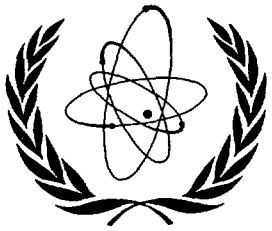

International Atomic Energy Agency

PROGRESS IN PEACEFUL APPLICATIONS OF NUCLEAR ENERGY DURING THE YEAR 1968/69

Statements by Member States

GC(XIII)/INF/113/Rev.1

Printed by the
International Atomic Energy Agency
in Austria - March 1970

PROGRESS IN PEACEFUL APPLICATIONS OF NUCLEAR ENERGY DURING THE YEAR 1968/69

Statements by Member States

This booklet contains the 14 statements on the progress made during the year 1968/69 in peaceful applications of nuclear energy which Governments of Member States had communicated to the Director General by the end of November 1969.

1. BELGIUM

Developments in the field of nuclear energy in 1968-1969

RESEARCH PROGRAMMES

1. The Belgian five-year nuclear programme covering the period 1968-1972 received official government approval in 1968. The various activities provided for in the programme were initiated as from the beginning of 1968 and on the whole are proceeding according to plan. The main subjects of interest in the programme are described below.

Fast reactors

Belgian participation in the project for a joint Federal German, Netherlands and Belgian SNR (Schneller Natriumgekühlter Reaktor) (fast sodium-cooled reactor) prototype

2. The development of the process for fabricating the pins containing UO_2-PuO_2 has proceeded successfully. Test pins have been irradiated in the BR-2 reactor (MFBS loop, FAFNIR capsules) and the DFR reactor (central hexagon, trefoils). The three pins irradiated under extremely severe conditions of linear power and sodium temperature in the MFBS 4 loop attained a burn-up of 28 000 MWd/t, as was established when they were examined.

3. The design and development of the core and blanket assemblies of the SNR prototype required numerous theoretical and experimental studies. Models, test sections and loops are under construction both at industrial undertakings and at the Nuclear Energy Research Centre (CEN).

4. A study of hot argon cleaning of the pins and sections of fuel assemblies which have been in contact with sodium was carried out in a loop installed at the Free University of Brussels.

5. New powders for the purpose of simulating the maximum accident characteristics of a large fast reactor have been developed with the collaboration of the Powder and Explosives Industry Research Centre and the Belgian High Pressure Institute. The powders have been calibrated with the help of numerous instruments, including instantaneous pressure gauges developed by the Ispra Joint Research Centre. Tests on reactor vessel models have been prepared and some of these have been carried out.

6. The in-pile instrumentation of the SNR prototype has been selected. Conventional instrumentation has been studied in detail. New instruments are under study and the results of preliminary tests have been satisfactory.

7. Problems connected with inspection and dismantling prior to the reprocessing of the irradiated assemblies of the SNR have been the subject of a detailed joint study with Luxatome and CEN.

8. A treatment and disposal unit for radioactive effluents has been designed to meet the specific needs of the SNR. A prototype will be installed at the CEN for preliminary testing.

General research and development programme

9. This programme comprises mainly work in the fields of fuel, cladding and sodium technology, the development of new irradiation devices and support activities. The main assignments undertaken by CEN and industrial concerns have been:

(a) The development of techniques for the production of cans by dispersion of a ceramic in a ferritic steel matrix;

(b) The improvement of methods of manufacturing mixed uranium and plutonium oxides;

(c) The production of stoichiometric uranium carbide stabilized by the addition of vanadium;

(d) Corrosion tests in an existing out-of-pile loop and commencement of the construction of a 3-MW loop with a sodium throughput of 100 litres/sec;

(e) The design and construction of new irradiation loops capable of reaching a level of 500 kW and permitting 19 pins to be irradiated simultaneously in the BR-2 reactor; and

(f) Reactor physics support programmes, especially the development of new codes and the making of a Belgian contribution to the international effort in the field of nuclear constants, involving in particular the measurement of total and differential cross-sections.

Dry reprocessing of fuel

10. During the past year considerable attention has been devoted to the volatilization and retention of plutonium and to the start-up of experimental installations. Studies have also been aimed at developing a continuous system permitting simultaneous volatilization of uranium and plutonium by means of fluorine. At the same time considerable progress has been made in the development of a decanning method involving the use of molten metals.

Proven reactors

11. The programme has mainly been concerned with the improvement of equipment and of calculation methods, the development of uranium and plutonium fuels and, to a lesser extent, the development of fuels containing burnable poisons.

12. With regard to equipment, industrial undertakings have chiefly been studying new drive mechanisms for pressurized water reactor control rods. Particular attention has been paid to the mechanical, static and dynamic stability of the internal reactor components and fuel assemblies. In this connection the construction has begun of a test loop, which will be put into operation in 1970.

13. The work on the improvement of calculation methods has included the development of new codes permitting the three-dimensional calculation of a lattice with a small number of points and the study of the dynamic behaviour of the primary system in the case of normal or abnormal transients.

14. With regard to uranium fuel, the first models of elements for the Doel and Tihange power stations have been produced and are currently undergoing various tests. At the same time, an effort has been made to improve fabrication and control techniques, particularly in connection with the zircaloy-clad pins to be used in future. This work has been supplemented by irradiation experiments carried out largely in the BR-2 reactor.

15. Work on the recycling of plutonium in thermal reactors, performed jointly by CEN and industrial undertakings, has comprised theoretical and experimental studies, principally in the field of critical and sub-critical assemblies, and the improvement of techniques for the manufacture of pelletized, vibro-compacted, mixed uranium-plutonium oxides.

Gas-cooled high-temperature reactors

16. Although this field of activity is not specifically included in the five-year plan, Belgian industry has entered into an association with other European enterprises to form the "Internuclear" company, and has decided to undertake certain work with a view to tendering for the supply of high-temperature reactors. Efforts in Belgium in this respect have concentrated on fuel, in particular the fabrication of coated particles, which was already in hand under the DRAGON programme. Samples containing plutonium and fabricated in Belgium were irradiated successfully up to depletion of 90% of the fissile plutonium.

Basic research

17. The university laboratories have carried out research with protons in the low-energy field. In order to improve the facilities available to research workers the University of Louvain has ordered an isochronous cyclotron with a power which is variable up to a maximum of 80 MeV. The University of Louvain hopes there will be co-operation on a national scale in connection with the use of the cyclotron.

18. The low-energy laboratory at the University of Ghent has continued studies with the help of the 40-MeV electron linear accelerator, whose power may subsequently be increased to 80 MeV.

19. As regards high energies, the teams interpreting the films made of bubble chamber experiments have continued their current work, within the framework of the European Organization for Nuclear Research (CERN). The high-energy laboratory is planning to acquire a new piece of equipment (a spiral reader) to enable it to continue to play an active role at European level. In addition, teams of research workers have participated in electronics research, also within the framework of CERN.

20. In nuclear chemistry the University of Ghent reactor has been used for activation analysis work, while other university laboratories have undertaken various studies on theoretical physics and nuclear chemistry.

21. CEN itself has concentrated on studies in solid-state physics, nuclear physics and radiobiology. In solid-state physics, research has been concentrated on the mechanism of radiation damage, structural defects and the magnetic structures of various materials.

22. In nuclear physics, mention should be made of work in neutron spectrometry, neutron spectroscopy, fission phenomena and theoretical physics.

23. The radiobiology laboratory of CEN has directed its efforts to the study of the mechanism of action of radiation, the diagnosis and treatment of irradiation-induced lesions, and environmental contamination by radiation.

Radioisotope production and applications

24. Radioisotope production underwent rapid development at CEN in 1968. During the year the total activity of the radioisotopes produced by CEN reached the record level of 310 000 curies, of which some 270 000 curies are accounted for by cobalt-60 sources and 36 000 curies by iridium-192 sources. Side by side with the production of radioisotopes a more modest programme has been carried on which is aimed at the development of industrial processes involving the use of radiation and at the application of tracers to solve certain problems.

Operation of the BR-2 reactor

25. A contract was signed in December 1968 between CEN and the Gesellschaft für Kernforschung m.b.H., Karlsruhe, (Karlsruhe Nuclear Research Centre), for the joint operation of the reactor with a view to making full use of it, particularly in the fast reactor programme undertaken by the Federal Republic of Germany and the Benelux countries.

26. In 1968, 234 experiments were carried out in the reactor, in addition to the regular production of radioisotopes. On average, 45 irradiation channels were occupied, and the reactor was kept in operation at its rated power for 210 days. It should be noted that during this period three large-size loops were operated simultaneously and that one of them permitted irradiation with power cycling in the test device.

Actinium programme

27. CEN and Belgian industry have initiated a programme aimed at developing a heat source for power generation by thermionic conversion. This involves transformation of radium-226 into actinium-227 by irradiation. The irradiation devices and the installations required for the chemical processing of several grams of actinium had been constructed during the previous period. Studies have also been made of separation and purification methods for the production of the actinium oxide to be inserted in the form of coated particles in a tungsten capsule. Regular production of actinium is to start at the end of 1969 or the beginning of 1970.

Budgetary matters

28. The national nuclear energy budget in 1969 will be of the same order of magnitude as in 1968, i.e. about B.Fr. 1400 million. Most of this sum will be devoted to activities on the national level, which will absorb 69% (as compared with 63% in 1968), while the proportion used to finance Belgian participation in international bodies will drop from 37% to 31%.

29. The allocation of funds between basic research, technological research and public service and support activities will remain practically unchanged. Mention may be made, however, of a slight increase in the funds made available to industry (31% instead of 28%), which is offset by a slight reduction in CEN's share (56% instead of 60%).

30. It should be noted that the expenditure relating to research on nuclear technology is clearly higher than the amount contributed by the State, since CEN's own sources of income and the financial participation by industry in certain programmes must be taken into account.

NUCLEAR POWER STATIONS

BR-3 Vulcan Power Station

31. Irradiation of the second reactor core of the BR-3 nuclear power station at Mol was completed on 18 November 1968. The first phase of the irradiation of this core, which lasted until 22 April 1968, had yielded a maximum burn-up of 40 000 MWd/t U. During this period the station had run practically continuously at full power (41 MW(th) = 11.45 MW(e)), the load and availability factors being 91.2% and 98.6% respectively.

32. The excess reactivity still available in April 1968 was used until November 1968 and permitted an increase in burn-up until average and maximum rates of 23 000 and 52 000 MWd/t U respectively were obtained. During the latter period the reactor operated at levels of between 40% and 100% of full power and slight contamination of the water in the primary circuit, which became apparent in May, did not exceed 15 Ci/m^3 at the end of its period of service.

33. Upon unloading, each fuel assembly was examined by the dry sipping method. Leaks in six fuel assemblies were found in this way, and examination under water with a periscope revealed the seven cracked pins responsible. Post-irradiation examination is currently in progress in Belgium and the United Kingdom.

34. Thirty-nine of the fuel assemblies already irradiated in the previous core were reloaded in the reactor to form a renewed core containing 34 additional assemblies, for the most part zircaloy-clad. The irradiation of this core under light water containing boric acid, which was begun in 1969, is to be continued until mid-1970.

Ardennes Nuclear Power Station at Chooz

35. During the preceding period repair work was carried out on the SENA (Société d'énergie nucléaire franco-belge des Ardennes) reactor following failure of certain internal components in 1968, due to vibration. After a complete check had been made on the core and the thermal shield had been removed, the fuel elements were reloaded and the tank was closed. The reactor is expected to be started up again in stages as from the end of 1969.

Doel and Tihange Power Stations

36. On 31 December 1968 an order was placed with ACEC, in association with the Cockerill-Ougrée-Providence Company, for the reactors for Doel, and on 14 January 1969 ACEC, in association with the Cockerill-Ougrée-Providence Company, and a French construction group were awarded the contract for the Tihange reactor.

37. For the power station at Doel, the electric utilities decided on twin pressurized water reactors, each with an output of 1192 MW(th). The electrical output of each unit is approximately 400 MW. Each core, containing 32.1 tons of uranium, will comprise 121 fuel assemblies, the fuel elements being zircaloy-clad. The average burn-up at the equilibrium planned is 33 000 MWd/t U.

38. For the Tihange power station the utilities have chosen a single pressurized water reactor with three primary loops, and with a thermal power of 2660 MW at a steam temperature of 267° C. The core, containing 71 tons of uranium, will comprise 157 fuel assemblies of the same type as those used at Doel. The electrical output of the power station will be of the order of 800 MW.

2. CANADA

Developments in 1968-1969 in the peaceful applications of nuclear energy in Canada

1. The past year has been one of solid progress and, in some areas, of considerable achievement in the Canadian nuclear and uranium mining industries. In the nuclear power programme, the most important development was the firm commitment by the Hydro-Electric Power Commission of Ontario to build and operate a 3000-MW nuclear power station at Douglas Point, Ontario at an estimated cost of $760 million. This new development, known as The Bruce Generating Station, will consist of four 750-MW CANDU reactors, with the first scheduled to come into service in 1976 and the others following at yearly intervals. The installation at the Douglas Point site will thus comprise the original 200-MW Douglas Point Station, owned by Atomic Energy of Canada Limited (AECL) and operated by Ontario Hydro, and the new 3000-MW station with a nuclear steam supply system designed by AECL.

2. Steady construction progress has been made at Ontario Hydro's four-unit 2000-MW Pickering Generating Station. The current schedule calls for the reactors of Units 1 and 2 to reach criticality in 1971 and the reactors of Units 3 and 4 to reach criticality in 1972 and 1973. With The Bruce Generating Station, Ontario Hydro will have 5400 MW of nuclear capacity within its system and will become one of the world's largest producers of electricity from nuclear energy.

3. Construction of the 250-MW Gentilly nuclear power station in the province of Quebec has also progressed satisfactorily and it is scheduled to go into operation in 1971.

4. To help meet the demands of the expanding nuclear power programme in Canada and the requirements of prospective CANDU purchasers overseas, AECL was authorized early in 1969 to build a heavy-water production plant at Douglas Point with a capacity of 800 tons a year. This plant, to be operated by Ontario Hydro, is scheduled for completion in 1972-73 and will be similar in design to the 400-ton plant being built at Port Hawkesbury, Nova Scotia by Canadian General Electric Co. Ltd.

5. Construction of two 200-MW CANDU stations at the Rajasthan Atomic Power Project in India is proceeding as anticipated. Civil engineering work for one unit is virtually complete. The Unit Two reactor building structure is well advanced and many of the equipment orders have been placed. A major objective of this project is the development of indigenous capability in India. End shields, moderator heat exchangers, boilers and fuelling machine heads have all been ordered from Indian suppliers.

6. Construction of a 125-MW heavy-water natural uranium nuclear power plant being built by Canadian

General Electric on a turn-key basis for the Pakistan Atomic Energy Commission is scheduled for completion in 1970. Building construction is nearly finished and major equipment is currently being installed.

7. By the end of March, 1969, seven Canadian-designed nuclear power stations in Canada and abroad were either in operation or under construction. Their total design capacity is more than 6000 MW.

8. The Commercial Products group of AECL, responsible for the processing and distribution of radioisotopes and for designing and marketing of associated equipment, established a new record this year regarding sales of Eldorado and Theratron cobalt-therapy machines. There are now more than 700 Canadian-made units in service throughout the world. The average curie strength of cobalt sources used with these machines is steadily being increased, thereby permitting shorter treatment time and hence greater utilization of the equipment. Radioactive material shipped during the year totalled 1 800 000 curies, bringing the cumulative total to nearly 10 million curies. Most of the material was cobalt-60 in a variety of forms.

9. Canada is also an important supplier of uranium. In accordance with its long-established practice of promoting the use of uranium for peaceful purposes only, the Canadian Government reaffirmed its policy of supplying uranium and thorium only to customers in countries with which Canada has completed a safeguards agreement or, following the entry into force of the Treaty on the Non-Proliferation of Nuclear Weapons (NPT), with customers in countries which have concluded the necessary safeguards agreement with the International Atomic Energy Agency. Details of this policy were outlined to the House of Commons in a statement made by the Honourable Otto E. Lang on June 19, 1969.

10. As a member of the Eighteen-Nation Committee on Disarmament, Canada contributed to the achievement of an agreed draft of NPT which was presented at the April 1968 session of the General Assembly of the United Nations. Shortly thereafter, in January 1969, Canada ratified NPT. Canada is of the view that a prolonged delay in the coming into force of the Treaty or in the ratification of it by States which have, or are reputed to have, the ability to produce a nuclear weapon within the next few years would be a lamentable setback to the cause of nuclear disarmament and of freeing the world from the menace of nuclear war.

11. Uranium production from Canada's four operating uranium mines during 1968 was an estimated 4100 tons of uranium oxide concentrates. Of this, the companies shipped 3700 tons valued at an estimated $45 482 000, the remaining production being kept in inventory. Meanwhile, the industry proceeded with several development programmes in anticipation of the growth in demand over the next few years. Although phasing out production at its Noric Mine temporarily, Rio Algom Ltd. announced in October 1968 that it would spend approximately $26 million on the reactivation of additional production facilities in the Elliot Lake area of Ontario. The project will take some four or five years, if markets develop as expected, and will be carried out in two phases. Denison Mines Ltd. continued with its long-range programme of underground development aimed at increasing its production capability by the early 1970s. Eldorado Nuclear Ltd. announced in early 1968 its decision to proceed with the construction, at its Port Hope refinery in Ontario, of facilities to produce uranium hexafluoride (UF_6). In addition, construction of the zirconium production facilities of Eldorado Nuclear Ltd. at Port Hope was completed in 1968 and production began in the second quarter of 1969.

12. Uranium exploration activity in Canada continued throughout 1968 with interest being shown in most areas of known uranium occurrences as well as in several new areas not previously investigated in detail. One such new region for uranium exploration is the basin of the flat-lying Athabasca Formation in northern Saskatchewan, which is bounded on the north by Lake Athabasca and on the south east by the Wollaston Lake structural trend. Both the sandstones in the Athabasca basin and the underlying Wollaston Lake structural break are believed to be favourable for uranium occurrences. Although activity throughout Canada may have exceeded that reached in the peak years of the early 1950s, few quantitative measurements of results were available at the end of 1968 to illustrate the success of the programmes.

13. Of particular importance to the development of an effective safeguards system was the establishment in December 1968 of a joint Canada-USA programme for the development of safeguards instrumentation and techniques, with special reference to on-power fuelled reactors. The objectives of this development programme are:

(a) To develop and evaluate prototype instrumentation (unattended and secure) which may be used in the safeguarding of power reactors and other nuclear facilities; and

(b) To test tamper-resistant/tamper-indicating techniques and devices in the severe environment of an operating power reactor.

Testing of the instrumentation and techniques will be conducted on the Nuclear Power Demonstration Reactor at Rolphton, Ontario, which has used on-power fuelling successfully for a number of years.

14. In July 1969 the Government of Canada and the Government of the United States of America formally advised the Director General of the International Atomic Energy Agency of the objectives of the joint programme and offered to make available to the Agency the results that would be forthcoming.

3. CONGO, DEMOCRATIC REPUBLIC OF THE

Progress made in the peaceful uses of atomic energy during the year 1968-69

INTRODUCTION

1. During the period 1968-69 nuclear energy activities in the Democratic Republic of the Congo were directed mainly to the following ends:

(a) Conversion of the TRIGA Mark I reactor into a TRIGA Mark II reactor;

(b) Construction of new laboratories for the Regional Nuclear Centre;

(c) Organization of the Symposium on the Peaceful Uses of Atomic Energy in Africa held by the Organization for African Unity (OAU);

(d) Diversification of nuclear research in the TRICO Nuclear Centre.

CONVERSION OF THE TRIGA MARK I REACTOR INTO A TRIGA MARK II REACTOR

2. All the parts of the new reactor, which were ordered during the period 1966-67, are now on site and ready for installation. It is intended to shut down the old reactor at the beginning of 1970 and install the new one in about July 1970. The new reactor will be installed under the supervision of experts from General Atomic, San Diego. Construction of the hall in which the new reactor will be housed started in September this year.

CONSTRUCTION OF THE NEW LABORATORIES FOR THE REGIONAL NUCLEAR CENTRE

3. It will be recalled that at a meeting of the OAU Heads of State at Kinshasa in 1967 it was decided to convert the TRICO Nuclear Centre at Kinshasa into a regional centre which would be at the disposal of the OAU Member States. The change-over programme was started in June 1969 with the construction of laboratories for the various research departments of the Regional Centre. It is planned to complete this programme of construction towards the end of 1970.

ORGANIZATION OF THE OAU SYMPOSIUM ON THE PEACEFUL USES OF ATOMIC ENERGY IN AFRICA

4. With the support of the Agency the Commissariat des Sciences Nucléaires of the Democratic Republic of the Congo organized a Symposium on the Peaceful Uses of Atomic Energy in Africa. This Symposium was held in Kinshasa from 28 July to 1 August 1969 and was attended by more than 100 research workers and scientists from 23 African countries. The Symposium served a dual purpose:

(a) To make known what is being done in Africa in regard to the use of nuclear energy for peaceful purposes, and to enable participants and Member States of OAU to exchange views and report on their experience in this field; and

(b) To determine and delimit fields of activity (such as the training of professional and auxiliary staff, and the extraction of appropriate minerals) which could constitute future programmes for incorporation in the development plans of Member States, on an individual or collective basis.

DIVERSIFICATION OF NUCLEAR RESEARCH AT THE TRICO NUCLEAR CENTRE

5. Research at the TRICO Nuclear Centre was concentrated on the following fields:

(a) *Radioagronomy*

(i) Studies under way:
Systematic determination of aluminium and silicon in Congolese soil;
Study of the influence of trace elements on the yield of orchards at the M'vuazi Agricultural Station;
Study of insecticide absorption by plants;
Determination of phosphorus and potassium in sugar-cane leaves at the Moerbeke plantation;
Study of the hydric state of the synthetic maize population at the Nsele plantation;

(ii) Studies planned:
Uptake of sulphur by poultry;
Planting and selection of soya;

(b) *Nuclear medicine and biology*

Studies under way or already completed:
Intestinal absorption of iron;
Thyroid fixation of iodine;
Study of Rhizobium-Leguminosae relations with reference to DNA metabolism;

(c) *Radiochemistry*

(i) Studies under way or completed:
Study of antimony and tin impurities in type lead;
Determination of silicon, aluminium, manganese, sulphur, copper and antimony in slag, pig iron and white metal produced in the Congolese metallurgical industry;
Determination of molybdenum and uranium in various Congolese ores;

(ii) Studies planned:
Routine determination of vanadium in Congolese crude oil for the Moanda refinery;
Industrial-scale production of radioisotopes;

(d) *Training of personnel*

The students of the Lovanium University have continued to use the facilities of the TRICO Nuclear Centre in their work for bachelor's and doctor's degrees.

4. GERMANY, FEDERAL REPUBLIC OF

Advances in nuclear energy: 1968-69

INTRODUCTION

1. The first two years of the Third German Nuclear Programme (1968-1972) has brought progress in all activities connected with the peaceful use of nuclear energy and especially the rapid development of a competitive nuclear industry.

2. From its very beginning the nuclear programme in the Federal Republic has been characterized by close and efficient co-operation between the Government, universities, national research centres and industry. Meanwhile industry has taken over major responsibilities in the field of nuclear applications and today nuclear energy can be regarded as an integral part of the German economy.

PUBLIC FUNDS FOR NUCLEAR RESEARCH AND DEVELOPMENT

3. Nevertheless nuclear research and development still require public support in order to ensure the continuity of recent progress. Consequently the Federal and State Governments allocated to their nuclear research and development programmes DM 965 million in 1968 and about DM 1100 million in 1969 - a 14% increase for this year. The ratio of the Federal to State contributions to the nuclear research and development budget is about 4 to 1.

4. Financial contributions to such international organizations as the Agency, the European Atomic Energy Community (EURATOM), the European Organization for Nuclear Research (CERN), the European Nuclear Energy Agency (ENEA) and EUROCHEMIC, as well as the Franco-German Max von Laue-Paul Langevin Institute, amount to about 20% of the national expenditure on nuclear research and development.

5. There are about 23 000 employees engaged in nuclear research and industry.

NUCLEAR RESEARCH AND DEVELOPMENT AT THE NATIONAL RESEARCH CENTRES AND UNIVERSITIES

6. The two largest nuclear research centres in the Federal Republic, the Karlsruhe Nuclear Research Centre and the Jülich Nuclear Research Establishment, which are equipped for broad activities in nuclear research and development, are attaining their final stage of extension with about 3300 employees each.

7. The Plasma Physics Institute at München comprises about 1 000 employees, the German Electron-Synchrotron (Deutsches Elektronen-Synchrotron) (DESY) at Hamburg 900, the Radiation Research

Corporation at München-Neuherberg 600 and the Hahn-Meitner Institute at Berlin and the Corporation for Use of Nuclear Energy in Shipbuilding and Shipping at Hamburg about 400.

8. Plans are under discussion for a diversification of the nuclear research centres' activities to include non-nuclear fields of interest such as information science, data processing and systems analysis, biophysics and biochemistry, ecology and health protection, materials research and low-temperature physics and technology. The work of the Radiation Research Corporation, for example, will be extended considerably for this purpose. Recently a decision was made to found a Central Institution for Solid State Physics; two institutes are being set up, one at Jülich and one at Stuttgart. The Jülich institute will mainly be concerned with the investigation of metal properties and the dynamics of solids, and generally will be concerned with the application of nuclear methods to solid-state physics. The Stuttgart institute will focus its interest on the investigation of semiconductors and insulators.

9. For basic nuclear research in the medium and high energy range a new type of isochron cyclotron for producing deuterons with energies between 45 and 90 MeV, designed and constructed by a German company, has been in operation at the Jülich Nuclear Research Establishment since 1968. An identical accelerator will be installed at Bonn University before the end of this year.

10. Another accelerator of the same type but giving somewhat lower particle energies has recently started operation at Hamburg University. Altogether there are now 44 particle accelerators of different types giving energies above 10 MeV in operation in the Federal Republic, 19 of them for basic research in the physical sciences and 25 for biological research and medical applications.

11. Construction work on a new research establishment with a heavy ion accelerator of 7 MeV per nucleon has been started on a site near Darmstadt. This accelerator will be the first of its kind in the world and is expected to open up a new field of nuclear research. The high versatility of this instrument will facilitate new approaches to problems of nuclear structure, chemistry and solid-state physics.

12. In 1969 the installation of a new injection linear accelerator for the 6. 5-GeV electron synchrotron DESY will be completed. Construction of the 3-GeV electron positron storage rings for DESY is under way.

13. For the various purposes of low-energy nuclear research a total of 20 research reactors and critical assemblies and 10 training reactors of the Siemens-type SUR are available.

POWER REACTOR DEVELOPMENT

14. During the period of time covered by this progress report developments in the conventional light water reactor (LWR) and heavy water reactor (HWR) fields have shifted entirely into the industrial sphere. The final breakthrough to commercialization and competitiveness of these reactor lines in the Federal Republic, marking the completion of the preceding nuclear energy programmes, may be illustrated by two facts:

(a) Mergers have given rise to a notable increase in the technological and organizational efficiency of German nuclear industry; and

(b) Based on the growing experience gained with domestic nuclear power plants, export orders have been placed with German nuclear industry.

15. In 1969 Siemens and AEG-Telefunken combined their respective departments to form the Power Plant Combine, which now offers complete LWR power stations of the boiling or pressurized water type, as well as all nuclear and conventional components. Furthermore Siemens and NUKEM have founded the Reactor Fuel Company, primarily in order to ensure the supply of LWR fuel elements, but also to provide for the continuous improvement of nuclear fuel for other types of reactors. Finally the recently established Power Plant Combine will become the major shareholder of INTERATOM via its parent companies Siemens and AEG-Telefunken. One major consequence of this arrangement will be the concentration of all industrial development of sodium-cooled fast breeder reactors at INTERATOM. This firm has already played an important role as an architect-engineer in the nuclear field.

16. Meanwhile the efforts of German nuclear industry over the past years have been recognized abroad, resulting in export orders for the construction of a 320-MW(e) pressurized HWR power station at Atucha in Argentina, the first on the South American continent, and a 400-MW(e) LWR power station at Dorssele, near Vlissingen, in the Netherlands province of Zeeland, in 1968 and 1969 respectively.

17. At present there are in the Federal Republic nuclear power plants with a total capacity of 2300 MW(e) either installed or under construction. Of these, the demonstration plants at Lingen on the Ems and Obrigheim on the Neckar, with capacities of 250 MW(e) and 300 MW(e) respectively, went into operation in 1968. The construction of two large commercial nuclear power stations at Würgassen on the Weser and Stadersand on the Elbe, with a capacity of more than 600 MW(e) each, is going on apace. Up to now German nuclear power stations have produced about 5 million MWh of electrical energy.

18. For the next few years at least six more nuclear power plants with a total capacity of 3500 MW(e) are being planned. The first of these, a 1100-MW(e) LWR station to be built at Biblis on the Middle-Rhine, has already been ordered. Furthermore, the chemical companies BASF of Ludwigshafen, Hoechst of Frankfurt, Bayer of Leverkusen and Hüls of Marl intend to set up nuclear plants for the generation of both process heat and electrical energy. As a first unit of this series, the BASF plant is designed for about 1200 MW(e). Altogether an installed nuclear capacity of about 8000 MW(e) is to be expected in the Federal Republic by 1975.

DEVELOPMENT OF ADVANCED REACTOR SYSTEMS

19. The Third German Nuclear Programme gives priority to the development of sodium-cooled fast breeder and gas-cooled high-temperature reactors. The co-ordination of activities in these fields is concentrated at the nuclear research centres of Karlsruhe and Jülich respectively, and is again characterized by close co-operation with industry.

20. As the result of a public hearing held in January 1969 by the Federal Ministry for Scientific Research, in which the responsible Parliamentary Committee participated, the steam-cooled fast breeder project, which until then had been pursued parallel to the sodium-cooled line of research, was cut down to the development of fuel elements on a small scale.

21. The construction of the 20-MW(e) compact sodium-cooled test reactor KNK at Karlsruhe will be completed before the end of 1969; the insertion of a fast core into this reactor is being prepared for 1970. Studies for a 300-MW(e) fast breeder prototype plant are under way in collaboration with the Benelux countries; an offer to build such a plant will be submitted in 1969 by the reactor building industries to the utilities of the four countries.

22. The necessity for a fast high-flux test reactor is the subject of studies. To a limited extent studies on a gas-cooled breeder are also being carried out at Karlsruhe and Jülich.

23. In the high-temperature reactor (HTR) field the 15-MW(e) AVR reactor of the pebble-bed type at Jülich continued to operate very satisfactorily. Construction plans for a 300-MW(e) uranium-thorium fuelled prototype station based on the AVR concept have been submitted by the industrial consortium BBC/Krupp and are being examined by the HKG consortium of utilities. In February 1969 the firms of Gutehoffnungshütte AG and Schleswig-Holstein Nuclear Power Company signed a contract for the construction at Geesthacht near Hamburg of a 25-MW(e) HTR experimental plant with an integrated helium gas turbine. The German HTR programme aims at the construction of a 600-MW(e) HTR power plant with an integrated helium turbine.

24. In co-operation with the Jülich Nuclear Research Establishment, a consortium of industrial firms started work on the development of a compact 20-kW(e) in-core thermionic reactor to be used as an electrical energy supply system for satellites.

NUCLEAR SHIP PROPULSION

25. Late in 1968 the nuclear cargo ship "Otto Hahn" — the first European merchant ship with nuclear propulsion — left on her maiden voyage. Since then she has proved her operational reliability and safety under the severe conditions of heavy seas and tropical climate on long voyages across the North and South Atlantic. Negotiations on the entry of the "Otto Hahn" into foreign harbours are under way.

NUCLEAR FUEL CYCLE

26. There are several German industrial firms engaged in the prospection, mining and production of natural uranium. Two companies have established contacts with firms overseas. The Uranium Company participates in prospection projects in Canada, the United States of America and the Niger; the Uranium Ore Mining Company has started prospection activities in Ghana and Togo. Both companies have been granted concessions in Somalia.

27. Before the end of 1969 the WAK reprocessing plant for nuclear fuel elements (with a capacity of 40 tons a year) will go into operation at Karlsruhe. The development of reprocessing methods for advanced reactor fuel elements will also be a major objective of the plant. A new laboratory for the separation of special fission products and actinides of interest in science and technology will closely co-operate with the WAK facility.

DEVELOPMENT OF NUCLEAR SAFEGUARDS METHODS

28. The programme of research and development on safeguards methods has made good progress at the Karlsruhe Nuclear Research Centre and has met with increasing international interest.

29. The programme aims at an instrumented safeguards system for the entire fuel cycle. The safeguards system is based mainly on the concept of automatic control of the flow of fissile material at certain points of the fuel cycle. Four major lines

of development are being pursued: systems analyses, control experiments and direct and indirect safeguards methods. Experiments carried out at the EUROCHEMIC reprocessing plant at Mol in Belgium and at the ALKEM fuel fabrication plant at Karlsruhe have confirmed the feasibility of the control concept.

INTERNATIONAL CO-OPERATION

30. A large part of the nuclear activities of the Federal Republic are being undertaken in international co-operation, as has already been noted in the preceding paragraphs. Apart from membership of the Agency and ENEA, special importance has in the past year again been attributed to co-operation within EURATOM. The Federal Republic also participates in the work of CERN, including the preparation of its 300-GeV proton synchrotron project.

31. Provisions for the implementation of the memorandum on Belgian-Netherlands-German co-operation in the field of fast reactors, now extended to Luxembourg, have been put into effect. Thereby, close co-ordination of research and development work undertaken in the research centres as well as in the industries of the four countries is ensured. By the end of 1969 industry is to submit a detailed design, together with a firm offer for a 300-MW(e) fast reactor prototype, to the utilities of the four countries[1]. They are to be organized as a single company for which the status of a Joint Enterprise under the EURATOM Treaty could be envisaged.

32. Towards the end of 1968 the Governments of the Netherlands, the United Kingdom of Great Britain and Northern Ireland and the Federal Republic started negotiations for an agreement for co-operation in the development and exploitation of the gas-ultracentrifuge process for enriching uranium, in order to cover the growing demand of nuclear power stations. The establishment of two international industrial enterprises is envisaged, one to be responsible for the design and manufacture of centrifuges, and the other to be entrusted with the commercial operation of enrichment plants. During a first phase, two enrichment plants are to be constructed in the Netherlands and in the United Kingdom. The aim of the three Governments is to conclude the necessary agreements as early as possible. Collaboration with other countries, in particular European countries, is envisaged once the project has been established.

33. The joint Franco-German very high-flux reactor project of the Max von Laue-Paul Langevin Institute at Grenoble has made good progress. The reactor is being set up according to schedule, and an increasing number of scientists are preparing experiments to be executed at this facility.

34. Apart from its long-established co-operation with France and the other EURATOM countries, as well as with Canada, the United Kingdom, the United States and other European countries, the Federal Republic has extended its bilateral relations in respect of the peaceful uses of atomic energy to a growing number of countries, among them Argentina, Brazil, India, Japan, Pakistan, Romania, Spain and Turkey.

5. INDIA

1. Nuclear activities during the year reached a climax with the completion of India's first atomic power station at Tarapur about 100 kilometres north of Bombay. On 1 April atomic energy made its debut in the country as a source of electricity when power at low level began flowing from the Tarapur Atomic Power Station. The Station will be reaching its full output of 380 MW(e) very soon.

2. Besides the completion of Tarapur and the continuous progress in the construction of the two other nuclear stations in the country — the 400-MW(e) Rajasthan Atomic Power Station at Rana Pratap Sagar and the first unit of 200 MW(e) of the Madras Atomic Power Station at Kalpakkam — there was considerable expansion of activities in other parts of the atomic energy programme.

3. The Bhabha Atomic Research Centre at Trombay continued its diverse research and development activities.

4. At the Isotope Division of the Centre, several new radiopharmaceuticals were developed for possible use in nuclear medicine; preliminary studies using these products have been conducted on animals. A number of carbon-14 and tritium labelled compounds were synthesized. Ten new carbon-14 labelled compounds were prepared by biosynthesis using the alga chlorella, and purified to obtain various uniformly-labelled amino acids. In radiation technology, considerable progress was made in developing a field irradiation unit "Gamma Shine"; a prototype of this unit has been made and tested. Besides its research and development activities, the Division also kept up its export of isotopes, equipment and services. Australia, Burma, Ceylon, Denmark,

1) See para. 21 above.

France, Korea, Kuwait, Lebanon, Romania, Taiwan, Thailand and the United Arab Republic are among the countries which bought radioisotopes, equipment or services from the Bhabha Centre during the year. Among radiation equipment sold were irradiation units "Gamma Chamber 900" exported to Lebanon and to Romania.

5. Besides production of radioisotopes and related equipment, the Bhabha Centre continued research and development work relating to applications of atomic energy in agriculture, industry, medicine, biology and other areas. The Biology Division of the Centre continued its plant breeding programme, among other investigations. Promising mutants of rice and groundnut developed by it are currently being subjected to field trials. A programme of work has also been taken up to induce dwarf mutants in otherwise potentially high-yielding varieties of rice.

6. Work on development of radiation preservation procedures for perishable foods was intensified at the Food Irradiation and Processing Laboratory of the Centre. With the completion of the facilities at the Laboratory, experimental programmes have been accelerated. Large-scale studies with mangoes and sea food (Bombay duck, shrimp and pomfret) have yielded promising results. Activities relating to radiosterilization of medical supplies were undertaken and facilities were made available for exposing other products to gamma rays. Plans have been completed for large-scale feasibility studies on grain disinfestation by gamma rays.

7. At the Fuel Element Fabrication Facility of the Centre, development work connected with the fabrication of fuel elements and components for future nuclear power stations was continued. The Facility meets the requirements for metallic fuel elements and sub-assemblies of the CIRUS and ZERLINA reactors at Trombay. In addition, it continued the production of high-density sintered UO_2 pellets. The Facility is also fabricating the initial half-charge for the first unit of the Rajasthan Atomic Power Station.

8. In the field of fast reactors, work was done at the Centre on the design of the Indian Fast Test Reactor and a pulsed reactor. Detailed analysis was made of the physics experiments carried out abroad. The Experimental Reactor Physics Section of the Centre directed its efforts towards the setting up of experimental techniques for subsequent use in the study of power reactor configurations. Planning for the Fast Reactor Research Centre at Kalpakkam was initiated. The design of the engineering laboratories has been finalized and it is expected that the laboratories will be commissioned some time next year.

9. The Electronics Division of the Centre designed and built an electronic digital computer, TDC-12. This fast computer is capable of performing 250 000 additions and subtractions in a second, and is intended for real time applications. This is the first real time digital computer developed in the country. Commercial production of this computer will be taken up by the Electronics Corporation of India Ltd. at Hyderabad, an industrial unit under the Department of Atomic Energy.

10. The Laser Group of the Division recently built and operated a helium-neon laser. It is also working on the development of several other types of lasers, ruby, neodymium-doped glass, argon ion, carbon dioxide and liquid lasers.

11. Measurements were continued at Bombay and ten other stations in the country of bomb-produced radioactivity in the atmosphere and in surface deposits. Analytical work on various food samples from Bombay, and milk samples from country-wide stations for caesium-137, strontium-90 and potassium-40 was undertaken.

12. Consistent with the policy of development of indigenous know-how for nuclear power generation, work on engineering systems for the second unit of the Rajasthan Atomic Power Station has been undertaken by the Bhabha Centre.

13. About 100 new institutions, representing nearly 1500 radiation workers, joined the Film Badge Service of the Directorate of Radiation Protection during the year. The service now covers 1110 institutions and monitors a total of nearly 13 500 radiation workers in the country. The Directorate has also developed and built a wide variety of instruments, most of them specially suited for work under the widely varying climatic conditions encountered in field use. The Electronics Corporation of India Ltd. at Hyderabad is mass producing some of the instruments developed by the Directorate.

14. At the Tata Institute of Fundamental Research a wide range of experiments in nuclear physics (nuclear reactions and nuclear spectroscopy), on nuclear and electron magnetic resonance, in chemical and solid-state physics, on primary cosmic rays with high altitude balloon flights, in high-energy physics through bubble-chamber film analysis, in hydrology and other isotope-based geophysical studies, in radio-astronomy, in molecular biology, etc. are in progress. For example, the study of defects produced by ionizing radiation in solids is in progress, with a view to understanding their effects on the conductivity and atomic diffusion of irradiated solids.

15. The operation of five telescopes and two magnetic spectrographs for the Tata Institute-Osaka City University-Durham University neutrino experiment at a depth of 2400 metres in the Kolar Gold Fields is being continued.

16. In oceanography rapid geochemical reactions occurring in the upper layers of the oceans were studied using natural thorium-234 as a tracer. These studies lead to a value of about 50 years for the residence time of chemically active elements like thorium in ocean water.

17. The 530-metre long cylindrical radiotelescope at Ootacamund for studies in radioastronomy is expected to be operational during 1969.

18. The National Computation Facility based on the CDC 3600-160A computer system completed its fourth year of operation, and is now operating 24 hours a day throughout the week, except for Sundays.

19. In Operations Research, in collaboration with the Power Project Group of the Department of Atomic Energy, a computer programme has been developed for computing the optimal mix of thermal, hydro and nuclear power generation. Using this programme, an analysis has been carried out for the planning of power requirements in the northern-region grid.

20. The Atomic Minerals Division of the Department is continuing the underground development work at the Narwapahar and Bhatin deposits and in the assessment of nickel and molybdenum reserves at Bhatin.

21. Among industrial units associated with the Department is Indian Rare Earths Ltd., which is responsible for commercial exploitation of the mineral sands in the country. For the first time the Company sees signs of being able to export a sizable quantity of rutile. It may be noted that hitherto rutile has always been imported.

22. All the major construction and erection works of the Uranium Corporation of India Ltd. at Jaduguda have been completed. The uranium mill was commissioned for commercial production in May 1968.

23. A Nuclear Fuel Complex is being set up at Hyderabad with the object of attaining self-sufficiency in fuel element supplies for the country's nuclear power programme.

24. At the Electronics Corporation of India Ltd., Hyderabad, there was steady progress in the production of the following new items:

(a) Components such as carbon and metal film resistors, tantalum capacitors, germanium power transistors, zener diodes, silicon rectifiers and thermoelectric modules;

(b) Nuclear instruments for medical, agricultural, research and industrial purposes; and

(c) Instrumentation and controls for nuclear power stations.

A separate unit of the Corporation, known as the Power Reactor Instrumentation Division, undertakes work of fabrication and assembly of control panels, consoles and instruments for nuclear power plants.

25. It is proposed to set up a heavy water plant alongside the Rajasthan Atomic Power Station to produce 100 metric tons per year of nuclear-grade heavy water.

26. The Bhabha Atomic Research Centre will be building an AVF variable energy cyclotron at Calcutta during the Fourth Five Year Plan period, in collaboration with the Saha Institute of Nuclear Physics.

27. A project for nuclear research in agriculture under the Special Fund Component of the United Nations Development Programme started functioning at the Indian Agricultural Research Institute, New Delhi. The purpose of this project is to expand research and training facilities for radiation applications in agriculture at the Institute and at three other centres - the Bhabha Atomic Research Centre at Trombay, the Indian Veterinary Research Institute at Izzatnagar and the National Dairy Research Institute at Karnal.

28. The possibility of low-cost power production as a result of the scaling-up of nuclear power reactors to large sizes and the scope for reduction in the production costs of water by desalination as a result of advancing technology are of major significance for large power consuming industries and agriculture in India. Production of ammonia by electrolysis of water, of phosphatic fertilizers through the electric furnace and of aluminium are some of the important industries. Low-cost power can also be profitably used for pumping of underground water, where available, for agriculture; alternatively, desalinated water can be made use of even for agriculture under controlled conditions in arid regions. The development of agro-industrial complexes based on the utilization of low-cost power and water in the vicinity of the power plant has been studied by a working group set up by the Atomic Energy Commission with special reference to Indian conditions. Two regions were considered for specific project evaluations:

(a) The Gangetic Plain in Western Uttar Pradesh, where underground water is available, along with fertilizers, for use for agricultural purposes; and

(b) The Kutch-Saurashtra area, where the use of desalinated water for agricultural purposes is envisaged.

The group has submitted a preliminary report. Further work is continuing on detailed investigations.

6. INDONESIA

ORGANIZATION

1. A reorganization of the National Atomic Energy Agency (Badan Tenaga Atom Nasional) (BATAN) was carried out in 1967 when a programme of consolidation was launched which, due to the limited funds available, has continued into its third year. The aim of the consolidation programme was to enable a suitable five-year plan to be drawn up and implemented within the framework of the over-all Five-Year Development Plan, which was begun in April 1969.

2. In accordance with the national priorities, stress has been laid on the application of radioisotopes and of irradiation in suitable fields. These activities were mainly the concern of the scientific staff at the Pasar Djumat Research Centre near Djakarta and at the Bandung Atomic Reactor Centre. In Jogjakarta a modest but important programme of training and research in physics and electronics is being pursued, and at Serpong near Djakarta a similar programme on radiation protection.

3. The efforts to develop the use of nuclear energy in Indonesia will continue to require substantial foreign assistance in the coming years. For this purpose a co-operative agreement was signed by the Governments of France and Indonesia on 3 April 1969 and should mark the beginning of an increased level of activities. The agreement provides for the training of Indonesian personnel, the sending of French expert missions and the exchange of information. Another agreement signed on the same day provides for the execution of a uranium exploration programme in Kalimantan by the French Atomic Energy Commission.

4. Co-operative agreements have also been signed by BATAN with other government departments, namely the Public Works and Power Department, the Health Department and the National Logistics Agency. The joint efforts for which they provide include investigations of hydrology projects, the development of nuclear medicine at the Bandung General Hospital and research on food preservation by irradiation.

5. In order to advise the President on nuclear energy matters, an Atomic Energy Council was set up in October 1968 in accordance with the provisions of the Atomic Energy Act of 1964.

HIGHLIGHTS AND DEVELOPMENTS

6. 5 December 1968 was the tenth anniversary of the establishment of BATAN, formerly known as Lembaga Tenaga Atom or the Institute for Atomic Energy. The occasion was celebrated by a Presidential visit to the Pasar Djumat Research Centre and the inauguration of a cobalt irradiator. Work is now in progress on the preservation by irradiation of rice, flour, dried salted fish and other dried foods. A Visiting Seminar on Food Irradiation to South East Asia and the Far East was held by the Agency in Djakarta in January 1969, and an Agency expert on this subject is now at Pasar Djumat to provide services for a year. An Agency gamma-radiography expert is stationed at the same Centre for a period of six months.

7. The reactor at Bandung is primarily used for radioisotope production, although some research work is also carried out; in particular a research contract for work on the chemistry of labelled compounds was awarded last year by the Agency. The demand for radioisotopes, however, has increased to such an extent that it is evident that continuous operation of the reactor for 24 hours a day will soon be required. Plans to increase the maximum power level from 250 kW to 1000 kW are also under way.

8. The increased demand for radioisotopes has arisen primarily out of hydrological projects, medical applications and research on agriculture. Production of bromine-82 and sodium-24 for the hydrological projects so far this year has reached 133 curies, which is about ten times last year's production. Other radioisotopes produced in quantity are iodine-131, which is produced in batches of 22 millicuries, and phosphorus-32, at present produced in batches of 9 millicuries, both radioisotopes being for medical applications. Production of labelled compounds is also being developed and a continuing increase in demand is foreseen in the coming years.

9. A seminar on the Introduction of Nuclear Power held in November 1968 concluded that there is a possibility of installing a nuclear power plant in the 1980s on the island of Java.

7. MONACO

Activities of the Applied Radioactivity Laboratory of the Scientific Centre in peaceful applications of nuclear energy

1. The Laboratory is completing the tenth year of its existence. It has issued some fifteen specialized publications, and there does not seem to be any slowing down in the rate at which these publications are appearing.

2. Forming an integral part of the Oceanographic Museum, it enjoys the advantages, as an eminent expert put it, of "a favourable atmosphere for scientific work", thanks to the proximity of other laboratories, such as the International Laboratory of Marine Radioactivity of the Agency and the scientific infrastructure of the museum.

3. Supported and stimulated in its efforts by the Commissariat à l'énergie atomique (French Atomic Energy Commission), the Laboratory of the Scientific Centre has been able to attain its initial objective during these ten years, carrying out purely analytical work for the benefit of other laboratories. It hopes in the near future to widen the scope of its basic activities.

4. Set up for the purpose of promoting the use of radionuclides in the marine sciences and assisting in the technology of their application, the Laboratory has not pursued this objective owing to the lack of research contracts. The efforts made to develop methods for the measurement of low-level radioactivity have nevertheless enabled it to strike out in two directions:

(a) Monitoring the radioactive contamination of fall-out and its effects on the marine environment;

(b) Analytical measurement of carbon-14 for dating purposes, on behalf of numerous investigators, who are mainly but not exclusively concerned with Mediterranean studies in the fields of archaeology, geology or palaeogeography.

5. Co-operation with the Agency Laboratory in Monaco started immediately after its establishment and is still continuing. This collaboration relates mainly to matters of instrumentation: the Laboratory of the Scientific Centre maintains all the Agency Laboratory's electronic measuring equipment, from pH meters to radiation detectors. It often happens that the Laboratory of the Scientific Centre is called upon to construct apparatus or modify existing equipment to meet the special needs of Agency research workers. For example, it has recently constructed a large variable high-voltage unit for electrophoresis, and a gamma radiation detector has been mounted on a chromatography unit. Mention should also be made of numerous gamma spectrometry measurements carried out by the Laboratory of the Scientific Centre for investigators and scientists under training, the testing of radionuclides used by the Agency Laboratory, etc. The advisory role which the Laboratory of the Scientific Centre fulfils for the radionuclide users of the Agency Laboratory, while not perhaps vital, does allow them to avoid costly errors.

6. The scientific results obtained in the last few years by the Laboratory of the Scientific Centre will be discussed further in the following paragraphs.

7. As far as monitoring radioactive contamination of the atmosphere is concerned, the results of routine measurements of air and precipitation, although they have not been compiled in a comprehensive report, have been incorporated as and when they were obtained in the general body of data collected by numerous other stations in various national territories and published by large international organizations, such as the European Nuclear Energy Agency and the Organisation for Economic Co-operation and Development.

8. Work concerning the uptake of radionuclides by marine organisms has formed the subject of several publications, certain of which were produced in collaboration with Agency research workers. Among the latter category the following titles may be mentioned:

In 1961: Test analyses of the radioactivity of the *Hircinia variabilis* sponge;
In 1963: Aspects of research by the Scientific Centre on pollution of the sea;
In 1964: Future of the direct, in situ method of detecting radioactivity in sea-water;
In 1968: Manganese content and presence of manganese-54 from fall-out in certain Mediterranean marine biotopes.

9. Carbon dating, however, appears to be the field which has contributed most to the scientific

reputation of the applied radioactivity section. In this connection, the following information may be of interest:

(a) As each analytical measurement of carbon-14 has its own special characteristics, which cannot be separated entirely from the nature and history of the sample to be measured, the operator is almost forced to work together with the investigator who provides it. It is for this reason that the Laboratory of the Scientific Centre has so often acted in association with other laboratories of different disciplines, such as palaeogeography, archaeology or sedimentology, in the various publications which have been issued, but it has specialized more particularly in measuring marine sediment uptake rates and in the chronology of the deposits characteristic of Quaternary sea levels

(b) The titles of the main publications are as follows:

(The first three refer to articles which appeared in the American journal "Radiocarbon")

In 1964: Monaco radiocarbon measurements I
In 1966: Monaco radiocarbon measurements II
In 1969: Monaco radiocarbon measurements III
In 1964: Validity of the dating of recent Quaternary sediments by analysis of the carbon-14 content of sea shells
In 1965: The radiocarbon content of deep and surface water in the Indian Ocean (Sea of Oman)

Some limitations of the carbon-14 method of dating shells

In 1967: The distribution of natural carbon-14 content in the various constituents of the biophase of a surface sediment in the western Mediterranean
In 1968: Radiocarbon dating of certain submarine sediments in the Nice area
The counting and automatic printing unit used for dating by the carbon-14 method
The absolute chronology and sequence of prehistoric civilizations in North Africa
In 1969: The age of the rock outcrops of the Roussillon continental plateau
Tests on the determination of sedimentation rates in the eastern Mediterranean by means of carbon-14 measurements

(c) The results of the carbon-14 measurements of the Laboratory of the Scientific Centre have also been used to support a thesis for a doctorate (B. Chassefière, 1968) and have also been incorporated in the following:

In 1966: The use of vermetus in the determination of former sea levels
In 1967: The possibility of dating Quaternary levels by means of vermetus
In 1968: Note on the marine environment of Wreck M 1 (Malta) in "Gallia Préhistoire"

(d) The large number of requests for analyses results in long waiting periods. The waiting periods are currently more than a year. The project for trebling of the carbon-14 measurement facilities, which has been under study for many years and is currently being implemented, should in principle allow us to solve this problem. With the increase in the number of our dating projects, the investigation of the new scientific problems almost invariably raised by current measurements, which are of necessity limited in number, will allow us to deal more thoroughly with the subjects studied and even to tackle subjects of wider scope, such as the movement of sea-water masses.

10. Dating by carbon-14 does not allow us to go back further than 35 000 years. At the request of other establishments, in particular the Museum of Prehistoric Anthropology of Monaco, the Laboratory of the Scientific Centre is considering the application in the near future of other methods, for which it has the equipment.

11. Finally, in the field of the medical applications of radioactivity, the Laboratory of the Scientific Centre intends to collaborate in the maintenance of the equipment used by the medical service of the Principality at the Princess Grace Clinic.

8. PAKISTAN

INTRODUCTION

1. The Pakistan Atomic Energy Commission (PAEC) is charged with the development of the nuclear power programme and the application of radioisotopes and radiation in medicine, agriculture and industry. It is also engaged in collaborative research with universities and other scientific and development institutions and organizations in the country.

NUCLEAR POWER

2. Pakistan's first nuclear power station, having a generating capacity of 137 MW(e), is in an advanced stage of construction near Karachi. The plant is a natural uranium heavy-water type. It is expected to become operational in 1970.

3. A second nuclear power station is being planned for the northern part of East Pakistan. Its generating capacity is expected to be 200 MW(e) and it will form the baseload station in the western grid of East Pakistan.

4. PAEC is making a survey of power requirements in the country and the part nuclear power has to play in this respect. Studies are also in progress on the feasibility of establishing dual-purpose, nuclear power plants, especially on the Mekran Coast of West Pakistan, where there is a great dearth of water.

AGRICULTURE

5. Useful development work is being carried out in the agricultural field at the Atomic Energy Agricultural Research Centre, Tandojam and the Atomic Energy Centre, Dacca. Certain improved varieties of food and cash crops have been evolved which are under observation. Efficiency of fertilizer applications is under study. Plans are under way for the application of the sterile male technique for the eradication of certain crop pests. A number of collaborative research programmes have been undertaken with various local development organizations. The Agency is providing helpful assistance in these projects.

6. An Institute of Radiation Genetics has been set up at Lyallpur, West Pakistan and a similar institute is under construction at Mymensingh. An Irradiation and Pest-Control Research Institute is being planned at Tengi, East Pakistan for work on pest control and preservation of food on a pilot-plant scale.

HEALTH

7. PAEC has initiated a regular programme of establishing Medical Radioisotope Centres at the principal medical institutions in the country. At present, such medical centres are in operation at Karachi, Lahore, Jamshoro, Multan and Dacca. Two more centres are almost complete at Chittagong and Rajshahi. Several thousand patients suffering from malignant diseases have been referred to the Medical Centres and diagnostic investigations have been carried out. Of these patients, a few hundred were given suitable radiation therapy.

INDUSTRY AND OTHER APPLICATIONS

8. A number of useful instruments for the industrial use of radioisotopes have been designed, constructed and used by the Atomic Energy Centres at Lahore and Dacca. Gamma-radiography has, in many cases, been used for checking joints in natural gas pipe-lines and finding defects in castings and moulds.

9. The Commission is collaborating with the Karachi Port Trust in tracing the movement of sand and silt near Karachi harbour. It is also assisting the East Pakistan and West Pakistan Water and Power Development Authorities in locating underground water resources.

10. Work on the harnessing of solar energy for small-scale but important uses such as rural lighting, running low-power irrigation pumps for villages and operating small, family-size stills to convert brackish water into fresh water, has been initiated at the Atomic Energy Centre, Lahore and at Karachi.

RESEARCH AND DEVELOPMENT

11. In support of the practical applications of atomic energy, research and development work is in progress at the Atomic Energy Centres at Lahore and Dacca and at the Pakistan Institute of Nuclear Science and Technology (PINSTECH) which has a 5-MW swimmingpool reactor facility. Production of radioisotopes from the PINSTECH reactor has started. Research in theoretical and experimental nuclear physics has been undertaken in collaboration

with local educational institutions. Certain developmental work has been carried out in electronics instrumentation. Basic work is in progress in radiation and nuclear chemistry.

SEARCH FOR NUCLEAR MINERALS

12. PAEC has undertaken a scientific survey of nuclear minerals in the country. In East Pakistan encouraging deposits of a number of minerals including rutile, ilmenite and zircon have been discovered. A pilot plant for their exploitation is being planned. In West Pakistan a significant deposit of uranium and traces of other valuable minerals have been found in Dera Gazi Khan and Gilgit Agency respectively. Detailed investigation to find out the extent of such deposits and the chemical and economic evaluation of the extraction of low-grade ores are in progress.

9. PHILIPPINES

Progress in the peaceful uses of atomic energy during 1968-69

GENERAL

1. There was continued progress and expansion in the work of the Philippine Atomic Energy Commission. Some of the activities which might be of interest to the Agency and the Member States are briefly summarized in this report.

RADIATION MUTATION

2. Several promising mutants have been developed by the irradiation of IR-8 rice seeds. The IR-8 is a high-yielding variety developed by the International Rice Research Institute. It suffers from two important defects: low resistance to the blast disease and poor table quality.

3. Mutants being tested by the Commission include types that are earlier maturing, shorter stemmed, higher yielding, blast resistant and give grains of superior quality.

4. Radiation mutation studies are also being undertaken on soy bean, corn, mongo bean and coconut, in addition to work being done to induce seedlessness in several important Philippine fruits.

FOOD PEST CONTROL

5. Studies on the life history of the melon-fruit fly (*Dacus cucurbitae*), on the techniques of mass rearing them in the laboratory and on their radiosensitivity have been started with a view to applying the sterile-male technique to control this insect pest. Several insects which cause damage to stored grain are also being dealt with. They include the saw-toothed grain beetle (*Oryzaephilus surinamensis*), the flour beetle (*Tribolium castaneum*), the rice weevil (*Sitophilus oryzae*) and the grain moth (*Corcyra cephalonica*).

6. A study has also been started to determine the effects of orally-administered tritiated thymidine in the production of dormant lethal genes in the field rat which is a major agricultural pest in the Philippines.

CONTROL OF SCHISTOSOMIASIS

7. Work involving the use of radioisotope techniques to find methods for the control of the schistosomiasis disease has been going on in the Commission for several years. Several studies have begun to yield encouraging results. The cercariae of the *Schistosoma japonicum* have been successfully tagged with carbon-14, which permitted the determination of their distribution and fate inside the body of the infected host.

8. Further studies deal with the development of vaccine in which irradiated cercariae for immunization against schistosomiasis are used. The dispersion and movement of the intermediate host snail of liver fluke is being studied by cobalt-60 labelling.

SOME RADIOISOTOPE APPLICATIONS IN INDUSTRY AND MINING

9. Studies on the production of hard wood from inferior wood are in progress. At least eight varieties of soft and semi-hard wood have been experimented on, involving the use of monomers and monomer combinations and irradiation by a cobalt-60 source. A project has been started involving the grafting of several types of monomers to important Philippine textile fibres such as kenaf, ramie and abaca by irradiation to improve their properties.

10. Studies are also being carried out on the use of atomic absorption spectroscopy for testing for

magnesium and chromium in minerals and on the use of neutron activation analysis in mapping the geochemical distribution of economically important mineral occurrences.

11. The Commission provided technical advice and services relating to the use of radiotracers in a study of sewerage pollution in Manila Bay carried out with the assistance of the World Health Organization.

NUCLEAR POWER DEVELOPMENT

12. The laying of the groundwork for the eventual introduction of nuclear power in the country is being continued. Following the passage in 1968 of an Atomic Energy Regulatory and Liability Act, the Commission is preparing appropriate rules and regulations for the licensing of atomic energy facilities and for the use of nuclear materials. A 16-week nuclear reactor technology course was conducted for engineers, mostly from the Manila Electric Company (MERALCO), the largest private electrical company in the country which has plans for the use of nuclear power.

LOCAL TRAINING IN NUCLEAR SCIENCE

13. As in past years, the Commission provided the main facilities, through its Nuclear Training Institute, for local training in atomic energy. In addition to the nuclear reactor technology course mentioned above, seven other courses were conducted for some 160 scientists, engineers, doctors and teachers. They included two sessions of the basic radioisotope technique course, a course on elementary statistics for scientific research, a first course on the agricultural uses of radioisotopes and radiation, a seminar in nuclear science for elementary and high-school teachers and a seminar in nuclear technology for university faculties.

REGIONAL CO-OPERATION

14. A notable regional co-operative undertaking in the peaceful uses of atomic energy under the auspices of the International Atomic Energy Agency was phased out last August after five years of successful operation. This was the IPA project, so called after its sponsors, India, Philippines and the Agency, which was established to provide facilities for training and research on neutron diffraction for scientists from Member States of the Agency in South Asia, South East Asia and the Pacific, and the Far East. India helped to initiate the project by the loan and subsequent donation of a neutron crystal spectrometer and the assignment of Indian experts. The Philippines provided the supporting facilities, including the 1-MW research reactor in the Philippine Atomic Research Center in Quezon City where the project was set up. The Agency, for its part, contributed financial assistance to defray the travel and living expenses of the Indian experts and provided fellowships for participants.

15. Eleven scientists and technicians from Indonesia, Korea, the Republic of China, Thailand and the Philippines received intensive training under the programme on the installation, operation and use of the neutron crystal spectrometer. Most of them now have their own neutron diffraction projects in their respective centres. In Indonesia and the Philippines at least, participation in the project has resulted in the building of their own spectrometers.

16. The high quality of the research work done under the programme is attested to by some 20 reports and papers that have been produced. Results of studies have been published in the following journals: Nuclear Instrumentation and Methods, Physical Review and Philippine Nuclear Journal. Two recent papers have been submitted for publication in Acta Crystallographica.

17. But over and above these specific achievements, it is believed that the greater importance of the IPA project lies in the fact that it successfully demonstrated a practical approach towards promoting regional co-operation in Asia. Encouraged by this success the Agency convened last March in Manila a meeting to assess the possibility of organizing a new project to replace the IPA project. Participants in the meeting recommended a co-operative project in nuclear science on a wider scale. The proposal has been transmitted to the countries concerned and it is gratifying to note that a number of them have already officially agreed with the recommendations.

AGENCY ASSISTANCE

18. As in past years, the Agency was the chief source of technical assistance for atomic energy work in the Philippines. It made available to the Commission the services of one expert in radioisotope production, one expert in neutron diffraction, one expert in activation analysis, and a fourth one in food preservation. Equipment provided included a multi-channel analyser, cryogenic equipment and a portable X-ray fluorescence analyser with a total value of more than $35 000. Ten new fellowships requested by the Philippine Government were approved.

19. In addition, the Agency awarded two new research contracts on gamma irradiation of foodstuffs and fish, worth $7500. Five research contracts were renewed. They related to studies on the sorptive and exchange capacity of tuff, studies on the nutrition of the coconut palm, studies on the

effects of ionizing radiation on certain Philippine fruits, studies on the effects of neutron irradiation on seeds and studies on the use of induced mutation in rice breeding. The latter contracts involve an additional award of $ 19 200.

AGENCY MEETINGS

20. The Philippines was host to three Agency meetings held consecutively in Manila. They were the Panel on the Utilization of Reactor Centres in Training Staff for Nuclear Power Systems, held from 10 to 13 March, the Organizational Meeting for a Regional Co-operative Project to Succeed the IPA Project, held from 14 to 16 March, and the Study Group Meeting on Research Reactor Utilization, held from 17 to 20 March. Fourteen countries were represented at these meetings.

21. An FAO-IAEA Visiting Seminar on Food Irradiation was held in Manila from 30 to 31 January.

10. POLAND

Advances in the peaceful uses of nuclear energy

GENERAL BACKGROUND

1. Research in Poland on nuclear energy and its peaceful applications is co-ordinated and directed by the Office of the Government Plenipotentiary for Applications of Nuclear Energy, which was created in 1956. The Institute for Nuclear Research (Institut Badań Jądrowych) (IBJ) is the main research and technical centre. It has laboratories at Swierk (30 kilometres from Warsaw), Zerań (a suburb of Warsaw) and in the centre of Warsaw, where the Departments of Warsaw University, which co-operate with it, are also situated. In Kraków-Bronowice there is the Institute of Nuclear Physics (Institut Fizyki Jądrowei) (IFJ), which co-operates with the Departments of the Jagellonean University and with the Institute of Nuclear Techniques of the Academy of Mining and Metallurgy (Institut Techniki Jądrowei, Akademia Górniczo-Hutnicza) (ITJAGH), both in Kraków. The Department of Physics of Lódź University and the Institute of Radiation Chemistry of Lódź Technical University have arrangements for co-operating with the appropriate centres at IBJ. Nuclear research and work on the separation of stable isotopes are carried out by the Physics Department of M. Curie-Skłodowska University at Lublin. Some problems concerning radiochemistry and radiation chemistry are being studied in the Institute of Low-Temperature and Structural Research (Institut Niskich Temperatur i Badań Struktury) (INTBS) of the Polish Academy of Sciences at Wroclaw and in Wroclaw University, and at Warsaw University and the Technical University of Warsaw.

2. Work on problems of radiological protection is concentrated at the Central Radiological Protection Laboratory (Centralne Laboratorium Ochrony Radiologicznei) (CELOR) in Warsaw. The construction and design of nuclear equipment and installations on an industrial scale are the responsibility of a special Centre for Nuclear Technique Installations (Biuro Urzadzen Techniki Jądrowei) (BUTJ), which exercises control over a number of industrial establishments.

BASIC RESEARCH

Nuclear physics

3. Basic research in physics is carried out in three main disciplines: low- and intermediate-energy physics; high-energy and elementary-particle physics; and liquid- and solid-state physics.

4. Studies relating to *low- and intermediate-energy* physics are carried out with a 3-MeV Van de Graaff accelerator, a 600-KeV cascade accelerator, the C-48 cyclotron and the W-120 cyclotron (25 MeV for alpha particles), fast neutron generators and the 10-MW EWA light water reactor. International co-operation, in particular with the Joint Institute for Nuclear Research (JINR) at Dubna near Moscow, provides a sound basis for the development of research, making available the advantages of the unique U-200 and U-300 heavy-ion accelerators, the 600-MeV synchrocyclotron and the 10-GeV proton synchrotron. This work involves the investigation of nuclear reactions and the use of nuclear spectroscopy, and is concerned with the structure and dynamics of atomic nuclei, especially deformed nuclei. In recent years work on this subject has been extended, particularly to reactions with heavy ions.

5. Research on *high-energy* and *elementary-particle* physics is conducted almost exclusively on the basis of extensive international co-operation, principally with JINR, the Institute of High-Energy Physics (IHEP) at Serpukhov, the European Organization for Nuclear Research (CERN) at Geneva and the

High-Mountain Laboratory (HML) at Ararat in Armenia (USSR). Particularly valuable is the recently developed co-operation with IHEP, which possesses the world's biggest protonsynchrotron (76 GeV), offering unique opportunities for research.

6. The work relating to the physics of *hyperfragments* and the *fragmentation* of atomic nuclei is the continuation of research which started in 1952 with the discovery in Poland of the first hyperfragment. This work is being conducted in co-operation with JINR, IHEP and CERN.

7. The research on *high-energy particles* is carried out in co-operation with JINR, IHEP, CERN and HML. In this experimental work use is made of bubble chambers, nuclear emulsion and ionization chambers involving the use of the nuclear emulsion technique. The introduction by the Kraków centre of a bicentric model to explain reactions involving high-energy collisions and the subsequent development of this model are considered to be among the most important achievements in this field. The studies relating to large cosmic ray beams are concerned with the muon component of these beams. They have yielded data which prove the existence of a photon component having an energy of 10^{15} eV in the original cosmic radiation. Theoretical work includes studies on strong and weak reactions between elementary particles, on resonances and on symmetries. Among the more outstanding achievements have been investigations of elastic and inelastic scattering of electrons and of particles acting strongly on atomic nuclei which have made possible the uniform treatment and consolidation of many processes in the physics of elementary particles and of the atomic nucleus.

8. Work on the physics of the *condensed matter phase* has been concerned with the structure and dynamics of solids and liquids, which are investigated by using the neutron diffraction method. This work is carried out mainly with the EWA reactor at IBJ and, in particular, the IBR reactor pulsed at JINR, and also with the reactor at the Boris Kidrič Institute at Vinča (Yugoslavia). The studies of the effect of nuclear radiation upon solid-state matter and structure are carried out by using the nuclear magnetic and electron resonance method as well as the Mössbauer effect.

Nuclear chemistry

9. Basic research in chemistry is being carried out in the following three main branches: physical chemistry of radioactive elements, radiochemistry and radiation chemistry.

10. Research in the physical chemistry of *radioactive elements* is concentrated mainly at IBJ, INTBS and at Wroclaw University. The properties of uranium, thorium, plutonium, and technetium compounds are being studied. Most progress has been made in the investigation of the electronic structure and magnetic properties of uranium and technetium complex compounds. Extensive research on the structure of intermetallic compounds of uranium and of compounds of technetium with nitrogen, phosphorus, and carbon is being carried out by means of X-rays and neutronography, magnetic techniques and low-temperature calorimetry, including studies of superconducting properties of technetium alloys.

11. The investigations in *radiochemistry* are concerned first and foremost with separation processes of fission products, mainly consisting of extraction and chromatography, and are carried out at IBJ. One particular achievement has been the development of a successful method of separation of radioactive isotopes by means of reversed phase chromatography, which embraces the advantages of extraction and chromatography. Research is also being done on the chemical effects of nuclear reactions and radioactive transmutations. Among the subjects being studied are the behaviour of carrier-free radioactive isotopes, including the absorption of such isotopes on metallic surfaces, and the mechanism of chemical reactions using radioactive tracers. The structure of complex compounds and their behaviour in solution are being investigated by using the isotopic exchange method. Some work concerning hot-atom chemistry has also been done at IBJ. Research connected with the production of radioactive isotopes and highly active tracer compounds is carried out exclusively at IBJ; it is concerned primarily with isotopes produced by the (n,d) reaction and with organic compounds labelled with iodine I-131, carbon C-14 and tritium.

12. Analytical radiometric methods, mainly consisting of neutron activation analysis involving the use of thermal neutrons at IBJ and fast neutrons at ITJAGH, and the X-ray fluorescence method involving the use of X-rays generated by radioisotopic sources at ITJAGH, are being developed, with special emphasis on trace analysis and the fast control of industrial processes. Radioisotopic tracers are also widely used in controlling the unit operations when conventional analytical methods are employed.

13. Work on *radiation chemistry* is done at IBJ, at the Institute of Radiation Chemistry of Łódź Technical University and at the Technical University of Warsaw. It is concerned with the effect of ionizing radiation on matter and with the utilization of the ionizing properties of radiation for initiating chemical and other processes. Transmutations of complex compounds are investigated by employing the method of pulsed radiolysis, using a linear accelerator. The processes of radiolysis of organic compounds in liquid and frozen states in water and multiphase

systems are among the subjects being studied. Research is being carried out on oxidation and reduction processes in aqueous solutions of inorganic and organic compounds. In the study of radiation effects in inorganic solids, the phenomena connected with the production and disappearence of colour centres are attracting a good deal of attention. With regard to the possible future industrial applications, the investigation of the influence of ionizing radiation upon the catalytic properties of contacts and the investigation of polymers are being carried out. Pioneer work in Poland has been done at IBJ on degradation, polymerization, heteropolymerization, and the grafting of polymers.

REACTOR TECHNOLOGY

14. With regard to nuclear power engineering, work is being done on reactor physics and the theory of neutron transport, the utilization and modernization of reactors, nuclear metallurgy and chemistry, the design and construction of reactors, and the technology of nuclear fuel and reactor materials. The facilities being used in this work are the ligh-water, 10-MW EWA reactor at IBJ in Swierk, the graphite and water moderated ANNA critical assembly which has been in operation since 1961, and the MARYLA critical assembly put into operation in 1963. As part of the programme of co-operation with Norway and Yugoslavia under the NPY project[2], the reactors at Kjeller and at Vinča are also utilized.

15. The experimental work mainly concerns physical measurements of reactor parameters in multiplying systems as well as of physical parameters of moderators involving the use of pulsed techniques. Theoretical work on neutron transport phenomena in liquids and solids is also being carried out, in which the eigenfunction method is mainly used. Other important work consists of the elaboration of reactor codes and the carrying out of reactor calculations for the purpose of designing or comparing experiments.

16. Activities concerned with the operation and modernization of reactors have been concentrated on the EWA reactor and the ANNA and MARYLA critical assemblies at IBJ. The light water moderated EWA reactor, whose original power was 2 MW, which has been operating since 1958, has been twice rebuilt to raise its flux to 2×10^{14} n/cm^2 sec and its power to 8-10 MW.

17. A project for a high-flux beryllium and water moderated research reactor with a power up to 30 MW has been worked out. The reactor is suitable for investigations in nuclear physics, the physics of condensed matter and reactor physics, as well as for experiments in radiochemistry and radiation chemistry. It will, however, be utilized mostly for material testing in order to provide the basic data which are indispensable for building and operating power reactors. A technical project for the development of university-type, swimmingpool, 100-kW reactor, intended as equipment for future physics and reactor technology centres at universities, has been undertaken.

18. As regards the chemistry and technology of nuclear fuels and reactor materials, methods of producing some reactor materials, as well as fuel elements for the existing reactors and those under construction, are being elaborated. The necessary analytical control methods have been worked out. Some preparations are being made for fuel reprocessing. The construction materials are examined and specifications for them drawn up.

NUCLEAR EQUIPMENT AND INSTALLATIONS

19. Nuclear equipment production in Poland is mainly concentrated at BUTJ and IBJ. IBJ carries on its activities through three experimental centres producing special equipment on an individual basis, as well as prototype equipment intended for serial production. One of these centres also produces and distributes radioactive isotopes. BUTJ is an enterprise comprising a number of establishements; it manages six production facilities and six training centres for radioisotopic techniques located in the main industrial areas of the country. Working closely with IBJ, BUTJ is responsible for manufacturing equipment developed in IBJ as well as in its own laboratories.

20. The following items of equipment are being produced in Poland:

(a) Apparatus for laboratories using physical and nuclear techniques, including neutron spectrometers, gamma spectrometers, reactor equipment components, helium cryostats, and low-remperature plasma physics equipment;

(b) Dosimetric equipment of wide application, such as radiation detectors, therapeutical dosimeters, thermoluminescence dosimeters with reading devices, and contamination dosimeters;

(c) Radioisotope equipment for industrial purposes, including transistor level gauges, thickness gauges for cold-rolled strip, single-point relays, densitometers, and measuring instruments for the paper industry;

(d) Special equipment for radiochemical laboratories: glove boxes, radiochemical laboratory furniture, manipulators, etc; and

2) Co-operative research project in reactor physics between the Agency and the Governments of Norway, Poland and Yugoslavia; the agreement relating to the project is reproduced in document INFCIRC/55.

(e) A wide variety of radioactive isotopes, sealed sources indluding alpha, cobalt-60 and iridium-192 sources, as well as organic compounds labelled with carbon-14, phosphorus-32, iodine-131 and tritium.

APPLICATION OF RADIOISOTOPIC TECHNIQUES

21. In view of the possibility that they represent a source of important economic advantage, radioisotopic techniques are finding ever greater application in Poland. They are ousting or complementing conventional methods of measurement and control of production processes. In various sectors of the national economy several thousand instruments and devices involving the use of radioisotopic techniques are being utilized. The new techniques which are already being used and are most promising include the following:

(a) The measurement and regulation of physical parameters, such as thickness, density, level, and load;

(b) Radiometric methods of chemical analysis, particularly neutron activation and X-ray fluorescence generated by radioactive sources;

(c) Autoradiography for non-destructive testing of castings and welds; and

(d) The use of radioactive tracers for studies of technological processes, e.g. agglomeration, calcination, materials flow in rotary and shaft furnaces etc.

22. Successful results have been achieved in all these applications. Radioisotopic techniques are now being applied systematically in heavy and light industries in the chemical industry and in food production. They are widely applied in coal mining, where they afford solutions to a number of problems of automation and regulation in output processes, e.g. vertical and horizontal transport. In the chemical industry they constitute the most modern methods of measuring various physical parameters. The paper industry is making successful use of isotopic thickness gauges in the wet and dry stages of the production process, as a preliminary to automation. The results obtained in the use of such equipment in training facilities and in experimental operations serve as a basis for the design and production of new apparatus.

23. The use of radioisotopes in medicine started in Poland in the 1930s with the establishment of the Radium Institute in Warsaw, to which Maria Curie-Skłodowska presented the first gram of radium. This Institute is still the leading centre of cancer research in Poland. Following the development of radioisotopic techniques used in medicine for research, diagnosis and treatment, a large number of clinics and hospitals introduced these techniques into routine practice.

PROTECTION AGAINST RADIATION

24. The technical and scientific problems of radiation protection are dealt with mainly by CELOR, whereas the medical problems are handled by the Ministry of Health and Social Welfare. The principal activities in this connection are the following:

(a) Research dealing with radiological safety, radioactive pollution of the environment and radioactive waste treatment, including the development and design of necessary equipment;

(b) Training of radiation protection staff;

(c) Personal dosimetry;

(d) Prophylactic medical examination;

(e) Supervision of the use, storage and transport of radioactive substances; and

(f) Supervision of the use of nuclear techniques and of installations containing sources of ionizing radiation.

The treatment, storage and disposal of radioactive waste is the concern of the Central Office for Radioactive Waste at IBJ.

11. SOUTH AFRICA

Summary of nuclear research work: 1968-69

INTRODUCTION

1. Details of the South African nuclear research programme have been described in an earlier summary[3]. During the past twelve months the research facilities available have been supplemented in two important respects:

(a) The power of the Atomic Energy Board's research reactor SAFARI I has been raised to the full design rating of 20 MW, and the reactor is now regularly operated at powers of between 10 and 20 MW according to demand; and

(b) A new 18000 curie cobalt-60 radiation source has been fully commissioned and is in regular use for radiation chemistry experiments. Its main purpose, however, will be the study of potential large-scale applications of radiation such as sterilization, chemical processing and food preservation.

2. In addition a universal rig for the reactor has been acquired and will be used primarily for the irradiation of locally produced fuel samples under varying conditions.

3. These acquisitions have added yet further impetus to the various aspects of nuclear research being undertaken in the Republic, and the following status report may be of interest to Member States working along parallel lines.

NUCLEAR POWER

4. Following on the completion early in 1968 of the first report on the economic feasibility of introducing nuclear power in South Africa, work on the second phase of the investigation is now well advanced. These studies include the consideration of enriched-fuel reactor systems, and should be completed by the end of 1969.

5. The Electricity Supply Commission's Nuclear Power Section is now making active preparations for South Africa's first nuclear power station, which should be in operation in 1978. In preparation for this the Atomic Energy Board has formed a Site and Installation Licensing Division which is formulating licensing philosophy and procedures.

NUCLEAR MATERIALS

6. The mining industry drilled more than 130000 feet during 1968 in its search for uranium, and some of the promising results are being further investigated. The number of applications for prospecting rights, from mining companies and from private individuals, is increasing considerably.

7. Research work on the Purlex process[4], for extracting high-purity uranium direct from gold-plant slurries, has now been completed and several mining companies are taking steps to install full-scale Purlex-type plants. The "Felix" project for improving leaching efficiency at reduced cost has successfully reached the pilot plant stage. This process aims at the more efficient use of oxidizing agents in the acid leach system, the agent used being ferric sulphate.

8. The UO_2, UF_4 and UF_6 experimental programmes are approaching finality and it is now possible to produce UO_2 pellets of high standard on a pilot plant scale. The moving-bed UF_4 reactor of the Nuclear Fuels Corporation is now operating successfully, and a detailed study of the possibilities of producing UF_6 in South Africa is nearing completion.

9. Work on the specification of high-purity, nuclear-grade uranium, was concluded. Methods are being developed and equipment commissioned for the analysis of large numbers of geological samples on a routine basis by neutron activation techniques.

HEALTH AND SAFETY

10. An interesting study now being carried out relates to the dispersion and dilution of air-borne effluents. Inactive tracers are being used for the study, and the subsequent fall-out is measured by activation analysis. The results will be applicable to problems connected with accidental release of activity from reactors, as well as to conventional air pollution.

3) See document GC(XI)/INF/97/Rev.1., statement H.

4) See document GC(XII)/INF/101/Rev.1., statement 24, para. 4.

11. The International Pneumoconiosis Conference, held in Johannesburg early in 1969, included a session on radon hazards in uranium mining and processing. This subject is of special interest in the study of South African mining conditions.

REACTOR PHYSICS

12. The first experiments on the critical assembly PELINDUNA-ZERO, involving the measurement and analysis of reactor physics parameters on a four-element assembly, have now been completed. The assembly is now being changed to an arrangement of seven shorter elements, a mock-up of the original PELINDUNA power reactor design.

RADIOISOTOPE PRODUCTION

13. Apart from the increased experimental capacity now available in the reactor SAFARI I as a result of its increased power, it is now also possible to expand the manufacture of radioisotopes considerably to satisfy the rapidly increasing demand for them in South Africa. Evidence of their increasing use can be found in import figures for 1968, when the total imports of radioisotopes into South Africa amounted to 28 682.1 curies as compared with 11 077.5 curies in 1967.

14. South Africa continues to maintain a small but significant export of specialized neutron-deficient isotopes made by the Council for Scientific and Industrial Research. These include isotopes such as beryllium-7, cadmium-109, cerium-139, sodium-22 and strontium-85.

BIOLOGICAL STUDIES

15. Among research projects completed has been an investigation into the extracorporeal irradiation of blood, the preliminary results of which were presented at an international symposium on the clinical and experimental use of extracorporeal irradiation at the Weizmann Institute in Israel. In addition, work first begun a few years ago to develop improved methods of scanning the placenta in pregnant women with the aid of radioactive compounds has resulted in publication of two such methods which have been favourably received. Yet another method is now being investigated.

16. The studies on carbohydrate derivatives, aimed at the production of a synthetic antibiotic, continued. Preliminary studies on the addition of acyl nitrites to 1.2-unsaturated sugars, and the investigations of various chemical transformations of the adducts have presented a facile route to the required compounds. A paper on this aspect of the work has been submitted for publication.

17. Limited though South Africa's nuclear research activities may be in relation to those of some of the larger advanced Member States, they are nevertheless vigorous and it is clearly evident that they yield tangible results of benefit both to herself and to the world in general. The Government of the Republic remains willing to collaborate with Member States working in similar fields and in particular to entertain requests for technical assistance from developing countries, especially those in the region of Africa and the Middle East.

12. SWEDEN

Progress in the peaceful uses of nuclear energy in 1968-69

NUCLEAR POWER DEVELOPMENT

1. Last year the ordering of two large power stations, Ringhals 1 and Ringhals 2, was reported to the General Conference[5]. This development, which reflects the rapid progress being made in carrying out the Swedish nuclear power programme, continued this year when two new power stations were ordered, this time by the private utilities, Oskarshamns Kraftgrupp AB and Sydkraft. The two reactors, Oskarshamn 2 and Barsebak 1, are almost identical and are to be delivered by the Asea-Atom company and the turbines by Brown Boveri/Stal-Laval. The net electrical output from the stations are calculated at about 580 MW each.

2. The State Power Board and the private power companies have made a new study of the estimated growth of nuclear power in Sweden as well as the size and locations of the nuclear power stations. According to this study Sweden will in the year 1980. have about 7500 MW installed. The actual stations are given in the following table.

5) See document GC(XII)/INF/101/Rev.1, statement 26, para. 2.

Swedish nuclear power stations ordered and planned

Name	*Owner*	*Electric Power MW(e)*	*Type of Reactor*	*Start of Operation*
Ordered				
Agesta	Stockholms Elverk/Swedish State Power Board	10	Pressurized heavy water	1964
Marviken	Swedish State Power Board	140	Boiling heavy water	1970
Oskarshamn 1	Oskarshamnsverkets Kraftgrupp AB	440	Boiling water	1970
Ringhals 1	Swedish State Power Board	760	Boiling water	1973
Ringhals 2	Swedish State Power Board	830	Pressurized water	1974
Oskarshamn 2	Oskarshamnsverkets Kraftgrupp AB	580	Boiling water	1974
Barsebäck 1	Sydkraft AB	580	Boiling water	1975
Planned				
Swedish East Coast	Swedish State Power Board	750		1976—77
Vårtan, Stockholm	Stockholms Elverk	500		1976—77
Barsebäck 2	Sydkraft AB	750		1977—78
Swedish East Coast	Swedish State Power Board	750		1978—79
	Swedish State Power Board	750		1978—79
	Swedish State Power Board	750		1979—80

The siting of large nuclear power stations for combined district heating and electricity production close to population centres is of great interest to Sweden and is at present being studied.

AB ATOMENERGI

3. The formation of Asea-Atom has resulted in a reorganization of AB Atomenergi. From the middle of this year the company has been wholly State owned. As mentioned last year, it will concentrate its activities in its research station at Studsvik. The direct participation in industrial reactor projects will gradually decrease and the company will devote its resources to the support of the nuclear manufacturing industry and the power utilities as well as to long-range research and development work.

4. The Marviken reactor is now in its final stage of construction and will become critical around the end of this year or the beginning of next year.

5. The company's uranium mill at Ranstad, using shale with only 300 grams of uranium per metric ton, has been a technical success and the plant has a capacity of around 140 metric tons of uranium per year. In comparison with the needs of the total Swedish nuclear programme during the late 1970s, this production is much too low. It has been decided to carry out a three year study with a view to achieving further development of the process and a reduction in the cost of production and a project study of a plant producing about 1000 tons per year.

ASEA-ATOM

6. The Asea-Atom company now has the following reactors ordered or under construction: Oskarshamn 1, Ringhals 1, Oskarshamn 2 and Barsebäck 1. Fuel for these reactors as well as to fulfil some export orders will be manufactured at the company's fuel element plants. The above-mentioned four reactors are all of the boiling light-water type and represent a total power of 2350 MW(e).

UDDCOMB SWEDEN

7. In order to increase the manufacturing resources in Sweden for steel pressure vessels for water reactors a new company, Uddcomb Sweden Aktiebolag, was formed in the beginning of July as a joint enterprise between the Swedish State, Uddeholms AB and the American company, Combustion Engineering Inc. The Swedish State owns half of the shares of the company and the two other participants one quarter each. The company will manufacture and sell heavy components for nuclear power stations and the chemical industry.

CO-OPERATION BETWEEN THE NORDIC COUNTRIES

8. For a number of years the Nordic countries have been co-operating in the nuclear energy field. The co-operation takes place within the framework of a co-ordination committee which was set up by the Nordic Contact Committee for Atomic Energy Questions. The work is performed within several fields of mutual interest such as heat transfer and dynamic flow tests of full-scale fuel elements, reactor dynamics, concrete pressure vessels, heavy water reactors and nuclear safety.

The possibility of increased collaboration is being studied in the present negotiations between the Nordic countries regarding a common economic market.

13. UNITED KINGDOM OF GREAT BRITAIN AND NORTHERN IRELAND

Advances in nuclear energy: 1968-69

INTRODUCTION

1. To equip the British nuclear industry to meet the increasing demands that will be made upon it at home and from abroad, the design resources of the various industrial organizations and the United Kingdom Atomic Energy Authority (UKAEA) are being concentrated into two design and construction companies, The Nuclear Power Group and British Nuclear Design and Construction Limited. These two companies are formed from firms of wide experience which cover the whole technological spectrum necessary to the successful design and construction of complete nuclear power stations, and are equipped to deal with all existing and future British reactor systems. Thus, effective competition within the United Kingdom will be retained along with a more efficient and economical integration of technological and industrial resources. It is also planned to create an independent nuclear fuel company from the UKAEA's fuel production organization. These new companies will continue to be supported by nuclear research and development establishments with a total staff of about 20 000. The Government believes that the new arrangements will facilitate the forging of industrial links abroad, now that nuclear power production is a commercial matter.

NUCLEAR POWER PROGRAMME

2. The proportion of electric power which is generated in the United Kingdom by nuclear power stations continues to increase. Wylfa, the ninth Mark I gas-cooled (MAGNOX) station in the first nuclear power programme, will come on power in the next few months. The reliability of these stations is impressive. After two or three years of operation, their annual load factors average upwards of 80%. Their monthly load factors are often much higher, sometimes exceeding 100% of designed output capacity.

3. The second nuclear power programme based on the Mark II advanced gas-cooled reactor (AGR) system is making good progress, with four stations totalling about 5000 MW(e) currently under construction at Dungeness 'B', Hartlepool, Hinkley Point 'B' and Hunterston 'B'. The Hartlepool station is being built within five miles of where nearly 200 000 people are living. This follows acceptance by the Minister of Power and the Secretary of State for Scotland of the advice of the Nuclear Safety Advisory Committee that the safety of a gas-cooled reactor in a prestressed concrete pressure vessel is such that it may be constructed and operated much nearer built-up areas than hitherto permitted in the United Kingdom. In addition, the Central Electricity Generating Board has increased its assumption (for accountancy purposes) as to the life of AGR power stations from 20 to 25 years as a result of satisfactory experience of the Windscale AGR.

NUCLEAR FUEL SERVICES

4. The past year has seen a considerable expansion of the UKAEA's production and commercial activities. Fuel production for existing United Kingdom power reactors reached a peak, new oxide fuel manufacturing plant was brought into operation and additions were made to the UKAEA's reprocessing capacity.

5. Throughput of the Springfields uranium hexafluoride production plant has significantly increased. The new plant is now proved and is capable of meeting all requirements for feed material to the Capenhurst enrichment plant and in addition is being used increasingly for the conversion of overseas customers' uranium ore concentrate to uranium hexafluoride for subsequent enrichment. The new oxide fuel plants are producing fuel for the United Kingdom AGR programme and are being used to

manufacture fuel for water reactors both at home and overseas. A fast reactor plutonium fuel fabrication plant is scheduled to be in production in 1970 to meet the fuel requirements of the prototype fast reactor at Dounreay.

6. A plant for the assembly of MAGNOX fuel under licence from the UKAEA has been built and commissioned at Rotondella in Southern Italy by Combustibili Nucleari, a joint company formed by Somiren (E.N.I.) and the UKAEA. The plant will produce fuel for the Latina reactor.

7. The new head-end plant at Windscale is now operational. This facility, in conjunction with the reprocessing plant, will be used to reprocess irradiated oxide fuels from reactors at home and overseas.

8. Substantial capacity has now been added to the Capenhurst enrichment plant as part of its programme of expansion to provide the necessary enriched uranium for AGR fuel. Development of the gas-centrifuge process for enriching uranium has been brought to the stage where the United Kingdom believes it can successfully be used on a production scale. The United Kingdom Government has therefore entered into negotiation with the Governments of the Federal Republic of Germany and of the Netherlands — where work on the centrifuge has also been going on — with a view to collaboration by the three countries in the establishment of uranium enrichment plants, using the centrifuge process, in Western Europe. Negotiations are proceeding and given their successful conclusion it is envisaged that two jointly-owned enrichment plants will be built — one in the United Kingdom, the other in the Netherlands. Thought is also being given to the ways in which other countries might be associated with the enterprise once it has been set up.

REACTOR DEVELOPMENT

9. Work continued during the year on the development of the Mark II AGR, and effort has been concentrated mainly on confirmation of fuel design. The Windscale AGR, which has now operated for over six years with an availability of nearly 85%, has been used extensively for testing fuel for the reactor power stations operated by the regional generating boards. In addition, there has been continued work aimed at the exploitation of the considerable development potential of the AGR system. This work has confirmed the economic advantages of AGR reactor designs using fuel in the form of graphite-coated particles, and a development programme has been initiated using low-enriched coated-particle fuel in graphite tubes cooled by helium.

10. Faulty operation of the water purification plant associated with the steam generating heavy water reactor (SGHWR) at Winfrith, which caused deposition of solids on the fuel elements, with consequent failure of the cladding material of some fuel elements, has now been rectified. Apart from the consequences of this malfunctioning of the water purification plant, SGHWR has performed very well and has generated almost 500 million units of electricity since it achieved full power in January 1968. Design studies have been completed for full-scale SGHWR stations which would use fuel operating at a higher specific power than that at present in use at the Winfrith reactor. Experimental operation of certain fuel channels at Winfrith at these higher ratings has confirmed their suitability for full-scale use.

11. The Dounreay fast reactor has been used throughout the past 12 months as a fast-flux testing facility. Irradiation space in the reactor has been used by many countries for the irradiation testing of their fast reactor fuel elements. The irradiation experience with fast reactor fuel elements is increasing steadily and shows that the prospects for this reactor system are good. Experience with the handling of sodium and with the development of fast reactor components continues to grow at an increasing rate. The construction of the 250-MW(e) fast reactor at Dounreay was delayed owing to difficulties in welding the roof of the biological shield: this is a conventional engineering structure, and detailed changes in design and manufacture will prevent any recurrence of the problem in future reactors. While construction of the reactor has been continuing, laboratory and irradiation experiments have confirmed the design and performance characteristics selected for the first fuel charge. Work has continued during the year on a series of fast reactor designs for full-scale generating stations.

DESALINATION

12. The United Kingdom is ideally situated in having both nuclear power and desalination development programmes. This puts Britain in a special position with regard to the development of nuclear desalination techniques. During the year a British firm obtained the order for what will be by far the largest electrodialysis unit in the world. Research continues into the problems of various systems of desalination with the participation of the UKAEA and various companies in this field.

MARINE PROPULSION

13. Work has continued on the burnable poison pressurized water reactor which might find particular application in ships. Government departments are carrying out economic studies of nuclear ships for

a range of applications and powers. The UKAEA, in conjunction with a ship-building firm, has studied in detail a scheme for a container ship of 40 000 shaft horse-power.

NUCLEAR RESEARCH

14. A reassessment of the UKAEA's longer term research programme as a consequence of the achievement of economic nuclear power resulted in a reduction and a change in emphasis in much of the work. The Harwell reactor BEPO was closed down in December 1968 after twenty years of valuable operation, and closure of the Dounreay materials testing reactor followed in May 1969.

15. The primary aim of the longer term research programme is to study the effects of irradiation and impurities on the mechanical, physical and chemical properties of materials of interest for the reactor and applied research programmes. Specific areas which have so far received attention include radiation-induced void formation in metals and structural changes in refractory ceramic oxides, as well as the effect of radiation on the reactivity of water and carbon dioxide, and the strength and cohesion of multiphase alloys and composites.

16. Increasing use is being made, especially by universities, of neutron beam equipment to study interatomic forces and atomic motions, magnetic structure and other atomic and physical properties. Notable progress has also been made in physical and chemical studies of all the types of nuclear reactions of importance in reactor technology.

17. Nuclear fusion research at the Culham Laboratory continues to be carried out in accordance with the programme. There is a full exchange of imformation between the Culham Laboratory and the principal world laboratories engaged in this field. Over-all plasma confinement times continued to increase and show promise that the confinement needed for a fusion reactor can be realized.

18. During the year experiments on ZETA, the first major toroidal device for the containment of high temperature plasma, were brought to a successful conclusion; work has continued on two other closed-line devices, a small stellarator and a toroidal multipole. Valuable results are also being obtained on simpler open-ended systems such as the 8-metre thetatron and the magnetic mirror machines.

19. Advances in the densities, temperatures and containment times of plasma in all these devices have been recorded, as well as excellent progress in the basic understanding which is essential in order to extrapolate from the present-day experiments to fusion reactors, the technology of which is now being actively studied.

20. The UKAEA has continued to exploit the use of radioactive isotopes and radiation in solving problems of importance to industry. The package irradiation plant at Wantage was increased in irradiation strength to meet the demands for sterilization of medical supplies and animal foods. Laboratory animal feeding studies designed to reveal any toxicity of irradiated fish were completed and similar toxicological studies were carried out on irradiated meat intended for pet food. Industrial interest is growing in the use of radiation for polymerization in situ of plastic-impregnated wood; and expertise in the electro-chemical field was successfully applied to several specific electroplating problems. Radioactive tracer techniques were applied to problems of water flow, conservation and supply, and to sediment movement in the sea and in estuaries.

21. The isotope-heated thermoelectric generator programme RIPPLE is nearing completion. All the prototype generators have performed exactly as predicted, powering off-shore marine lights and a navigational beacon; and a generator system has been developed which can be assembled to give generators of any power between 8 and 64 watts. An encapsulation plant for strontium-90 titanate is nearing completion.

INTERNATIONAL COLLABORATION

22. United Kingdom policy continues to be to collaborate to the full in the peaceful uses of atomic energy, both through international organizations such as the International Atomic Energy Agency, the European Nuclear Energy Agency and the European Community, with which the UK-EURATOM agreement has been extended, and bilaterally.

23. The United Kingdom has thus continued to support the Agency by the provision of voluntary financial contributions, material, experts, fellowship places, and consultants, and to participate fully in all its activities. The exchanges of information conducted by the Agency are regarded as of the greatest importance, as is the technical assistance afforded by the Agency. Of major importance to the safe and progressive expansion of the peaceful uses of nuclear energy is the Agency's safeguarding responsibility. The United Kingdom participates to the full in the relevant Agency studies and developments in this field, to which it brings considerable operational experience, while continuing research and development on procedures and methods relevant to the current expansion of the nuclear industry, and to the requirements of the Treaty on the Non-Proliferation of Nuclear Weapons.

24. During the year the United Kingdom Government signed a new agreement with the Government of Chile, and agreements with Finland and Japan came into force. A trilateral safeguards agreement with the Agency and Japan came into effect. In addition the UKAEA now has agreements for collaboration with organizations in 18 countries.

14. VIET-NAM

Progress in the peaceful uses of nuclear energy in 1968-69

INTRODUCTION

1. During the past year the regular activities have been proceeding in a normal manner. Research activities, on the other hand, have suffered to some extent from the manifold difficulties due to the war and break-down of the irradiation device in the VNR-1 reactor.

REGULAR ACTIVITIES

2. The regular activities included:

(a) Production of radioisotopes for local needs;

(b) Diagnosis of disorders of the thyroid gland by the radioactive method;

(c) Treatment of cancerous tumours by gamma rays;

(d) Monitoring of the radioactivity of air and water;

(e) Personnel monitoring by photographic films;

(f) Monitoring at facilities using ionizing radiation sources, as a part of the activities of the National Radiation Protection Commission.

RESEARCH ACTIVITIES

3. Research activities were restricted mainly to the applications of nuclear energy in medicine and agriculture.

4. Studies on primary cancers of the liver in Viet-Nam were undertaken in the Isotope Laboratory of the Cho Rây Hospital under a research contract with the Agency.

5. Under another research contract with the Agency, the Nuclear Research Centre at Dalat and the Radioisotope Laboratory of the Directorate of Agricultural Research participated in the Co-ordinated Programme of Research on the Use of Induced Mutations for Rice Improvement.

6. In the field of fundamental research, the Science Faculty of Saigon is beginning to develop research in nuclear physics.

7. The Nuclear Research Centre at Dalat carried out technical studies on the feasibility of installing a 5000-curie cobalt-60 gamma source for preservation of foodstuffs.

8. Following the stimulus given by the Sub-Committee on Energy Resources and Electric Power, which met in Singapore in 1968, we have studied the technical and economic aspects of introducing nuclear electric power in Viet-Nam.

TRAINING AND EDUCATION

9. During 1968 Viet-Nam benefited from a number of training and advanced training fellowships awarded by the Agency and friendly countries. The local training of nuclear technicians and scientists was, however, not neglected; the teaching of atomic and nuclear physics was included in the syllabus of the Science Faculty of Saigon and an introductory course on radioactive techniques was held at the Pharmaceutics Faculty of Saigon.

10. With a view to facilitating teaching, the Atomic Energy Office published a "Glossary of Nuclear Terms" in Vietnamese as a part of the activities of the National Commission for Scientific Terminology. In addition, a French-Vietnamese nuclear dictionary is in the press.

11. Finally, the problem of popularization of the nuclear sciences continues to receive our full attention. A book entitled "The Atomic Treasure" has been published in Vietnamese in order to acquaint the general public with the benefits of uranium fission.