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

Statements by Member States

Note by the Director General

1. In a circular letter sent to the Governments of Member States on 30 June 1967 the Director General referred to a suggestion made at the General Conference's session in 1966 to the effect that Members might like to provide for future sessions statements on the progress they had made during the preceding year in the peaceful applications of nuclear energy [1]. He invited Governments that so wished to provide him with such statements for incorporation in an information paper for this year's session.

2. By 18 September six Governments had responded to the invitation, and the statements they have provided are reproduced in the attachment to this document.

1) See document GC(X)/OR.107, para. 127.

A. GERMANY, FEDERAL REPUBLIC OF

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

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

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

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

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

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

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

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

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

37 per cent on international co-operation:

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

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

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

2 per cent on radiation protection and nuclear safety.

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

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

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

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

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

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

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

4. Fast breeder development is nearing industrial exploitation

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

The TRIGA Mark I, a homogeneous reactor of the German cancer research centre at Heidelberg, which is also used for burn-up measurements on spherical fuel elements for the Jülich reactor, as well as the SNEAK facility at Karlsruhe, wich is of importance to the neutron physics of fast reactors, went critical for the first time during the period under review.

Three research reactors are established at universities, 14 at research institutes outside the universities, whereas eight of the ten small training reactors are installed at universities or schools of engineering.

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

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

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

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

9. Progress in biology, medicine and radiation protection

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

10. International co-operation

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

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

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

B. JAPAN

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

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

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

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

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

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

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

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

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

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

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

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

B. Outline of nuclear power development

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

I. Nuclear power generation

12. With the rapid progress in the technology of nuclear power generating plants, which has subsequently been followed by improved economics of the plants, much interest and expectation have been shown in nuclear power generation as the most promising energy source in the future of Japan.

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

14. The outline of these three light-water-cooled nuclear power plants is as follows. The first one is the 322 000-kW(e) boiling-water reactor which

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

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

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

II. Development of power reactors

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

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

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

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

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

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

III. Nuclear fuel

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

which has hitherto been in governmental ownership. The necessary measures for implementing the policy are now under consideration within the Government.

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

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

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

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

IV. Nuclear-powered ship

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

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

V. Radiation Utilization

30. Since the early stage of atomic energy utilization in Japan, radiation has been widely used in various fields, ranging from basic science to medicine, agriculture and different branches of industry. The number of firms utilizing radioisotopes and particle accelerators reached 1 425 at the end of March 1967; many of these firms are provided with radiation generators such as particle accelerators, the total number of installations reaching 178.

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

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

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

C. NEW ZEALAND

Atomic Energy in New Zealand

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

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

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

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

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

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

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

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

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

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

In 1966 the Auckland Hospital Board entered into a contract with the Agency to carry out investigations in Nepal relating to endemic goitre. This work was featured in the *IAEA Bulletin* of June 1967.[1]

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

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

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

D. SOUTH AFRICA

Nuclear Research in South Africa

Summary

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

South African Nuclear Research: Facts and Figures

Universities undertaking nuclear research:

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

Capital cost of National Nuclear Research Centre, Pelindaba:

R10 630 000 (Approx. $15 000 000)

Main facilities of the Atomic Energy Board:

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

Staff employed by the Atomic Energy Board:

749 (as at 30 June, 1967)

E. SWEDEN

Recent developments in the Swedish nuclear power programme

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

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

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

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

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

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

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

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

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

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

F. UNITED KINGDOM OF GREAT BRITAIN AND NORTHERN IRELAND

Advances in nuclear energy — 1966/67

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

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

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

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

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

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

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

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