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

Further Statements by Member States

CANADA

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

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

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

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

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

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

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

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

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

ITALY

Main features of nuclear Progress during 1967

Since last October, Italy —and in particular the National Nuclear Energy Commission (CNEN), working closely with the national bodies and industries concerned — has launched the programmes outlined at the 10th regular session of the General Conference[1]. In some cases decisive progress towards carrying them out in full has recently been achieved.

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

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

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

A. Reactors

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

CIRENE — CISE[2] (CIse REattore a NEbbia or **CISE** fog-cooled reactor). On 7 July 1967, the CNEN and l'Ente Nazionale per l'Energia Elettrica (ENEL) signed the agreement for the joint construction of a prototype reactor CIRENE as the first real step towards construction of a power reactor of Italian design. With the CIRENE prototype reactor of 110 MW thermal and approximately 35 MW electric, the CNEN will be entering the promising field of advanced converters.

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

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

2) Centro Informazioni Studi ed Esperienze.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

B. Fuel cycles

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

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

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

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

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

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

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

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

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

Fuel reconditioning and recycling

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

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

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

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

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

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

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

The plutonium programme

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

C. Other activities

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

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

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

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

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

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

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