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ADVANCES IN THE APPLICATION OF NUCLEAR ENERGY FOR PEACEFUL PURPOSES

Information received from Governments

By 4 September 1975, the Director General had received from five Governments, for the information of the General Conference, material on the advances made in their respective countries during the year 1974-75 in applying nuclear energy for peaceful purposes. The material in question is reproduced below. That of other Governments will be reproduced in addenda to this document as it is received.

BELGIUM

1. Progress in the peaceful uses of nuclear energy in Belgium is slow but sure.

2. The first Belgian power reactor, the BR-3, which went critical in August 1962, is installed in the Nuclear Energy Study Centre (CEN/SCK) at Mol. It is a pressurized water reactor (PWR) with a capacity of about 11 MW(e), and has been used to train a large part of the operating staff for the commercial units now being exploited by Belgian power producers.

3. In October 1966, the Franco-Belgian power reactor at Chooz, France, was put into service. This 266 MW(e) PWR is installed in the nuclear power station of the Franco-Belgian Nuclear Power Company of the Ardennes (SENA). In 1974 the reactor power was increased to 280 MW(e).

4. An important event in the Belgian power sector was the commissioning, on 18 July 1974, of the first Belgian commercial nuclear power station - the Doel 1 station - equipped with a 393 MW(e) PWR. The station was connected to the grid on 28 September 1974 and full power was reached on 2 April 1975.

5. This event was soon followed by the commissioning of the 870 MW(e) nuclear unit of the Tihange power station, belonging to the Belgian-French Mosane Nuclear Power Company (SEMO). The reactor at this power station went critical on 21 February 1975 and, after being connected to the grid on 5 March, reached its maximum power (100%) on 30 July 1975.

6. When the second 393 MW(e) Doel unit - Doel 2, connected to the grid on 21 August 1975 - becomes fully operational in 1976, nuclear fuel will account for almost 19% of the country's electric power production.

7. The nuclear power programme of the Belgian electricity producers provides for the commissioning of two more units in the medium term - Doel 3 at the end of 1979, and Tihange 2 at the beginning of 1980 - each with a power of 900-1000 MW(e), and for the installation on sites still to be chosen of three 1000 MW(e) nuclear units during the period 1981-83. By that time, half the country's electric power requirements will be covered by nuclear production.

8. The Doel 3 and Tihange 2 power stations have already been ordered from the FRAMACECO combine (FRAMATOME, ACEC, Cockerill) and for two of the remaining three

programmed power stations, letters of intent have been sent by the operators to the ACECOWEN association (ACEC, Cockerill, Westinghouse Nuclear Europe).

9. Since Belgium's electricity producers believe that from 1983 onward the nuclear power station park will have to be enlarged by a unit of approximately 1000 MW(e) every year, while on the other hand various personalities in the scientific and sociopolitical spheres have expressed misgivings about the development of nuclear power production, the late Mr. Oleffe, Minister for Economic Affairs, established in March 1975 a committee of experts to provide him, as well as the Government and Parliament, with an overall report before the end of 1975 on the consequences of the anticipated development of the nuclear power industry in Belgium. This committee of experts, composed of prominent persons in scientific and economic life, is asked to inform the Minister for Economic Affairs and the Government of the exact consequences of the decisions to be taken regarding future progress in the peaceful utilization of nuclear energy. The Government's decision, based on the opinions expressed by the committee of experts, will be of very great importance for the power production sector and for Belgium's nuclear industry.

10. Belgian nuclear industry is in fact playing an active part in the development of electronuclear equipment. The TRABEL Company provided consulting engineers for the Doel 1, Doel 2 and Tihange 1 power stations, and many Belgian firms have participated in the construction of these three power stations, in the operation of the Chooz power station, in the construction of the SNR-300 by the Schnell-Brüter-Kernkraftwerksgesellschaft (SBK) (Fast Breeder Nuclear Power Station Company), and in the construction of the enrichment plant by Eurodif.

11. Belgian nuclear industry is capable of providing various components for nuclear power stations, in particular reactor vessels and steam generators (Cockerill); primary pumps, handling equipment, control mechanisms and core equipment (ACEC); special pipes (Fabricom); special supports, tanks, etc. situated within the nuclear containment of power stations (Mercantile Marine). In addition, in the field of fuel-element fabrication, the Belgian company Métallurgie et Mécanique Nucléaires (MMN) is continuing the fabrication of uranium fuel elements in collaboration with the Franco-Belgian Fuel Fabrication Company (FBFC), while Belgonucléaire S.A. is proceeding with the development of its plutonium fuel fabrication plant at Dessel - where plutonium fuel elements have been fabricated for the Chooz power station - to promote the recycling of plutonium produced in light-water reactors; in this

same plant, preparations are also being made for the fabrication of 40% of the fuel elements for the first core of the SNR-300 prototype fast reactor.

12. In this connection, it may be mentioned that Belgium is participating actively with the Federal Republic of Germany and the Netherlands in the construction, at Kalkar in the Federal Republic of Germany, of a power station equipped with a sodium-cooled fast reactor. The plan is that this plant should eventually replace the light-water reactors, which do not adequately use the potential energy of uranium. The Belgian State is making a 15% contribution to the construction of this power station, a project of the Schnell-Brüter-Kernkraftwerksgesellschaft (SBK) to which the Belgian electricity producers belong. Belgian participation in this advanced project is possible only thanks to the past and future research and development efforts of Belgian industry and of the Nuclear Energy Study Centre (CEN/SCK). These efforts are being made with State support under the "National Five-Year Plan for Nuclear Technology", the most recent of which started in 1973 and provides for an average annual expenditure of about 1400 million Belgian francs (1973 value) on the part of the State.

13. Although the fast-breeder reactor remains one of the priority items in the 1973-77 five-year plan, the plan also provides for further research and development work by the National Institute of Radioelements (IRE), whose activities and turn-over have greatly increased since its establishment in 1971. It should not be forgotten that radioisotopes and ionizing radiations are destined to play a role of increasing importance, especially in industry, medicine and biology and in the various branches of research.

14. Since the peaceful applications of nuclear energy have now definitely got under way on a commercial scale in Belgium, everything must be done to ensure that the nuclear power stations are reliably supplied with nuclear fuel, to reprocess irradiated fuels and to ensure proper management of the radioactive wastes resulting from the various stages of the nuclear power production cycle.

15. By its participation in Eurodif S.A. through the Belgian Company for Uranium Enrichment (SOBEN), in which the Belgian public sector and the Belgian electricity producers participate equally, Belgium has shown that it wants to take no risks as regards the supply of enriched uranium for its nuclear power stations. Eurodif S.A. is at present constructing a uranium enrichment plant at Tricastin in France, to go into operation in 1979. As a result of the withdrawal of Sweden and the

participation of Iran, Belgium's share in the Eurodif project has increased from 10% to 11.11%. Belgium's participation in the construction of the Tricastin plant is through several Belgian undertakings which have formed a group within the SYBEDIF combine.

16. As regards uranium enrichment, Belgium does not exclude the possibility of participation in other multinational projects. The Belgian Syndicate for the Study of Isotopic Separation (SYBESI), composed of the Nuclear Energy Study Centre, the electricity producers and the fuel manufacturers, is closely watching developments in the enrichment sector and has the possibility of participating in studies whose purpose is to evaluate the economic aspects of a project for the construction of a uranium enrichment plant using any available process. Thus, SYBESI is participating in the research of the multinational Association for Centrifuge Enrichment (ACE) established by the Federal Republic of Germany, the Netherlands and the United Kingdom, countries which are jointly developing the ultracentrifuging process.

17. In view of the size of Belgium's present nuclear power programme and the necessity of being equipped to reprocess irradiated fuels from nuclear power stations now in operation and from those still to be constructed, the Belgoprocess Study Syndicate was established on 30 September 1974 by the Belgian State and Synatom - a group of Belgian electricity producers - in equal participation. One purpose of Belgoprocess, an association without legal personality, is to study all the problems relating to the reprocessing of irradiated fuels. In this connection, the Syndicate is responsible for undertaking a technical and economic evaluation of the possibility of carrying out reprocessing on a national or multinational basis at Mol in the installations of the Eurochemic Company, which terminated its activities in 1974.

18. Another problem which arises as a result of nuclear development is the management of radioactive wastes. So far, CEN/SCK - in collaboration with Belgonucléaire S.A. - has been responsible for the management of wastes from nuclear installations in Belgium, but the present and future expansion of nuclear power installations and of the nuclear fuel elements industry calls for the establishment of an organization capable of assuming all the necessary responsibility as regards the management of radioactive waste.

19. For this purpose, the BELGOWASTE Syndicate was established on 18 July 1975 by the Belgian State and by the private sector, represented by the electricity producers and the fuel manufacturers. The purpose of this association without legal personality is to study all the problems related to the management of radioactive waste and to pave the way for the establishment of an organization which will be responsible for the management of radioactive waste in Belgium.

20. Belgium's nuclear programme has entered resolutely on its industrial phase. As has been said before, the public sector in Belgium and private undertakings are collaborating to ensure that the best possible use is made of nuclear energy for peaceful purposes and for the benefit of the entire population of the country.

PHILIPPINES

GENERAL

1. The promotion of the peaceful uses of atomic energy in the Philippines reached new heights late in 1974, the upward trend continuing until the end of the period covered by this report (September 1974 to August 1975). In December 1974, President Marcos issued Presidential Decree No. 606 which formally transferred the Philippine Atomic Energy Commission (PAEC) from the National Science Development Board to the Office of the President, to reflect the Philippine Government's declared policy of utilizing atomic energy for peaceful purposes in the acceleration of the country's progress. About the middle of 1975, the Philippine atomic energy programme received a further boost when the Office of the President approved in toto the main plans for atomic energy utilization presented by the PAEC.

NUCLEAR POWER

2. Nuclear power development in the Philippines continues to be a major concern of the Philippine Government. Since the President's declaration that the Philippines intends to "go nuclear", the Government has been enlisting resources with a view to achieving this end. For example, negotiations for the financing of the construction of the country's first nuclear power plant are in progress.

3. Meanwhile, the PAEC, on its own initiative, has prepared a nuclear power programme which has been approved for implementation. The programme covers uranium prospecting, radioactive waste management, public information and manpower development.

4. Precedence is being given to uranium prospecting since the announcement early in 1975, by the Office of the President, that there is a possibility of uranium deposits being discovered in the Philippines. This official announcement was supported by the findings of a team of PAEC scientists who, with assistance from the Agency, have found evidence that uranium may abound in the country.

5. The PAEC's activities in the field of radioactive waste management are to be expanded. A study has already been carried out, again with the Agency's assistance, on whether the low-level radioactive wastes which it has been proposed should be discharged into a waterway near the Philippine Atomic Research Centre would adversely affect the environment. In addition, the PAEC has been conducting periodic environmental monitoring studies, especially in places where nuclear power plants are to be established, and expects to intensify such activities as the nuclear power programme approaches realization.

6. As regards public information, the PAEC has launched a campaign which has already made many Filipinos aware of the benefits of atomic energy in general. In future, however, increasing emphasis is to be placed on nuclear power, so that, by the time the country's first nuclear power plant goes into operation, Filipinos will be in a better position to appreciate atomic energy as a source of power rather than a means of destruction. It is hoped that by the early 1980s, when nuclear reactors are providing power for homes and industry, Filipinos will fully realize what benefits atomic energy can offer.

7. In the field of manpower development the PAEC has drawn up a programme for the training of nuclear power project personnel by means, among other things, of fellowships made available through the Agency, the United Nations Development Programme (UNDP), the Colombo Plan for Co-operative Economic Development in South and South-East Asia (the Colombo Plan) and various educational institutions abroad. It has also extended its local training activities to include the training both of reactor operators and of engineers who may become involved in the country's nuclear power programme. In addition, it has obtained the agreement of the University of the Philippines to a revival of its graduate programme in atomic energy, which led to the award of a master's degree.

NUCLEAR SERVICES

8. The PAEC is promoting the use of large radiation sources, with resulting emphasis on the provision of nuclear services to Philippine industry. In particular, members of the industrial and medical communities have expressed interest in the radiosterilization of medical products, and the PAEC has already done a great deal of preliminary work which may lead to the establishment of a pilot radiosterilization plant. In addition, radioisotope production is being stepped up, so that low-cost radioisotopes should be available in a few years' time.

FOOD PRODUCTION

9. The PAEC has been fairly successful in activities connected with increasing food production, and particularly in crop improvement. In fact, its scientists have developed a new variety of rice using ionizing radiation, and mutation breeding will remain one of the main activities in the country's atomic energy programme.

PROTECTION OF THE ENVIRONMENT

10. During the past year the Philippine Government, together with various sectors of industry, launched a follow-up to its earlier environmental protection activities, including the dredging of heavily silted rivers and the warning and penalization of polluters. People engaged in the country's atomic energy programme have become involved in matters of environmental protection and a decision has been taken to determine, using nuclear techniques, the role of pesticide residues and radionuclides in the pollution of the environment, with a view to the subsequent reduction of pollution levels.

BASIC RESEARCH

11. The PAEC's research and development programme has been reviewed and reoriented to meet the challenge presented by the demands of national development, and especially those connected with the introduction of nuclear power into the country. However, basic research still enjoys high priority, and research in agriculture, biology, medicine, chemistry, health physics, nuclear engineering, physics, and reactor engineering will continue to be pursued with vigour - not as a concession to research scientists but in recognition of the proven importance of basic research. In the past year, the PAEC has been engaged in more than 30 basic research projects, most of which have yielded very encouraging results.

CONCLUSION

12. The Philippine atomic energy programme has gone very far since its modest beginnings and has acquired national prominence. However, its successes would not have been achieved without encouragement from the Agency, UNDP, the Colombo Plan and other international bodies which have found in the Filipinos a versatile people.

SOUTH AFRICA

NUCLEAR POWER

1. Following the assessment of outline tenders, the Electricity Supply Commission (ESCOM) had approved a programme for the Koeberg nuclear power station at Duinefontein, which will consist of two light-water reactors, each of between 900 MW(e) and 1000 MW(e). Final tenders from three consortia selected by ESCOM from its short-list of tenderers are scheduled to be submitted by November 1975, and the contract is expected to be awarded in March 1976. The two units are expected to be commissioned in September 1982 and September 1983.

2. Drilling and seismic investigations at Duinefontein, and also oceanographic studies of the physical characteristics in the vicinity (covering sea bed conditions and their effects on inlet structures, the direction and velocity of currents, tidal characteristics, etc.), have been performed. Refined investigations of the permissible concentrations of radionuclides in liquid effluent to be discharged into the sea, and also micrometeorological studies, are continuing.

3. The Atomic Energy Board, using 1974 costs, has published a report on the likely pattern of nuclear power installation in South Africa. The report is the result of a study by the Board and does not necessarily reflect the views of the Electricity Supply Commission. It is predicted in the reference case that 1850 MW(e) of nuclear power will be installed by 1985, 3000 MW(e) by 1990, 6000 MW(e) by 1995 and 12 250 MW(e) by 2000. These figures are sensitive to coal and nuclear fuel costs and will have to be modified if the latter undergo significant changes.

LICENSING OF NUCLEAR FACILITIES

4. The programme for land-based nuclear facilities has gathered momentum with the issue of outline and final tender invitations by the Electricity Supply Commission. The Licensing Branch of the Atomic Energy Board has been closely involved in assessing the safety aspects of proposed plants at the preliminary and final tender stages, and it has continued to provide guidance to ESCOM and potential suppliers on the safety requirements relating to such facilities.

5. The Licensing Branch has also been involved in the safety assessment of the pilot uranium enrichment plant currently being erected by the Uranium Enrichment Corporation. A licence has been issued to permit operation of the part of the plant already commissioned.

NUCLEAR MATERIALS

Uranium exploration

6. Prospecting for uranium in the Karoo Supergroup by both South African and overseas companies has been marked by an upsurge of activity. The State has approved a programme (including aeroradiometric surveys) for uranium exploration throughout that part of the Karoo Supergroup which lies within the Republic of South Africa; the results will be made available to industry as soon as possible. The available information on exploration undertaken to date does not permit proper assessment of the economic potential of the area, but there are some promising indications.

7. Successes with four uranium standards - against which scintillation counters used in uranium exploration are being calibrated with consequent improvements in accuracy - have led to the preparation of three thorium standards, a mixed uranium-thorium standard and a borehole simulation standard composed of uranium ore for the calibration of spectrometers. A technique for determining radon gas as an indication of underground uranium has been developed.

Uranium extraction

8. Intensive research into improved processes and equipment for the extraction and recovery of uranium from low-grade ores and residue dumps is being done by the Atomic Energy Board in collaboration with the uranium mining industry at the National Institute for Metallurgy, where the research facilities enable complete development projects in connection with any uranium ore deposit to be undertaken. Projects involving all aspects of the research and development work necessary for the exploitation of specific ore deposits - from preliminary mineralogical and extraction tests, through laboratory and pilot plant investigations to full-scale plant design and economic feasibility studies - are in progress.

9. Typical South African uranium ore slurries are difficult to filter and clarify after leaching, and the solid/liquid separation processes are costly. With a view to the future economical recovery of uranium from residue dams and dumps, the possible establishment of further uranium ore-processing plants and the expansion of existing uranium recovery facilities at certain plants, a programme was started in 1970 to improve the continuous countercurrent ion-exchange (CIX) technique (based on the Cloete-Streat principle) and to develop a system capable of handling dilute slurries produced by a relatively simple and cheap sand/slime separation technique.

10. The first phase of this programme has been successfully completed, the reliability and stable hydraulic characteristics of a CIX pilot plant being proved at one of South Africa's uranium-producing mines by its successful operation for extended periods with unclarified liquors containing 200-300 ppm of suspended solids. The successful practical application of the CIX technique to slimes containing up to 10 mass per cent of -200 mesh suspended solids has been adequately demonstrated. Two operating parameters of importance for the successful application of the CIX technique - the resin loss due to attrition and the resin entrainment in the barren stream from the extraction column - are being investigated in detail, with large-scale plant tests to be conducted over an extended period at another uranium-producing mine.

11. Much effort has also been devoted to the application of ore preconcentration techniques such as gravity concentration, flotation and wet high-intensity magnetic separation, particularly in uranium and gold recovery from cyanidation tailings that have accumulated from the treatment of Witwatersrand gold ores. Considerable progress has also been made with regard to the fundamental aspects of the acid and alkaline leaching of uranium ores and to various other aspects of uranium extraction and recovery, particularly from newly discovered deposits in Southern Africa.

FUEL DEVELOPMENT

12. Work on the possible development of nuclear fuels in the UCS system has continued, and it has been shown that, at temperatures above 1600°C, compositions in this system may become depleted in sulphur and carbon through loss as carbon disulphide. The system UC_2 + US is being studies and it has been confirmed that the compounds form a complete series of solid solutions. These are being examined by X-ray and neutron diffraction.

13. Initial compatibility tests on low-sulphur solid-solution UCS fuels and stainless steels have shown that interactions similar to those encountered with UC itself are to be expected in the UCS fuels. Compatibility tests on UC powders and stainless steels have also shown that surface oxidation of the powders is partly responsible for the carburization of the cladding specimens.

URANIUM ENRICHMENT

14. Rapid development took place in the field of uranium enrichment during the year under review. The first part of the pilot enrichment plant being constructed to demonstrate the feasibility of the South African enrichment process on an industrial scale was successfully commissioned and came up to theoretical predictions in all respects.

15. As a result of the development of the helikon cascade technique, which is well suited to commercial plants, and due to the large modules which are envisaged for a full-scale commercial enrichment plant, it will not be possible to move directly from the pilot plant to a commercial plant. Consequently a large-scale prototype development programme is under way.

16. The design of a prototype module with a separative work capacity of 6 t/a has been completed and erection is in progress. The prototype module will serve to verify process characteristics and important aspects of the mechanical design of modules. Final verification is to be provided by a full-scale prototype, the design of which has commenced.

17. Feasibility studies for the erection of a full-scale commercial plant in South Africa have been satisfactorily completed.

REACTOR EXPERIMENTS

18. Besides a cryogenic facility and a single-crystal neutron diffractometer, new facilities on the 20 MW research reactor SAFARI-1 include a high-temperature irradiation rig for fission-gas release studies, a rotating ore-irradiation rig for the activation of relatively large quantities of crushed ores for tracer studies, and an assembly for studying the scattering of sub-thermal neutrons at very small angles.

ISOTOPE PRODUCTION

19. The production of radioisotopes in the reactor increased considerably during the past year, particularly of radioisotopes for use in medicine. Following successful development work, $^{99}Mo/^{99m}Tc$ generators (sterile), ^{131}I-Hippuran and ^{131}I-rose bengal are being produced on a weekly basis. The development of ^{99m}Tc-labelled compounds is receiving attention and the production of ^{131}I solutions, which are supplied to virtually the whole local market, is running smoothly.

20. A 30 kCi cobalt-60 source with low specific activity has been built and supplied to the sterilization plant at Pelindaba. Small cobalt-60 radiation sources for use in level gauges and glass-sealed krypton-85 sources for smoke detectors employed in mines are also being produced.

NEUTRON ACTIVATION

21. Studies of the role of trace elements in dental diseases and oesophageal cancer are continuing. The object is to determine the relationship between dietary deficiencies and the incidence of these clinical conditions. New equipment now permits the routine determination of uranium in geological material by the delayed-neutron counting technique.

RADIATION TECHNOLOGY

Wood-polymer composites

22. The ever-increasing price of noble hardwoods has resulted in renewed interest in wood-polymer composites. The South African Lumber Millers' Association is providing financial support for further development work and about 25 m^3 of wood-polymer composites is to be manufactured during 1975 with a view to the evaluation of their acceptability in fields where noble hardwoods are now utilized. The possibility of partial impregnation of wood with the object of lowering costs is being investigated, special attention being paid to the influence that such treatment will have on the physical properties of the material. In general, the future of wood-polymer composites appears brighter than ever before.

Radiation sterilization

23. The total source loading of the semi-commercial irradiator at Pelindaba has been increased to 370 kCi of cobalt-60 to keep up with the demand by local industry for sterilization services, and the product-handling system at the plant is being completely redesigned to meet the anticipated growth in sterilization services to the local pharmaceutical and medical products industry. Special attention has been paid to plant records and routine dosimetry in order to bring the local processing techniques into line with Agency recommendations.

Cross-linking of high-density polyethylene

24. The use of gamma irradiation to cross-link high-density polyethylene prostheses for orthopaedic purposes has been investigated in detail. Very promising results have been obtained in the case of knee prostheses and more than sixty treated high-density polyethylene prostheses have been implanted for in vivo tests. The commercial exploitation of this technique is under consideration.

FOOD IRRADIATION

25. During the period under review, the food irradiation programme was extended to cover a wider variety of foodstuffs. The top priority project remained the extension of the shelf life of mangoes: two notable occurrences during the past season were the transport of a trial batch of treated fruit to Europe by sea for evaluation at Wageningen, in the Netherlands, and the treatment of 1400 kg of mangoes for wholesomeness testing under the auspices of the International Project in the Field of Food Irradiation. The provision, treatment and transport of these mangoes, in the form of frozen pulp, to the feeding study contractor are being undertaken by the South African Atomic Energy Board as a voluntary contribution to the Project.

26. Other sub-tropical fruits have been studied and extremely promising results have been obtained, particularly in the case of papayas where good fungal control is achieved in addition to shelf life extension. Work is now being intensified in this field. Results of preliminary investigations on other commodities indicate that strawberries and poultry deserve more detailed study.

27. Technological investigations of sprout inhibition in potatoes stored under local climatic conditions are nearing completion, and it is intended to submit the results, together with wholesomeness data obtained in other countries, in a petition to the national health authorities for clearance of the process early next year. Although potatoes were chosen purely as a "model" foodstuff for the first South African petition, the sponsors of the work have requested the treatment of semi-commercial quantities for factory processing and evaluation.

HEALTH AND SAFETY

28. Health and safety have continued to be a field of considerable investigation, and a technique in which harmless inactive tracers are used to determine the dispersion and dilution of effluents in the atmosphere has been developed and tested at Pelindaba. It is already being applied to conventional pollutants at Richards Bay and will later be applied at Duinefontein, the site of South Africa's first nuclear power station. Atmospheric monitoring for trace elements by means of analytical nuclear techniques has progressed to the stage of base-line monitoring throughout South Africa, including impact areas such as Saldanha Bay.

29. A study of radon hazards in uranium mining and processing, which is of special interest to the South African gold-mining industry (in which uranium is mined together with gold), has been carried out. It indicates no increased incidence of lung cancer in South African gold/uranium mines; it also sheds light on the deficiencies in existing methods for evaluating individual exposures.

NUCLEAR TECHNIQUES

30. The practical application of nuclear techniques is arousing growing interest in non-nuclear circles. X-ray fluorimetry, using radioisotope sources, has been applied with great success in uranium analysis and promising results have been obtained in the determination of slurry particle sizes and of the ash content of coal. The investigation - using tracer techniques - of process dynamics in, for example, the extraction of gold, platinum and iron from ore and in sugar refining has revealed unique possibilities, especially as regards the application of mathematical models. Methods using tritium and deuterium have been developed and applied in the study of water movement (including evaporation) in soil and plants and in practical drainage experiments at two sites. Methods for the characterization of underground water bodies have been developed and applied with success.

31. In the medical field, whole-body counters are in full-time use for diagnosis and research in all the teaching hospitals in the country; they are proving of immense value in malabsorption studies. South Africa is still among the world's leading countries as regards the diagnostic use of radioimmunoassays, a technique now also being employed by a large number of medical practitioners outside the bigger hospitals; during the year, human growth hormone was completely purified and estimated by this means. The purification method yielded, for the first time anywhere in the world, an absolutely purified hormone which now permits the treatment of dwarfism at reasonable cost.

32. Research on liver cancer continues. With the collaboration of the Medical Research Center of Brookhaven National Laboratory, a biochemical study on cancer has made good progress, as have further studies on pellagra and the metabolism of tryptophan. The publication, in an international journal, of the report on a diagnostic study - using radioisotopes - of a large number of patients with liver abscesses has evoked wide interest; the study has been shown to provide the best guidelines for the diagnosis and treatment of this condition.

33. Modern gamma cameras with on-line computers are now in use in the country's teaching hospitals; this technique greatly extends the clinical uses of radioisotopes, especially in kinetic studies of the vascular system and of the respiratory and renal organs.

SPAIN

1. PRODUCTION OF NUCLEAR RAW MATERIALS

1.1. Uranium ore potential in Spain

In accordance with the nomenclature adopted by the OECD Nuclear Energy Agency and the IAEA for classifying uranium resources, the situation in Spain is as follows:

Uranium resources (t of U_3O_8)

Price range	Reasonably assured resources	Estimated additional resources
\$15/lb U_3O_8	11 700	10 400
\$15-30/lb U_3O_8	110 000	115 000

The Spanish Government has recently approved the National Uranium Prospecting Plan, which is to be implemented over the next 10 years. Investment during this period will total more than 12 thousand million pesetas and the studies proposed cover an area of 100 000 km^2.

1.2. Production of concentrates

At present there is one concentrate production plant in Spain, located at Andújar (Jaén), which has a production capacity of 70 t/yr of U_3O_8.

In May 1975, another concentrate production plant was started up in the region of Ciudad Rodrigo; its initial production capacity is 112 t/yr of U_3O_8, but this figure is expected to increase to a production level of 400 t/yr by 1979, following expansion of the plant.

Another plant at present under construction is located near the El Lobo deposit (Badajoz); it will have an estimated production of 30 t/yr of U_3O_8, which figure is expected to double in the near future.

Disregarding new discoveries, the anticipated production figure for 1980 is 800 t/yr of U_3O_8.

1.3. Uranium enrichment

Spain is participating in the activities of the Eurodif company. Its share is 11.1%.

1.4. Fuel element fabrication

The fabrication of fuel elements for light-water reactors is about to be started up on the basis of licensing contracts and technical assistance agreements with the National Uranium Company.

Fabrication of the fuel elements for Spanish research reactors has taken place in Spain and this will be continued.

1.5. Reprocessing of irradiated fuel elements

Spain has a pilot plant for reprocessing irradiated fuel elements which is designed for any degree of enrichment and concentration. Its continuous operational capacity (inclusive of MTR elements) is 500 g/d of 20% enriched uranium. This plant has reprocessed fuel elements from Spanish and foreign research reactors.

The project for a large pilot plant to process fuel elements from power reactors is now under way.

2. NUCLEAR POWER PRODUCTION - NUCLEAR POWER PLANTS

2.1. Present situation

At present (Table 1), nuclear power accounts for 4.4% of the total installed capacity, and 8.9% of the total power generated in 1974.

The nuclear power plants in operation are listed in Table 2.

Table 1

Structure of installed capacity and energy output in 1974

Type of energy	Installed capacity on 31 December 1974 (MW(e))	%	Energy output in 1974 (10^6 kWh)	%
Hydroelectric	11 700	47	31 692	39.3
Fossil thermal	12 100	48.6	41 703	51.8
Nuclear thermal	1 100	4.4	7 205	8.9
Total	24 900	-	80 600	100.0

Table 2

Nuclear power plants in operation

Power plant	Location	Owner	Capacity (MW(e))	Type	Year of start-up
José Cabrera	Almonacid de Zorita (Guadalajara)	Unión Eléctrica	160	PWR enriched U	1968
Garoña	Santa María de Garoña (Burgos)	Nuclenor Iberduero 50% Viesgo 50%	460	BWR enriched U	1970
Vandellós	Vandellós (Tarragona)	Hifrensa Fecsa 23% Enher 23% H. Cat. 23% H. Segre 6% EDT 25%	500	Graphite gas natural U	1972

2.2. Nuclear power plants in operation, under construction or scheduled for construction

The nuclear power output of plants in operation, under construction or scheduled for construction is shown in Tables 2 and 3, and amounts to 7675 MW(e).

2.3. Spanish participation in the manufacture of nuclear components

The present participation by Spain in the manufacture of heavy equipment for nuclear power plants is as follows:

	Capacity (MW(e))	
Pressure vessels	Steam generators	Turbine generators (1975)
Two units in 1978 and three units as from 1979	At present, the top structures for three reactors (9 generators), with Spain participating to the extent of 32% of the total; 6 generators in 1978, and 7-9 as from 1979	Stationary turbine and generator components for three units, with 40% Spanish participation (corresponding to a power output of 2790 MW(e))

At present, domestic production accounts for 60% of the total of a nuclear power plant in the country and by 1978 this figure will reach 80%.

2.4. Spanish participation in civil engineering work connected with nuclear power plants

Since 1968 Spanish participation in civil engineering work, services and building activities connected with nuclear power plants has been steadily increasing: whereas in 1968 the figure for participation in LWR plants was 90%, by 1974 it had reached 100%.

3. DESIGN AND CONSTRUCTION OF EXPERIMENTAL REACTORS

3.1. Pool-type reactors

Spain has assisted in the designing and construction of the main components of the Lo Aguirre reactor (Chile), which is at present being assembled and has a rated output of 10 MW(th). The fuel elements required for it are now being fabricated.

Table 3

Nuclear power plants under construction or scheduled for construction

Power plant	Location	Owner	Capacity (MW(e))	Type	Year of start-up
Almaraz 1	Almaraz (Cáceres)	Unión Eléctrica Hidroel. Española Sevillana Elec.	930	PWR enriched U	1977
Almaraz 2	"	"	930	"	1978
Lemóniz 1	Lemóniz (Vizcaya)	Iberduero	930	PWR enriched U	1977
Lemóniz 2	"	"	930	"	1978
Ascó 1	Ascó (Tarragona)	Fecsa	930	PWR enriched U	1979
Ascó 2	"	Fecsa Enher Hidroel. Cataluña Hidroel. Segre	930	"	1979
Cofrentes	Cofrentes (Valencia)	Hidroel. Española	975	BWR enriched U	1979

4. PRODUCTION AND USE OF ISOTOPES

4.1. Domestic production

Spanish production of radioactive isotopes in 1974 represented a value of 10.5 million pesetas. During the first half of 1975 the figure amounted to 6.5 million.

4.2. Domestic consumption

Domestic consumption of radioisotopes supplied by the Spanish Nuclear Energy Board (JEN) attained a value of 35.7 million pesetas in 1974, and 20.9 million in the first half of 1975. Apart from this source of supply, there are a number of private companies not covered by the above-mentioned data, which distribute isotopes to authorized persons in the country.

4.3. Number of isotope users and facilities where radioactivity is used

At present, the number of facilities using radioactivity is 378.

The number of isotope users was 1050 at the end of 1974.

4.4. Stable isotopes

Apart from the plants producing radioisotopes, there is a plant for the production of stable isotopes and labelled molecules. Sales of isotopes of this type represented a value of 1.5 million pesetas in 1974 and one million pesetas in the first half of 1975. Almost all this production is sent abroad, going to more than 40 countries.

YUGOSLAVIA

INTRODUCTION

1. Yugoslavia was among the first countries in the world to initiate research in the field of nuclear energy. With a view to promoting international co-operation in general and international co-operation in the application of nuclear energy in particular, Yugoslavia has been a Member of the Agency since its establishment. The resulting co-operation, based on contacts with countries and institutions throughout the world, has taken various forms, including joint long-term projects.

2. In accordance with its policy of peaceful co-operation among nations, Yugoslavia signed the Treaty on the Non-Proliferation of Nuclear Weapons in 1968 and ratified it in 1970.

3. For a number of years the emphasis in the application of nuclear energy in Yugoslavia has been on radioisotope production and applications and on nuclear power generation. The application of radioisotopes in agriculture, medicine, industry, hydrology and other fields became established about ten years ago, and during the past few years there has been an intensification of efforts directed towards solving the country's energy problems through the use of nuclear power. The competent Government bodies have been drawing up a long-term programme for nuclear power generation, work on which has been speeded up partly as a result of the recent energy crisis. The construction of a 632-MW pressurized-water nuclear power plant near Krško, in the Socialist Republic of Slovenia, is under way, the necessary uranium enrichment services to be provided by the United States Atomic Energy Commission through the Agency. A preliminary safety analysis report on the plant has been submitted to the Agency for assessment, this being the first time that a Member State has submitted such a report on a power reactor.

4. In addition, work has started on examining locations for two further nuclear power plants.

NUCLEAR INSTITUTES

5. There are several institutes in Yugoslavia, employing altogether about 1000 research workers, which may be described as primarily nuclear institutes or institutes for nuclear energy applications: the "Boris Kidrič" Institute for Nuclear Sciences at Vinča, near Belgrade, the "Rudjer Bošković" Institute at Zagreb, the "Jožef Stefan" Institute at Ljubljana, the Institute for Geological and Mining Investigations of Nuclear and Other Mineral Raw Materials at Belgrade, the Institute for the Technology of Nuclear and Other Mineral Raw Materials at Belgrade, and the Institute for the Application of Nuclear Energy in Agriculture, Veterinary Medicine and Forestry at Zemun.

6. These institutes were established primarily for work in the field of nuclear energy. For various reasons, however, part of their energies became diverted to work in other fields, in particular environmental pollution, materials development and testing, biological research, the development of modern instrumentation, the development and application of computer techniques and systems analysis, the training of professional personnel, and economics.

7. With the revitalization of the country's nuclear energy programme, the nuclear institutes are now beginning to play a major role in research relating to nuclear power plant construction, nuclear fuel fabrication and processing, environmental protection and the formulation of proposals for new legislation in all these fields.

8. The nuclear institutes have a fine tradition of fundamental research, in which they have gained international recognition, and have helped to educate the scientists who today represent the basis for the application of nuclear power in dealing with the country's energy problems.

9. Because of their high reputation, the nuclear institutes have on many occasions been asked by international organizations to make professional members of their staffs available as experts. In addition, they have organized and hosted many international meetings and seminars, and have provided specialized training in their laboratories for about a hundred scientists and technicians from abroad. Much of this has been done in co-operation with the Agency, whose financial support under research contract agreements is greatly appreciated.

OTHER INSTITUTES

10. Apart from the institutes already mentioned, there are a number of institutes where atomic energy and nuclear techniques are of importance. They include the Centre for the Application of Radioisotopes in Science and Industry at Skopje, the Institute for Materials Research and Construction at Ljubljana, the Institute of Medical Research at Zagreb, the Institute for Occupational Medicine and Radiological Protection at Belgrade, and "Energoprojekt" (an organization providing design, consulting and engineering services in connection with the construction of power and industrial plants) at Belgrade.

11. It is expected that the Centre for the Application of Radioisotopes in Science and Industry, which was established with great professional and financial assistance from the Agency, will become a regional centre for the application of radioisotopes in hydrology. The other institutes are engaged in various kinds of research relating to the development of materials for, and design and engineering problems connected with, nuclear facilities and to the effects of natural and artificially produced ionizing radiation on man and his environment.

RADIOISOTOPE PRODUCTION

12. Radioisotope production on a well organized basis has existed in Yugoslavia for 15 years. The "Boris Kidrič" Institute, using the RA reactor (6.5 MW), produces annually about 150 Ci of radioisotopes in the form of open sources (^{131}I, ^{198}Au, ^{32}P, etc.) and about 3000 Ci in the form of closed sources (^{60}Co, ^{191}Ir, $^{152-154}Eu$, etc.). The production of open sources meets almost 90 per cent of Yugoslavia's needs. In recent years there has been a steady increase in radioisotope production; an international exchange of sources has also been established.

13. The Triga Mark II reactor at the "Jožef Stefan" Institute is being used in the production of short-lived radioisotopes for special purposes, while the cyclotron at the "Rudjer Bošković" Institute is being used in the production of short-lived radioisotopes such as ^{68}Ga for medical diagnostic purposes.

APPLICATIONS OF RADIOISOTOPES AND IONIZING RADIATION

In medicine

14. Almost all the main towns in Yugoslavia now have nuclear medicine centres of which there are over 30 and where use is made of radioisotopes and ionizing radiation. The principal application of radioisotopes is in diagnosis, but they are also employed to a considerable extent in radiotherapy. Irradiation using closed sources or accelerators represents the standard treatment for malignant tumours.

15. Three betatrons and about 20 closed cobalt sources are being used in Yugoslavia for medical therapy. On average 6500 examinations weekly were performed last year in the nuclear medicine departments of 25 medical centres. For diagnostic purposes, use made mainly of ^{131}I, ^{32}P and ^{198}Au from the "Boris Kidrič" Institute.

In industry

16. Isotopes are being used at a number of industrial enterprises in standard measuring devices and for the control of industrial processes. A project for the construction of a facility for sterilizing medical equipment is being implemented within the framework of UNDP's country programme for Yugoslavia and with the Agency's assistance.

In agriculture

17. Yugoslavia attaches particular importance to agricultural applications of radioisotopes. Besides the Institute for the Application of Nuclear Energy in Agriculture, Veterinary Medicine and Forestry, in the establishment of which the Agency and UNDP played a large part, the Agricultural Faculty at Novi Sad and a number of other centres are engaged in such applications.

18. The most important agricultural applications are in plant genetics, plant physiology, soil and fertilizer studies, domestic animal physiology and nutrition studies, animal health including radiation immunobiology, insect control, plant protection and microbiology.

URANIUM PROSPECTING

19. Great attention is being paid in Yugoslavia to uranium prospecting, and about 25 per cent of the country has been explored. A uranium mine with an annual capacity of 300 tons has started operating in the north-west of the country and a uranium ore processing plant is being designed.