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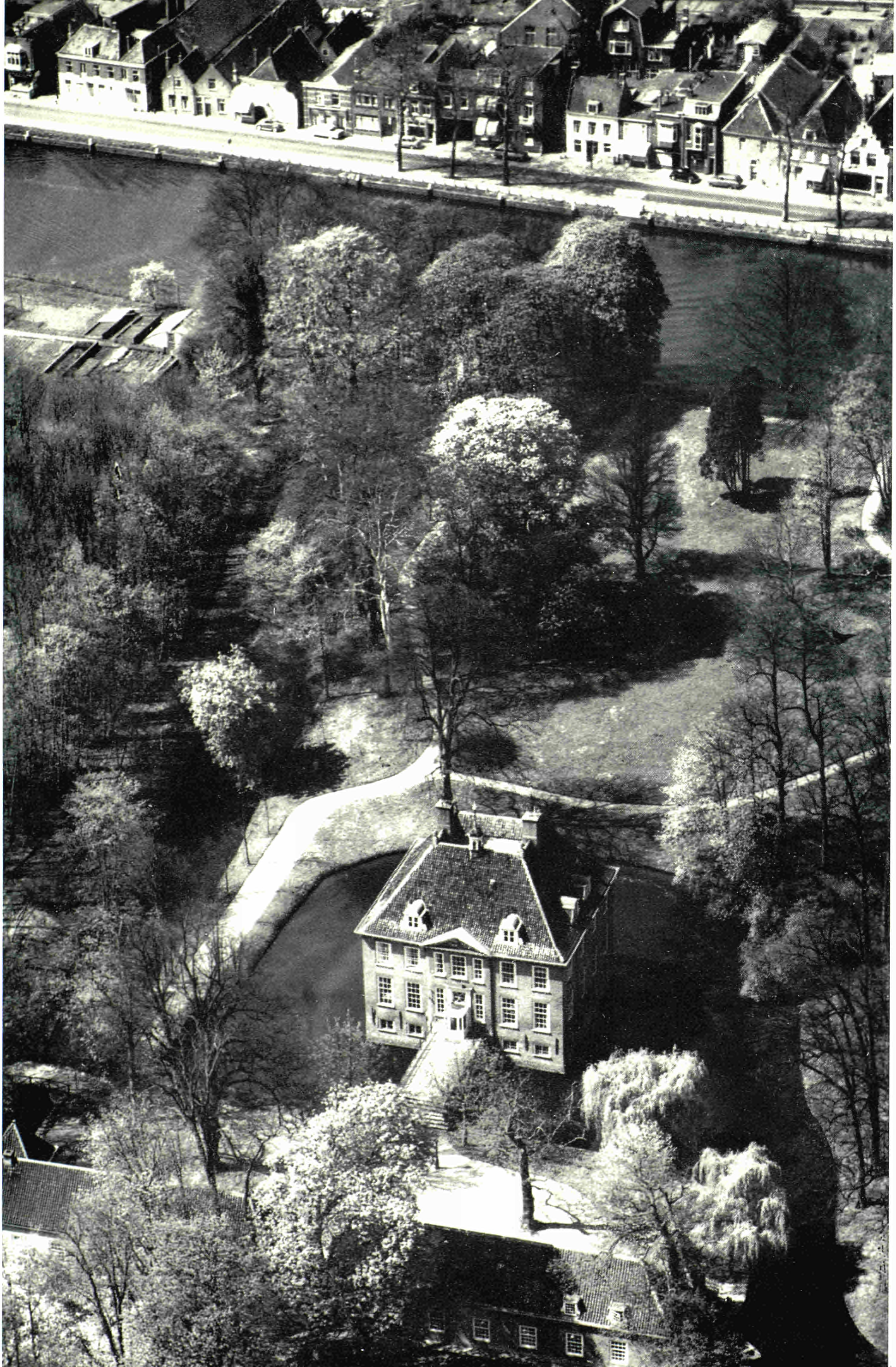

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1965-3

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◀ *Ultra-modern activity in old-world setting: this manor-house is the headquarters of the Dutch F.O.M. Institute, which specialises in plasma physics.*

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Cover: Clay tablet, 6th Century B.C.—Mine worked by gods

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Quarterly Information Bulletin of the European Atomic Energy Community (Euratom)

1965 - 3

The Community's mission is to create the conditions necessary for the speedy establishment and growth of nuclear industries in the member States and thereby contribute to the raising of living standards and the development of exchanges with other countries (Article 1 of the Treaty instituting the European Atomic Energy Community).

topi radioisotopen ship propulsion schiffsantrieb propulsion navale propulsione navale scheepsvoortstuwing biology biologie biologie biologia biologie medicine medizin médecine medicina geneeskunde health protection gesundheitsschutz protection sanitaire protezione sanitaria bescherming van de gezondheid automatic data processing automatische information information automatique informazione automatica automatische verwerking van gegevens insurance versicherungswesen assurances assicurazione verzekeringen economics wirtschaft économie economia economie education and training ausbildung enseignement insegnamento onderwijs en opleiding power reactors leistungsreaktoren réacteurs de puissance reattori di potenza energie reactoren nuclear fusion kernverschmelzung fusion nucléaire fusione nucleare kernversmelting radioisotopes radioisotope radioisotopes radioisotopi radioisotopen ship propulsion schiffsantrieb propulsion navale propulsione navale scheepsvoortstuwing biology biologie biologie biologia biologie medicine medizin médecine medicina geneeskunde health protection gesundheitsschutz protection sanitaire protezione sanitaria bescherming van de gezondheid automatic data processing automatische information information automatique informazione automatica automatische verwerking van gegevens insurance versicherungswesen assurances assicurazioni verzekeringen economics wirtschaft économie economia economie education and training ausbildung enseignement insegnamento onderwijs en opleiding power reactors leistungsreaktoren réacteurs de puissance reattori di potenza energie reactoren nuclear fusion kernverschmelzung fusion nucléaire fusione nucleare kernversmelting radioisotopes radioisotope radioisotopes radioisotopi radioisotopen ship pr

The drive to develop nuclear energy in the European Community is vindicated by the favourable cost outlook and by the desire to avoid undue dependence on imported energy supplies. Now, however, vast resources of relatively cheap energy have been discovered on Community territory in the form of natural-gas deposits in the Netherlands. Does this mean that the effort expended on the development of nuclear power reactors has been, if not entirely pointless, at least premature?

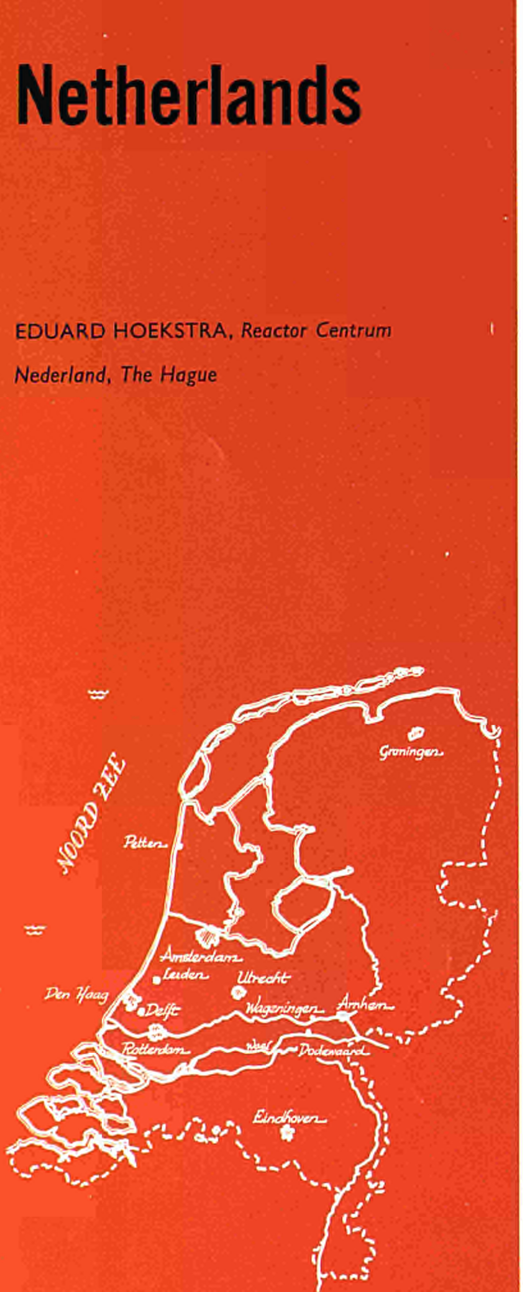
To accept such a conclusion one would have to ignore the rapid growth of energy consumption as a result of the Community's economic expansion and also to disregard certain finer points in the interplay of competitive forces on the power market. Obviously, if this market is viewed as a whole a certain rivalry can be seen to exist between nuclear energy and natural gas, but they are not really running in the same race; for whereas nuclear energy is essentially a source of electricity, natural gas will be used primarily as a source of heat in a wide range of industrial and household applications.

The use of natural gas in electricity-generating stations is by no means ruled out, but in view of its great versatility the tendency will be to seek more profitable outlets for it.

There is consequently every reason to believe that natural gas will play an important part in the indispensable harnessing of the Community's energy resources, side by side with nuclear energy, whose progress towards competitivity has been faster than anyone had hoped and whose full technological potential is still far from being reached.

Nuclear energy in the Netherlands

EDUARD HOEKSTRA, *Reactor Centrum Nederland, The Hague*



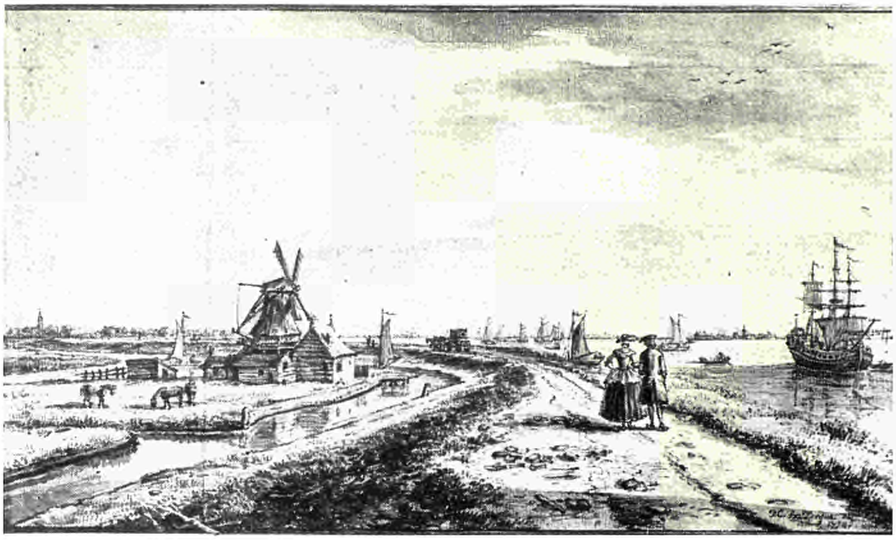
Since time immemorial the Netherlands has been a country of wind and water, and through the ages these two elements have made their mark on the development of this land, a large part of which lies below sea-level.
The sixteenth century saw the beginning of a massive offensive against the sea, which at that time held vast areas of land in its grasp and constantly threatened to reach out for more. In previous times man had already expended considerable efforts to erect refuges, mounds, earthworks and dikes.

The first form of energy

This large-scale counter-attack against the sea called for large energy supplies. This, in the form of wind power, which had hitherto merely helped the sea in its conquests, was now used with the aid of windmills to repair the damage. In the seventeenth century and later, land was first reclaimed and then drained by wind-powered water-mills. But in other respects also the sea was conquered with the aid of the wind. Ships left Dutch ports to sail across the world, returning laden with goods from the four corners of the earth.
The situation did not change radically with the invention of the steam engine and later the diesel engine and electric motor in the nineteenth century. On land and sea the Dutch set about mastering the use of an ever-increasing amount of energy in new forms.
The modest steam pump was superseded by the powerful electrically-operated pump. The small sailing ship gave way to steam- and diesel-powered ships displacing thousands of tons. The shipyards grew in size and number and ship-building became one of the country's major industries. The fight against the sea has become second nature to the Dutch but the fickle ally, windpower, has given way to the 50-cycle pulsation of the power grid.
It is therefore not surprising that the most modern sources of energy, consisting in the fission of heavy atoms or the fusion of light nuclei, should have appealed to the imagination of the Dutch people. The interest displayed in nuclear energy in the Netherlands is a vivid illustration of this, as is shown by the pure and applied scientific research carried out there, which has culminated in the development, in collaboration with Euratom, of a land-based reactor of the homogeneous suspension type for producing electric power *(KSTR)* and a marine pressurised-water reactor for ships *(NERO)*.
In addition, a 50 MWe boiling-water nuclear power plant of American/Dutch design is to be built with the participation of Euratom, with which it is planned to carry out optimisation experiments and at the same time gain experience in power generation.
Pure research in the field of nuclear energy is the province of the *FOM* (Foundation for Fundamental Research on Matter), in whose laboratories research on plasma physics is currently being conducted in collaboration with Euratom. These investigations may represent an initial, important step on the road to controlled nuclear fusion.
Normally, as soon as an *FOM* investigation begins to pass from the stage of fundamental to that of applied scientific research it is dropped and, as in the case of nuclear research, then becomes the concern of the *Netherlands Reactor Centre (RCN)*. Subsequently, when the applied research is nearing completion, the *RCN* in turn makes the knowledge acquired available to industry.

Natural gas

The recent discovery of large deposits of natural gas in the north of the country, which will constitute an almost inexhaustible supply of cheap power for several decades, have not undermined the Netherlands' resolution to make a contribution towards the development of nuclear energy. On the contrary they have acutely perceived that energy requirements in the future—after exhaustion of the natural-gas reserves—will far exceed present-day consumption. By that time the steady progress of nuclear research will have made possible the economic exploitation of atomic energy, thus broadening the basis for the generation of electricity. It is expected that by about 1970 the cost of nuclear electricity will be 2 Dutch cents per kWh, which is not much higher than the present cost of current generated at power stations running on fossil fuels. However, for the time being nuclear electricity is only likely to be competitive in the case of large generating plants (500 MWe); since the Netherlands have no urgent need of these large plants



at the moment, they will have greater freedom of choice later, when the time comes to decide on the type of reactor to be used.
The Netherlands' coal consumption—only part of which is met from indigenous production—will decline as a result of the increased availability of natural gas. It is estimated that the excess of coal imports over coal exports will consequently disappear and there will even be a small export surplus.

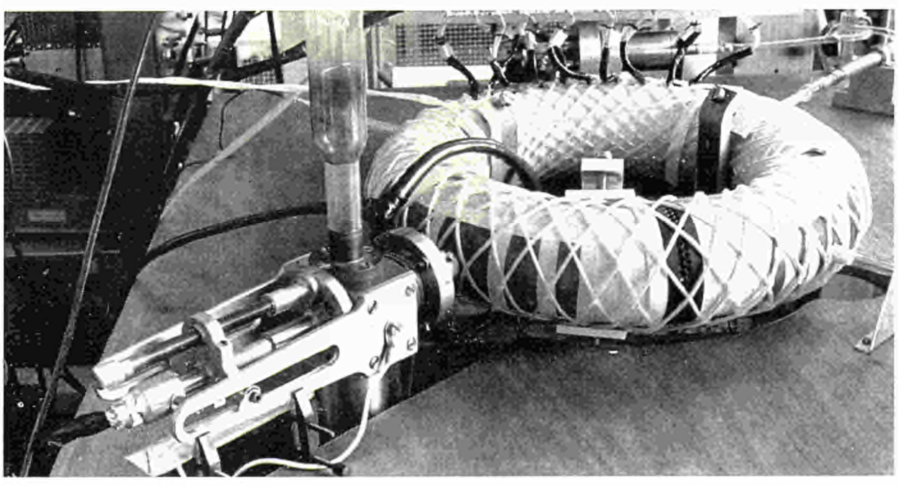
Nuclear energy

The Dutch are fully aware that the use of nuclear energy in all spheres is going to increase rapidly in the near future, though for the time being this may not apply to their own country. Nowadays an industrialised country cannot afford to lag behind in the field of reactor technology, and it must, in order to keep up, maintain a research and development programme.
The choices made in this connection were a reactor for marine propulsion—an application for which natural gas does not offer an alternative—and a thermal breeder reactor for electricity generation. As a matter of policy, firms working in the field of atomic engineering were brought into these development projects with a view to encouraging Dutch industry to manufacture components for nuclear plants and place them on the world market at competitive prices.

Research programmes and research facilities

Before delving deeper into the projects aimed at the development of nuclear power, it would be advisable to glance at the research work in progress in the Netherlands and at the facilities available for it.
The entire nuclear research effort in the Netherlands is carried out in a spirit of collaboration between independent bodies engaged on pure or applied scientific research, universities and energy producers, without any co-ordinating organisation above them, as is the case in some countries. Nuclear research is even to a greater or lesser extent interwoven with other development work. The State, which provides most of the funds (the electricity producers and industrial companies make only a modest contribution), is advised by three councils, responsible respectively for scientific, industrial and health affairs. The basic principles of the use of nuclear energy in the Netherlands and the provisions for government intervention are laid down in the Nuclear Energy Law, which was given its present form in February 1963 after lengthy deliberations.
Supplementary regulations with regard to third-party liability in the field of nuclear energy, based on the Treaties of Paris (1960) and Brussels (1963), have since come into force.
Among the independent institutes mention must be made first and foremost of the *Netherlands Reactor Centre (RCN)*, which was set up in 1955 jointly by the government, the *FOM*, the electricity undertakings and private industry. The task of the *RCN* is to acquire scientific and technical knowledge, together with experience of nuclear reactors and their applications, and to make this knowledge and experience, as well as the facilities procured, available to all inter-

Alternating pinch device for obtaining a stable plasma



ested parties and in particular to Netherlands institutes and Netherlands industry.

The high-flux reactor in Petten

An important part of the knowledge was gained during the construction of and initial experiments with the 20 MW high-flux reactor *(HFR)* at Petten, in North-Holland. This reactor was presented to Euratom by the Netherlands Government in 1962 but Euratom has entrusted its operation to the *RCN* for a number of years.
In this way the *RCN* is in a position to carry out its own research work, consisting of a number of neutron physics and irradiation experiments, in addition to an extensive Euratom programme. Several of these experiments are being carried out in the *HFR* in collaboration with the *Norwegian Atomic Energy Institute (IFA)*, under the terms of a joint agreement of long standing.

Five of the ten horizontal neutron-beam channels in the *HFR* are now being used for neutron-physics experiments covering neutron diffraction, inelastic scattering of neutrons and research on the gamma-radiation which occurs when neutrons are captured by certain nuclei. This last series of investigations is not being carried out by the *RCN* but by teams from the universities of Leiden and Utrecht.
In the majority of irradiation tests use is made of instrumented capsules placed in or near the reactor core and containing samples of the material to be irradiated. The other irradiation experiments are conducted in special loops set up partly inside and partly outside the reactor.
The irradiation experiments are largely used for testing on non-fissile materials, but some for research into reactor fuels.
Moderator *graphite* is irradiated for various organisations, for example. The irradiations for the *OECD Dragon Project* are carried out in a special capsule designed by the *RCN* in which the graphite samples are irradiated at temperatures of 600, 900 and 1200°C.
A number of *steels* used in the construction of reactor vessels are being tested under joint *RCN/IFA* projects: at low temperatures in a capsule installed in a reflector-element position and at high temperatures in a loop cooled with an organic liquid. Euratom itself has embarked on the irradiation of stainless steels.
Other positions in the reactor are used for irradiations of a large variety of materials, including *beryllium, beryllium oxide, Zircaloy, zirconium hydride* and *instruments* such as thermocouples and strain gauges.
The reactor is also fitted with equipment for the series *production of radioisotopes* for both commercial and research purposes.
As part of a project devoted to the development and fabrication of *reactor fuel elements*, in collaboration with industrial concerns, two irradiation experiments are being carried out with uranium-oxide fuel, one at low pressure in a water-cooled loop in a reflector element position *(RCN/IFA)*, the other with a loop in which prototype fuel elements are irradiated under pressurised-water reactor conditions.
For the mechanical and metallurgical testing of the irradiated materials after the irradiation capsules concerned have been removed from the reactor and dismantled, the *RCN* at Petten has an extensive "hot" laboratory. In addition, the cold laboratory is used for carrying out chemical and metallurgical tests on the corrosion and welding properties of materials used in reactor construction.

Reactor physics

A building in Petten named after the nuclear physicist *Enrico Fermi* houses a critical and sub-critical facility for research work on reactor physics; here neutron-flux distribution and reactivity effects are measured on various critical fuel-element configurations for power reactors now being developed.

Separation of uranium isotopes

In Amsterdam, the *RCN* has built a new laboratory where, in collaboration with

Neutron physics experiments with the HFR *in Petten*

Tomato plants in the neutron irradiation chamber below the BARN *reactor in Wageningen*

industrial companies, pioneering research conducted by the *FOM* on the separation of uranium isotopes by means of ultracentrifuges is being continued with a view to the development of a production process. As soon as this process can be used for the economic production of enriched uranium, the fabrication of reactor fuel elements in the Netherlands will be less dependent on supplies from abroad.

Reactor development

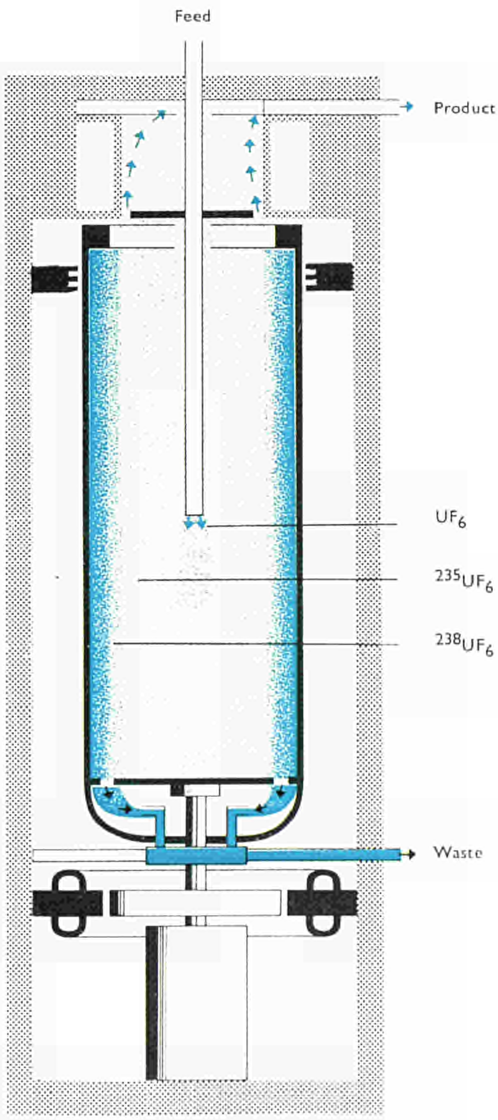
The *RCN*'s reactor development team is established at the well-known coastal resort of Scheveningen. It is on the drawing-boards of this team that the majority of the Netherlands' existing and planned nuclear installations first saw the light of day. The team also acts in an advisory capacity to industries working on nuclear energy projects in the Netherlands and abroad.
One of the most successful creations of the *RCN* reactor development team is without doubt the 100 kW Netherlands *Biological and Agricultural Reactor (BARN)*, which was designed for *ITAL (Institute for Atomic Sciences in Agriculture)* at Wageningen and built by Dutch industry.

Atomic sciences in agriculture

ITAL was set up in 1957 as an advisory centre on experiments involving radioisotopes for the various laboratories and institutes in Holland engaged in agricultural and biological research. Moreover, by placing the available irradiation facilities at the disposal of these establishments it was possible to achieve a centralisation which ensures efficient use of the expensive equipment installed, including the *BARN* reactor.
In a space underneath this swimming-pool reactor, fitted out as an air-conditioned growth chamber, plants and seeds are irradiated with a thermal-neutron flux averaging 5×10^6 n/cm².sec. at one metre above the floor. Other experiments can be carried out with the aid of two neutron-beam channels and a "rabbit" (pneumatic conveyor tube) system. Further facilities such as caesium sources, an electron generator and X-ray apparatus are used here for theoretical and experimental studies in agriculture and biology. This work aims at developing new varieties of cultivated plants, e.g. improved vegetables, by causing permanent hereditary changes, or mutations, by means of ionising radiations. Parallel studies are being conducted on means of increasing the keeping qualities of fruit, potatoes and fish by surface pasteurisation with ionising rays.
Tracer techniques, whereby absorbed radioisotopes and labelled compounds can be detected in biological material by the radiation they emit, are also useful for improving artificial fertilisers and obtaining a better knowledge of plant physiology. Agricultural applications of nuclear energy have proved of great value, especially in cases where they lead to increased productivity in agriculture, which is the mainstay of the world economy. Euratom concluded a contract of association with *ITAL* as long ago as 1961 (see *Euratom Bulletin* Vol. III, No 3, p. 1–19).

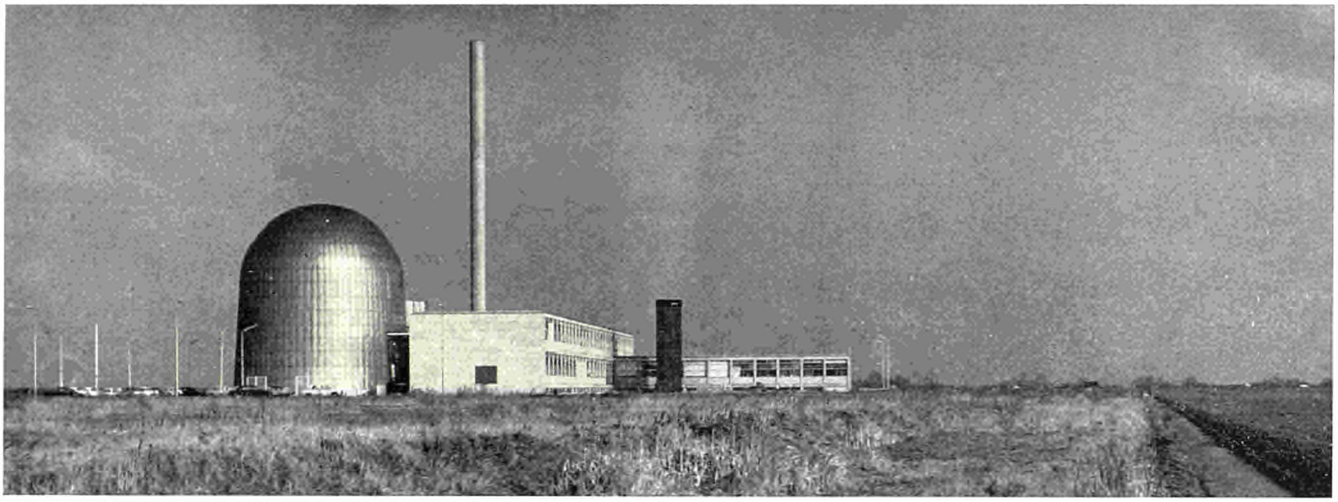
Nuclear research at the universities

As is the case in other countries, Dutch universities, in addition to training students, also play a part—indeed a major one—in nuclear research. Under Euratom's research programme the *Amsterdam Municipal University* is carrying out research on the use of mathematical logic for documentation purposes; *Groningen State University* is studying the detection of, and chemical protection against, rapid biological reactions induced by low-energy irradiations; *Leiden State*



Separation of uranium isotopes by means of an ultracentrifuge

Natural uranium is introduced in gaseous form (uranium hexafluoride—UF_6) into a drum rotating at high speed. Owing to centrifugal force, the heavier uranium-238 isotope tends to be driven towards the walls and to come out at the bottom of the drum.



Swimming-pool reactor of the Reactor Institute *in Delft*

University is investigating the effects of radiation on macromolecules and biochemical systems; the *Eindhoven Technological University* is using test loops for heat-transfer and dynamics research in connection with boiling- and pressurised-water reactors. Furthermore, the *Utrecht State University* and the *Delft Technological University* are also carrying out nuclear research either for their own account or on a national basis.

Inter-university Reactor Institute

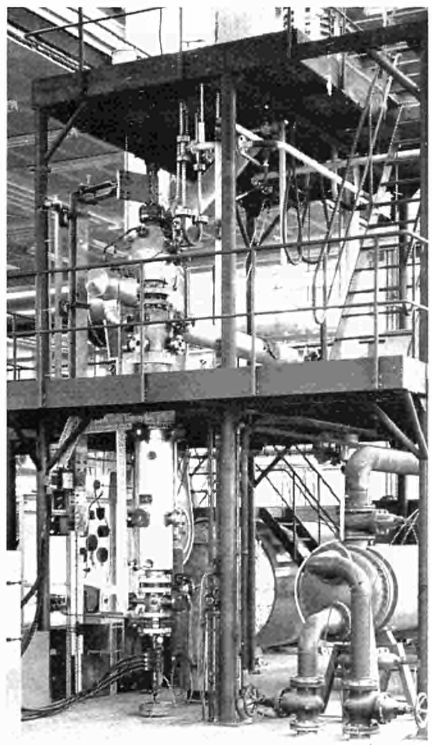
A striking landmark in the Delft polder land is the glittering aluminium dome of the nuclear reactor belonging to the inter-university *Reactor Institute.* The activities of this establishment can be divided into two groups. Firstly, students from all universities and technological institutes can receive training in reactor physics, neutron physics, solid-state physics, radiation chemistry, radiochemistry and biology. Secondly, research in these same fields is conducted by the Institute staff as well as by students and visiting scientists. In addition to the swimming-pool reactor, the output of which is to be increased in due course from 200 kW to about 2 MW, there are also water- and graphite-moderated sub-critical assemblies (which receive the required neutrons from the thermal column of the swimming-pool reactor), a neutron generator and a 1600-curie cobalt source for research purposes.

Interesting investigations were recently conducted here on a number of white-lead samples taken from pictures dating from 1515 to the present time.
Activation analysis of samples weighing one milligram or less showed that the concentration of minor impurities—copper, silver, manganese, chromium, zinc and antimony—in the white lead used was characteristic of particular periods. By the extension of research of this kind it is hoped eventually to obtain more data on the kinds of pigment used by certain painters in certain countries at certain times.

Research by TNO

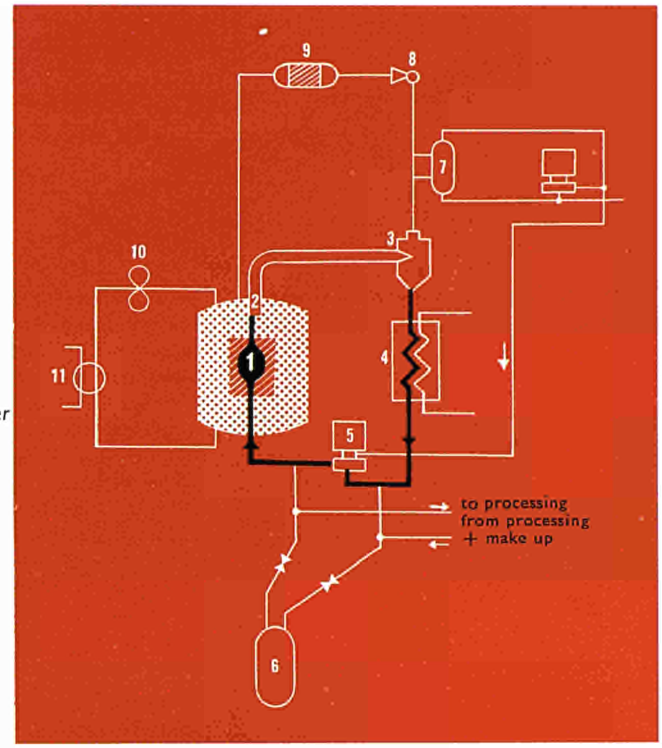
Delft also houses the complex of laboratories belonging to the *TNO (Organisation for Applied Scientific Research).* This organisation, which was set up by the Netherlands Government, carries out research in many fields of applied physics, chemistry and mechanics both for outside customers and for its own account.
It is therefore not surprising that the *TNO*, with its excellent facilities, is awarded a wide variety of contracts for special development work from nuclear research centres in the Netherlands and abroad.
The *TNO* receives a government subsidy to finance, among other things, the research it conducts on its own behalf. The remainder of its income is derived from the com-

High pressure boiling-water experimental loop at the Eindhoven Technological University



missions executed for industrial concerns and for other scientific institutes.
In connection with the testing of the various steels used in reactor-vessel construction, mention should be made of the Euratom-financed development of a new method for determining the transition temperature—i.e. the temperature at which brittle fracture occurs—in small test-pieces. Ultra-rapid photographic techniques have shown that brittle fracture is propagated in a non-continuous manner and that a shock-wave of about 15 kbar is emitted at each interval. By measuring the absorbed energy of the shock-wave in miniature samples it was possible to determine the arrest temperatures. These were in close agreement with the arrest temperatures which were obtained with the same materials by the familiar Robertson test.

1. Reactor vessel
2. Hydrogen injection
3. Gas separator
4. Main heat-exchanger
5. Suspension pump
6. Dump vessel
7. Spray condenser
8. Water jet pump
9. Hydrogen/oxygen recombiner
10. CO_2 blower
11. Heat-exchanger

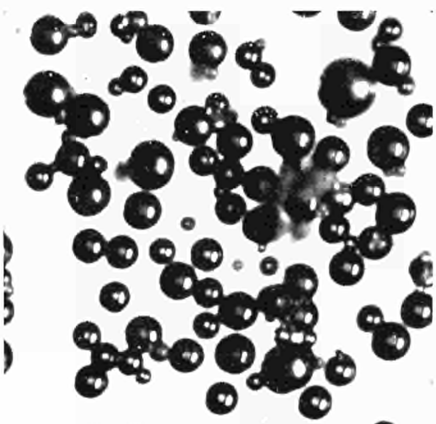


Simplified flow-scheme of the KSTR (KEMA *Suspension Test Reactor)*
The KSTR *is a "homogeneous suspension" reactor, i.e. a reactor in which the fuel is in suspension in a liquid, in this particular case water.*
The suspension circulates continuously, but it is only in the reactor vessel (1) that sufficient fuel particles are brought together to reach critical conditions. The heat generated by fission is extracted from the suspension as it passes through the heat-exchanger (4).
The reactor vessel is surrounded by blankets of beryllium oxide and graphite, the main purpose of which is to reflect neutrons back into the reactor. The reflector is cooled by carbon dioxide.
Hydrogen is injected (2) into the system for a number of reasons, one of which is that it makes it possible to remove gaseous neutron poisons such as xenon-135 from the reactor circuit.

Institute for Nuclear Physics Research (IKO)

A specialised form of nuclear research is carried out in Amsterdam, where the *Institute for Nuclear Physics Research (IKO)* is engaged on reactor experiments with the aid of a 26 MeV deuteron cyclotron and a 6 metre-long linear electron accelerator with a nominal energy of 50 MeV. The *IKO* was originally set up by representatives of the *FOM*, the *Municipality of Amsterdam* and *Philips Gloeilampenfabrieken NV*, who supplied the cyclotron. The research based on the cyclotron falls into three main categories:
– determination of nuclear properties through the study of nuclear reactions and the immediately ensuing de-excitation processes;
– nuclear spectroscopy of radionuclides for the purpose of collecting data on the energy levels excited during alpha-, beta- or gamma-decay processes;
– radiochemistry, including the preparation and study of radionuclides, activation analysis by direct deuteron irradiation, etc.

Uranium oxide/thorium oxide fuel particles for the KSTR *reactor (Arnhem) produced by the* Sol-Gel *process (enlargement × 1200).*

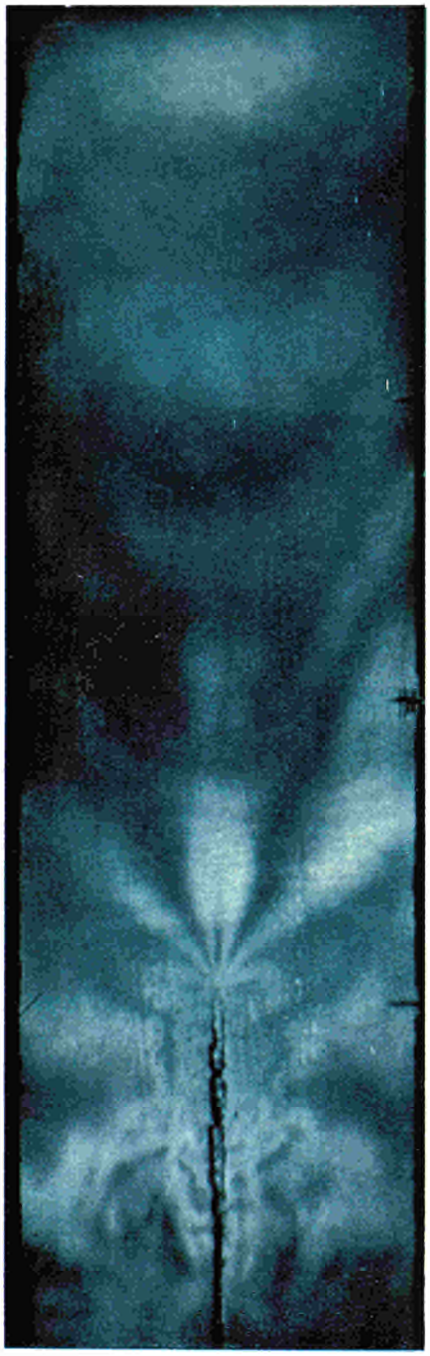


Netherlands Atomic Forum

The Netherlands Atomic Forum was set up in 1961 for the benefit of Dutch firms engaged in nuclear activities and also for research establishments, insurance companies, etc. The purpose of this organisation, which is affiliated to the *Forum Atomique Européen (FORATOM)* and maintains close ties with atomic forums in other countries, is to promote the development and use of nuclear energy by widely publicising the activities of Dutch industrial concerns and establishments working in this field by means of literature, information meetings and exhibitions. The *Netherlands Reactor Centre* supports these activities by providing facilities in the field of public relations, films, publications, technical advice and documentation.

International relations

In the nuclear sphere the Netherlands maintains various international contacts. The oldest and strongest ties are with Norway, with whom the Dutch have been working jointly both at Petten and at Kjeller, near Oslo, since 1950.
These ties were recently extended by the



'Brittle'' crack propagating in a steel plate (TNO, Delft)

direct participation of the *RCN* in the *OECD Halden Project* (research on a boiling-heavy-water reactor plant); this follows several years of Dutch collaboration under Euratom auspices. The Netherlands is taking an active part in the work of the *International Atomic Energy Agency (IAEA)* in Vienna, the *ENEA* in Paris, and Euratom, of which it is one of the six Member-states. Finally, agreements for co-operation in the field of nuclear energy are in force with the United States, the Soviet Union and Great Britain.

Development of power reactors

After this survey of the various aspects of applied research in the field of nuclear fission and the organisations which are playing a part in these developments, the time has come to cast a glance at the projects aimed at the construction of power reactors for electricity generation and for ship propulsion.

The KEMA project

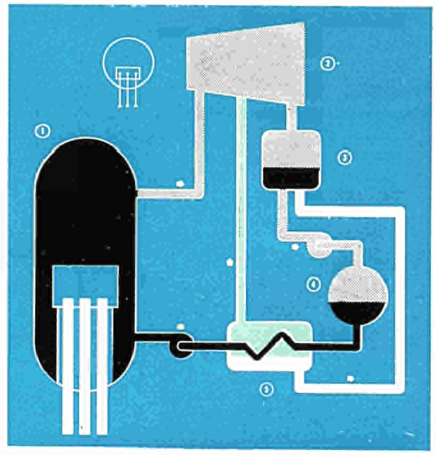
The power-reactor project of *KEMA* (the research and materials-testing laboratories of the Netherlands electricity-production undertakings) is based on the view that in the long term the development of breeder reactors is essential if economic use is to be made of the world's uranium and thorium reserves. The homogeneous suspension reactor seems to offer possibilities as a thermal breeder reactor powered with cheap fuel in the form of spherical ThO_2-UO_2 particles having a diameter of 5 microns. These are present in the heavy water which serves both as the moderator and as the heat-transfer medium.

At Arnhem this type of reactor was developed jointly by *KEMA*, *RCN* and Euratom, and a sub-critical assembly which has since been constructed provides data on the fuel's kinetic, physical and chemical behaviour. The fuel particles are fabricated in a pilot plant based on the *Sol-Gel* process.

In view of the next essential step of testing the suspension under actual power-reactor conditions, a prototype reactor is at present being built at Arnhem. This *KEMA Suspension Test Reactor (KSTR)* of 100 kW will not, however, use heavy water; instead, ordinary water at a temperature of 250^{0}C will serve as moderator and coolant. This necessitates enrichment of the fuel, which will consist of particles of $^{235}UO_2$ (13%) and ThO_2 (87%). The primary circuit comprises the reactor vessel, a heat-exchanger and a circulation pump, the whole being surrounded by a gas-tight containment shell.

The Dodewaard power plant

As early as 1956 *SEP* (*Samenwerkende Elektriciteitsproductiebedrijven*, an association of Netherlands electricity undertakings) were planning to build a nuclear power station. A comparative study, based on ten foreign quotations for the supply of 150 MWe nuclear generating plants equipped with water or graphite reactors, revealed that in no case was economic operation possible



Flow scheme of the SEP Nuclear Power Plant (single cycle natural circulation boiling-water reactor)

1. *Reactor vessel*
2. *Turbo-alternator*
3. *Condenser*
4. *Demineraliser*
5. *Feed-water heaters*

for the Netherlands. Awareness of the unprofitability of building a nuclear power plant of any present-day proven type led to a search for a size at which the deficiency would be justifiably offset by the knowledge acquired on design, construction and operation. The choice fell on a single cycle 50 MWe boiling-water reactor.
In view of the experimental nature of this *SEP* plant, Euratom was willing to contribute to the project.

The NERO programme

Since 1958 the development of an advanced pressurised-water reactor suitable for marine propulsion has loomed large in the *RCN* programme. A provisional design based on a preliminary study was produced and in 1960 a development programme was drawn up.
This *NERO* programme, in which Euratom has participated since mid-1961, aims at acquiring sufficient knowledge for the construction of a prototype marine reactor. The principal characteristics of the reactor are as follows:

— burn-out prevention by internal recycling of the primary cooling water inside the reactor vessel;
— a core life of four years, owing to the use of burnable poison in the UO_2 fuel;
— a compact reactor unit housed in a containment shell 9 metres in diameter;
— minimum weight;
— use of moderately superheated steam.

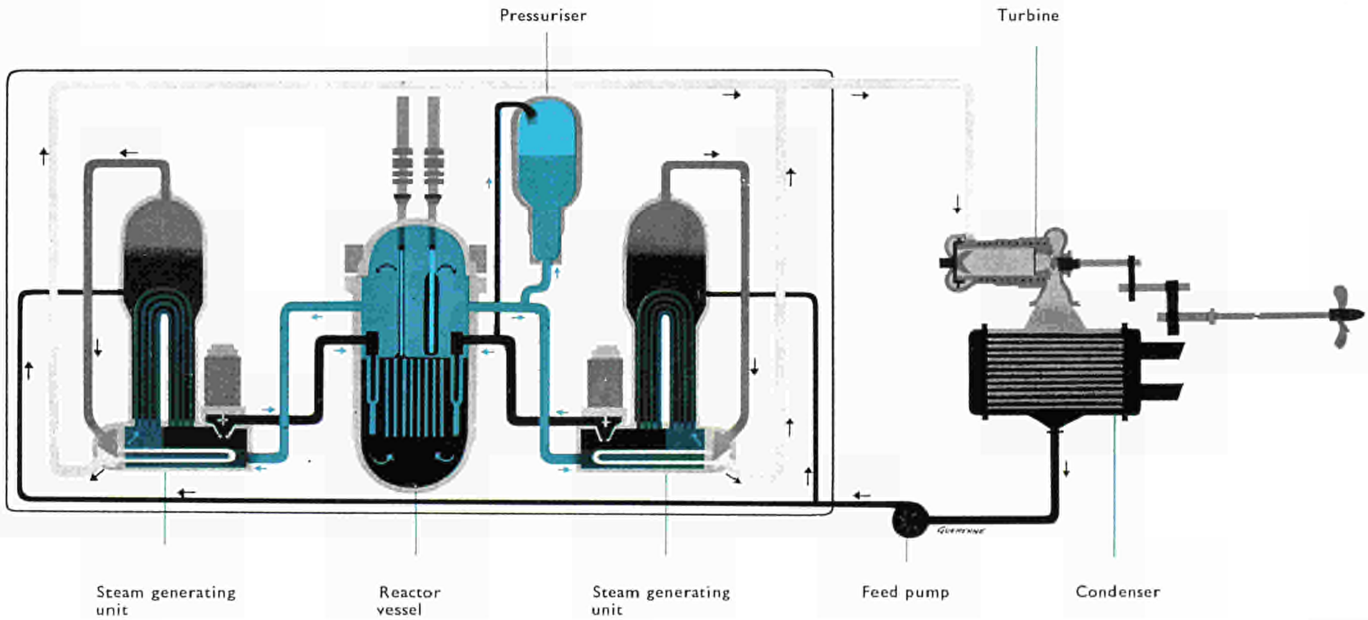
The development programme has since made such good progress that the results it has yielded have enabled the design of a prototype to reach an advanced stage. The thermal power envisaged is 67 MW, which should deliver 22,000 horse-power at the shaft.

Nuclear fusion

Besides development in the field of nuclear fission a great deal of attention is being given to pure scientific research on the generation of energy by nuclear fusion. The *Foundation for Fundamental Research on Matter (FOM)*, in association with Euratom, is investigating the properties of ionised gases and the problems of producing usable power from thermonuclear reactions. Also under development are a number of experimental techniques of a distinctive nature which are important for pure research in plasma physics.
This research is being conducted by the theoretical and experimental sections of the *FOM Institute for Plasma Physics*, which was set up a few years ago on the "Rijnhuizen" estate in the municipality of Jutphaas, near Utrecht. *FOM* teams are also taking part in the research being carried out in this sector at the *FOM* mass separation laboratory in Amsterdam, at the *State University of Utrecht* and at the *KEMA* laboratories in Arnhem.

The Netherlands is one of the smaller Member-states of Euratom, and obviously if it desired to carry out independent research and development work in the field of nuclear energy it could only do so on a modest scale. The enormous sums inevitably required for thorough investigations are one of the reasons for the Netherlands' ever-growing interest in scientific research carried out on a co-ordinated basis.

Flow-scheme of the NERO ship propulsion pressurised-water reactor. The primary (pressurised circuit is shown in blue, the secondary circuit feeding the turbine in black.



The impact of natural gas on Europe's energy economy

JEAN LECLERCQ *and* MICHEL VAN MEERBEECK, *Directorate-General for Industry and Economy, Euratom*

During the past few years, natural gas has acquired a place in the European Community's energy economy. Whereas in 1950 its share in the member countries' overall energy production amounted to no more than 0.4%, it had risen by 1963 to 3.3%. So far, however, this increase has been due solely to the exploitation of relatively modest resources in West Germany, France and Italy; the tremendous potential opened up by the recent discovery of deposits in the Sahara and the Netherlands was still playing no part in 1963.

The trend which has thus developed raises certain questions. For example, to what extent can natural gas provide a solution to the problem posed by the inadequacy of the Community's indigenous primary energy resources in the face of a steady rise in consumption? What repercussions will it have on the development of nuclear energy, regarded as the key to the future?

Natural gas and its outlets

Natural gas consists chiefly of methane and its calorific value usually ranges from 8,000 to 10,000 kilocalories per cubic metre (kcal/m^3). that is to say twice as much as that of town gas (4,250 kcal/m^3).

What are its possible uses?

Fuel and raw material alike, natural gas has vast outlets.

As a raw material, it provides the basic products for chemical syntheses (acetylene, chlorinated derivatives, ammonia), carbon-black for the rubber industry, etc. It can also be used as a reducing agent in blast-furnaces.

In the energy field, it constitutes a clean, rich fuel, extremely versatile and eminently suitable for use in automatic control and precise regulation of temperatures. A wide range of applications is consequently open to it—space-heating and other domestic uses, as well as in industry, especially for steam-generation and furnace-heating.

Electricity generating stations, too, may show interest in a fuel which offers, among other assets, that of requiring neither storage nor preliminary handling.

Natural gas transport

While the exploration and production methods are largely the same for natural gas as for petroleum, this does not hold good for transport and distribution, in which respect natural gas is less adaptable than oil and its liquid derivatives. Notwithstanding what is said further on about methane-tankers, natural gas is wholly dependent on pipelines for delivery to the consumer, and this form of transport, although offering unquestionable cost advantages, is attended with various drawbacks which militate against operating flexibility.

The route and diameter of a gas pipeline must be carefully determined after a study of the market and in accordance with the possible throughputs; once it has been laid it cannot be altered, no matter how the market changes. If the size of the pipeline has been calculated too generously, its profitability will become questionable, since amortisations will burden selling prices unduly, while the utilisation factor can scarcely be stepped up without adversely affecting these prices. If, on the other hand, the pipeline has been under-sized, the result, by reason of the difference between the maximum possible throughput and the saleable quantities, will be a lack of earning power which can only be remedied by sinking further investments (in particular, boosting of pumping stations).

A new technique has recently provided an alternative solution to piping, hitherto the only method of transporting natural gas. The gas is now liquefied at very low temperature and carried in liquid form aboard ships specially equipped for this purpose. Consequently, this method enables natural gas to be transported on ocean routes where the construction of a pipeline would be difficult or impossible; nevertheless, pipelines remain indispensable for conveying the gas from the gas-field to the liquefaction plant and for distributing it after ocean transport.

Natural gas in the Community

The production of natural gas in the European Community increased from 1.1 million tons coal equivalent (*t.c.e.*) in 1950 to 18.3 million in 1963.

This production is consumed predominantly in the countries concerned and the relative magnitude of the consumption is therefore proportional to the output of each country. In 1963, Italy, hitherto the biggest producer of natural gas in the Community, consumed 9.5 million *t.c.e.*, representing approximately 11% of its total consumption. France was next with 6.6 million *t.c.e.*, representing 4.5% of the total consumed. Then came Western Germany and the Netherlands with 1.5 and 0.7 million *t.c.e.* respectively, or 1.2 and 1.9% of their total consumption. In Belgium, only very small quantities of methane were consumed, while the Grand Duchy of Luxembourg neither produces nor consumes any natural gas.

The new finds

So far, therefore, the quantities of natural gas produced in the Community countries have been too small to disturb the energy markets. They have been more in the nature of supplementary supply which has easily been absorbed into the energy economies of the producing countries.
This pattern, however, has now been completely disrupted by the discovery of the vast natural-gas occurrences in North Africa and the Netherlands.

The Saharan gas-fields

Gas reserves amounting to 1,100,000 million cubic metres, of which 800,000 million cubic metres are commercially exploitable, were discovered at Hassi R'Mel. Other occurrences, located near the Libyan frontier, are reported to contain at least 600,000 million cubic metres.
Only the Hassi R'Mel gas-field is at present being exploited, the gas being piped to the Mediterranean coast. Since the output greatly exceeds the local demand, it is necessary to export the enormous surplus available.
Nevertheless, the prospects for disposal in Europe are hampered by serious technical problems, notably as regards transport. In this respect the ultimate choice will lie between methane tankers and an under-sea pipeline.

The Groningen gas-fields

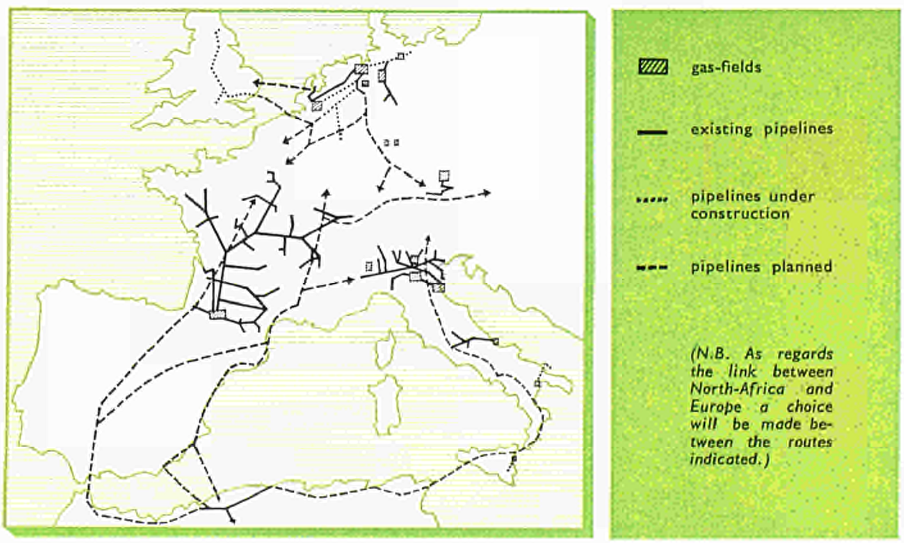
The first commercially exploited oil occurrences in the Netherlands were discovered in 1943 as a result of systematic exploration which had been in progress since 1923. Further drilling led in 1948 to the discovery of dry-gas fields, and in 1959 the presence of the Slochteren field, near Groningen, was revealed. Estimates of the content increased with subsequent surveys of the field: 60,000 million cubic metres in 1960, 150,000 million in 1961, then 450,000 million and, later, 1,100,000 million in 1962 and finally 1.600,000 million at the beginning of 1965. It is even possible that this gas-field may contain considerably larger quantities still; figures of 4,000,000 million and even 6,000,000 million cubic metres have been mentioned in the Press, though these should be treated with reserve.
However that may be, the distribution area for Dutch natural gas cannot be limited to the home market; the available quantities are so great that an outlet must be found outside the Netherlands.
The problem is therefore twofold: it is necessary, on the one hand, to organise the domestic energy market so as to encourage the maximum use of natural gas—if possible without seriously affecting the other energy-sources—and on the other hand, to build up sales in foreign markets where natural gas will have to compete with alternative forms of energy which may be protected by taxes or subsidies.

Netherlands sales policy on natural gas

Various proposals have been put forward by the interested parties with regard to the policy that should govern the distribution of methane.

— The oil companies and the Netherlands State Collieries, who hold the exploitation rights, as well as the state-owned gas-supply undertaking, recommended a system of sales based on strictly commercial criteria, with a view to obtaining the highest possible income.
— Certain municipalities in the north of the country advocated a system of priority allocation which would favour local industrialisation. Prices would be fixed from case to case according to the profitability of the industrial projects, without reference to the competing fuels, so as to ensure competitive prices for the products.
— A third proposal was that the natural gas should be devoted largely to electricity production for generation of the base load. The price would be kept in line with that of other fuels, according to the calorific value. The transport networks would be built and managed by the electricity undertakings.
The Dutch authorities decided on a sales policy based on the application of purely commercial criteria guaranteeing the maximum revenue, i.e.:
— The public supply system will be converted entirely to natural gas; in this sector natural gas will completely replace other gaseous fuels. The network will be progressively extended in order to serve an increasing number of consumers. It is ex-

Natural gas in Western Europe. Principal gas-fields and pipeline networks



pected that the price of the gas will be sufficiently attractive to enable it to be used for space-heating, thus permitting a considerable expansion in household consumption.

— In industry, preference will be given wherever possible to natural gas for specific applications.

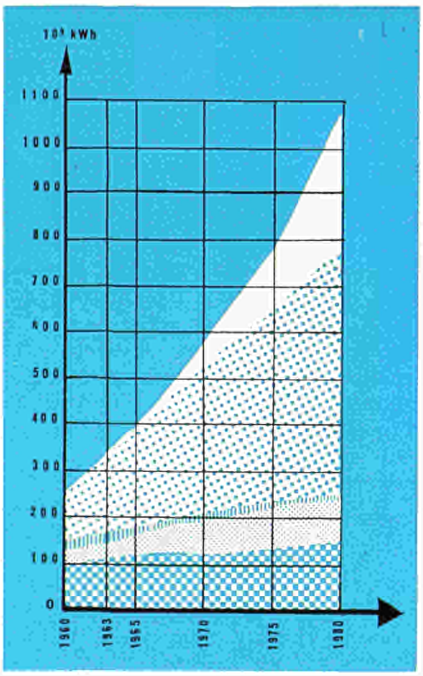
— As regards thermal power stations, these could serve as an emergency outlet for the disposal of temporary or seasonal surpluses. Indeed, rather than feed the gas permanently to numerous power stations, it seems preferable in principle to export it to countries which will put it to more specific uses and can therefore pay a higher price. Electricity producers can in fact easily import their fuels—coal and petroleum products—at low cost.

In other words, natural gas is a noble energy source which, both from the technical and from the economic viewpoint, can lay claim to more appropriate—and consequently more profitable—applications than mere combustion in the furnaces of electric power plants.

— Finally, there are two considerations which restrict the prospects of the Groningen methane as a raw material for the chemical industry: firstly, the competition from coke-oven gas and refinery gas, which are better suited by reason of their chemical composition and will become more plentiful as natural gas supersedes them to an increasing extent in other sectors; secondly, the fact that the suppliers have no reason to lower their prices in order to make natural gas attractive to the chemical industry as long as they can sell it profitably elsewhere.

— With regard to local industrial development the Dutch authorities have rejected the principle of preferential rates, which amounted to operating price discrimination against other forms of energy or to making other sectors throughout the country as a whole pay for the subsidies granted to certain new activities. On the other hand, they have undertaken to set aside 25,000 million cubic metres of gas for industrial development in the north of the Netherlands and to grant special rates to all enterprises set up in that region. This policy has already aroused the interest of groups both in Holland and abroad who propose to build factories near the gas-fields for the production of aluminium, carbon black, ammonia, acetylene, fertilisers, etc.

Breakdown of net electricity production by energy source for the period 1960-1980



nuclear production

conventional production

blast-furnace gas and other manufactured gases

lignite

hydro- and geothermal power

Integration of natural gas into the Community's energy economy

The discovery on Community territory of an important and commercially exploitable source of energy will have a beneficial effect on the Community's energy economy, which on the whole is marked by a shortage of indigenous resources.

The Community's annual availability of natural gas, according to present estimates, is given in Table I.

It is currently estimated that the annual production from the *Groningen gas-field* will reach a maximum of 35 million metric tons coal equivalent, half of which would be exported.

In the Netherlands, the impact of methane on the energy market will be greater than in the other Community countries. In fact, the 17 million or so metric *t.c.e.* of natural gas to be integrated into the Dutch energy economy in 1975 represents 30% of the total primary energy consumption.

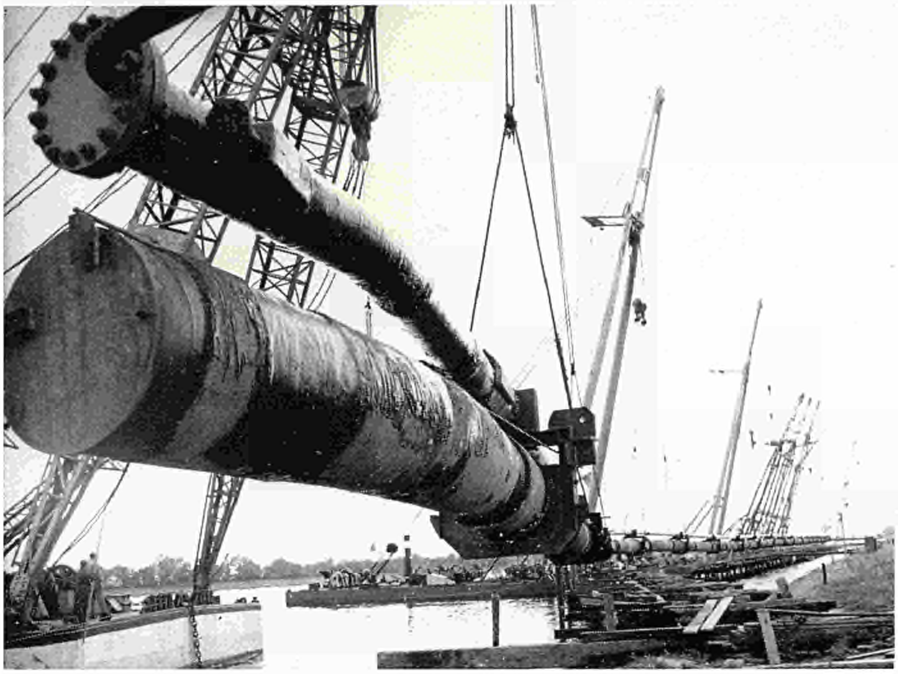
Natural gas will rapidly supersede all the gases now distributed through the public supply system, and its advent will mark the end of gas-works and the feeding of coke-oven gas, refinery gas, blast-furnace gas and chemical by-product gases into the grid. These sectors will thus be faced with the supplanting within a very short time of a large part of their gas production.

The loss of coal offtake can be made good either by cutting imports and boosting exports or by consuming more Dutch coal in the electricity generating stations.

In the other countries, except for the adjacent

Table I: Estimate of the Community's availability of natural gas in 1970, 1975 and 1980 (in million metric tons coal equivalent)

	1970	1975	1980
France	7	8	8
West Germany	4 to 6	10 to 12	13 to 15
Netherlands	10 to 15	25 to 30	32 to 35
Italy	7	7	7
Production	28 to 35	50 to 57	60 to 65
Imports from Sahara	—	10 to 15	18 to 25
	28 to 35	60 to 72	78 to 90



A natural-gas pipeline under construction in the Netherlands

areas of northern Germany, it will be 1975 before the normal throughput of Groningen gas is attained, since the pipeline traces are as yet by no means definite and the laying of the lines could take several years. The same problems resulting from the substitution of natural gas for traditional fuels will arise, but they will no doubt be less acute. The natural gas will be still more in the nature of a complementary supply and the principal offtakes will be in regions where energy is expensive or scarce. Some of the gas will also be unloaded on new markets, where it will be put to specific uses which do not necessarily involve competition with other fuels.

In view of the foregoing, and when account is taken of the widening gap between the consumption and production of energy, it can be seen that the 15 to 20 million metric *t.c.e.* of natural gas which the Netherlands plans to export annually by about 1975 must be capable of being integrated into the energy economies of the other countries without causing any disruption. After deduction of the quantities to be exported to non-Community countries (Britain, Switzerland, Austria, etc.), the *E.E.C.* countries other than the Netherlands will share between 10 and 15 million metric *t.c.e.* of Groningen natural gas, representing less than 6% of the overall consumption increase in these countries during the period 1963-1975.

As regards the *Hassi R'Mel gas*, this is first transported to the coast, 800 km away, through a pipeline which has branches ending at Oran and Algiers and also serves the liquefaction plant at Arzew.

Although the transport cost of liquefied gas per calorie is still substantially higher than that of crude oil, the possibility of using large-capacity methane tankers is being examined with growing interest. This tendency is further stimulated by the reduction in the installation costs for the liquefaction units.

Also under consideration is a plan for the piping of Saharan natural gas across the Mediterranean, since the potential markets lie in central and southern Europe (France, southern Italy, Spain, and probably Austria and Switzerland).

The impact of natural gas on other forms of energy

Whereas in 1963 the Community possessed only 18 million *t.c.e.* of natural gas, by 1975 it will have additional resources totalling some 50 million *t.c.e.* What impact will this have on other sources of energy?

As regards *public supply*—which is to be very largely converted to methane—and *industry*, it is estimated that natural gas consumption in 1975 will be about 20 million *t.c.e.* up on 1963.

The *electricity generating plants* have hitherto used relatively little natural gas. In 1963, the 3 million *t.c.e.* of methane consumed accounted for only 2.5% of the Community's total electricity production. In view of the additional availability of fuels replaced by natural gas in other sectors, it is likely that in 1975 the thermal generating stations will absorb slightly more than double their present consumption, i.e. a further 3 million *t.c.e.*

This leaves some 20-30 million *t.c.e.* to be integrated into the Community's energy economy: this quantity will supplant coal and fuel-oil.

The collieries, already hard pressed by competition from fuel oil and imported coal, may well be subjected to increased pressure in the methane-using regions. With prices constantly rising, sales of Community-produced coal will therefore continue to dwindle and even protective measures could not prevent penetration of the markets by natural gas.

Finally, fuel oil is bound to be affected in certain of its outlets. The Community's iron and steel industry, for example, constitutes a market for more than 3.5 million tons, two-thirds of which is consumed in oil-fired open-hearth furnaces, and here too natural gas will gain ground.

However, the oil companies—which, both in the Netherlands and in the Sahara, control in varying degrees the natural-gas production and sales organisations—will endeavour to safeguard their interests by maintaining the market equilibrium.

Possible repercussions on nuclear energy development

As regards nuclear energy, we shall confine ourselves to assessing the repercussions of natural gas on electricity production.

A study on the long-term energy prospects in the European Community (published in 1962) contained an appraisal of the electricity requirements up to 1975; it also attempted to estimate the proportions which will be accounted for by the various categories of primary energy in meeting these requirements. The trends outlined in this study were extrapolated to 1980.

According to this study, the pattern of electricity production is likely to be as follows:

"privileged" production (i.e. hydroelectric power and thermal generating plants using low-cost fuels):

- gradually declining growth rate of hydroelectric power;
- relatively moderate increase in lignite-based production;
- stabilisation of the production from generating stations attached to smelting plants and operating on blast-furnace gas;

"competitive" production:

- increase in the share of coal, fuel oil, natural gas and nuclear energy in electricity production from 47% in 1960 to 75% in 1980.

The problem therefore boils down to ascertaining the share of natural gas in the competitive thermal production of electricity. Being, as we have seen, a rare fuel which is very attractive for other uses, natural gas does not in the present circumstances seem destined to play an important direct part in electricity generation.

Some generating stations erected near the gas-fields will undoubtedly run entirely on methane, but these will be few in number. Furthermore, given certain conditions, multi-fuel power plants will absorb seasonal surpluses of natural gas, as well as temporary surpluses occurring mainly during the another Community country. The consequences of such discoveries would differ somewhat, according to the countries in which they were made; in the market for the fuels used in thermal generating stations, their exploitation could give rise to a degree of dislocation proportional to the size of the new productions.

In the Netherlands, where—at least for the foreseeable future—the energy market will be virtually incapable of absorbing any more gas than the quantities now envisaged, any appreciable increase in availability as a result of new discoveries or a revised estimate of the Groningen reserves would be used largely for the electricity generating stations—hitherto excluded for reasons of cost—and for export.

and a reliance on imports that is gradually assuming disquieting proportions.

The quantities of natural gas placed on the market as from 1975/1980 will in fact represent only a small part of the total energy consumption at that time. Furthermore, a deduction must be made for the quantities used as raw material.

A further necessity is to locate and gradually exploit new gas-fields, in order to replenish the reserves as and when they become exhausted.

Consequently, the known gas occurrences and any further discoveries resulting from current exploration work cannot affect the urgent necessity of resorting to nuclear energy in order to meet the increasing power requirements.

One solution to the problem of transporting natural gas: the methane tanker

Off-shore drilling platform

initial operating phases of the pipeline networks, in order to ensure an adequate utilisation factor for the latter. Consequently, the great majority of the competitive-production thermal generating stations which will be built in order to meet the growing demand for electricity will continue to burn mainly solid and liquid fuels, competition between which will be intensified, notably as a result of the displacement of substantial quantities of these fuels owing to the advent of natural gas.

It is possible that very important new discoveries of natural gas may be made in the Netherlands, under the North Sea or in

In the other Western European countries, on the other hand, there are still extensive markets open to natural gas. Consequently, any substantial additional availability would be reflected in an expansion of the distribution networks to serve new areas of consumption rather than in a systematic large-scale supply to the thermal generating stations at low prices.

Conclusions

Natural gas can therefore play a useful part in the Community's energy economy, which is marked by a growing structural deficit

Moreover, the methane placed on the market will wherever possible be set aside for specific applications in which it is of special value, rather than consumed on a large scale in generating stations; to some extent, therefore, it will preserve its character of rarity.

Thus, since there is no change as regards the essential aims in the generation of electricity to satisfy the future demand, the use of nuclear energy in electricity production remains indispensable for solving the problems associated with the cost of electric power and the Community's dependence on imported fuels.

Uranium prospecting — An introduction

FERNAND SPAAK, *Director-General of the Supply Agency of the European Atomic Energy Community*

Early in 1963, a report was published by the Supply Agency's Consultative Committee on uranium reserves and the Community's long term supply problem. At that time, the contracts governing the supply of uranium for the defence needs of the United States and the United Kingdom were about to expire, and "atoms for peace" still appeared to be far from competitive with energy obtained from conventional sources. Under the circumstances, it would seem that uranium reserves exceeded the foreseeable demand and that the outlook for the uranium industry was neither settled nor brilliant.

Yet the Consultative Committee's report stated that, if no new large-scale uranium deposits were discovered in the near future, the supply of uranium would between 1970 and 1980 be beset by difficulties which would inevitably be reflected in an inordinate rise in price.

The Consultative Committee therefore recommended that, in order to assure the Community of an equitable and regular supply of fissile materials, the following measures should be taken:

– vigorous resumption of prospecting with a view to discovering new uranium deposits in and outside the Community;

– acquisition of interests in the existing uranium-mining industry, and/or conclusion of long-term supply contracts, possibly in conjunction with a uranium-stockpiling programme.

The Euratom Commission duly adopted these findings, especially in view of the fact that, apart from France, which since 1946 had continuously pursued a very active policy with regard to supply and, in particular, prospecting, the efforts of the Community countries in the field of prospecting had been extremely modest.

Thenceforward, the Supply Agency and its Consultative Committee embarked upon a series of investigations aimed at determining the uranium potential of such member and non-member countries as might develop into suppliers of that material. Its findings have confirmed that there is enough uranium in the world to rule out any risk of shortage in the next few decades. On the other hand they also show that if uranium is to be obtained at satisfactory prices from 1975-80 onwards, intensive prospecting programmes have to be launched without delay.

Today, nuclear energy is already acknowledged to be capable of competing with fossil-fuel energy and preoccupations with the long term supply problem are becoming widespread. That these preoccupations are well-founded was borne out at the Third Conference on the Peaceful Uses of Atomic Energy, held at Geneva in December 1964. In consequence, both the governmental authorities of the producing countries and the uranium industry itself are awakening to the new and encouraging prospects. In Canada as well as in the United States, private companies are displaying rekindled interest in uranium prospecting. Furthermore, the Canadian Government has recently announced the introduction of a stockpiling policy and also initial measures for restricting the sale and exportation of uranium. These restrictions are dictated by economic considerations bearing upon the problem of dependability of supply for Canadian users themselves.

Other countries with a uranium potential have already taken, or signified their intention of taking, legislative and administrative measures to curb exports of uranium concentrate so that their own resources can be used to cover requirements stemming from their programmes in the field of nuclear energy production.

This trend highlights the advantage and the urgency of adopting a common supply policy for the European Community, as there is every reason to assume that the latter, despite its fairly limited uranium reserves (about 30,000 tons of proven reserves, as against estimated needs up to 1980 of 60,000 tons), will become one of the world's leading uranium users. This being so, the development of prospecting programmes by European enterprises, in both Community and non-Community countries, appears to be of capital importance. In the light of all these factors, Mr. Van Wambeke's article provides valuable and timely information on the subject.

Detailed radiometrical prospecting in the Val Rendena (CNEN, Italy)

Prospecting for uranium

LEOPOLD VAN WAMBEKE, *Ispra Establishment of Euratom's Joint Research Centre*

History of uranium prospecting

Before the last war, uranium ore was mined, in a small number of mines, not in order to extract the uranium from it, but in order to produce radium, or, alternatively, it was a by-product of the production of silver, gold and, more rarely, platinum.

Knowledge of uranium geology at that time was limited and it seemed, on the basis of the data acquired, that the pitchblende veins constituted the main type of uranium deposit.

The advent of the atomic age and the absolute necessity of finding uranium ore, for uses which were at first mainly military, gave a major boost to uranium production, such as at Shinkolobwe in the Congo, and led to the re-opening of the closed mines in Colorado and Canada. It was at this time, also, that work was commenced, notably in the United States and Canada, on prospecting for uranium with the aid of the first Geiger counters on the basis of the still very scanty knowledge of uranium geology then available.

Immediately after the war, uranium became of greater interest as a future source of energy and prospecting for this metal began to be stepped up. In Europe, France was the first country to undertake actively prospecting for uranium, through the *Commissariat à l'Energie Atomique*, in order to ensure a supply of nuclear source materials. This prospecting work, which was carried out with modest funds and, initially, on the basis of a limited amount of mineralogical data, was rewarded in 1948 with the discovery of a workable vein of pitchblende at La Crouzille in the Limousin area.

In the United States and Canada, uranium prospecting, which was at first assumed by government departments, was soon handed over to private industry. Up to 1950 prospecting was mainly confined to the Colorado plateau area in the United States and to those areas on the edge of the Canadian shield which seemed most promising. In South Africa, the radioactivity of conglomerates was rediscovered.

Between 1950 and 1956, there was a marked increase in the prospecting for uranium in the free world, helped to a large extent by the development of new equipment, notably more sensitive Geiger counters and the first scintillation counters. A veritable uranium boom took place. Aerial and car-borne prospecting were used for the preliminary surveying of vast areas. At the same time, geochemical prospecting was born, but prospecting on foot, with the aid of counters, still remained one of the best ways of carrying out systematic studies of

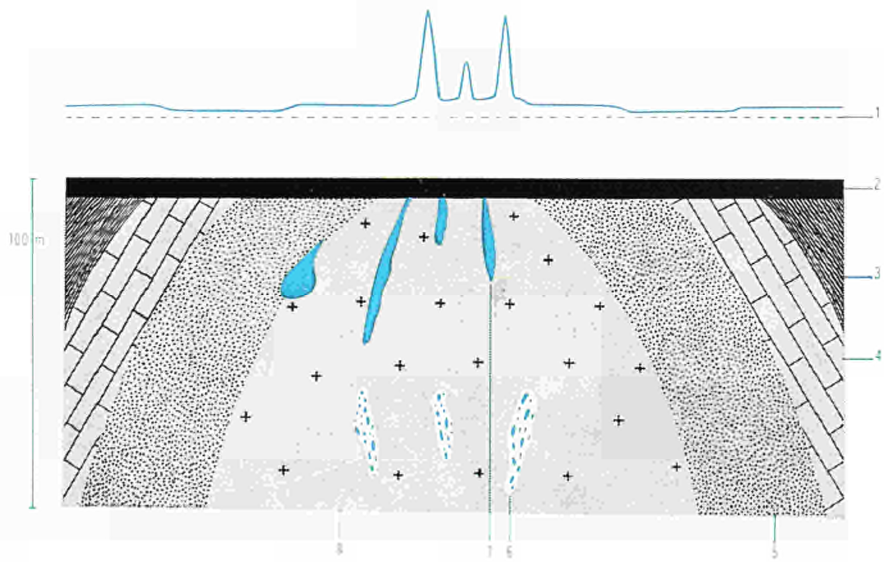


Fig. 1: Uraniferous deposits in connection with granite
1. Radioactivity (c.p.s.); 2. Soil; 3. Schist; 4. Limestone; 5. Sandstone; 6. Uraniferous pegmatites; 7. Uraniferous veins; 8. Granite.

an area which was felt to be promising. Techniques involving soil-resistivity measurements were widely used in detailed studies of radiometric anomalies.
This period was marked by the major discoveries (Blind River, Canada; Ambrosia Lake, United States; etc.) and by appreciable advances in prospecting and exploration methods. It revealed the importance of sedimentary deposits as the main source of uranium. During this period, the first prospecting operations were organised in Italy and then in Germany, where several indications were known to exist, while in France major deposits were discovered in the Massif Central (Forez, Limousin) and in the Vendée and in the Vosges mountains (St. Hippolyte).
The period after 1956 was marked, particularly in the United States and Canada, by a general drop in prospecting work, due mainly to the fact that the volume of reserves discovered was already considerable and also owing to the transition from the ore-prospecting stage to that of production. After 1959, a year in which the free world's uranium output reached a record figure of about 33,000 tons, a new falling-off occurred, this time due to the disparity between supply and demand, the latter being still principally contingent on military requirements.
After 1960 the reserves of uranium which were exploitable at a price not in excess of $8 a pound of U_3O_8 were re-estimated in numerous countries and it was found that in the majority of cases they had been set too high. Although in the Community prospecting activities have continued merely at a moderate rate, especially since 1960, they have nevertheless demonstrated the existence of uranium sedimentary type deposits, especially in France, (Massif Central, Hérault), while other deposits have been discovered in Germany (Ellweiler, Menzenschwand) and Italy (Novazza).
It is certain that this period of recession in uranium mining cannot be of anything but a temporary nature, for nuclear energy is now reaching the point where it is competitive with other forms of power, so that power reactors will become more and more numerous. Thus, in order to meet the uranium requirements of the period 1975-80, it will be essential to launch a major prospecting action before 1970.

Where is uranium to be found?

It is now known that the uranium contained in the earth's crust totals barely four grams per tonne and that its concentration is markedly lower than that of other common metals. It happens, however, that it tends to concentrate considerably, thus causing deposits which can be grouped under two main classes: deposits related to granite and other igneous rocks, and sedimentary type deposits (see Figs. 1 and 2).
The uranium-bearing formations of the first category are generally located, if not in the granite itself, then at least in its immediate vicinity. In order to discover its origins, we have to go back to the granitisation cycles of the earth's crust which accompanied the formation of the large mountain ranges.

In Europe, for instance, almost all these deposits, consisting mainly of veins of pitchblende, were formed about 280 million years ago at the end of the great thrust which created the Hercynian mountains. They are mainly located in the axial area of the Hercynian range, which extends from Cornwall to the Erzgebirge in Saxony, passing through Brittany, the Massif Central, the Vosges, the Black Forest and the Fichtelgebirge. These fairly extensive granitised regions form an *uranium metallogenetic province* where the likelihood of finding workable deposits is relatively good.
Other areas of granitisation or areas characterised by a volcanic activity of Hercynian age are known in Portugal, Spain, Italy, the East European countries, Central Asia and China and are also accompanied by uraniferous deposits.
Sedimentary deposits, which consist in particular in sandstone formations and con-

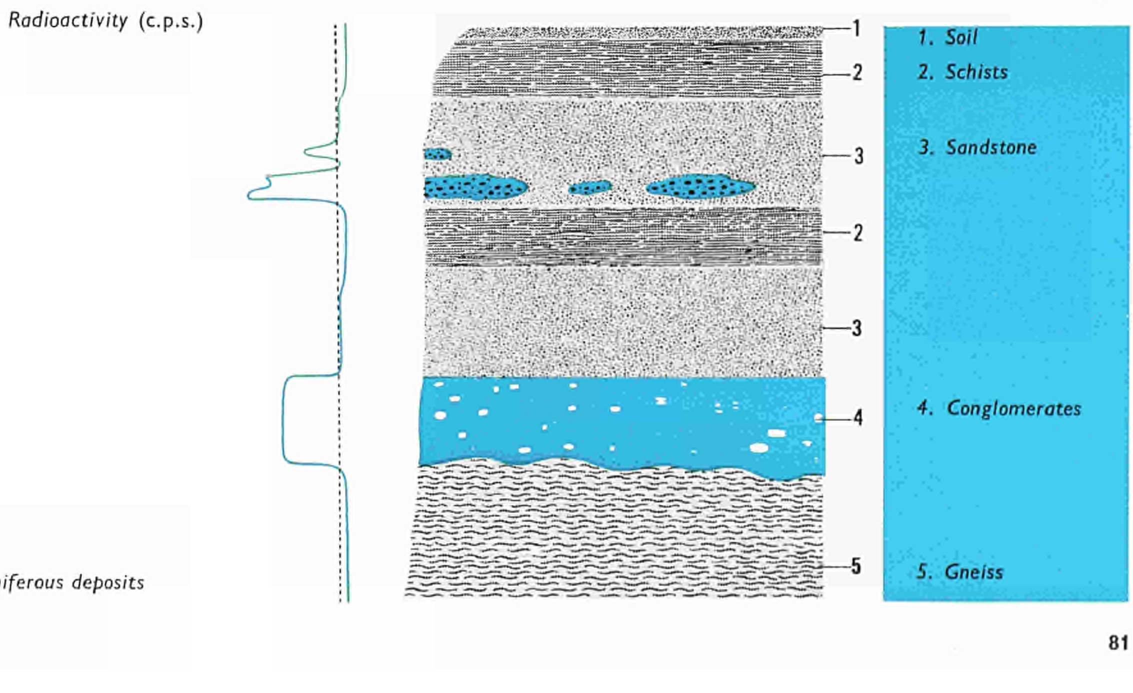


Fig. 2: Sedimentary uraniferous deposits

glomerates, make up more than 90% of the free world's workable uranium reserves. The conglomerates, which themselves contain 63% of the free world's reserves, are located mainly in the old shields of pre-Cambrian age (3,000 to 510 million years), which constitute the first continents. The best examples of these conglomerates are found in Canada (Elliot Lake Basin) and South Africa (gold-bearing basin of the Witwatersrand).
The deposits located in uraniferous sandstone are mainly found in the mid-West of the United States, in Argentina and in the Soviet Turkestan.
This brief description of the location of the main types of uraniferous deposits shows that the uranium concentration in the earth's crust did not occur accidentally but that there are uraniferous "provinces" (see Fig. 3). The search of such favourable provinces constitutes the first step, or preliminary stage of prospecting.

The first problem—where to start?

The basic problem of all prospecting work lies in the selection of the areas where there may be a reasonable chance of success. Quite apart from economic, legal and, sometimes, political factors which have to be allowed for, this choice is based not only on a good knowledge of the geology of the metal in question and of the data already available, but also on a prior study of the geological and tectonic evolutions and of the mineralisation cycles.
In 1945 geological data on uranium were still relatively sparse and in the Community countries, for instance, nothing was known of any deposits apart from a few rare mineralogical indications. The granitic massifs and then the volcanic manifestations of the Hercynian Age were selected as the regions to be surveyed, and the first discoveries of deposits confirmed the interest of these well-mapped geological units for uranium-prospecting. As veins of pitchblende and uranium-bearing sedimentary deposits are frequently found together, prospecting was performed after 1955, with success, in the continental sedimentary basins situated mainly within and on the edge of the Hercynian granitic areas.
However, the problem of the choice of the best areas for uranium-prospecting becomes much more complex if there are no radioactive indications or geological data, as it is the case for vast regions of Africa, South America and Asia. For the preliminary surveying of such regions, use is often made of photogeological techniques, by which

Figure 3: Main types of uranium deposits

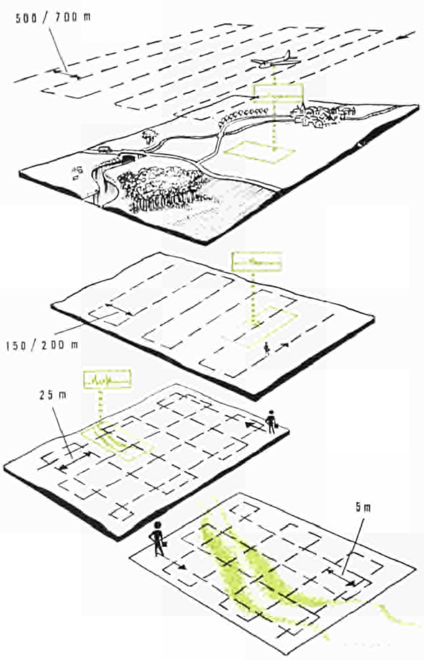


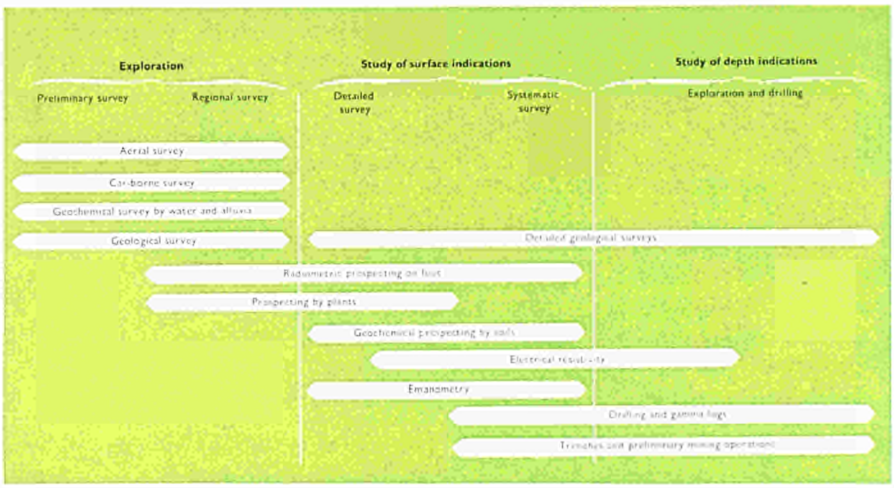
Fig. 4: From regional to systematic prospecting. During the regional prospecting (by aeroplane in this instance), the slightest anomaly is picked up by the radioactivity-detection device. The next stage is more detailed prospecting, e.g. survey on foot, by which means the existence of the anomaly can be verified. By gradual tightening of the mesh, the site of the anomaly can then be pinpointed.

fairly accurate geological maps are drawn up with the aid of aerial photographs. Photogeology is used in conjunction with aeroradiometric measurements.
Although the geological data about uranium have increased considerably, especially during the last ten years, there are still a large number of basic problems to be solved before a better choice of the most promising regions or zones to be prospected can be made. Let us quote an example.
Our knowledge of the geochemistry of granite, which is a common rock of many Hercynian massifs in the Community, is still inadequate to enable a clear distinction to be drawn between those which are likely to contain uranium deposits and those which are not. A basic study of this problem would be of great interest to the Community and could provide a complete picture of the geochemistry of granites after computer processing of the results. It offers a threefold advantage:
— it would bring about a marked reduction in the cost of uranium-prospecting by delimiting the prospecting zones more efficiently;
— on the basis of the results obtained, it would be possible to delineate areas which seem liable to be of interest for the prospecting of other metals such as tin, antimony, zinc, lead, barium, etc.;
— it could make a direct contribution to the development of the mining industry in certain poorer regions of the Hercynian massifs in the Community.

The selection of prospecting methods

The choice of the method or methods to be used constitutes the second problem in prospecting. Efficiency, speed and low cost are the basic criteria adopted here, but other considerations also play a part, such as the nature and morphology of the terrain, the type of deposit sought, the personnel and equipment available.
The majority of uranium-prospecting methods used are based on the radioactive properties of this metal. Depending on circumstances and according to the stage reached in the survey, one or other of these methods are used, or even several together. Fig. 4 illustrates the principle by which the transition from one prospecting stage to the other is effected, while Fig. 5 gives a survey of the various methods used in the successive stages of prospecting, from the first phase, i.e. preliminary exploration, up to the final stage, involving location of the mineralisation and drilling.

Fig. 5: The methods employed in the various stages of prospecting for uranium



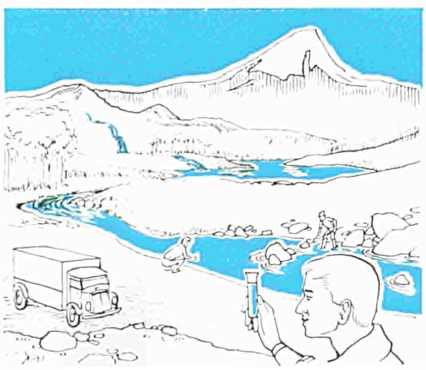
Detection equipment used for aerial prospecting, consisting of a scintillation-counter and measuring and recording equipment (German Federal Ministry for Scientific Research).

Aeroradiometric surveys

Aerial surveys are usually carried out with light aircraft fitted with very sensitive scintillation-counters and a camera to facilitate detection of the radioactive anomalies observed and possibly the plotting of geological maps.
The aircraft flies at low altitudes (200-500 ft) along straight lines spaced an equal distance apart and preferably in a direction at right angles to the main tectonic structures.
This method is used for the preliminary or regional surveying of vast areas and has yielded particularly encouraging results in the detection of radioactive anomalies in the case of uraniferous deposits in sandstone (United States, Argentina). The use of a gamma-spectrometer, to discriminate between radioactivity due to uranium, thorium and potassium, is advisable when prospecting is done in old shields.

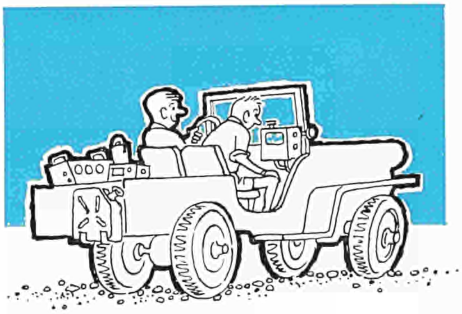
Geochemical prospecting by means of water and alluvial deposits

As a result of the erosion of uraniferous formations and their washing by flowing and ground water, the uranium content of water and alluvial deposits in the corresponding hydrographic basin is abnormally high. Detection of these geochemical anomalies forms the basis of geochemical prospecting by means of water and alluvia. By taking successive samples in an upstream direction, it is generally possible, after adequate interpretation of the analytical results, to locate the uraniferous deposit which is responsible for it.
The uranium contents to be measured are extremely low (only a few parts per 1000 million in the case of water). The method most commonly used to determine them is fluorimetry, based on the ultra-violet fluorescence of certain uranium compounds.
Geochemical prospecting by means of water and alluvia is a favoured method not only because of its speed but also by dint of its relatively low cost. In particular, prospecting is possible over a fairly large surface, which may sometimes be somewhat inaccessible by other methods.



Moreover, since uranium is frequently found together with other metals in some uraniferous "provinces" (e.g. vanadium and

Mobile geochemical prospecting laboratory (German Federal Ministry for Scientific Research)



Car-borne surveys

In addition to airplanes, motor vehicles are also used for surveying purposes. The detection equipment employed is similar, but the vehicles can be fitted with an audible signal for picking up radioactive anomalies. The cruising speed cannot exceed 12-15 m.p.h.
This method has been used with considerable success in regions where there is a good network of roads or in relatively flat countries with little vegetation, such as certain semidesert zones.

Type of scintillation-counter used for prospecting on foot (Brunhilde Company, Germany)

Plotting of a radioactivity map for systematic prospecting (CEA, France)

Prospecting on foot

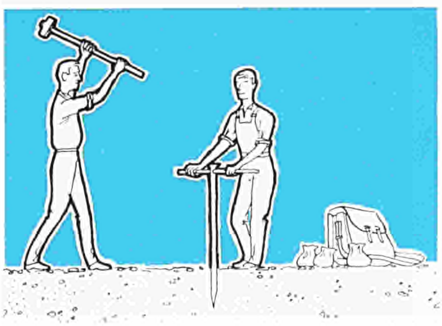
Prospecting on foot, which is done with the aid of light-weight detection apparatus such as Geiger and scintillation counters, is the method most commonly used, especially for detailed and systematic operations. It has been organised on a large scale in France and has led to the discovery of the deposits now known. It has also been employed in Germany and Italy.
When an anomaly is detected, the survey is carried out on a smaller grid scale and all the measurements are reported on a radioactivity map which will give a fairly accurate picture of the surface radioactivity distribution.

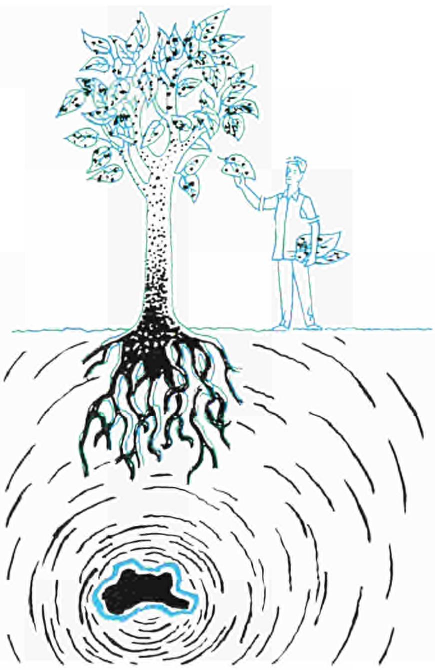
Prospecting on foot is particularly advisable for surveying for uranium-bearing veins, which are not usually very thick (10-15 cm), and for the detailed examination of certain geological formations which are known to be promising.

copper), it is sometimes a help to use these metals as guides in the prospecting of radioactive deposits (*indirect* geochemical prospecting of uranium).

Geochemical prospecting by means of the soil

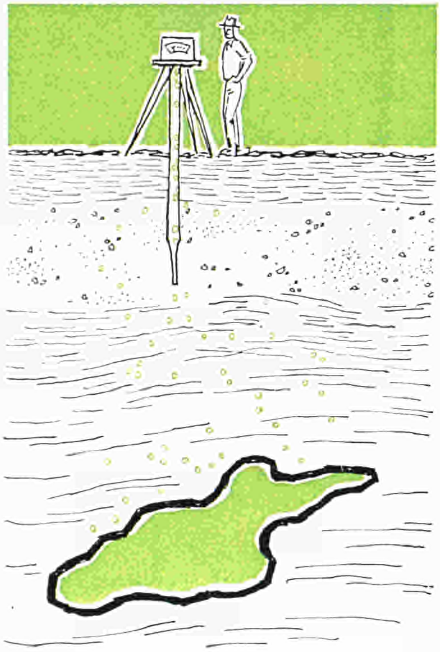
As a result of the weathering of the uraniferous formations by atmospheric agents, a certain diffusion of uranium occurs in the soils in the vicinity of deposits. The detection of this diffused uranium forms the basis of geochemical prospecting by means of the soil. A fairly expensive method, it is used particularly in regions where soil cover makes it impossible to acquire reliable radiometric indications.





Prospecting by means of plants

There are two methods of prospecting based on the use of plants. The first is "biochemical" prospecting, illustrated in the figure, which involves detecting abnormal uranium contents in plants, and the second "geobotanical" prospecting, which uses certain guide plants which indicate directly or indirectly the presence of abnormal quantities of uranium or associated elements, such as selenium.



Emanometry

This method, which is fairly recent, is based on the detection of radon in the soil. Uranium ores give off through desintegration a certain quantity of radon, a radioactive gas, which tends to accumulate in the mineralised structures. Its presence can be detected by pumping it into an ionisation chamber and measuring its alpha-radioactivity.
This method is particularly useful in regions where the direct radioactivity of the uranium is prevented from rising to the surface by the soil cover.

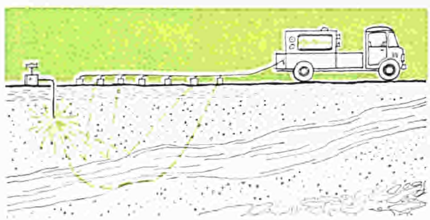
Emanometry is certainly a promising method destined for wider use.

Electrical resistivity

Electric resistivity is a method for determining the location and extent of the mineralised structures which have abnormal resistivity values vis-à-vis the surrounding rocks. This is an indirect method since it does not identify uranium specifically. It is commonly used in France for more accurate determination of the surface and depth characteristics of a known uraniferous formation.
In the United States this method is used either for detecting favourable sedimentary structures or for studying the lateral extent of mineralised zones.

Seismic surveying

Seismic methods are indirect in the same way as the electrical resistivity technique. The reflection and refraction of waves provide indications as to the location of various structures likely to contain uranium ore.



Exploration and drilling

Exploration and drilling constitute the final stage of prospecting, their main purpose being to determine whether a deposit can be worked or not. They yield data on the width and the depth of the deposit, its quantity, its average uranium content and the physico-chemical characteristics of the ore. The information is obtained by trenches and in particular by drillings combined with gamma-logs.

Conclusions

The European Community is marked out to be one of the world's largest, if not the largest consumer of uranium. It would therefore be improvident were it not to concern itself with the matter of prospecting. It is not a question of the Community's having to contend with a possible shortage of uranium; even if there are assumed to be no more than four grammes per ton in the earth's crust, this gives virtually unlimited quantities – and does not include the uranium recoverable from sea-water. Rather is it a question of ensuring supplies *at the optimum price*, which amounts to searching for the most economically workable deposits.
As time goes on and the number of nuclear power plants increases, the need to ensure these supplies is being felt more urgently. It follows that the Community countries will shortly have to take action, making sure that the technical resources they employ are used efficiently and constantly refurbished. With so much at stake, there is a clear call for a combined-operations policy on the part of the six countries concerned.

Radio-core-sampling by means of a Geiger-Müller counter (CEA, France)

The storage of radioactive effluents in salt formations

DR. H. KRAUSE, *Karlsruhe Nuclear Research Centre*

The radioactive effluents produced by nuclear energy

Nuclear energy has made such strides in the last few years that it is impossible to imagine our economy without it. The fission of atomic nuclei, however, as well as generating the enormous energies which we obtain from nuclear reactors, also gives rise to radioactive fission products. For this reason one of the problems which must be tackled right at the outset is the way in which radioactive effluents can be treated and stored so that they do not constitute a hazard to human beings. At the same time the cost involved must not be so high as to jeopardise the economic production of nuclear energy.

Radioactive waste processing techniques are sufficiently well advanced for the activities obtained from the air, water, equipment, etc., to be reduced to levels low enough to permit their discharge to the environment without any hazard.

The radioactive residue is then concentrated and stored on the site. This latter practice is, however, only feasible in the case of small quantities. A nuclear energy output of 10,000 MWe is accompanied by about 100 m^3 of high-activity liquids a year, with a total activity of some 300 million curies. Even after concentration by reprocessing, the volume of the low-activity effluents occurring at the same time is likely to total about 50-100,000 m^3. Such quantities cannot, of course, be stored on site, and it is quite a problem to store these effluents in the environment in such a way that they cannot possibly enter the biocycle until their activity has dropped to a negligible amount.

Possible methods for the final storage of radioactive waste

Basically, there is a whole range of possibilities for the final disposal of radioactive waste. One of these is burial in the ground. Although practised in the United States under propitious geographical, geological and climatic conditions, this method can only be used to a very limited extent in densely populated Central Europe, with its high rainfall, and therefore will certainly not make a decisive contribution to the solution of our problem.

Dumping in the sea has, it is true, been vehemently criticised in the past, but it is a fact that by this process the large quantities of weak radioactive waste could be disposed of without creating serious hazards to the sea or its fauna. The main pre-requisites for this are that the dumping points must be carefully selected and must be at least 2,000 m deep. In addition, the radioactive waste must be enclosed in concrete blocks or other containers solid enough to withstand the prevailing pressure at these points and prevent activity from escaping over a fairly protracted period. These requirements, however, make dumping at sea so costly that the method so far has not really succeeded in gaining acceptance.

There remains, then, the third possibility, namely that of storage in deep-lying geological formations. As contact of radioactive substances with water, which forms part of the biological cycle, must definitely be ruled out, the choice of storage places is not easy. Even formations such as granite, which to the layman appear to be thoroughly solid and watertight, are invariably full of crevices and fissures through which water can seep. Clayey formations are certainly to all intents and purposes impervious, but they entail the danger that cavities may be breached and thus link up with water-bearing layers in the surrounding formation. Thus there can be no storage over long periods of time.

Rock salt as a storage medium

Salt formations, on the other hand, are ideally suitable for radioactive waste storage. Where there is sufficient rock pressure, salt becomes plastic, as a consequence of which any fissures which may occur close up again. The salt is therefore completely gas-tight and impermeable to water. A further asset is that large cavities can be made in salt at a relatively low cost. Where appropriately formed, these are so stable that they can be left without buttressing for a very long time.

In the storage of high-activity waste, care must be taken to ensure that the heat generated by radioactive decay can be adequately evacuated, as otherwise temperatures may rise high enough for the storage containers to be destroyed. The conductivity of rock salt is appreciably higher than that of other formations and is sufficient to conduct off the decay heat.

Finally, it should be pointed out that a salt deposit, even if it should become flooded with water, does not let any activity escape to the environment. Admittedly the water dissolves a certain quantity of salt, but this process ceases as soon as a saturated solution is obtained. Since the salt formation, as already said, is impervious to liquids and gases, no brine release is possible. The cavity must, however, be made so far inside the salt massif that, even in the event of partial dissolution following water ingress, salt pillars of sufficient strength remain erect. This requirement is easy to fulfil on account of the considerable thickness of most salt deposits.

The bulk of Western Europe's salt deposits are in the Federal Republic of Germany. As Fig. 1 shows, there are in both northern and southern Germany numerous flat horizontal deposits with thicknesses ranging from several tens to several hundreds of metres and areas extending over many square kilometres. In northern Germany, there are also some 200 salt plugs, also called diapirs. These are salt masses which have mushroomed out of deep-lying salt layers. The salt plugs may be a few kilometres in diameter and well over 1,000 m deep. Many of them, too, take the form of ridges and may be as much as several hundred kilometres long. Both types of deposit, namely horizontal salt formations and salt plugs, are shown schematically in figures 2 and 3. Other countries besides Germany in the European Community which possess fairly substantial salt deposits are the Netherlands, France and Italy.

On the basis of the foregoing considerations, storage in salt formations has become the main plank in the German programme for the final storage of radioactive waste. In keeping with its special situation, the Federal Republic has assumed responsibility for salt-storage within the Community as its part in a waste-disposal co-ordination programme.

Fig. 1: Salt deposits in the Federal Republic of Germany

(according to records of the Federal Institute for Soil Research)

The storage of radioactive waste in a salt mine

There are two distinct possibilities as regards the storage of radioactive waste in salt, namely in mine openings or in caverns. Mine openings suggest in the first place derelict workings that could still be used in this way. It would also, however, be possible to construct a new mine specially designed to meet waste-storage requirements. The advantage of a mine lies in the fact that the waste can be stored in a fixed location. This is particularly important where high-activity waste or spent nuclear fuels must be disposed of, as both generate heat. Furthermore, materials can be recovered from the mine at any time for re-use. Yet another advantage of significance offered by the mine is that it affords the opportunity of carrying out tests on the behaviour of salt in radioactive-waste storage conditions. Its main disadvantage is that the waste has to be loaded and unloaded and possibly also handled several times, at the place of storage. This involves considerable expense for manpower and anti-radiation devices.

Quite apart from all considerations regarding the advantages and drawbacks of a mine, there is the question of the practicability of such a project. The construction of a new mine is a very costly business. Salt mines abandoned for some time are usually in a condition which makes it difficult to re-open them. Thus the only type which can be considered is a mine which has just been closed down, always provided it is suitable for the storage of radioactive waste. The *Gesellschaft für Strahlenforschung* engaged in negotiations on behalf of the Federal Ministry for Scientific Research for the acquisition of an abandoned salt mine and reached an agreement with the owner in March 1965. The necessary conversions to the pit are at the moment being carried out to fit it for its future duties.

The salt dome as the final storage site for radioactive waste

It is by no means an easy matter to find, when required, an abandoned salt mine that is suitable for radioactive-waste storage. On the other hand, there are any number of salt plugs in northern Germany which can be used for the construction of a dome. In order to lose no time in opening up possibilities for the final storage of radioactive waste and acquiring experience in this field, it was decided a year ago to start at once on the construction of a prototype dome.

For some years it has been a practice to store liquids or gases in salt domes; millions of cubic metres of coke-oven gas, natural gas and suchlike have been stored in this way. In the construction of such an artificial cavern, which can have a capacity of several hundred thousand cubic metres, a borehole is first drilled through the cap rock down into the salt formation and then cased. Fresh water is pumped in to dissolve salt, which then flows off as brine (Fig. 4). The technician is able to give the cavern the shape desired, which may, for example, be spherical, pear-shaped or cylindrical. In order to prevent the water from eating its way upwards into the salt, the latter is protected with a layer of gasoline, light oil or the like. On completion of the leaching operation, all the water is pumped out of the cavern.

To dissolve the salt, large quantities of water are required. Unless the resulting brine can be sold for salt production, a method of disposing of it must be devised. Should the cavern lie in the immediate vicinity of the coast, the brine can simply be discharged into the sea. If the brine has to be pumped into a river, the latter must have a considerable flow of water if its salt content is to be kept to an admissible level or the leaching process is not to be greatly slowed down. It is also possible, however, to force the brine into deep-lying porous formations by means of special drilling techniques. This procedure has already been adopted with success on numerous occasions where geological conditions were suitable, though it entails additional costs. Considerations of disposal greatly restrict the choice of a site.

The radioactive waste is introduced into the cavern via the borehole. With large-diameter boreholes this presents no major difficulty. The installation costs do, however, rise very sharply as the diameter increases. Narrower boreholes render the introduction of the waste more difficult and necessitate higher technical expenditure. The radioactive material, which ranges from metals, plastics, paper and chemical slurries to animal corpses, would have to be reduced to a powdery or lumpy mass or to a pulp which can be shifted by pump. Nevertheless, it seems doubtful whether such products could be injected year after year, without any operational breakdowns, through a narrow tube into a cavern which may lie 1000 metres below the surface. The German concept is therefore based on the use of a transport capsule in which the waste is lowered to the bottom of the borehole (Fig. 5). There the floor of the capsule is opened, the waste falls out and the capsule can be hauled up and reloaded. With this procedure the nature of the waste does not matter and there is consequently no need for a special waste-processing plant.

The advantage of the salt dome is that the waste need only be handled during the loading of the capsule. The radiation danger to the workers is correspondingly slight, so that expensive radiation safeguards are unnecessary. Owing to the simplicity of the entire installation the operating costs are likely to be very low. When a cavern is full, others can be constructed in the immediate vicinity. As a disadvantage of salt domes must be counted the fact that there is a limit to their suitability for the storage of highly radioactive waste and that once inside them, the waste cannot be recovered. Since, however, most of the radioactive waste is neither highly active nor ever required for salvage, these objections do not weigh very heavily. Undoubtedly, therefore, salt domes offer a promising solution for the final storage of radioactive waste.

The German project for the construction of an experimental storage cavern has aroused the interest of the Euratom Commission, which has approved the conclusion of a research contract. The work is to be carried out by the *Gesellschaft für Strahlenforschung mbH*, Munich, in colla-

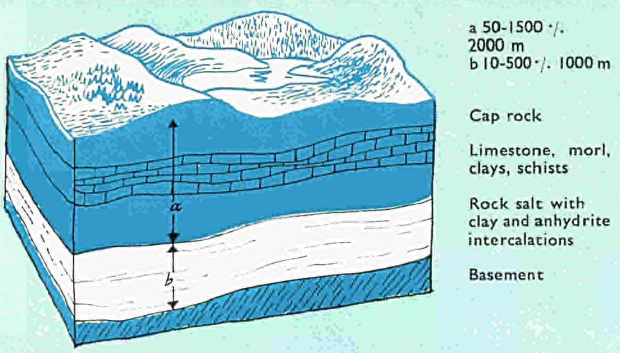


Fig. 2: Stratified salt formations

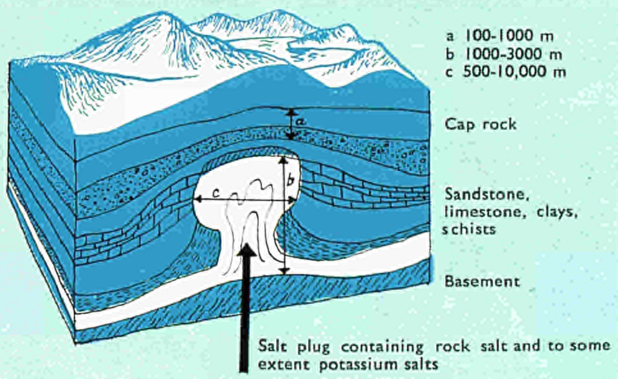


Fig. 3: Salt plugs

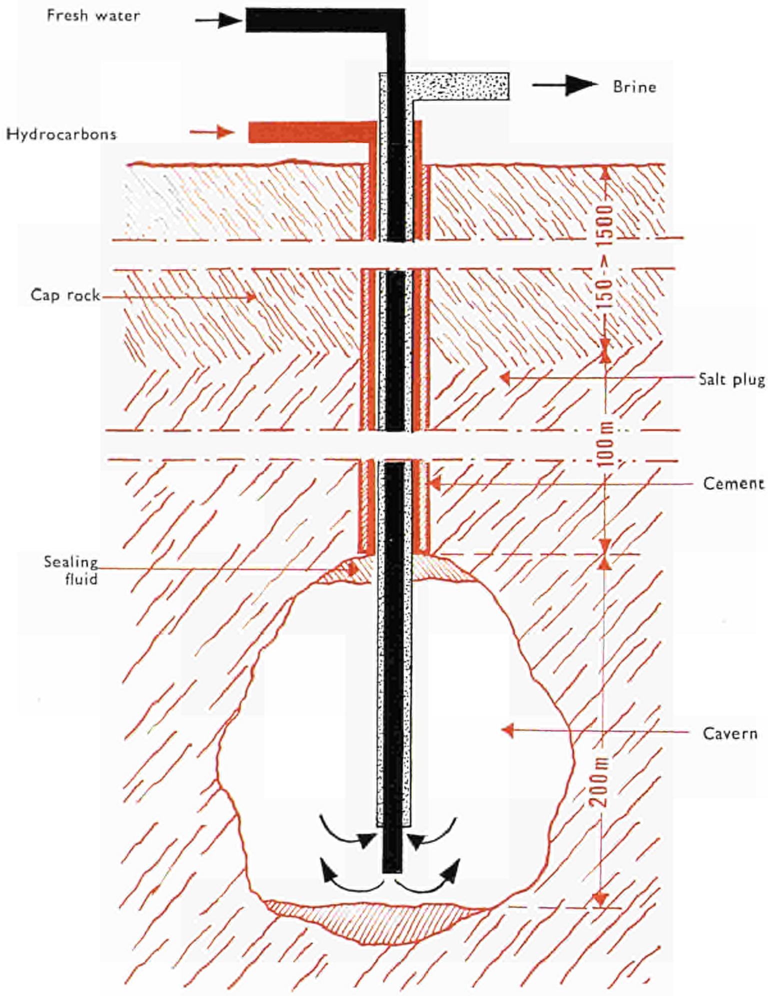


Fig. 4: *Leaching-out of a cavern*

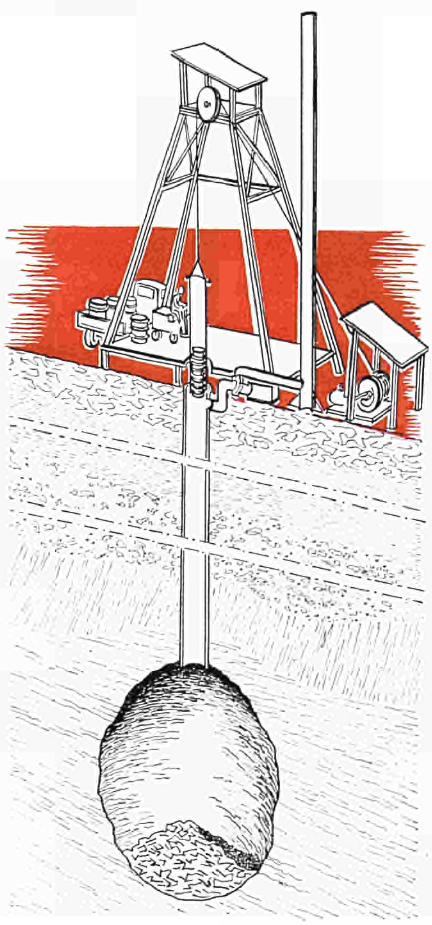
boration with the *Gesellschaft für Kernforschung mbH*, Karlsruhe, and in particular with the Study Group on Underground Storage of Radioactive Waste which has been set up at the Karlsruhe Nuclear Research Centre.

The German effort under the Euratom research programme

The research and development programme covered by the contract with Euratom provides specifically for initial studies concerning the choice of a site for the cavern. The questions to be examined in this connection include the suitability of the salt deposits, the geological conditions and the possibilities of brine disposal, in addition to topographical factors and the installation and transport costs as determined by the location. On the basis of these investigations it will then be possible to select the most favourable site. The next step will be the detailed technical planning of the entire project, in the course of which the size and shape of the cavern, the diameter of the borehole, the type of loading system employed and many other points will be decided. This phase of the work will also cover safety considerations. As soon as test borings have confirmed the suitability of the site, tenders will be invited and the leaching of the cavern can then begin. The last stage will be the manufacture of the insertion equipment.

On completion of these activities and after a fairly long trial, it will be possible to state whether salt domes are suitable for the final storage of radioactive waste and to answer questions as to the optimum size of the cavern, the form taken by the technical installation, operating costs and safety aspects. Most of the results obtained, including methods of initial exploration, will also be applicable elsewhere. For this reason the construction of an experimental cavern is of great interest to all the Community countries with respect to the ultimate storage of radioactive waste.

Fig. 5: Glance at the future - Introduction of radioactive waste in a salt cavern



Euratom's target programme

DR. HANS MICHAELIS, *Director of Economy, Euratom*

Article 40 of the Euratom Treaty requires the Euratom Commission to publish regular target programmes setting out nuclear energy production aims and giving details of the investments necessary for their attainment. The first such programme drawn up by the Commission has now been submitted to the Economic and Social Committee under the procedure laid down in the Treaty.

In relation to the data published in the last issue of the Bulletin (vol. IV, No. 2, p. 61), this programme incorporates certain improvements which underscore the important part to be played by nuclear energy in the course of the years ahead. In particular, the present programme embodies the results of the talks held in Venice in April 1965 and in Stresa in May 1965 with representatives of the governments of the six countries, as well as electricity producers, industry and trade unions.

The programme solely covers the use of nuclear energy for the generation of electricity in large land-based power plants. The prospects for the development of this field of technology are governed by two criteria—the type and extent of energy demand and the structure of the energy supply available to meet it, especially the supplies of competing energy sources. The memorandum on energy policy submitted by the three European executives in June 1962 and in the protocol on energy problems passed by the Council of Ministers of the Communities on 21 April 1964 largely concurred in their adoption of these criteria.

The following factors governing selection are important:

— energy supplies must be as cheap as possible;
— energy supplies must be as reliable as possible;
— phasing-out in the energy field must be gradual;
— economic and social stresses must be avoided;
— the nuclear energy policy must not be at variance with the general economic policy;
— the supplies of economically exploitable fossil fuels, which are available only in limited quantity, must be made to last as long as possible so that future generations can also benefit from them.

On the basis of these criteria the programme has tackled the question as to the place to be occupied by nuclear power in the context of the overall energy supply. In order to do this, information had to be obtained on the factors determining economic development. The following annual rates of growth are likely during the present decade:

— gross national product 4.7%;
— industrial output 6.1%;
— number of persons in employment 0.6%.

This gives an annual increase in primary energy consumption of 4.3%. In 1964 the six Community countries consumed primary energy to the tune of 580 million tons of coal equivalent. This figure is expected to rise to 750 million in 1970 and 910 million in 1975.

Electricity consumption, which, not including the energy used by power plants, amounted to 365,000 million kWh last year, will climb even more rapidly. It is reckoned that this figure will in the future continue to double at least every ten years. Since 1950 the average yearly increase has been as high as 8.5%, corresponding to a doubling of consumption every $8^1/_2$ years. About two-thirds of this rise can be put down to industrial expansion, the other third being the result of the continuous changeover from other forms of energy to electricity, which has the twin virtues of versatility and simplicity.

According to the programme, the electricity comsumption growth rate is expected to drop from 7.5% between 1965 and 1970 to 6% after 1980. By 1970 electricity consumption, not including the captive consumption of power plants, will run to 575,000 million kWh, reaching, 1,080,000 million by 1980 and 3,450,000 million by the end of the century.

The programme shows that the 1980 target of a nuclear contribution of 40,000 MWe, fixed by the Euratom Commission back in 1960, can be reached[1], and the various national estimates even exceed a total of 60,000 MWe. In concurrence with the forecasts made at the last Geneva Conference we are reckoning with a nuclear contribution by the turn of the century of at least half the total installed power at the time. According to our figures this means a minimum nuclear capacity of 370,000 MWe. By that time at least two-thirds of the total current generated will be of nuclear origin, for the nuclear plants will be operating at greater capacity than the conventional ones. The experts consulted expressed the unanimous opinion, moreover, that our sights were set too low rather than too high. A calculation based on an economic optimisation also gives a higher figure for nuclear output.

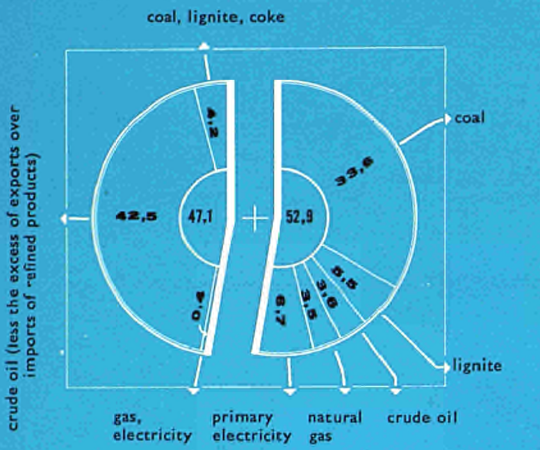
The target programme also had to provide the answer to a second fundamental problem, namely the choice to be made among the various available reactor techniques for the generation of nuclear energy. Calculations were in fact carried out for four alternative patterns of development. While the simplified patterns selected do not completely allow for the wide range of possibilities involved, they nonetheless give useful indications: they show the way in which certain typical developments are likely to affect costs and supplies. Thus a decision can be arrived at concerning the course to pursue and the successive technical solutions for which the established criteria dictate a preference.

The following four development patterns were considered:

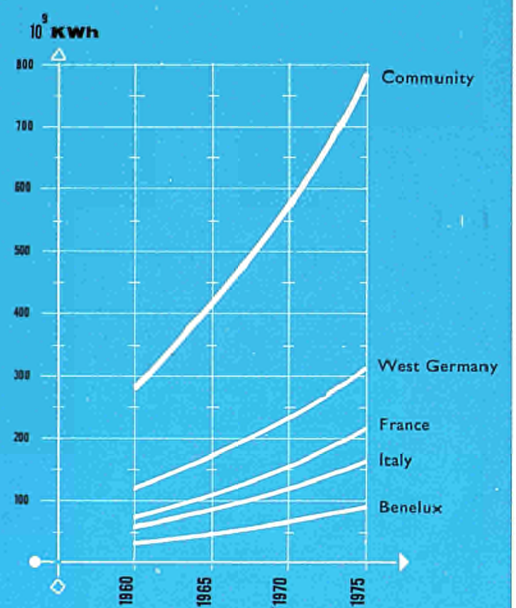
— developments will be limited to proven-type reactors, half of them graphite-gas and half light-water reactors;
— advanced converters, in this case predominantly heavy-water-moderated and high-temperature reactors, gradually replace proven-type reactors;
— breeder reactors go into service immediately after the proven-type phase, bypassing the advanced converter;
— proven-type reactors will first be backed up by advanced converters and then by breeders.

Alongside these, two other interesting variants were examined from the specific standpoint of reducing the fuel demand,

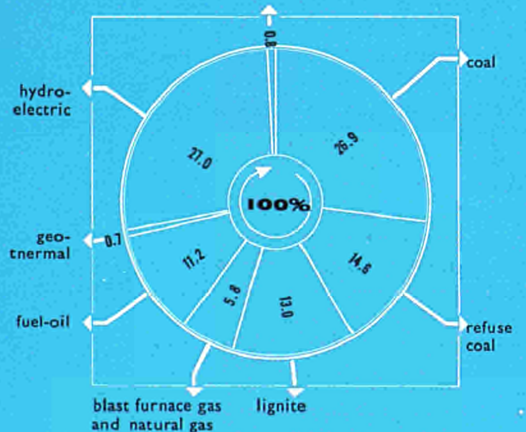
1. At the end of last year there were thermal power plants and hydroelectric stations with net maximum electric capacities of about 62,000 and 30,000 MWe respectively in the Community.



Energy supplies to the European Community in 1965 (breakdown as a percentage)
Right: *home output*
Left: *net imports*



Estimated trend of gross electricity consumption in the Community for the period 1960-1975



Electricity ouput in the Community in 1964, broken down according to energy sources used (as a percentage)

namely, the use of thorium and plutonium recycling in thermal reactors before the breeder phase.

On the basis of the criteria listed above, especially the need to obtain the cheapest and most reliable energy supply possible, the last of the above-mentioned four patterns came out ahead. The programme thus advocates the development of nuclear energy along these lines, the proven-type reactors being first backed up by advanced converters and finally by fast reactors.

At the same time an effort should be made to develop the thorium cycle and thermal recycling. Among the advanced converters, priority has been given to the heavy-water-moderated and high-temperature reactors because it is to these two types that Community industry is particularly heavily committed, which means that there is every likelihood of these developments reaching the stage of industrial maturity with the minimum delay.

The trend in nuclear energy as envisaged by the programme can be seen in greater detail from the graphs. The actual target programme does not go beyond 1980. The reason why the long-term pattern of nuclear energy, up to the turn of the century, was likewise examined and determined was that the lifetime of the investments which have to be decided on now will extend to the end of this period and a major criterion in their selection, namely developments with regard to the fuel supply situation, particularly plutonium, will not assume critical importance until after 1980.

The target programme also contains some details of the economic advantages of developing nuclear energy. In estimating the cost savings in comparison with a similar power programme based solely on the use of non-nuclear energy, certain assumptions had to be adopted concerning the price trends of alternative fossil fuels. The point to be borne in mind here was that the supply gap left by failure to resort to nuclear sources can be bridged only by the generation of electricity from coal—mainly imported—and oil.

The following particulars can be given concerning the present prices of the fossil fuels used in thermal plants:

The list prices, less tax, of boiler coal produced in the Community, which are published in accordance with the ECSC Treaty, are between 14.59 and 18.42 EMA u.a.[2] per ton, the Ruhr price being 16.68 EMA u.a. per ton.

Over the long term these prices will tend to rise rather than fall.

The boiler coal imported from the United States now costs 13-14 EMA u.a. per ton of coal equivalent c.i.f. European ports. The cost of heavy heating oil including tax and charges is 16-20 EMA u.a. per ton, corresponding to 12-14 EMA u.a. per ton of coal equivalent. The price of imported fuels might fall, but the general level is hardly likely to drop below 10 EMA u.a. per ton of coal equivalent.

Table I shows the savings effected as against a programme in which nuclear energy is dispensed with.

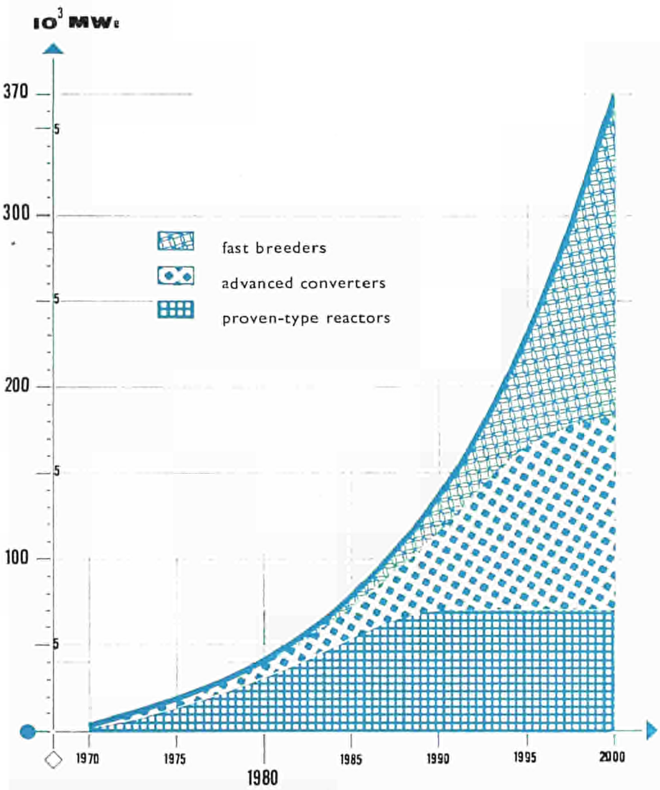
Assuming the most adverse development of nuclear energy, namely a reference price of only 10 EMA u.a. per ton of coal equiva-

2. I EMA u.a. = I US dollar.

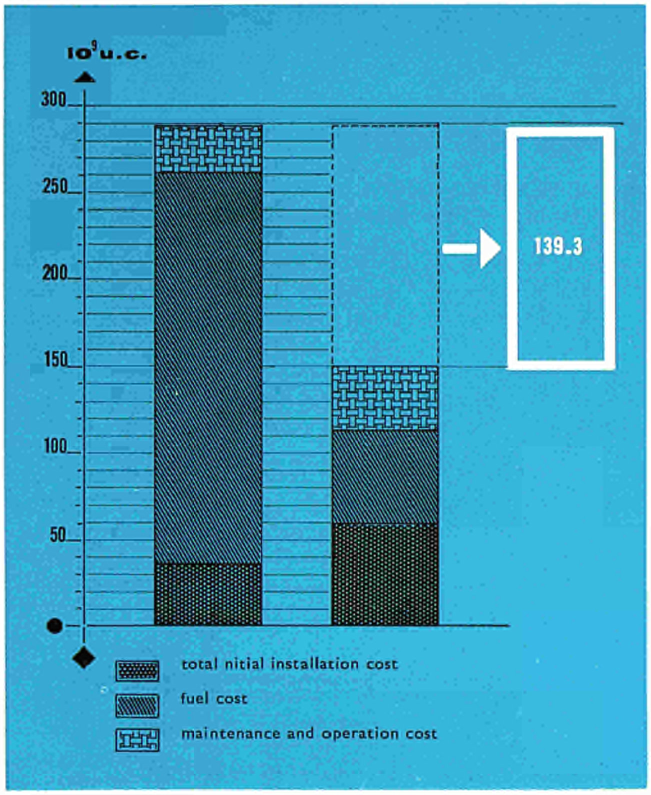
Table I

Savings effected by a nuclear energy programme compared with a non-nuclear programme. The calculation is based on the current generated by all nuclear power plants commissioned by the end of this century (in 1,000 million EMA u.a.)

	Reference prices of fossil fuels		
	10 EMA u.a./*t.c.e* lowest price	12 EMA u.a./*t.c.e* assumed average	15 EMA u.a./*t.c.e* lowest price for home-produced coal
Nuclear programme limited to proven-type reactors	61.4	97.6	151.8
Target programme	101.8	139.3	195.6



Trend of nuclear power to be installed in the Community in accordance with the Euratom target programme plus the long-term prospects, broken down into reactor types.



In 1000 million EMA u.a.:
Centre: *expenditure on the production of electric energy in the nuclear power plants to be installed in the Community up to the end of the century, on the basis of the Euratom target programme;*
Left: *expenditure involved in similar, exclusively conventional production, using fossil fuel at 12 EMA u.a. per ton of coal equivalent delivered to the plant;*
The white rectangle on the right shows the savings possible with the target programme.

lent, a nuclear energy programme confined to the use of proven-type reactors would effect a saving of about 60,000 million EMA u.a., while the additional economies to be made by the gradual introduction of advanced converters and breeder reactors run to about 40,000 million EMA u.a. This completely justifies the comparatively modest outlay necessary for the development of the new techniques. In comparison with the alternative, namely the use of domestic coal for electricity generation, the target programme even leads to a saving of about 200,000 million EMA u.a., the reference price of 15 EMA u.a. per ton being extremely low.

As far as supplies are concerned, the target programme represents a considerable improvement on a programme restricted to the use of proven-type reactors. The estimated total of 330,000 tons of uranium metal required under the target programme up till the turn of the century is less than half the amount which would be needed under a programme confined to proven-type reactors; furthermore, this calculation leaves thermal recycling of plutonium and the use of thorium out of account.

If the target programme is to be implemented, considerable industrial effort is necessary, coupled with maximum rationalisation, especially with regard to specialisation and the division of labour, in order to keep pace with technical advance and to ensure that no ground is lost in either domestic or foreign markets.

Research and industrial development work in the field of advanced converters and breeder reactors must be pursued with vigour. A properly dovetailed research and development programme, coordination of effort and a systematic division of labour are necessary, as well as consultations at the earliest possible stage with the electricity authorities and nuclear industry concerning the construction of prototypes, otherwise there is a great danger that Europe will fall behind in the nuclear field.

EURATOM NEWS

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Can you use a trial analysis by activation?

Activation analysis consists in irradiating the specimen to be analysed and then, by counting the radioactivity thus induced, obtaining an exact measurement of certain component elements. The particular asset of this method lies in its high sensitivity.
To quote an example from criminology, with no more than a single hair this process will reveal the distribution (typical for each individual person) of the trace elements it contains.
To those who are interested in obtaining first-hand experience of activation analysis, the *Bureau Eurisotop* offers the opportunity of sending a specimen, which will be analysed *free of charge* by fast neutron activation. Further information on the subject may be obtained by writing to *Bureau Eurisotop*, 51 rue Belliard, Brussels 4, Belgium. The analyses will be performed by the *Société Anonyme de Machines Electrostatiques (SAMES)*, Paris, who have been engaged by the *Bureau Eurisotop* to make a thorough survey of the technological aspects of activation analysis.

In another context, under a contract with the University of Ghent, a compact, automatic instrument for activation analysis has been developed and is now to be tested in a plant. Another contract, with the *ARBED* firm in Luxembourg, covers a world-scale investigation of the economic uses of activation analysis in the iron and steel industry.

Nuclear energy aid to coal industry?

Coal mines would be well on the way to rationalisation if they had cutting machines capable of adjusting automatically to the irregularities encountered in coal seams.

A method depending on atomic radiation offers some promise of this. It is based on the fact that when radiations penetrate matter certain of them are reflected, and the reflection differs according to whether the matter is coal or merely the neighbouring layers of rock.
The firm *Interatom*, of Bensberg, Germany, has been asked by the *Bureau Eurisotop* to ascertain the most effective method of applying this technique and then to develop the requisite equipment.

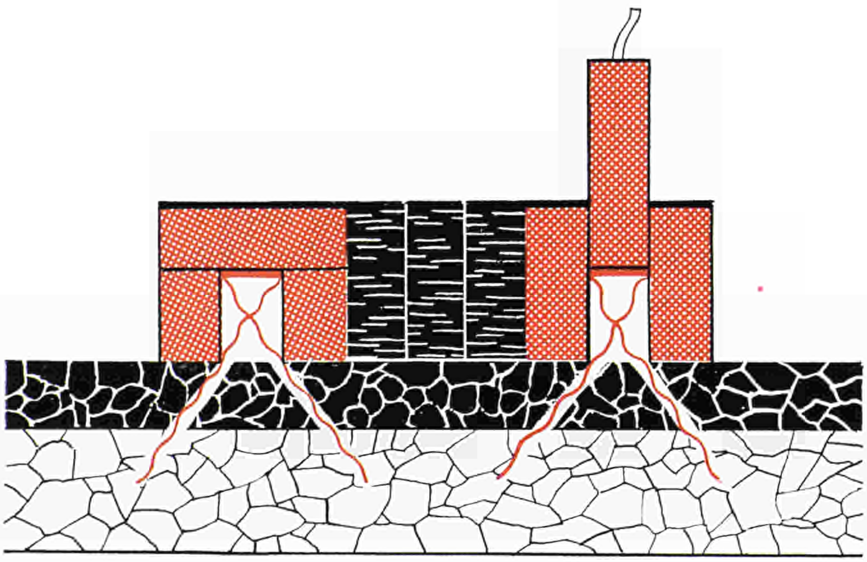

Diagram of the type of device with which automatic coal-cutting machines are to be fitted (left, radioactive source; right, detector for reflected radiations)

World's first thickness gauge for sheet glass

Under a research contract with Euratom, the firm of *Frieseke & Hoepfner GmbH*, Erlangen (Germany), has developed a device which uses radiations to gauge the thickness of sheet glass on its emergence from the glass-melting furnace. The general practice hitherto, of random sample gauging with mechanical instruments, can now be superseded by no-contact continuous measuring with the aid of radioisotopes. Continuous gauging means that the drawing speed of the glass can be controlled to give a uniform thickness.
A feature of this measuring device is that it can operate at temperatures up to 600°C; this makes it the first of its kind in the world. A unit is at present on trial at *Tafelglas AG*, of Weiden/Oberpfalz.

A Community programme for radioisotopes in the textile industry

Over 300 Community textile firms and 40 isotope and radiation experts are taking part in the textiles action programme launched by the *Bureau Eurisotop* (see *Euratom Bulletin* vol. IV, no. 1, p. 24). Under this scheme, the nuclear experts pay a certain number of visits to textile firms, according to a prearranged plan. So far they have completed about 500 visits.

The action programme, due to wind up shortly, included the drawing up of study reports. Thus it will soon be possible to move into the next stage where, on the basis of these reports, potential immediate uses of isotopes and radiations will be listed and a Community development programme mapped out.

Harmless tracers: the "activable" tracers

Radioactive tracers can be useful in a number of fields—for instance in medicine, for diagnosing diseases, or for examining industrial manufacturing processes. Their use is somewhat restricted, however, by the inseparable risk of radiocontamination. Because of this the *Bureau Eurisotop* has asked the firm of *L'atome industriel* in Paris to investigate a method which may retain most of the advantages of radioactive tracers without their drawbacks.

The method in question consists in using *inactive* tracer substances which are revealed by activation *after* completion of the experiment or operation in which they are employed.

Symposium on fuel cycles of high temperature gas-cooled reactors

On 10 and 11 June 1965 Euratom organised a symposium on "fuel cycles of high-temperature gas-cooled reactors". The participants, who numbered about 250, represented various public and private organisations from the European Community, Austria, Canada, Sweden, Switzerland, the United Kingdom and the United States; the *European Nuclear Energy Agency*, the *Dragon* Project, *Eurochemic* and the *International Atomic Energy Agency* were also represented.

Progress made on the *Dragon* Project in Winfrith (U.K.), on the *THTR* Project in Jülich (Germany) and on the American high temperature gas reactor programme suggests that the time is fast approaching when the industrial possibilities of this type of converter reactor can be assessed. As technological considerations affecting capital costs had already been discussed recently at other meetings, the purpose of this symposium was to provide opportunities for exchanges of ideas on fuel technology and fuel costs.

The first session of the symposium was devoted to fabrication methods and fuel element costs and the second to reprocessing and refabrication.

There followed a session on the various fuel cycles which can be envisaged for high temperature gas-cooled reactors, from the once-through system, in which spent fuel is simply discarded, to the breeding cycle, where the spent fuel is not only reprocessed and recycled, but an actual gain in the fissile material balance is obtained. Estimated fuel costs were given as 1.2-1.4 mills/kWh for a once-through system and 0.9 mills/kWh for recycled fuel, and calculations showed that an increase in price of uranium and thorium ores would have a substantially smaller effect on the fuel costs of these reactors than on those of light water and heavy water reactors.

The final session was focussed on the possibility of using plutonium for the initial fuel charge or as make-up fuel. This interest in the use of plutonium stems from the recognition that it is being produced in increasing quantities because of the expansion of civilian reactor programmes. The figures quoted at the symposium showed that high temperature gas-cooled reactors, because of the efficiency of the fuel cycles they could achieve using plutonium, could well become the best bidders for the stocks of this material which are being produced. They could in fact afford to pay for plutonium up to as much as the price of fully enriched uranium.

The conclusion to be drawn from these discussions is that the fuel costs of high temperature gas-cooled reactors are promising enough to justify further development towards industrial applications. The possibility of using plutonium economically was stressed particularly as an appealing feature of this reactor concept.

Gas turbines for high-temperature reactors?

The prospects opened up by the use of

EURATOM NEWS

gas turbines to tap off the power from high-temperature gas-cooled reactors were the subject of a colloquium held at the end of May in Paris under the sponsorship of the *Dragon* Project.

Figure 1 gives an idea of the basic cycle involved. Two shafts would be necessary, one for the high-speed compressor unit (about 6,000 r.p.m.), driven by its own turbine, and one for the turbo-alternator unit, whose speed is fixed at 3,000 r.p.m. in order to generate at a frequency of 50 cycles per second.

Can such a system compete with a heat-exchanger/steam turbine system? Judging by the information available today, it seems that the answer is yes.

The efficiencies which can be attained are of the order of 42 or 43%, in other words they are as good as those of an economic steam cycle. This being given, the decisive factor is the capital cost of the equipment required in each case. Cost evaluation studies still have to be made, but there are pointers which indicate that the cost of a gas turbine system could be lower. For instance, for a given power output, a gas turbine would be several times lighter than a steam turbine. Moreover, the aero-engine industry foresees no major difficulties in adapting existing turbo-machinery for aircraft to nuclear gas turbine requirements. If anything, the new specifications are less stringent, seeing that temperatures need not be higher than about 850°C and that the working fluid is helium, which does not present corrosion problems.

As can be seen from figure 2, the design for a 250 MWe plant is remarkably compact. Practically all components, with the exception of the alternator, could be integrated within the reactor pressure vessel.

Since the adoption of a gas turbine cycle instead of a steam cycle would hardly make any difference to the nuclear part of the plant, the fuel costs will be essentially the same in both cases. Any capital cost saving yielded by the adoption of gas turbines would therefore have the result of extending competitiveness of the high temperature gas concept to small size power stations, for which there is a large market in Europe.

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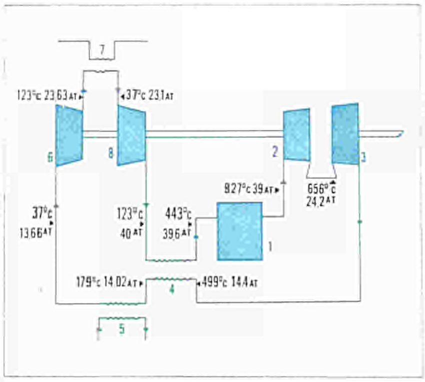
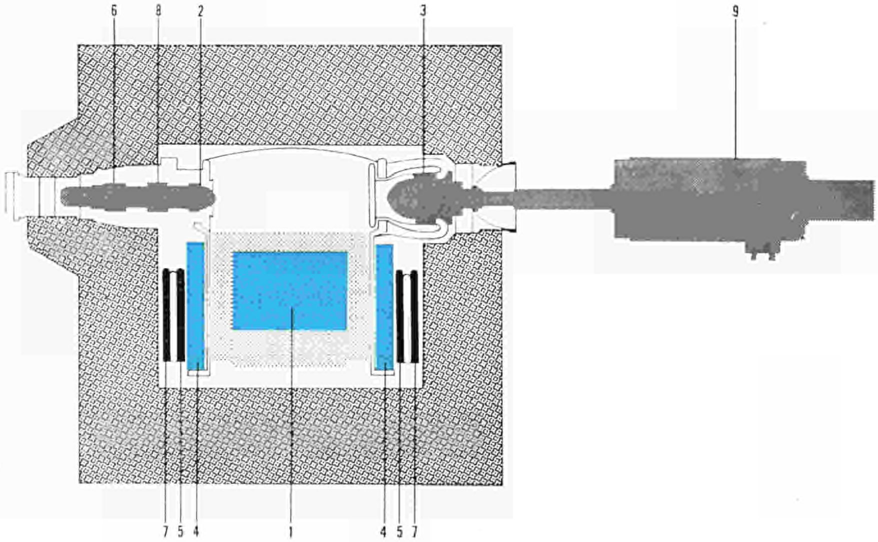


Figure 1: A typical gas turbine cycle for a high-temperature gas-cooled reactor.

Figure 2: Schematic arrangement of a high-temperature gas-cooled reactor with a gas turbine power plant of 250 MWe output.

1. Core 2. High-pressure turbine (driving compressors) 3. Low-pressure power turbine 4. Recuperator 5. Precooler 6. Low-pressure compressor 7. Intercooler 8. High-pressure compressor 9. 250 MWe alternator



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8th Euratom General Report

In June, the Commission forwarded to the European Parliament the 8th general report on Euratom's activities. The nuclear industry is now well and truly launched in the Community. In 1964 the operation of four power plants continued and work began on building or designing other units. All equipment for the power plants now under construction is being supplied by Community industries.

To meet the requirements of this expansion, the nuclear construction industries need to be firmly based and to have a go-ahead outlook. Certain sectors must be consolidated, while at the same time an effort must be made to check tendencies towards dispersal and water-tight compartmentation. This holds equally for proven-type reactors and for reactors of the second (*ORGEL* and advanced gas reactors) and third (fast reactor) generations. In this connection it is worth noting the interest aroused in the United States by the *ORGEL* string.

These are the considerations governing the Commission's insistence that common policies be laid down with regard to:

—the selection of industrial targets (the Commission is drawing up a target programme for this purpose, together with a paper on industrial policy);

—supplies (based on non-discrimination and easing of the rules governing the concluding of contracts);

—the aligning of programmes.

The remoulding of Euratom's second five-year research programme in May brought an increase of 5,500,000 EMA u.a. to the overall appropriation and released 34,000,000 EMA u.a. for top-priority projects. This decision expresses the policy adopted by the Member States, namely to tackle nuclear development on a Community-wide basis by means of Community procedure. The Commission is thus in a better position to carry out the spade-work for future activities.

With these prospects in view, the Commission has declared its conviction that the Community policy will be strengthened by the merger of the Executives. The experience it has acquired in scientific and industrial matters will be carried further by the special departments which have been set up in all fields covered by the Treaty.

The Commission intends to devote the last months of 1965 to drawing up a single Community-level action programme which will point the way ahead for the entire complex of nuclear energy developments.

Progress made with the Euratom power-reactor participation programme

Two hundred and seventy-five delegates, representing 135 Community firms and organisations, were present on 31 May and 1 June 1965 at the Fifth Information Meeting to hear progress reports on Euratom's power-reactor participation programme. During its first five-year plan Euratom signed participation contracts to the tune of 32 million EMA u.a. with two Italian (*SENN* and *SIMEA*), one Franco-Belgian (*SENA*), one German (*KRB*) and one Dutch firm (*SEP*), with the object of promoting industrial-scale construction of proven-type nuclear power plants in the Community and pooling the experience acquired in the course of designing, building and operating these plants. The information meetings are one means of pooling such knowledge. The fifth meeting marked a new departure in that speakers managed to suppress their natural desire to make great play of their successes and instead reported fully and frankly on the difficulties they had encountered, thus giving other participants the benefit of a most important aspect of their experience. The status of work at the five power plants can be summarised as follows:

Garigliano Plant (SENN): The plant, which has been running at full power since the end of May 1964, had supplied 1,400 million kWh by 31 July 1965. Its true power was found to be 5% to 10% higher than the rated power, while the thermal efficiency reached 31% instead of the 29% originally estimated.

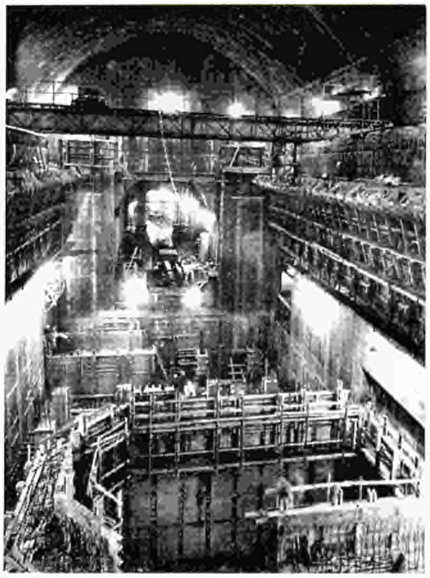
Latina Plant (SIMEA): The plant has been generating electricity since May 1963, and by 31 July 1965 had supplied 2,500 million kWh.

Chooz Plant (SENA): Excavation work for this underground plant was finished by the middle of 1964. The assembly work is so far advanced that trials can begin in a few weeks' time.

Gundremmingen Plant (KRB): This plant has reached roughly the same stage as Chooz. Tests will begin shortly.

Dodewaard Plant (SEP): The detailed design-study for this plant was completed in 1964 and on-site work began in October 1964.

SENA nuclear power plant at Chooz—reactor cavern



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