more nuclear power plants is now being planned. Including them, a total of 12 nuclear power plants will be in operation by 1975. According to the Long-Range Programme the estimated nuclear power generation capacity will possibly reach 30 or 40 million kW by 1985, and it is most likely that the total capacity will reach some 6 million kWe or more in 1975.

16. In promoting the development of nuclear power generation, the policy is to encourage as much as possible the domestic manufacture of nuclear power plants. As for the three light-water-cooled reactors mentioned above, major components are being manufactured in Japan.

II. Development of power reactors

17. Besides the power reactors, there are now in the country ten research reactors and seven critical assemblies. In addition, a high-flux test reactor with a thermal output of 50 000 kW is being built at Oaraimachi, Ibaraki Prefecture. These facilities will contribute to the accumulation of the necessary experience for nuclear reactor construction. Considerable achievements have been made in basic studies, engineering tests of materials, isotope production, training of scientists and engineers, etc.

18. The development of power reactors, which is designated as a "national project", aims at the development of a fast breeder reactor and an advanced converter reactor independently, taking into account the accumulated technological experience and based on the results of international co-operation.

19. The development of these power reactors is a large-scale project, which requires a long time, tremendous expenditure and a great deal of manpower. The implementation of the programme demands the maximum co-operation between governmental, academic and industrial circles. In order to meet these requirements the Government has decided to set up the Power Reactor and Nuclear Fuel Development Corporation, with which the Atomic Fuel Corporation was merged. This new body is expected to start work in October 1967.

20. The development programme of power reactors covers, first of all, the development of fast breeder reactors, which are to be put to practical use in the middle of the 1980's. The type to be developed is a sodium-cooled reactor, the fuel of which is a mixture of uranium and plutonium oxides. This type is taken as the most promising one at the present time in the light of the world trend of development. According to the development schedule, the construction of an experimental reactor with an output of 100 000 kW thermal capacity will be started by the end of the 1960's, and the construction of the prototype reactor with an output of 200 000 to 300 000 kW electrical capacity will be undertaken in the mid-1970's.

21. The aim in the development of the advanced converter reactor is to make the reactors available for commercial purposes by the first half of the 1970's, and the construction of the prototype reactor with an output of 200 000 kW of electrical capacity will be started by the end of the 1960's. The reactor to be developed will be the heavy-water-moderated, light-water-cooled, boiling water type. This type was selected because it will meet the present requirements of the country, and also because it does not take long to put into practical use. It will be initially loaded with low-enriched uranium or natural uranium together with plutonium, and at a later stage will be operated solely with natural uranium. Even after the fast breeder reactors have come into practical use the advanced converter reactor will perhaps play a part for a very long time by supplying the fast breeder reactors with the plutonium fuel necessary for their initial loadings.

22. The recent progress in the development of power reactors is as follows. With regard to research and development relating to the fast breeder reactor, the fast breeder reactor critical assembly which had been under construction at Tokai, Ibaraki Prefecture, since 1963 was completed in April 1967, facilitating the conduct of a variety of experiments on the fast breeder reactor. Besides this, research and development relating to sodium technology and plutonium fuel design and studies have been carried out in recent years. As to the advanced converter reactor, the development and co-ordination of various computer programmes for the heavy-water-moderated, light-water-cooled, boiling-water reactor are in progress, and in the meantime the conceptual design and studies of the prototype reactor are under way.

III. Nuclear fuel

23. In view of the fact that nuclear power generation is being undertaken by private electric companies, and that light-water-cooled reactors with enriched uranium are playing a major role at present, the Atomic Energy Commission, taking into consideration the legislation for private ownership of special nuclear material and the toll-enrichment system in the United States of America has

decided on a policy of private ownership of special nuclear material, such as enriched uranium and plutonium, which has hitherto been owned by the Government. The necessary measures for implementing the policy are now under consideration by the Government.

24. The Ministry of International Trade and Industry and the former Atomic Fuel Corporation have carried out exploration for uranium ore. It has been confirmed that, as on 1 April 1967, the deposits of uranium are 7 600 200 tons (3634 tons of U_3O_8).

25. As a first step towards establishing a nuclear fuel cycle appropriate for the country, the Government plans to take measures to foster nuclear fuel fabricating enterprises on a reasonable scale. Meanwhile, private industrial circles are also making preparations to cope with the future development of nuclear power generation. Five enterprises have already applied to the Government for permission to undertake nuclear fuels fabrication.

26. The Government further plans to conduct research and development on plutonium as fuel for fast breeder reactors. To ensure the efficient use of nuclear fuel, the Government intends to promote research and development work on plutonium, because, until fast breeder reactors can be brought into practical use, plutonium will be needed for the initial fuel charges of thermal power reactors. As facilities for plutonium development, the small-scale facilities at the Japan Atomic Energy Institute and the new plutonium laboratory of the Atomic Fuel Corporation can be used. In 1966 studies on nuclear fuels—plutonium-uranium oxide mixtures—for fast breeder reactors were also started.

27. For the development of thermal reactors, it has been decided to start construction next year of laboratories for handling alpha-and gamma-radiation. A plan to complete by 1971 a reprocessing plant, capable of reprocessing 0.7 ton/day of irradiated fuel, is also under way, and it is now being designed in detail by the Atomic Fuel Corporation. Construction of the plant is scheduled for 1970. Intensive studies and experiments are now being conducted on reprocessing methods for use in the planned reprocessing plant.

IV. Nuclear-powered ship

28. In 1963, the Government decided to construct the first nuclear ship. The Japan Nuclear-Powered Ship Development Agency, which is responsible for bringing the programme for the first nuclear ship into effect, promoted research and development relating to the construction ot the ship by domestic ship-builders. The Atomic Energy Commission revised the original programme in March 1967. According to the programme the first nuclear ship will be completed by 1971. The new ship is now being designed. The actual construction will be started after review of the design by the Safety Committee of the Commission.

29. The Commission reviewed the outlook for the utilization of nu lear-powered ships in its Long-Range Programme mentioned above. The Commission expects that in ten years' time, 30-knot nuclear-powered "container" ships and 500 000-ton nuclear-powered tankers will be competitive with conventional ships, and the Commission is accordingly promoting the development of an improved marine propulsion reactor.

V. Radiation utilization

30. Since the early stage of atomic energy utilization in Japan, radiation has been widely used in various fields, ranging from basic science to medicine, agriculture and different branches of industry. The number of firms utilizing radioisotopes and particle accelerators was 1425 at the end of March 1967; many of these forms are provided with radiation generators, such as particle accelerators, of which the total number available is 178.

31. Recent developments in the utilization of radiation are set out below:
(a) Domestic production of short-lived nuclides and labelled compounds is under way, and procedures for radioisotope utilization in various fields have been developed and put to practical use;
(b) Radiation detectors have been improved, which has made precision detection possible, and thus extremely small amounts of radiation including low-energy radiation, can now be widely utilized; and
(c) Domestic manufacture of high-energy radiation generators such as particle accelerators and neutron generators has made steady progress, so that techniques for irradiation with large doses and for activation analysis are being established.

With the introduction of these new techniques, radiation is expected to be used more widely in future.

32. Research and study relating to radiochemistry are conducted mainly by the Takasaki Laboratory of the Japan Atomic Research Institute in co-operation with industrial and academic circles in the country. Research on food irradiation will be carried out as a special integrated programme at the Government's expense.

F. NEW ZEALAND

Atomic Energy in New Zealand

The proposed establishment by about 1977 of the first New Zealand nuclear power station (of some 1000 megawatts capacity) has dominated recent New Zealand activities in the field of atomic energy. In this connection, New Zealand is indebted to the International Atomic Energy Agency and to many of its Members for valuable assistance and co-operation in planning nuclear power development in this country.

Particular reference must be made to the visit of an Agency Mission in July 1967. The Mission's primary task was to assist the New Zealand authorities in the study of siting and safety requirements relating to the proposed nuclear power station. Data and reports prepared by the New Zealand authorities formed the basis for the Mission's survey of possible sites and for consultations with the New Zealand co-oordination body, the Atomic Energy Committee, and with interested Government departments and other organizations involved in nuclear development. Suggestions and recommendations made by the Mission highlighted matters requiring further study or reappraisal by the New Zealand authorities and have provided impetus for further investigation and planning.

At the present time, co-ordination in the field of nuclear power development in New Zealand is provided by the Atomic Energy Committee. Established in 1958 when it was responsible to the Council of Scientific and Industrial Research, this body was reconstituted in late 1966. It is now directly responsible to the Minister of Science and works in close collaboration with Government departments and organizations concerned with nuclear power development. The Committee is concerned with all aspects of research, development and application of nuclear science in New Zealand.

Planning for a nuclear power station, combined with the increasing application of nuclear science in New Zealand, requires a review of existing legislative and administrative arrangements. Accordingly, a study is currently being undertaken with a view to setting up a new central authority or commission with powers and functions directed towards New Zealand's needs in the atomic energy field, especially the licensing and inspection of reactors.

Apart from current investigations into siting and safety requirements relating to the proposed nuclear power station, now being considered by a sub-committee of the Atomic Energy Committee, a review of manpower requirements, particularly power, service and research personnel, is currently being undertaken and should be completed by early 1968. In the meantime, a limited number of personnel are already undergoing specialist training overseas.

Studies have also been made concerning the acquisition of a research reactor. This facility would be an important ancillary to the nuclear power programme, and form part of the training and support services available in the country. The Institute of Nuclear Science, which is operated by the Department of Scientific and Industrial Research, is a major focal point for nuclear research and is considered the logical place to install a research and service reactor which, along with the Institute's present facilities, would be available to Universities, to other research organizations, and to industry. At present the Institute's major facility is a three million-volt Van de Graaff proton-electron accelerator. The Institute carries out valuable work in the field of isotope geo-chemistry — stable isotope variations in the elements oxygen (the "O^{18} to O^{16}" ratio), hydrogen (the "deuterium-hydrogen" ratio), carbon (the "C^{13} to C^{12}" ratio) and sulphur (the "S^{34} to S^{32}" ratio). The work of the Institute in the field of radioactive dating, using carbon-14 variations, tritium and potassium-argon methods, has aroused interest both in New Zealand and abroad and many samples from overseas have been sent to New Zealand for analysis. The Institute's 500-curie cobalt-60 source has been of considerable value to primary and secondary industry.

In addition to research outlined above, the Institute has developed for the New Zealand power authorities a gamma unit to enable radiographs to be taken of the jointing of high-voltage D.C. cables. A special instrument for the measurement of the densities of wood specimens has been developed for the forestry authorities and other similar instruments have also been constructed.

Studies in theoretical nuclear physics are mainly concentrated at the University of Auckland. The recent development there of a polarized-ion source has aroused wide interest overseas. The Auckland University and some of the other universities in New Zealand provide training in nuclear physics, radiochemistry and radiation chemistry. Programmes of research are carried out, often in collaboration with the Institute of Nuclear Science (which has special facilities for University staff) or with other organizations.

Some fifty laboratories throughout New Zealand are using radioisotopes in varying degrees as a tool for research, mostly in agriculture and biology. A limited number of commercial firms are using small radioactive sources as production aids. One firm recently put into operation a 150 000-curie cobalt-60 plant, primarily for the sterilization of medical supplies.

In medical diagnosis and therapy New Zealand is well advanced and the New Zealand authorities understand that for several years the country has had the highest density, in relation to population, of therapeutic nuclear medical facilities in the world.

In 1966 the Auckland Hospital Board entered into a contract with the Agency to carry out investigations in Nepal relating to endemic goitre. This work was featured in the *IAEA Bulletin* of June 1967[4].

Recently, the New Zealand Ministry of Works, Water and Soil Division, entered into a contract with the Agency to undertake a technical study, on a field trial, of radioisotope sediment probes. New Zealand is pleased to be able to co-operate with the Agency in such undertakings and to assist it in the development of research and investigations in other countries.

At its present early stage of development in the field of nuclear power, New Zealand is largely dependent on outside advice and greatly values the assistance and co-operation it receives from the Agency and its Members. Its geographical remoteness means that unfortunately it is not always possible for New Zealand to send representatives to all the various technical and scientific meetings convened by the Agency in which it would like to participate. As New Zealand's experience broadens in the coming years, it is hoped that its present reliance on outside advice and assistance will diminish and that New Zealand will be able to contribute increasingly to the pool of knowledge on the peaceful uses of atomic energy which is so important to the progress of man's social and economic development.

4) Vol. 9, No. 3, "Himalayan Expedition to study Goitre".

G. PHILIPPINES

Progress in the Peaceful Applications of Atomic Energy in the Philippines since the 1966 IAEA General Conference

A. United Nations Special Fund Pre-Investment Study on Power, including Nuclear Power in Luzon

This two-year project, undertaken with assistance from the United Nations Development Programme (UNDP) and implemented by the Agency was formally completed. UNDP allocated $477 500 for the project and the Philippine Government contributed $39 000 towards local operating costs of foreign project personnel plus $223 000 in counterpart funds.

The main purpose of the study was to develop an optimum expansion programme for the Luzon Crid for the period 1965-75.

It showed that the Luzon Crid would require an additional 1 000 MW(e) steam plant capacity in the period 1971-73 alone. Although the nuclear alternative consisting of two 300 MW(e) plants and one 400 MW(e) plant it would require an initial investment of about $35 million more than the conventional alternative of four 250-MW(e) oil-fired plants, the extra investment in nuclear power stations would be fully recovered by 1979 as a result of annual fuel cost savings. Afterwards, the nuclear plants could result in net operating cost savings of about $14 million per year. One of the recommendations in the report was that the Philippines should give serious consideration to the use of nuclear plants by the early 1970's.

The Manila Electric Company (MERALCO), the private utility company supplying electricity in and about the Manila metropolitan area, taking these findings into account, has invited international tenders for nuclear and conventional plants in the 300-500 MW(e) range.

The Philippine Atomic Energy Commission (PAEC) has taken appropriate measures to encourage the introduction of nuclear power in the country. The Draft atomic energy legislation is to be considered by the lower house of Congress at its regular session in January 1968. The Senate having passed the bill during its last session. Furthermore, preliminary studies have been started on licensing and regulatory procedures.

The PAEC will soon conduct a local reactor technology course at the request of MERALCO, which has decided to train some of its engineering staff in reactor engineering work in anticipation of the possible construction and operation of its first nuclear power plant.

B. IAEA Study Group Meeting on Problems and Prospects of Nuclear Power Applications in Developing Countries

This Study Group Meeting was organized by the Agency and was held in Manila from 27 October to 2 November 1966 primarily for countries in Asia and the Far East.

Fifty participants attended, including the Agency's Director General, the chairman of the Pakistan Atomic Energy Commission, the Commissioner of the PAEC and the Chairman of the New Zealand Atomic Energy Commission. The 12 countries represented were Australia, Canada, China, France, Indonesia, Japan, New Zealand, Pakistan, the Philippines, Thailand, the United Kingdom and the United States. Officials from the Agency and the United Nations Economic Commission for Asia and the Far East were also present.

Discussions indicated that nuclear power was very likely to progress rapidly in the region and that several countries were making plans for its early introduction. The pre-investment study completed by the Agency provided an excellent subject for discussion.

C. FAO/IAEA Inter-Regional Training Course on the Use of Radioisotopes in Soil and Plant Investigations

Conducted in the Greater Manila area from 30 October to 23 November 1966, this course drew 19 trainees from nine Asian countries, namely: Cambodia, China, India, Israel, Pakistan, the Philippines, Syria, Thailand and the United Arab Republic. The course director (the Director of the PAEC's Nuclear Training Institute) and the technical adviser were assisted by five visiting professors and a group of local lectures.

D. IAEA Regional Training Course on Planning for the Handling of Radiation Accidents

This short training course in scheduled to be held within the Greater Manila area, from 2 to 13 October 1967. The purpose of the course is to provide training for those persons who are responsible for organizing and executing emergency measures in the event of a radiation accident.

E. India-Philippines-Agency (IPA) Neutron Crystal Spectrometry Programme

Established at the Philippine Atomic Research Center (PARC), this co-operative venture aims to train scientists and technicians from any Member State of the Agency in Asia and the Far East in the construction, installation and use of a crystal spectrometer provided by India. A second spectrometer was designed and fabricated at the PARC under the project.

The IPA research and training programme, now in its third year of operation, was awarded a research contract by the Agency on the study of the static and dynamic structure of solids by neutron spectrometry. Four IPA participants from China, the Republic of Korea, the Philippines and Thailand completed their training. This brings the total of foreign participants trained to five. During the year, the fourth Indian scientist to serve as expert for the project arrived to assume his duties. The Project Director was invited by the Agency to make a four-month scientific visit to the Bhabha Atomic Research Centre in Trombay. He was followed by another Philippines participant who was sent under an Agency fellowship grant for further training in neutron spectrometry, also in Trombay. The fourth meeting of the Joint Committee for the IPA project was held in Quezon City, Philippines, on 13-14 March 1967.

F. Agency research contracts

Research contracts constitute an important source of funds to supplement meager local appropriations. Administered on a lump-sum, cost-sharing basis, they also represent a research partnership, so to speak, between the Agency and well-established research institutions in the country.

Grants received during the year totalled $23400, broken down into the following four separate research contracts:

1. **Study of sorptive characteristics of local tuffs and soils for waste disposal or treatment (Research Contract No. 428-B).**

This study is aimed at the possible use of natural sorbents — such as tuff materials for the decontamination and volume reduction of radioactive liquid wastes accumulating from the reactor and research laboratories. The research grant was awarded to the Health Physics Department of the PARC, with the Agency contributing $5300. The renewal of this research contract is now under consideration.

2. **Study of the static and dynamic structure of solids by neutron spectrometry (Research Contract No.450/RB).**

This contract was awarded to the Physics Department of the PARC, in support of the IPA programme. The project which will continue, started to receive Agency support, amounting to $8000, some time in July 1966. The purpose is to study the structure of condensed states of matter through the application of neutron diffraction techniques.

3. **Effects of ionizing radiations on mango, banana and chico fruits (Research Contract No.440/RI/RB).**

This contract which was awarded to the Philippine Women's University with an initial allocation of $4900 from the Agency, is part of a co-ordinated programme on the aspects of tissue physiology in food preservation. The project is specifically intended to study:

(a) The effect of gamma radiation on the shelf-life of mango, banana and chico;
(b) The effect of irradiation on the chemical and nutritive value of the irradiated fruits; and
(c) The radiosensitivity of the bacteria and fungi that cause decay or spoilage of fruits.

The preliminary results are promising.

4. **Studies on the effect of neutron irradiation on seeds (Research Contract No.460/RB).**

Part of a co-ordinated programme of research on the use of neutrons in seed irradiation, this contract was awarded to the Department of Botany, University of the Philippines' College of Arts and Sciences. The Agency allocated an initial grant of $5200 for the project.

Apart from the four new research contracts awarded, five old contracts were renewed, representing an additional contribution by the Agency of $9650. All in all, the Agency contributed $37850 for research contracts. The renewed research contracts are set out below.

1. **Studies on the nutrition of coconut palm (Research Contract No.293/RB).**

Originally started on 1 November 1964, this contract was renewed for the second time, with the Agency providing $2400. Previously the Agency contributed $2530 worth of technical assistance in the first year, and $2400 in the second year (first extension). The project, which is being undertaken by the Agricultural Sciences Department of the PARC, is expected to be finished by November 1967. The purpose of the project is to determine the best method of fertilizer placement in the culture of coconut with the use of superphosphate labelled with phosphorus-32.

2. **Radioisotope studies in schistosomiasis (Research Contract No.324/RB).**

The Bio-Medical Department of the PARC is undertaking this study, which was extended for a year with an Agency grant of $1600. It was started on 15 June 1965, with the Agency providing $1500 for personnel and expendable supplies. The year's extension ended in June 1967. The purpose of the project was to label the flukes of the Schistosoma japonicum and follow its distribution in the body of the infected host for the purpose of studying the pathogenesis of schistosomiasis. Partial immunication in mice and monkeys against schistosomiasis has been achieved.

3. Co-ordinated programme on the application of isotopes and radiation to rice fertilization (Research Contract No.149/RI/R4/0B).

This contract was originally awarded to the Soils Department, College of Agriculture, University of the Philippines (UP) in Los Baños, Laguna, on 15 June 1962. Completed on 28 February 1967, it received Agency support for five years: 1962 — $5000; 1963 — $3900; 1964 — $3100; 1965 — $3650; and 1966 — $2150. Its purpose was to study the supply and movement of nutrients in rice soils.

4. Co-ordinated programme on the use of induced mutations in rice breeding (Research Contract No.283/RO).

This contract was renewed for the second time, with an additional grant of $3500 from the Agency to the Agricultural Sciences Department of the PARC. Working on the project since 1 November 1964 are scientists from the Bureau of Plant Industry and the UP College of Arts and Sciences. Preliminary results are promising; certain rice mutants have been produced which mature much earlier than the regular varieties.

G. Technical assistance

The Agency continued to be the main source of technical assistance in atomic energy in the form of experts, equipment and fellowhips. During the year under review the Agency provided four experts under its Regular Programme and Expanded Programme of Technical Assistance, representing 32 man-months of nuclear expertise, various items of equipment worth $50 500, granted in respect of four projects, and ten new fellowships under the 1967 Regular Programme, UNDP/SF and the programme covering scientific visit.

H. Fabrication of fuel elements for the Philippine research reactor (PRR-1).

The replacement fuel elements have been fabricated from enriched uranium supplied through the Agency under the United States Government programme of assistance for the continued operation of the PRR-1. Delivery of the first batch of ten fuel elements was made by the fabricator in the United States last month. The second batch of ten more elements is expected to be shipped soon. The first refueling operation for the PRR-1 will be carried out late this year.

H. SOUTH AFRICA

Nuclear Research in South Africa

Summary

The Republic of South Africa has large reserves of uranium and is the third largest producer in the western world. Several new processes of uranium extraction and purification have been developed, and work in this direction is continuing. A process for producing uranium hexafluoride using oxygen instead of fluorine as the oxidizing agent is in the pilot plant stage. This process is of interest for toll-enrichment purposes. An expanded and accelerated fuel development programme is at present being launched.

Most of South Africa's applied nuclear research programme, covering raw materials, nuclear power and radioisotopes, is carried out at the National Nuclear Research Centre, Pelindaba. The main facilities at Pelindaba are an Oak-Ridge-type research reactor, now being converted to 20 megawatts thermal power, and a 3-MeV Van de Graaff accelerator.

With a view to the introduction of nuclear power into South Africa, its economic implications are being studied and existing reactor types evaluated.

Imports of radioactive isotopes into South Africa have risen from 20 curies in 1957 to 756 curies in 1966, and these are used for industrial, medical, agricultural and research applications. With the cyclotron of the Council for Scientific and Industrial Research and the Atomic Energy Board's reactor it is possible to manufacture any radioactive nuclide in South Africa. Research into new radioisotope applications is carried out, and several new techniques have been developed. The use of radioisotopes for medical research is well established in South Africa.

The Republic of South Africa is the third largest producer of uranium in the western world and, although production has been curtailed in recent years, her annual production capacity is in excess of 6000 tons of uranium oxide. Reasonably assured reserves of uranium oxide recoverable at below $10 per lb U_3O_8 are estimated at 250 000 short tons. Reserves recoverable at below $15 and $20 are estimated at 270 000 and 325 000 short tons U_3O_8, respectively. Since uranium is mined in South Africa as a by-product of gold, the exploitation of these reserves is, of course, dependent on the price of gold.

In addition, rich deposits of other raw materials of importance in nuclear technology, such as thorium, beryllium, lithium, tantalum, niobium, vanadium and chromium, exist and many have been mined in quantity for years.

The need to extract uranium present in low concentrations in gold-mine slurries led to the development in South Africa of the large-scale ion-exchange process for uranium extraction. Subsequently, the Atomic Energy Board and the mining industry jointly developed the "Bufflex" process in which ion exchange is followed by solvent extraction. Not only is the product sufficiently pure to approach nuclear grade specifications, but production costs are also lower than those of the present crude 90% product. The first production unit based on the "Bufflex" process has recently been commissioned at a uranium-producing mine.

Another investigation, known as the "Purlex" project, is now in the pilot plant stage. This is an extension of the "Bufflex" process and entails the elimination of the ion-exchange step. Although still in the early stages, research on the combined leaching of gold and uranium promises the possibility of extracting uranium in much lower concentrations than at present feasible.

Early work on the refining of uranium was concentrated on the production of the metal. A pilot plant for this purpose was designed and commissioned in only eighteen months, and was based on new processes specially developed to suit South African requirements. This plant, with a nominal capacity of 100 tons per annum of nuclear-grade metal or its equivalent in compounds, has been operating for some time on a regular basis, producing high-purity uranium and uranium compounds for research purposes. The metal is fabricated with a high degree of accuracy into a variety of finished forms such as spheres, cylinders and rods for use as fuel elements. The production of uranium-dioxide pellets is also being actively investigated and a fully integrated pilot plant has been commissioned. Other developments in the field of ceramic fuels include a process for producing uranium carbide of closely controlled stoichiometry direct from U_3O_8.

A project showing considerable promise is the development of the "Fluorox" process for the manufacture of uranium hexafluoride, which is of interest for toll-enrichment purposes. In this, oxygen is used as the oxidizing agent instead of fluorine, and indications are that the process will prove to be successful and economical on a large scale.

The extraction and refining activities are, of course, backed up by a continuous programme of systematically planned exploration for new deposits of nuclear raw materials.

Raw materials, however, represent only one aspect of the comprehensive research and development programme of the South African Atomic Energy Board. Most of the work on nuclear power and radioisotopes, together with some fundamental research, is carried out at the National Nuclear Research Centre at Pelindaba, near Pretoria. The main facility at Pelindaba is the research reactor SAFARI 1. Basically of the Oak Ridge type, this reactor incorporates experimental facilities and safety features introduced by South African engineers, making it more advanced than reactors of the same type elsewhere in the world. SAFARI 1 is at present operating at a thermal power of 6 2/3 megawatts, but minor additions to auxiliary plant are now being made to increase the power level to 20 megawatts. The maximum thermal neutron flux will then be 4×10^{14} neutrons per cm^2 per sec , and at this flux the reactor will be the most powerful research reactor on the African continent and in the southern hemisphere.

The work on nuclear power involves the study of economics, the evaluation of existing reactor types and the development of a power reactor suited to South Africa's requirements. A promising power reactor concept of a unique and advanced thermal converter type, called PELINDUNA, has been under active development for some five years. PELINDUNA is based on natural uranium as fuel, heavy water as moderator and liquid sodium as coolant. It incorporates several novel features, some of which have already been patented. The reactor physics of the design has been studied with the aid of an exponential assembly, fuelled with locally manufactured natural-uranium fuel rods. A critical facility, PELINDUNA-ZERO, has been designed and constructed by the Board's staff.

Progress in the development of PELINDUNA recently reached the stage where it became possible to evaluate its potentialities under South African conditions reliably. The most important advantage of PELINDUNA is the high specific power, in excess of 40 watts/g, that may be achieved. However, the smallest effective reactor fuelled with natural uranium which could fully utilize this high specific power potential is about 1000 MW(e).

Since it is unlikely that so large a power generating unit could be introduced into the South African system within the next 15 years, it has been decided to shelve the further intensive development of the PELINDUNA system. Work will, however, continue on certain facets of sodium technology, since this is basic to the successful development of fast breeders in the future.

The decision to shelve the development of PELINDUNA was greatly influenced by recognition of recent world-wide developments. The impending shortage of reasonably cheap uranium in the not too distant future, coupled with an expanding and competitive uranium market, dictated that it would be in the Republic's best interests to channel available research effort into a greatly expanded and accelerated fuel development programme.

Although South Africa has abundant supplies of cheap coal, the coalfields are situated inland at long distances from the coast. It is therefore very likely that coastal nuclear power stations will be able to generate power at economical cost within the next ten years. This possibility is further strengthened by the fact that water resources on the coalfields are limited, whereas coastal nuclear stations could use sea-water for cooling purposes. A special committee, comprising representatives from the Atomic Energy Board, the Electricity Supply Commission, the mining industry and the government departments concerned, is at present investigating the economic aspects of introducing nuclear power into South Africa.

Research in nuclear physics in South Africa has a relatively long history, the initiative having come from the Council for Scientific and Industrial Research and the universities. The former has for some years had a fixed-frequency cyclotron yielding 8-MeV protons, 16-MeV deuterons and 32-MeV alpha particles. This cyclotron was designed by the Council and built almost entirely in South Africa. It is used for studies in low-energy nuclear physics and also for the production of proton-rich carrier-free radioisotopes. These isotopes are exported to customers in several large developed countries overseas.

Research by the universities is in the vast field of nuclear structure and behaviour. Accelerators for carrying out this work are installed at the universities of Potchefstroom, Witwatersrand and Pretoria, and at the Southern Universities Nuclear Institute — operated jointly by Cape Town and Stellenbosch Universities. Pretoria University is also constructing a sub-critical assembly.

The research reactor at Pelindaba, although intended primarily for materials testing, is an important addition to South Africa's physics research facilities. Also at Pelindaba is a 3-MeV Van de Graaff accelerator which gives a pulsed beam of high intensity. Originally, this machine could produce a beam of particles pulsed at a fixed frequency of one megacycle, the duration of each pulse being ten nanoseconds. A new terminal, designed and built at Pelindaba, gives a frequency variable up to six megacycles, and shortens the pulse to 2.5 nanoseconds. Another terminal, which will reduce the pulse length to one nanosecond, is under construction. Instrumentation developed and built by the Atomic Energy Board to work in conjunction with the accelerator is among the most advanced of its type in the world.

Clear evidence of the growing utilization of radioisotopes in South Africa is the rise in isotope imports from about 20 curies in 1957 to 756 curies in 1966. These isotopes were imported on behalf of approximately 100 medical and 200 non-medical users. During the 10-year period, a total of some 2500 curies has been imported into South Africa for industrial, medical, agricultural and general research applications. Moreover, these figures do not include imports of multi-curie cobalt-60 sources, which in 1966 alone totalled 6000 curies.

Apart from importation, the production of neutron-rich radioisotopes in the Board's research reactor is now an established activity, and this, in conjunction with the production of the cyclotron of the Council for Scientific and Industrial Research, makes it possible to manufacture any radionuclide in South Africa.

Backing up the campaign to encourage the use of radioisotopes are investigations into new applications by the Atomic Energy Board and the Council for Scientific and Industrial Research on behalf of outside organizations. Examples of successful and original developments are an instrument for the instantaneous determination of silver as an impurity in gold and an instrument which measures the density and moisture content of soil. The latter instrument, called the Hydrodensimeter, is being manufactured locally and exported to a number of overseas markets.

Using a 500-curie cobalt-60 source, the possible production of useful mutations, the effects of irradiation on the storage qualities of produce, and biochemical studies of the ripening of fruit, are amongst the many investigations undertaken by the Department of Agricultural Technical Services.

Isotope-based medical research in South Africa covers a very wide field, and the diagnostic and therapeutic uses of radioisotopes are well established. Four hospitals and one private practice are each equipped with a cobalt teletherapy unit used for the treatment of cancer and allied conditions, while five hospitals have up-to-date diagnostic apparatus equal to the best in the world. Two whole-body counters are in use at the Pretoria General Hospital and the South African Institute for Medical Research, Johannesburg, respectively. Clinical research projects of vital importance to the developing peoples of Africa include studies on protein malnutrition, kwashiorkor, marasmus, anaemia in pregnancy, and disturbances in calcium and iron metabolism.

A safe and accurate method, the "Pretoria Technique", has been developed for placenta localization. Short-lived radioactive tracers are used, and the radiation dose to the mother and unborn child is several hundred times smaller that that administered by means of X-ray techniques.

Working at the Onderstepoort Veterinary Research Institute, the Atomic Energy Board is investigating the properties of lymphocytes and their effect on the rejection of transplanted organs. Twin calves are used for these studies, and a special technique for the extra-corporeal irradiation of blood was developed in conjunction with the Brookhaven National Laboratory of the United States of America.

In short, South Africa's activities in the field of nuclear energy are specifically related to her needs, thus ensuring constant interest and enthusiasm. Much of the work of the African continent and the results are freely available to any interested States whether or not they are Members of the Agency.

South African Nuclear Research: Facts and Figures

Universities undertaking nuclear research:

- University of Cape Town
- University of Natal
- University of the Orange Free State
- Southern Universities Nuclear Institute
- University of Potchefstroom
- University of Pretoria
- University of Stellenbosch
- University of the Witwatersrand

Capital cost of National Nuclear Research Centre, Pelindaba:

R10 630 000 (Approx. $15 000 000)

Main facilities of the Atomic Energy Board:

- 20-MW ORR-type research reactor
- 3-MeV particle accelerator
- Sub-critical assembly
- Critical assembly (under construction)
- 400-curie cobalt-60 irradiation facility
- Gamma spectrometer
- Mass spectrometers
- Electron-probe microanalyser
- Electron microscopes
- Comprehensive plant for treatment and disposal of active waste
- Whole-body counter

Staff employed by the Atomic Energy Board:

749 (as at 30 June, 1967)

I. SWEDEN

Recent Developments in the Swedish Nuclear Power Programme

An official committee on energy questions has recently published an analysis of the Swedish energy market and a forecast for the development until 1985. The forecast predicts that the rapid increase in energy consumption that has taken place in the period 1955-65 will continue at nearly the same rate through the 1970's and into the 1980's. The total energy input is expected to rely on different forms of energy sources as follows:

Energy source	Total energy input (million tons of oil equivalent)			
	1955	1965	1975	1985
Oil products	7.5	16.6	30.7 — 31.6	38.8 — 43.6
Coal and coke	4.0	2.1	1.8	2.1
Domestic fuels	2.5	2.7	2.8	3.1
Hydro power	2.2	4.6	5.8	6,1
Nuclear power	—	—	3.4 — 2.3	22.1 — 14.7
Total	16.2	26.0	44.5 — 44.3	72.2 — 69.6

The alternative forecasts for 1975 and 1985 differ primarily with regard to the share taken by electricity in the energy consumption. As shown in the table, the increase in energy consumption in the last decade has been met mainly by oil products and hydro power. The remaining economic hydro power resources will be exploited during the next few years and a continued increase in oil consumption is also expected for the coming decade. Since Sweden has no fossil fuel reserves this means an increased dependence on fuel import. Nuclear power will, however, make a considerable contribution already from the middle of the 1970's. The main part of the increase of the energy supply which is needed in the decade 1975-1985 to support a continued growth of Sweden's economy can be met by nuclear energy.

The forecast of the energy committee is based on the preliminary results obtained from a detailed analysis of the future expansion programme which is now being carried out by the Swedish power companies. According to these results, most of the additional power production in the 1970's and 1980's will be carried out by nuclear installations. Nuclear power production is expected to increase from 8-12 terawatt-hours (TWh) in 1975 to 60-90 TWh. in 1985. This corresponds to a total nuclear capacity of 10 000-15 000 MW in 1985. In addition, combined production of heat and electricity, based on nuclear power, may be carried out in some of the major cities.

The growing rôle played by nuclear power can diminish Sweden's dependence on fuel imports, and will strengthen the security of the energy supply and also ease the load that fuel imports place on the balance of payments. In addition, if nuclear energy were not available the increased energy demand would have to be met by fossil fuels, resulting in serious air pollution problems.

The Swedish nuclear energy programme has prepared the large-scale introduction of nuclear power. The first step in the development of commercial reactors was taken with the building of the nuclear power plant at Agesta with a pressurized heavy water reactor. First criticality was achieved in 1963 and the reactor is working excellently with a very high degree of availability. The work on the Marviken power station is proceeding according to plan. and the station is expected to be connected to the grid in 1969. It comprises a boiling heavy water reactor of 140 MW(e) which later can be increased to 200 MW(e) by internal super-heat. Swedish industry is building the first commercial nuclear power station for a group of private utilities at Oskarshamm. It has a boiling light water reactor of 400 MW(e) and is expected to be put into operation in 1970.

The Swedish State Power Board is planning a large power station at Ringhals on the West coast of Sweden. The first unit of 500-750 MW(e) is planned for operation in 1973, and the station will eventually comprise four units with a total capacity of some 3000 MWe. Also the private utilities are planning a further installation before 1975, and in the latter half of the 1970's at least one big unit will be added to the Swedish power grid every year.

Swedish industry is now capable of building water reactors of either the heavy water or the light water type and making fuel for them. Continued development work to improve and consolidate the technology of thermal reactors and of their fuel cycle is necessary, since they will dominate nuclear power expansion for at least another two decades. Sweden is, however, already starting work on fast reactor systems and is investigating the possibilities of establishing co-operation with other countries in this field. A zero-power fast reactor has been operating at Studsvik since 1964.

At Billingen Sweden has one of the largest deposits of uranium ore in the world. although of a low grade. Since 1965 the Ranstad uranium mill has been in test operation and the results are satisfactory and confirm the projected data. New extraction methods and other ways to improve the economy of production are now being studied.

The Swedish nuclear programme has entered into the commercial phase. The industrial effort is supported by research and development work carried out mainly at the research station at Studsvik.

J. SWITZERLAND

Progress Report on the Application of Nuclear Energy in 1966/1967

1. Nuclear power reactors

The Swiss utilities have publicly declared that, in accordance with the recommendations of the Federal Government, they will meet their future additional needs for electricity essentially by means of nuclear power plants. Since the possibilities for building cheap hydroelectric plants have been almost fully exploited, they plan to build only a few additional installations of this type. In view of pollution and other problems they will not order any bigger conventional thermal power plants.

The construction of the first commercial nuclear power plant of 350 MW(e) with a pressurized-water reactor is progressing well and on schedule at Beznau in the northern part of Switzerland so that the start of its operation is still planned for 1969. The erection of a second such plant of 306 MW(e) with a boiling-water reactor began last April at Mühleberg near Bern, the capital of Switzerland. The establishment, jointly by foreign and Swiss utilities, of two further plants, each with a capacity of 600 MW(e), at sites on the river Rhine is under consideration. The construction of a second plant at Beznau will soon have to be decided in which use would be made of an interesting option offered by the consortium building it on the basis of a turn-key contract.

2. Development of reactors

The group of Swiss industries interested in the development of a heavy-water moderated pressure-tube reactor continued its efforts, which are co-ordinated and financed by a national company, during the period under consideration. The main project involved, the construction of an experimental nuclear power plant of 5-6 MW(e) at Lucens, has been practically completed. Criticality was achieved at the end of December 1966, and the tests which should lead stepwise to the achievement of nominal power are under way. Studies of projects for power plants with several variants of the gas-cooled heavy-water moderated reactor have been worked out in collaboration with the French Commissariat à l'Energie Atomique. Since there does not seem to be any immediate prospect of constructing a prototype power reactor based on this technology, the Swiss companies involved have decided to discontinue the work on completion of the investigations now being carried out and to concentrate in the immediate future on the development and manufacture of components for nuclear power plants.

Another Swiss company has started working on a project for a 400 MW(e) nuclear power plant with a high-temperature, gas-cooled reactor. This effort is based on the technology which is available to Switzerland due to its participation, through the Organization for Economic Co-operation and Development, in the joint enterprise "Dragon" in Winfrith (Great Britain).

Because of the new situation which has arisen due to the decisions taken by the utilities and industry, the Government is reviewing its effort in this field. In particular it has already been decided to define a new programme for the Federal Institute for Reactor Research in Würenlingen which will be oriented increasingly towards longer-range objectives. The development of fast breeders and the use of plutonium in power reactors will be the two principal aims of the future work. In view of the limited means available different possibilities of incorporating these efforts in the framework of international collaboration are under consideration.

3. The Federal Institute for Reactor Research in Würenlingen

Studies and experiments in the field of heavy-water reactors, particularly concerning the light-water steam-cooled variant, have continued at the Institute. In several loops, the problems of heat transfer for fuel elements have been studied and a model of the Lucens fuel element has been tested in an in-pile loop of the research reactor "Diorit" (30 MW[th]). The construction of a versatile zero power reactor experiment (NRE) has been almost completed. The production of radioisotopes mainly for medical uses has been greatly increased in order to satisfy the rapidly growing demand of Swiss hospitals for short-lived isotopes to be used in therapy and diagnosis. The hot laboratory with its five hot cells has undertaken work for industry and in connection with reactor developments abroad, besides being used in the Institute's own work.

4. Application of ionizing radiation

Swiss industry is increasingly using radioisotopes for a number of applications. The Swiss Association for Atomic Energy advises interested parties on the possibilities existing in this field.

With regard to the irradiation of food, a federal commission has worked out a national programme aimed at creating the basis for the subsequent, practical application of irradiation techniques for conserving and improving foodstuffs. Experiments in the irradiation treatment of tomatoes, strawberries and fruit juices have been undertaken on a small scale. Switzerland continued its participation in the International Project for the Irradiation of Fruit Juices in Seibersdorf (Austria).

5. New projects in the field of basic research

Intensive work in basic research in many fields related to atomic energy is going on at the Federal Institute of Technology and at the Swiss univiersities. One large, new project, for which Parliament voted the necessary credits of about $22 million in 1966, is especially notable. It concerns the construction of a 500-MeV proton ring accelerator with a high intensity beam. Preparatory work has started at the site, which lies on the bank of the river Aare opposite the Federal Institute for Reactor Research. The accelerator and its injector, a cyclotron, will be jointly used by the Federal Institute of Technology and the Swiss universities. It is also planned to put the facility, which will offer possibilities for a large variety of experiments, at the disposal of foreign research groups. According to the plans, the installation should be finished by about 1973.

K. UNITED KINGDOM OF GREAT BRITAIN AND NORTHERN IRELAND

Advances in Nuclear Energy — 1966/1967

The past year has seen two anniversaries in the development of nuclear energy in the United Kingdom. There was, on 17 October 1966, the tenth anniversary of the official opening of the Calder Hall, the world's first industrial nuclear power station. Three months later, on 27 January 1967, came the 21st anniversary of the founding of the Atomic Energy Research Establishment at Harwell.

The rate of progress in the nuclear field has lost none of its impetus in the last twelve months. The first British nuclear power programme, based on the Calder Hall-type Magnox reactor, is nearing completion, and when the Oldbury station comes on power later this year, nuclear stations in the United Kingdom will be able to generate some 15 % of the country's electricity requirements. The United Kingdom Atomic Energy Authority's reactors at Calder Hall itself and at Chapelcross have operated regularly at 99 % load factor in the winter months of peak demand. Progress with the second nuclear power programme based on the Advanced Gas-Cooled Reactor (A.G.R.) has included agreement for the construction of the second and third stations, Hinkley Point "B" [1300 MW(e)] and Hunterston "B" [1250 MW(e)], and the Central Electricity Generating Board has also applied to build further stations at Heysham and Hartlepool, the first being a 2400 MW station with four reactors. The continuing research and development on gas-cooled reactors is aimed at achieving both the development potential of the A.G.R. expected to be realized in the second power programme and significant further reductions in cost with more advanced designs. The first stage of the production plant for A.G.R. fuel is now under construction at the Authority's Springfields Works and extensions are being made to the Windscale reprocessing plant for the treatment of oxide fuel.

Construction of the 250 MW(e) Prototype Fast Reactor (P.F.R.) at Dounreay is proceeding according to plan. The research and development effort on fast reactors is the major item in the Authority's civil research programme, with 660 qualified scientists and engineers deployed. To meet the needs of the P.F.R. a major plutonium fuel plant is now being built at Windscale with an initial annual throughput of 30 000 fast reactor fuel pins, starting in 1969.

Important progress has been made with two other major projects. Construction of the 100 MW(e) prototype Steam Generating Heavy Water Reactor (S.G.H.W.R.) at Winfrith is almost complete, with only minor divergence from the timetable set more than three years ago. The reactor went critical on 14 September 1967 and is expected to come on full power as planned by the end of the year. The United Kingdom has made proposals which it is hoped will enable the European collaboration to continue on the high-temperature gas-cooled DRAGON reactor which was built, also at Winfrith, under the auspices of the Organisation for Economic Co-operation and Development, and has been run successfully at full power.

The production of radioisotopes in the United Kingdom for medical, scientific and industrial applications continues to expand, and more than half of the output of the Radiochemical Centre at Amersham went to countries overseas. A new cyclotron now produces the whole of the Centre's output of the important isotopes radium-22, cobalt-57, arsenic-74 and cadmium-109.

In medical applications the predominant interest is in clinical diagnostic procedures, exemplified by the use of L-selenomethionine for scanning the pancreas in humans and by the routine use of xenon-133 in saline solution for studying lung functions in patients with respiratory disorders. Some 50 hospitals in the United Kingdom are now equipped with isotope scanners.

In academic work the use of carbon-14 and tritium tracer compounds continues to expand and regulates the rate of acquisition of basic knowledge in some sectors of biology and biochemistry. An incidental point of general interest, discovered in making labelled compounds at the highest possible specific activity, is that the alga *Chlorella vulgaris* grows readily on a diet where the carbon is 90 % carbon-14 without apparent ill-effects, though the cell size is considerable enlarged.

At the Wantage Research Laboratory a second package-irradiation plant is now in operation, capable of handling a wide variety of packages, and a pilot-scale processing plant for the use of radiation for the cold curing of paint is being built. The latter will be the first of its kind in Europe, as are also the commercial prototypes of the RIPPLE isotopic generator now in operation to power navigational lights at Dungeness and in Denmark.