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European Transuranium Institute (Karlsruhe)—plutonium handling in a shielded cell.

CONTENTS

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

1967-2

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).

Thirty or forty years ago the word "automation" conjured up the picture of a diabolical robot, at whose heels followed the spectre of unemployment; to certain humorists of the cinema automation was a subject for ridicule, but though we laughed, the joke was often sour, since the ultimate victim was man, becoming the plaything of the machine. Today it can be said that these fears were largely exaggerated. Certainly automation has completely changed industrial life, but the process has been one of gradual evolution rather than convulsive revolution; what is more, human dignity does not seem to have suffered too badly. And yet it is not merely man's hands that the machines are replacing, but his brain as well; look, for instance, at the computers that have started translating Russian into English.

Professional translators are not particularly worried by this; so far as we know, they have never tried to organise even one little march against automatic translation.

There are doubtless several explanations for this, and the main one, it must be admitted, is that where quality of work is concerned, the machine is a long way behind the translator. On the other hand, although the machine cannot render all the finer points of Tolstoy's style in English, it is capable of translating a Russian scientific or technical text faithfully enough to satisfy the expert, provided that he takes sufficient care not to be misled by the occasional eccentricity.

Such, at any rate, is Mr. Perschke's opinion, which he supports with more detailed arguments on page 54 of this number. By no means everybody will share his optimism. We can but hope that he is right, however, since automatic translation can open the way for an information-hungry world to unexploited sources.

Nuclear energy in Italy

PROF. CARLO SALVETTI, *Vice-President of the Comitato Nazionale per l'Energia Nucleare*

THE PRESENT trend of Italian nuclear projects is the result of a thorough re-appraisal in 1965 of the activities pursued in the nuclear sector. In the same year the Consultative Committee on Energy, set up on 25 March 1964, issued its first report, which contained a full assessment of the programmes and activities of each energy sector and in particular those of the nuclear industry. In the same period, moreover, the *Comitato Nazionale per l'Energia Nucleare* completed a comprehensive review of its own programmes.

Under the Enabling Law of 11 August 1960, one of the objects of the *CNEN* is both to conduct and promote studies and research in Italy in the various fields covering the peaceful uses of nuclear energy.

In both cases, it was constantly kept in mind that Italy should not be considered in isolation but as an integral part of the European Economic Community, as regards both the supply of energy sources and the dovetailing of research programmes with those of the Community and the Member States.

Italian nuclear energy production programmes

Europe is known to be the world's greatest importer of energy. While accounting for approximately 10% of the world's consumption of electric power, the European Community possesses no more than 5-6% of the total fossil fuel reserves. Thus it is obvious why imports of conventional fuel, which before the Second World War represented 5% of the Community countries' own requirements, jumped to 27% in 1960 and in all probability will top 47% in 1970 and 52% in 1975. It should be pointed out that this last figure allows for the contribution of nuclear energy, regarded as an internal source, which covers about 3-5% of total needs.

As far as the energy situation in Italy is concerned, electricity requirements for the coming years are forecast by *ENEL (Ente Nazionale per l'Energia Elettrica)* and industrial bodies as increasing at an annual rate of 9%, which compares with a figure of 7% given by the National Economic Programming Committee in respect of the next five years.

These two values may be considered as the upper and lower limits, on the basis of which consumption in 1968 should be around 100,000 million kWh and in 1970 between 112,000 and 127,000 million kWh. The corresponding values for 1975 may be set at 157,000 and 196,000 million kWh, with installed capacities ranging from 28,000 to 37,000 MWe.

Up to 1968, it is the view of the aforementioned Consultative Committee that it will suffice if *ENEL* can implement the programme upon which it is now engaged, which provides for the installation and commissioning of 1,350 MWe of hydroelectric power with a minimum capacity of 2,380 million kWh and 5,700 MWe of thermal power with a capacity of about 30,000 million kWh.

For the period from 1968 to 1975, on the other hand, it will be necessary to build new plants with an overall power of 10,700-17,500 MWe and an energy output in the 59,000-89,000 million kWh range, assuming respective annual increases of 7 and 9%. The estimated share of the new thermal and nuclear plants will be between 9,400 and 14,600 MWe.

It is, of course, more advantageous to use nuclear power plants for covering base loads, i.e. loads consistently meeting a demand of 7,000 hr/yr. This requirement circumscribes the maximum proportion of nuclear electricity that can be absorbed by the load diagram and hence the maximum nuclear capacity that can be fed into Italian grids at competitive prices.

This problem has been carefully examined by the Consultative Committee on Nuclear Energy, set up in 1965 by the Ministry for Industry. The present status of the Committee's activities indicates that in the five years from 1970 to 1975 it will be possible to install some 3,000 MWe of nuclear power.

Trend of research programmes in the nuclear sector

A brief summary of these data brings out the importance and urgency of determining a European and national industrial policy, as well as illustrating the extent of the problems facing the research activities undertaken in the pursuit of such a policy.

The aim of research in the nuclear sector is, in fact, to build up a fund of technological know-how which will act as a basis for the practical implementation of the policies adopted.

Since nuclear energy will in future play an ever-increasing part in meeting energy requirements, and since it is inconceivable that Europe, and in particular Italy, should rely solely on imported plant and know-how, it is felt necessary to lay the foundations for the development of a nuclear industry able to design and construct nuclear

Nuclear map of Italy

- INFN[1] *sections*
- INFN *sub-sections*
- INFN *groups*
- CNEN *Headquarters*
- CNEN *centres*
- CNEN *pilot plants*
- *Detached* CNEN *laboratories*
- CNEN *prospecting teams*
- ENEL *nuclear power plants*
- *Euratom Joint Research Centre*
- IAEA *International Theoretical Physics Centre*
- *Research centres run by other bodies or companies*
- *Research reactors*

1. Istituto Nazionale di Fisica Nucleare

installations and equipment on an expanding scale.

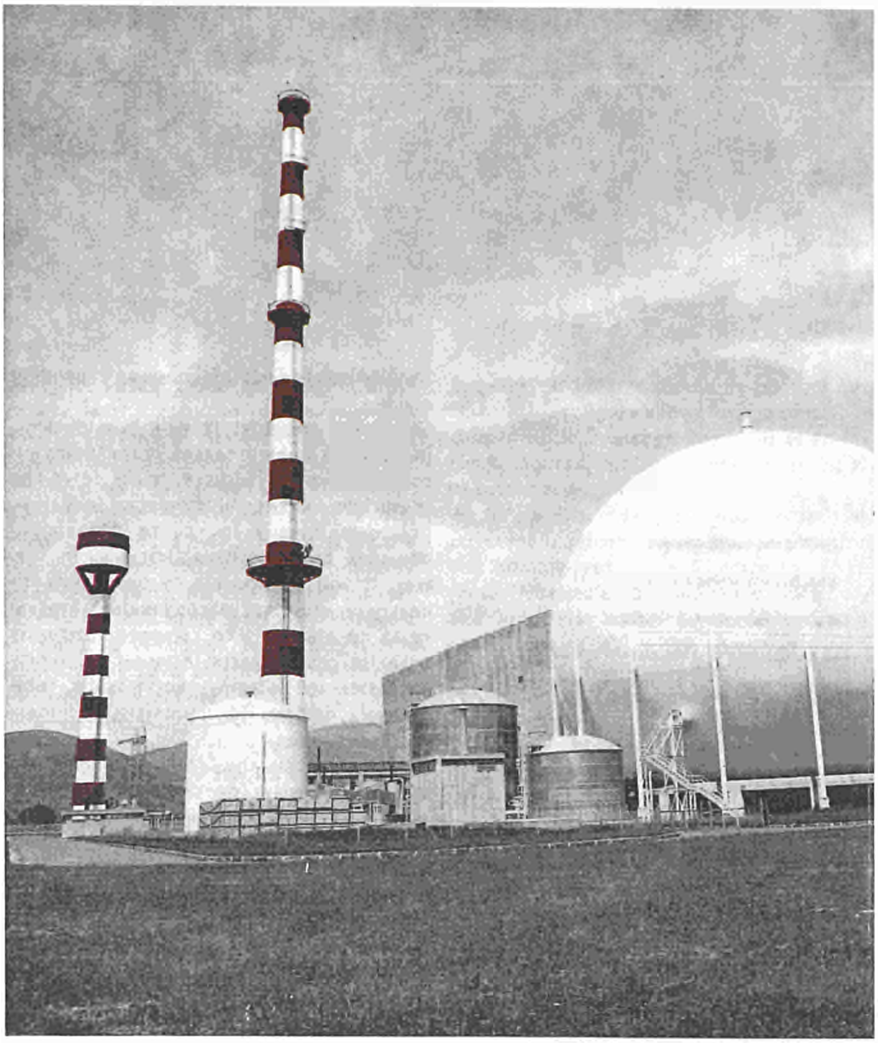
Generally speaking, it will be sufficient, in view of the high degree of technological sophistication in industry, to lay down the conditions for the adjustment of industrial processes already in use to the special demands of nuclear applications. In this way, it will be possible to put Italian industry on a more advanced technical footing so as to enable it to compete efficiently with its counterparts in non-Community countries by securing worth-while commercial outlets in industrially underdeveloped areas.

In view of all this, the *CNEN*, fully conscious of the necessity for close co-operation, reciprocal aid and co-ordination of activities among the six member countries, has organised its programmes in such a way that they may be used as an instrument of progress for the entire Community. This will help to remove the imbalance existing between the more and the less advanced countries in the nuclear field, which otherwise might have far-reaching economic and social repercussions.

As far back as the winter of 1963-1964, the *CNEN*, in an effort to improve the co-ordination and harmonisation of the Italian programmes, both on the domestic level and from the Community standpoint, carried out an assessment of the new situation which was developing in Italy as a consequence of the nationalisation of electrical energy, the incorporation of *ENEL* and the trend of research in the European Community. On the basis of its findings, it took the step of conducting an extensive review of its own policy, setting up study committees and working groups in which representatives of *ENEL*, the major industries with a stake in the nuclear sector and also the universities were invited to participate. A concrete result to emerge from these activities was the publication in June 1964 of the "Report on Nuclear Energy in Italy", submitted to Parliament by the then President of the *CNEN*, Senator Guiseppe Medici, Minister for Industry and Trade. The guide-lines contained in this report form the basis of the *CNEN*'s Second Five-Year Programme.

CNEN achievements and new programmes

The *CNEN*'s First Five-Year Plan, covering



Garigliano Nuclear Power Plant. This plant, which has an output of 170 MWe and is equipped with a boiling-water reactor, went into service on 23 January 1964.

the period from 1960 to 1965, for which it received a total grant of 75,000 million lire from the government, had as its principal aim the setting up of the required facilities and the training of the personnel necessary for performing the tasks laid down in the Enabling Law.
These aims have been fully achieved, with the result that it has been possible to plan and tackle with more mature judgment and greater responsibility the Second Five-Year Plan, already under way, which provides for the spending of a total of 150,000 million lire over the period in question, i.e. 1965-1969.
The *CNEN* programmes for this period have been drawn up on the basis of certain fundamental criteria.
The first of these concerns the necessity for greater concentration of programmes and resources in order to avoid wastage which the country's economy would undoubtedly be unable to stand.
The *CNEN* has therefore found itself obliged to steer a middle course between, on the one hand, allowing the widest possible latitude for fundamental and basic applied research and, on the other hand, concentrating efforts and resources in a few special programmes of greater interest as regards the industrial applications of nuclear energy. It has been the *CNEN*'s view that in the applied sector its task is mainly that of helping to develop the country's potential.
This involves pursuing specific aims of general benefit to the country's economy by launching large-scale programmes designed to boost participation by the national industry and by fulfilling a practical function in the nuclear field.
The second criterion consists in the *CNEN*'s pledge to develop those programmes in which there is the widest measure of common interest, both of industry and of *ENEL*. Every effort has been made, moreover, to ensure that this requirement is met right at the outset of the programme.

Large-Scale CNEN Programmes

The *CNEN*'s large-scale technological programmes are *CIRENE*, the nuclear marine propulsion programme, the fast reactor programme, *EUREX*, *ITREC* and the plutonium programme.

Advanced converters (CIRENE)

The reactors which seem to offer the best prospects from an economic standpoint compared with proven reactors after 1975 are advanced converters. Two main lines of development are being pursued here: heavy-water reactors and high-temperature gas reactors.
The *CNEN*'s choice between these two groups inclined towards heavy-water reactors,—in particular, a reactor type fuelled by natural uranium oxide and cooled by light water in a two-phase water/steam mixture (fog).
This choice was dictated by considerations not only of a strictly technical but also of a more general character, not least the need to use previously acquired skills, which ensures the achievement of valid results. Since 1959, in fact, basic studies on the possibility of using water/steam mixtures for cooling power reactors had been in

progress at the *CISE (Centro Informazioni Studi Esperienze)*, Milan.

With the desire to afford the greatest possible co-operation and the intention of developing worth-while new ideas from other sources too, the *CNEN* has included in its Second Five-Year Plan sufficient appropriations for completing the studies already embarked upon, through which it will be possible to acquire the necessary data for the designing and subsequent construction of a prototype power reactor.

The programme, called *CIRENE* (*CI*se *RE*attore a *NE*bbia = *CISE* fog-cooled reactor), is fundamentally divided into two phases. The first, which is being carried out in collaboration with Euratom, is aimed at developing, in a co-ordinated overall scheme of technological research and activity, know-how in the field of heavy-water-moderated pressure-tube light-water-cooled reactors; the second concerns the designing and construction of a prototype reactor with a power of approximately 100 MWth.

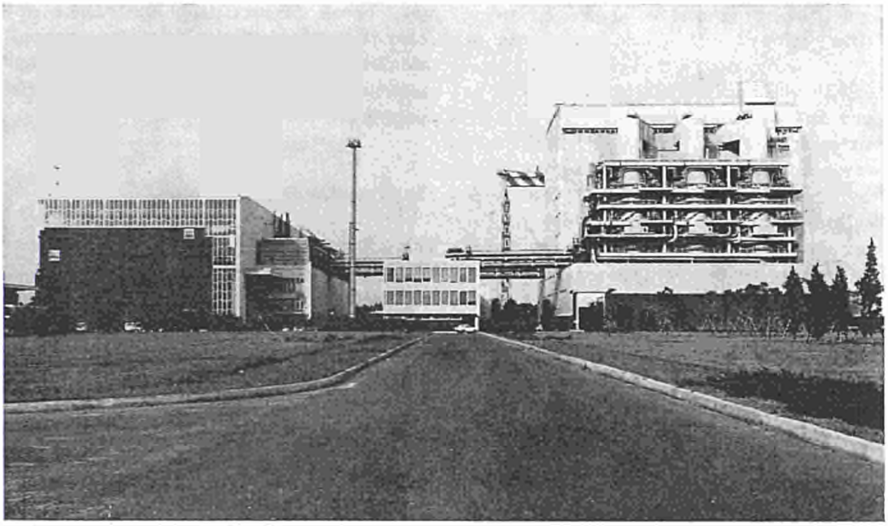
The programme is now at an advanced stage of completion. In the near future, the final decisions on construction of the prototype will be taken in the light of the results obtained at the preliminary research and planning stage. The building of the prototype is considered essential in order to arrive at a reliable estimate of the cost of energy produced by large-capacity plants and to secure a detailed analysis of the technological problems and the costs involved in the construction and operation of plants of the type under investigation.

Nuclear marine propulsion

Another particularly important field of nuclear energy application, marine propulsion, has been a constant focus of attention on the part of the *CNEN*, which sponsored a research programme together with the *Fiat* and *Ansaldo* companies in collaboration with Euratom.

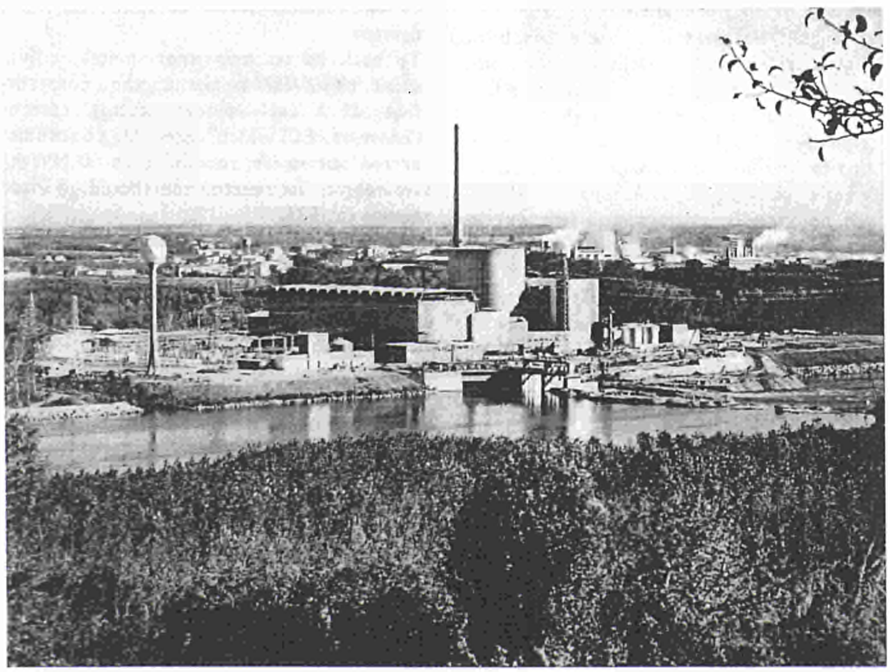
Towards the end of 1966, the *CNEN*'s activity in this sector was given a substantial fillip by the signing of an agreement between the *CNEN* and the Ministry of Defence. This agreement provides for the construction by Italian industry of a nuclear-powered logistic support vessel.

The experience to be derived from the design and construction of the nuclear part



Latina Nuclear Power Plant. This plant is equipped with a gas-graphite reactor and has an output of 210 MWe. It went into service on 12 March 1963.

The Enrico Fermi *Power Plant at Trino Vercellese. This plant is equipped with a pressurised-water reactor and has an output of 270 MWe.*



may prove of particular importance not only in the field of marine nuclear propulsion but also in the wider context of nuclear technology development for industrial purposes.

Fast reactor programme

This forms part of the long-term nuclear energy utilisation programme.

Because of the complexity and magnitude of the technical problems involved and also the considerable investments that a fast reactor programme of its own would necessitate, the *CNEN* adopted a policy of co-operation with the European Atomic Energy Community from the outset of its activity in this sector.

Moreover, Euratom is participating in the programmes of the other Community countries. This should (and, it is hoped, will) make for a rational distribution of tasks and projects. It should therefore form a sound precedent for co-operation, aid and co-ordination whereby the individual effort becomes an instrument of progress for all.

The Euratom/*CNEN* Association research programme provides in particular for research on and the development of U-Pu oxide fuel elements and the development of components for a sodium-cooled fast reactor.

To back up its own experimental equipment, the *CNEN* is planning the construction of a fuel-element testing reactor (known as *PEC*) which, according to studies carried out so far, should be an 80 MWth two-region fast reactor and should go into service in 1971.

The *CNEN* has also scheduled the construction by 1969 of a test plant for sodium cooling circuits and, in particular, for intermediate heat exchangers and steam generators.

It must be remembered that the *CNEN* fast reactor programme will be determined on a long-term basis and can therefore be geared to the programmes sponsored by the Community.

Plutonium programme

Operation of the existing Italian nuclear power plants will lead to the production of appreciable quantities of plutonium.

The *SENN*, *SELNI* and *SIMEA* power plants will supply an estimated 270 kg of plutonium annually.

This has prompted the *CNEN* and *ENEL* to launch a joint four-year programme of basic research aimed at assessing the technical possibilities and economic advantages of using plutonium as a fissile material in thermal and fast reactors.

The work will therefore be directed to the preparation and development of calculation methods for the study of lattices containing plutonium, as regards both its initial activity and its irradiation behaviour.

In the field of experimental neutron physics, the task will consist in experimental checking of the methods for calculating the lattice constants for plutonium-containing fuel elements; in the field of fuel technology, techniques will have to be developed for the reprocessing of plutonium-enriched fuel elements.

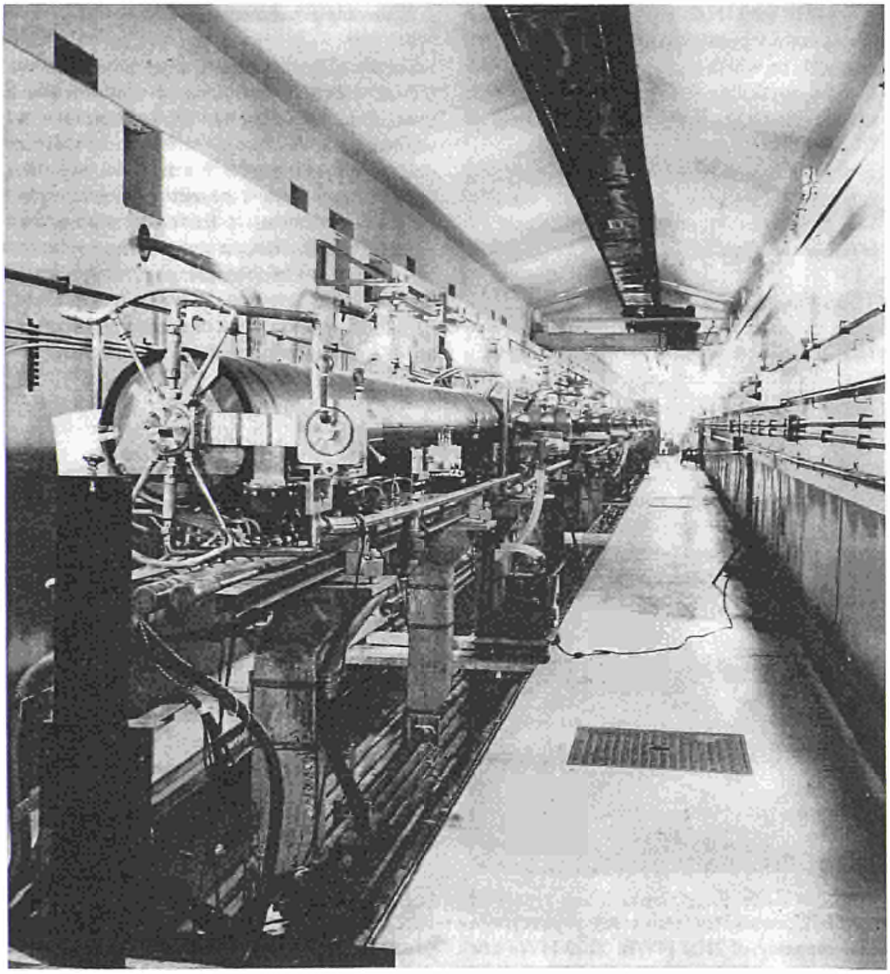
In its broad lines, the programme will also prove useful for the fast reactor programme. Indeed, the development of plutonium-based fuel technology involves the same requirements as does the fast reactor programme, beginning with the necessity of having facilities for the techniques relating to the handling of highly toxic emitters.

Another appreciable degree of integration will be feasible in the subsequent stages of the programme by reason of the large-scale equipment at the disposal of the *CNEN* in the fuel reprocessing and recycling sector. As will be shown below, the *EUREX* and *ITREC* plants, now under construction, will be required to comply with the time-limits involved in technological research on the reprocessing and reworking of recycled fuel.

Work is now in progress on the building of a plutonium research laboratory at the *CNEN*'s Casaccia Centre, and a contract has been concluded for collaboration with the *SNAM* Projects (*ENI* group) on research into and development of a method for preparing high-density mixed oxides.

Fuel reprocessing and recycling (EUREX and ITREC plants)

The problem of reprocessing fuel elements extracted from power plants has a considerable economic influence, in the case of enriched-uranium reactors, on the cost of the energy produced and, in natural-uranium



Frascati. Part of the ADONE *linear accelerator.*

reactors and reactors fuelled by thorium-elements with a low uranium 233 concentration, there is the possibility of recovering the plutonium and the uranium 233.

The fissile material obtained from reprocessing plants must therefore be employed for the fabrication of new fuel elements for use in the reactors.

The problem of reworking uranium 233 or plutonium-base elements should be tackled by taking suitable precautions, in view of the toxicity of these materials, or, for that matter, of the materials combining with them through decay nuclear reactions. The radioactivity of such materials, which is sometimes due to fission products the separation of which from the main material is not economically worth while, raises further shielding problems.

The projects already under way in this field in Italy, and in particular the construction of the *EUREX* (*E*nriched *UR*anium *EX*traction) and *ITREC* (*I*mpianto *T*rattamento *R*ifabbricazione *E*lementi *C*ombustibili = Fuel Element Reprocessing Plant) pilot plants at Saluggia and the Trisaia Centre (Rotondella-Matera) respectively will serve to provide the country with useful information in the next ten years.

The *EUREX* and *ITREC* (formerly *PCUT*) programmes are complementary, to the extent that the *EUREX* plant is devoted mainly to the technology of aqueous reprocessing (the initial product is irradiated fuel, the final product is uranium and plutonium purified of the fission products, which are stored separately), while the *ITREC* plant deals with the entire aspect of fuel recycling, which, as is known, has in some cases (U-Th converters, plutonium recycling in fast reactors) characteristics which necessitate remote-controlled reworking. *ITREC*'s activities transcend and complement the possibilities offered by *EUREX* in the field of U-Th and U-Pu fuels.

The main *EUREX* programme directive in the Second Five-Year Plan is the construction—which will be completed by the end of 1967—and commissioning, under an agreement for co-operation with Euratom, of an irradiated-fuel reprocessing pilot plant on a semi-industrial scale. There are also secondary directives relating to the most economic and technically optimum method of constructing the plant, which in about four to five years should yield the essential data for the building of an industrial-scale plant.

The *ITREC* Rotondella plant must also be considered more as a research than as a commercial installation. It owes its origin to the decision taken by the *CNEN* in 1959 to study the problems relating to the recycling of thorium- or U 233-base fuels. It should be completed by the end of this year. It will therefore be possible, after a few months' dummy run, to start on the operating programme, which provides for the reprocessing and reworking of fuel from the *Elk River* Reactor, as laid down in the agreement signed by the *CNEN* with the *USAEC*. Thus data will be available on methods and costs relating to the uranium-thorium fuel cycle and can be directly extrapolated to industrial-size plants.

The foregoing, then, provides a general survey of Italy's nuclear programmes.

It will readily be seen that the aims are fairly ambitious. It is our hope that, through the devotion and skill of Italian scientists and also through international co-operation, in particular that offered by Euratom, they will prove to be attainable. (EUBU 6-6)

The development of nuclear power plants from the viewpoint of energy economics

HANS MICHAELIS, *Director-General, Directorate for Economy, Euratom*

IN THE SPRING of 1966 the Euratom Commission published its first target programme, to which was appended a collection of data justifying Euratom's proposals for the development of nuclear energy in the Community.
Events and studies made since this programme was drawn up call into question the continued validity of the analysis and forecasts embodied in the first programme.

The present situation

The nuclear power plants in use in the European Community countries represent a total capacity of 2100 MWe; 2200 MWe are in the course of construction and a further 4000 MWe are planned, giving a total of 8300 MWe. The projects include the following:

— in Germany, two nuclear power plants of 600 MWe each;

— a German-Swiss power station of 600 MWe;

— two 600 MWe power plants in Belgium on the construction of which a decision has been taken;

— several projects in France, where the Fifth Five-Year Plan envisages a construction rate of 500 MWe per year, with possibly an additional 1,500 MWe in five years. Design work is in progress on the Fessenheim (Alsace) project (700 MWe), among others.

— in Italy, a nuclear power plant of some 650 MWe to be built in the near future, followed by orders for an extra 2,000 MWe before 1970.

A development model

Euratom's first target programme recommends the harmonious and simultaneous development of proven-type reactors, advanced converters and fast breeders. This development model for nuclear energy in three generations of reactors was chosen for two reasons: it leads to minimum expenditure both in absolute value and present worth, and it requires least natural uranium. Use of the thorium cycle was not explicitly decided upon, because of the lack of precise and generally acceptable information.

Since the middle of 1965, i.e. since the preparatory work for the programme was finished, some new facts have come to light, which influence both the economics of the reactor families considered and the supply question.
The cost price of the kilowatt-hour produced by light-water reactor plants has fallen, creating doubts as to the advisability of pursuing development work on advanced converters. An outline will be given below of certain factors which can be taken as a basis in assessing whether the conclusions drawn under the first target programme are still valid as regards the development model recommended.

Proven-type reactors

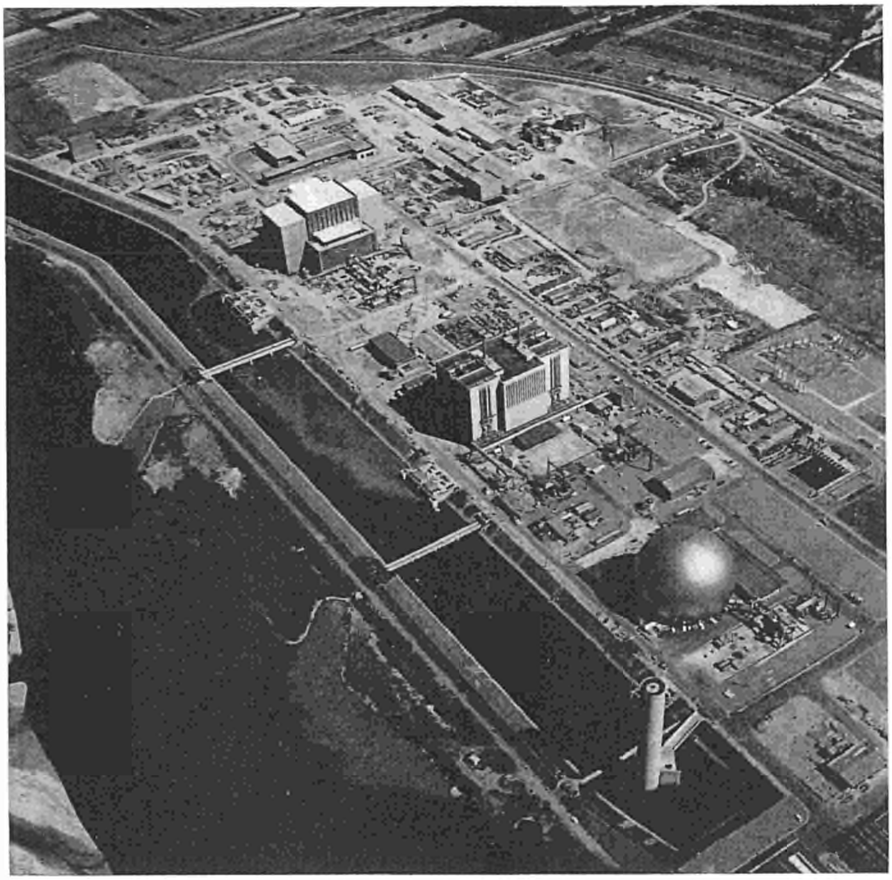
Light-water reactors

Although no further decision to build a light-water reactor plant has been taken in the Community since last year, the results of the tender invitations issued in Germany and elsewhere confirmed that the figures given in the target programme may be termed cautious and conservative.

According to the information supplied with regard to the plans for the construction of several large German power plants and a German-Swiss plant, each of 600 MWe capacity, the installation costs of light-water plants amount to 150 u.a./kWe.[1] This sum covers the turbo-alternator group and the transformer unit, including also the contractor's expenditure (land, site preparation, etc.), and the indirect charges (engineers' fees, administrative costs and overheads, interest during construction, reserves against price increases, customs duties, taxes and unforeseen expenses); however, it does not include the first fuel load. For a conventional thermal station, the corresponding installation costs amount to 125 u.a./kWe.

The cost price per kWh for plants of 600 MWe is around 4.5 mills/kWh for 7,000 hours a year, estimating fixed capital charges at 10% a year (taxes included). This price is only reached for a steady-state core (the third), and breaks down as follows:

— fixed capital charges	2.15 mills/kWh
— cost of fuel cycle	1.70 mills/kWh
— operation, maintenance, insurance	0.65 mill/kWh
Cost price of electricity produced	4.50 mills/kWh



EDF 1, 2 *and* 3 *reactors, Chinon, France.*

Graphite-gas reactors

In France work is in progress on the graphite-gas family. After the Chinon and Saint-Laurent-des-Eaux power plants, it was decided to build the first part of the Bugey plant (547 MWe). This is the first unit to use annular fuel elements *(INCA)* cooled internally and externally. It is hoped that this technique will lead to appreciable savings when used in plants of the order of 1,000 MWe.

Fessenheim 1, for which tenders are now being invited, seems to be the most economical graphite-gas plant so far envisaged. It is hoped to give it a capacity of 700 MWe, whilst keeping its size the same as EDF-4. The cost price per kWh would in that case be similar to that of a light-water reactor of equivalent capacity.

Advanced reactors

AGR reactor

The results of the call for bids for the *CEGB*'s Dungeness B plant were published at the end of July 1965. Installation costs amount to 220 u.a./kWe, and the cost price under the average conditions allowed for the Community (fixed capital charges of 10% a year), amounts to 5.2 mills/kWh. A feature of this project, which is being carried out by *Atomic Power Constructions (APC)* is a new type of fuel element, an on-power loading and unloading system, and an extremely compact structure. The fuel is slightly enriched (average of 2.25% in steady-state operation) and is expected to reach burn-ups of 20,000 MWd/t.

In subsequent projects, costs will certainly be able to be reduced. The results of calls for bids for this kind of plant in the Community must be known before it will be possible to determine whether the cost price per kWh will be as low as that of the light-water reactors at present used to generate electricity in the Community.

Heavy-water reactors

Research is going ahead on four types of heavy-water-moderated reactors (cooled by light water, heavy water, carbon dioxide and organic liquid). In the Community a comparison of economic estimates has been

1. 1 u.a. (unit of account) = 1 US dollar.

undertaken for types cooled by organic liquid, heavy water and carbon dioxide with a capacity of 500 to 600 MWe. The results of this comparison appear in Table 1 and are expressed as the percentage reduction in cost price per kWh in comparison with a light-water reactor of the same capacity and recent design.

Whilst the economic advantage of the first generation of heavy-water reactors over light-water reactors is arguable, the second generation, which is oriented towards the use of enriched uranium, offers prospects of slightly lower cost, even allowing for improvements in the performance of light-water reactors.

High-temperature gas reactors

The symposium held at London at the end of May 1966 emphasised the appeal presented by this type. With an installation cost of 165 u.a./kWh for a 500 MWe unit, prices of 3.9 to 4 mills/kWh are attained, according to whether or not the fissile material produced is recycled (see Table 2).

It should be remembered that this reactor uses highly enriched uranium and thorium. The use of slightly enriched, e.g. 4%, uranium would only raise the cost of the fuel cycle by 0.2 mill/kWh.

High-temperature gas reactors have consequently a part to play in the future development of nuclear energy. The possibility of using thorium, with a breeding ratio which could be pushed to almost 100% if the supply situation rendered it necessary, added to the prospect of savings being effected on a par with those obtained with light-water reactors and fast breeders, justifies the continuation of development work on this type.

Table 1: Economic advantage of heavy-water reactors over light-water reactors
(as a percentage of the cost price per kWh)
Annual utilisation time: 7,000 hours
Fixed capital charges: 10% a year

Coolant	Fuel	Cladding	Percentage
D_2O	Natural uranium oxide	Zircaloy	*Maximum 10%*
CO_2	uranium oxide, 1.7% enriched	stainless steel	
Organic	natural uranium carbide	SAP	
CO_2	natural uranium carbide	Beryllium*	*approx. 15%*
Organic	uranium carbide 1% enriched	SAP	

* NB. If a UC-Be fuel can be developed for use with CO_2 cooling, its use in the organic coolant should also be possible, as is shown by the compatibility tests carried out both at Ispra (ex-reactor test) and in Canada (in-pile test). If this were so, the performance obtained in an *Orgel* reactor optimised to run on natural uranium would be the same as that of an *Orgel* reactor optimised for use with *SAP*-clad enriched uranium fuel. However, it should be emphasised that this is a very long-term prospect.

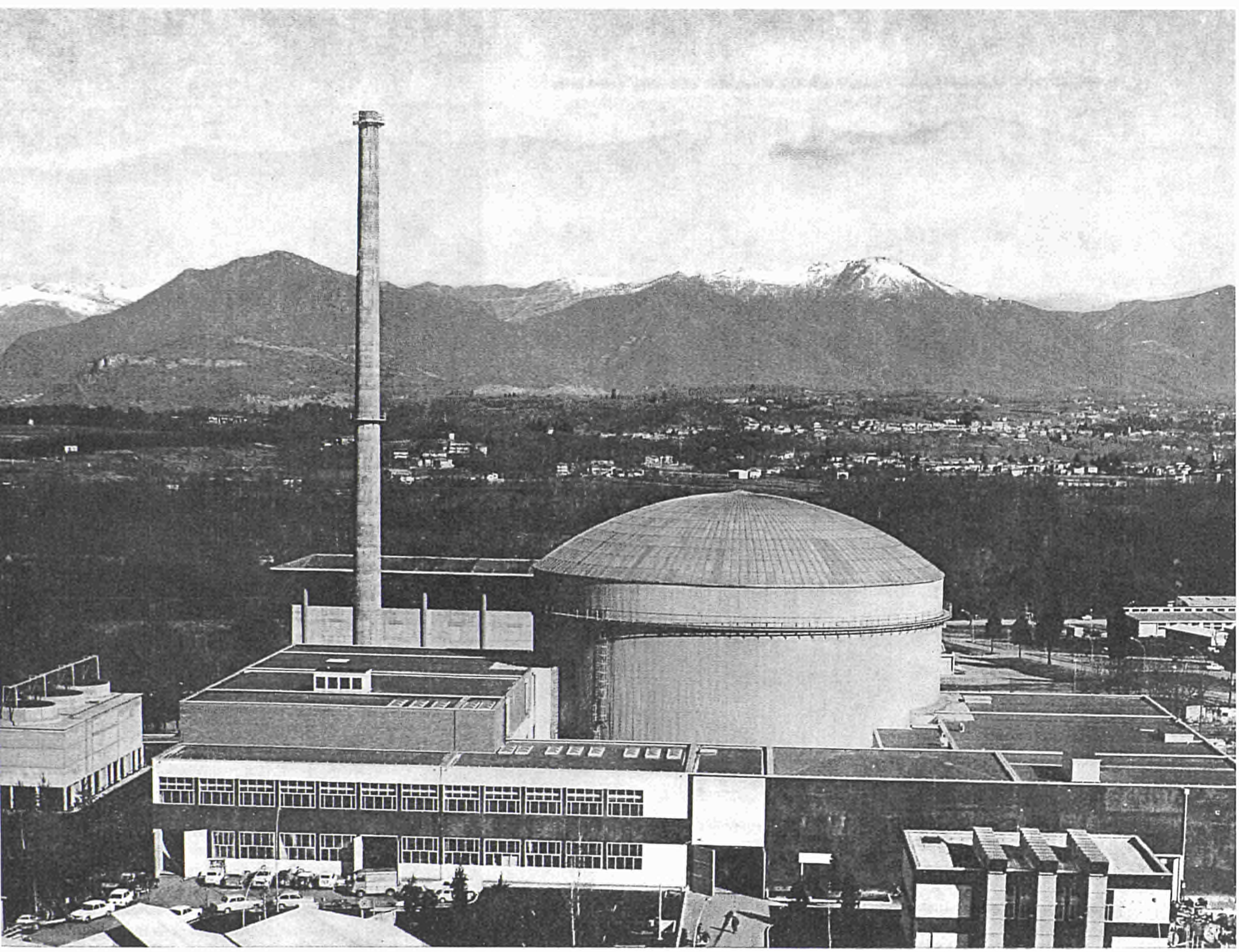
Fast reactors

The conference on fast reactors, also held in London in May 1966, yielded an amount of new information as a result of which the cost estimates will probably be revised, as well as the data on the requirements and specific production of plutonium. Here again, the figures contained in the target programme are obviously too cautious. The British estimates put the installation costs at 155 u.a./kWe and the cost price at 3.2 mills/kWh for installations of 2 × 1,000 MWe.

The Euratom Commission considers that fast reactors will be fuelled mainly with plutonium, as the likelihood of shortages of this material will diminish with the construction of ever larger nuclear installations in the Community in the years to come. If a shortage had at any time to be considered, then there would be grounds for examining whether there was any economic justification for the use of uranium 235 in fast reactors. If this were so, then provision should be made for extra capacity for isotope separation purposes.

The Euratom Commission is still convinced that the development model for nuclear energy adopted in the target programme, which includes three generations of reactors (proven-type, advanced and fast) remains valid. However, the advantage offered by this model over others, especially that in which proven-type reactors would be superseded directly by fast reactors, has diminished.

Further research and development work on advanced converters is justified on three counts: in the medium term, they still have a slight economic edge on proven-type reactors. The larger quantities of



The ESSOR *test reactor at Ispra, which is designed to permit a thorough study of the main components of an* ORGEL *nuclear power plant.*

fissile materials they produce can speed up the installation of fast reactors. Finally, only minor savings are expected from fast breeders as compared with advanced converters. The time required for the development of fast reactors and the outstanding technological unknowns are additional reasons for continuing work on advanced converters. It would even be preferable for them to benefit from a co-ordinated industrial effort.

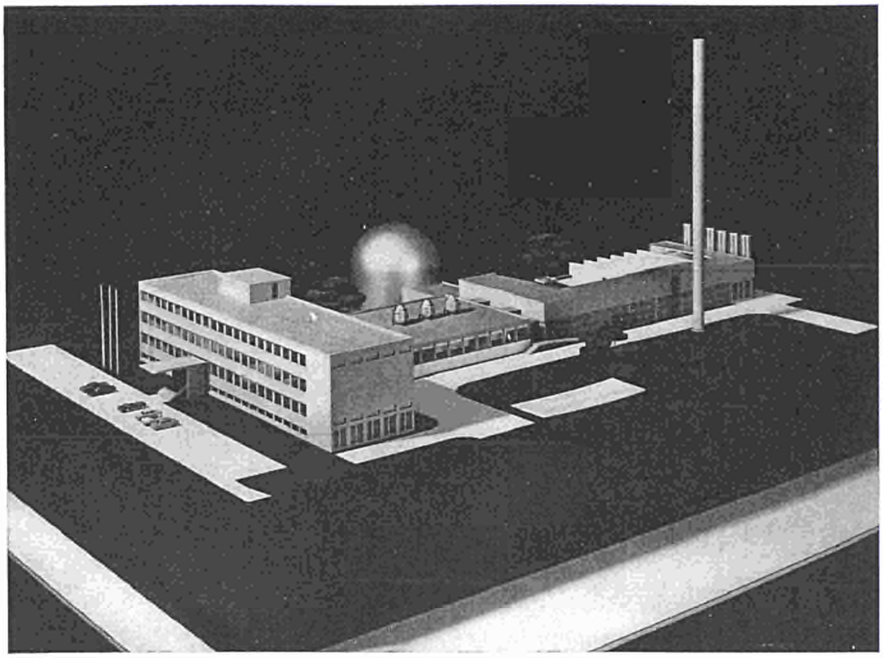
Competitiveness of nuclear power plants

Between *4.5 and 5.5 mills/kWh* will therefore be a reliable forecast for the cost price of the most up-to-date high-output (500 to 600 MWe) proven-type nuclear power plants which will go into service in the Community in and after 1971. This is based on the assumption that because of their proportionately lower costs, the nuclear power plants will operate on base-load (utilisation time of 6,000-7,000 hours a year). For the latest light-water plants, cost prices of *5.2 mills/kWh for 6,000 hours a year* and *4.8 mills/kWh for 7,000 hours a year* are obtained. The most sophisticated nuclear power plants will thus supply electricity at the same cost price as conventional thermal plants of the same size, whose fuel expenditure (coal, lignite, oil or gas) would be some 9 u.a./tonne of coal equivalent (tce) delivered free at plant gate. For the latest American designs, this price is estimated at between 5 and 6 u.a./tce.

The current market prices for fossil fuels are:

— between 15 and 18 u.a./tonne ex mine for industrial coal from Community mines, not including indirect taxes; because of the size and regularity of their orders, utilities obtain a rebate of almost 1 u.a./tonne;

— around 12 to 14 u.a./tonne cif for steam coal imported from the United States on long-term contract, delivered to port (not including customs duties); for short-term



Mock-up of the SNEAK *zero-power fast-neutron assembly (Karlsruhe).*

deals, the price is increased by around 1 u.a./tonne;

— generally between 15.50 and 21 u.a./tonne for heavy fuel-oil ex refinery (including taxes), which is equivalent to 10.75-14.75 u.a./tce.

So for both coal and oil a price of 10 u.a./tce can be considered as the long-term minimum price for imported fuels.

A simple comparison shows that the minimum price for fossil fuels is not below the cost price (9 u.a./tce) which can already be attained by nuclear power plants. The most advanced nuclear power plants which will come into use towards 1971 will therefore definitely be competitive in comparison with conventional thermal plants.

Forecasts for 1980

In the United States, nuclear energy has recently made startling progress, and the recently completed series of contracts for the construction of nuclear power plants will very probably cause the projects now in the design stage to be revised.

The long-term estimates will probably also have to be adjusted. For instance, the *USAEC*, in its "Report to the President" at the end of 1962, forecast 40,000 MWe of nuclear energy for 1980; in 1964 the figure wavered between 60,000-90,000 MWe, and a few months ago finally reached 110,000 MWe. This last estimate could well be exceeded by a wide margin even if orders for nuclear power plants did not maintain their 1966 pace over the next few years.

The information so far supplied by the Euratom Commission on the development of installed electrical capacity in nuclear power plants gave a figure of 40,000 MWe for 1980. As the 1965 target programme emphasises, this was a minimum target which would probably be overshot in practice.

The developments mentioned above open up ever more favourable prospects for the use of nuclear power in generating electricity. These prospects cannot fail to have repercussions in the Community, where electricity producers are particularly sensitive to the competitiveness of nuclear energy in the United States because fossil fuels are much cheaper there than in Europe, so that the forecasts will have to be revamped.

If the estimates recently made in the various Community countries are tabulated, the figures shown in Table 3 are obtained. From this table, it is henceforth permissible to adopt a minimum target of 60,000 MWe by 1980 for nuclear energy in the Community. *(EUBU 6-7)*

Table 2: High-temperature gas reactors—cost price of energy produced (in mills/kWh)
Annual utilisation time: 7,000 hours
Fixed capital charges: 10% a year

	500 MWe		2 x 500 MWe	
	without recycling	with recycling	without recycling	with recycling
Fixed capital charges	2,36	2,36	2,04	2,04
Cost of fuel cycle	1,07	0,93	1,07	0,93
Operation, maintenance, insurance	0,58	0,58	0,39	0,39
Cost price of energy produced	4,0	3,9	3,5	3,4

Table 3: Forecast of nuclear capacity installed in the Community by 1980 (cumulative capacity, in MWe)

	1970	1980
West Germany	1500	25000
France	1700	17000
Italy	610	12000
Belgium	150	4000
Netherlands	50	2000
Community	4010	60000

The nature of a plant is governed by the chromosomes of its parent cells; it is estimated today that these chromosomes are made up of 20 to 40 thousand different genes, each of which has a part to play in determining the plant's characteristics (Figure 1).

The traditional method of producing plants with new characteristics is cross-breeding, which involves, typically, fertilising an egg-cell of a particular plant with pollen from a plant of a different species or sub-species. If the genes of the female and male cells are likened to two lots of marbles of different sizes and colours, enclosed in two barrels, cross-breeding amounts to mixing all the marbles together and then filling the barrels up again to obtain two new sets.

Mutation breeding, on the other hand, simply involves bringing about minor changes in the genetic material of individual cells. It is rather like shooting at a barrel of marbles with a shot gun.

This may appear to be a somewhat destructive method, but it is probably fair to say that its destructiveness is that of the surgeon's scalpel. Chromosomes may be broken up, but the pieces may also rearrange to form new genetic material holding the key to useful characteristics. Similarly, it has been known ever since Mendel that there are "dominant" and "recessive" genes; it is likely that mutation treatment often brings about the elimination of certain dominant genes, thereby allowing certain useful recessive genes to surface and become operative.

Most of the mutation breeding work described in this article was carried out in the Netherlands. It should however be stressed that many interesting results are also being obtained in other countries of the European Community.

Similarly it should not be assumed, after looking at the photographs illustrating the article, that this work is concentrated on the development of new flower varieties, at the expense of what will very rightly be considered as a more urgent task, namely that of creating improved food-producing plant varieties. If mutations induced in flowers are those which have been taken as examples, it is simply because, in view of the ornamental nature of the plants concerned, the mutations which are of interest are those which the eye can readily see.

FROM THE EARLIEST times, man has tried to improve the characters of his crops, especially their yield and their quality. One of the first methods used consisted in sorting out the bad plants before using the rest for further propagation (negative mass selection) or to use the best plants only for planting and sowing (positive mass selection). Important steps forward were taken with the adoption of line selection, i.e. the development of whole generations of plants from single selected plants, and later with cross-breeding, which attempts at concentrating the good features of different varieties into one variety. It is largely thanks to the painstaking use of this last method over the years that we today have at our disposal a wide range of high-yielding, disease-resistant crops and varieties well adapted to mechanised cultivation or to extreme climatic conditions.

Progress in mutation breeding

CORNELIS BROERTJES, *Association Euratom/ITAL, Wageningen*

The youngest breeding method, mutation breeding, makes use of the possibility of inducing heritable changes by means of mutagenic chemicals or ionising radiations such as X-rays, gamma-rays and neutrons. Although mutation breeding research began around 1930, large scale practical applications started in most countries after 1945 only, under the stimulus of a keen interest in the peaceful uses of nuclear energy, which had made available cheaper and stronger irradiation facilities.

With the exception of very few experiments, no mutation breeding projects were under way in the Netherlands when the *Institute for Atomic Sciences in Agriculture (ITAL)* was founded in January 1957. One of the aims of this institute, some years later changed into the *Association Euratom/ITAL* through a contract with Euratom, is to carry out and promote mutation research as well as to promote, organise and co-ordinate practical mutation breeding work.

Organising research

The interest of a large number of institutes and laboratories of the *Wageningen Agricultural University* in mutation breeding was powerfully spurred when the *Association Euratom/ITAL* expressed its willingness to give effective support to research work by entering into a number of sub-contracts. Sub-contracts were in fact concluded with the *Department of Genetics* (bean, tomato), the *Department of Horticulture* (pea, tomato), the *Department of Plant Breeding* (potato), the *Institute of Horticultural Plant Breeding* (bean, tulip, carnation, fruit) and the *Foundation for Agricultural Plant Breeding* (pea, bean, potato).

Sub-contracts were also concluded outside the Netherlands, with the *Max Planck Institute for Breeding Research* at Cologne (Dr. Gaul—cereals), the *University of Bonn* (Prof. Gottschalk—pea), the *University of Cagliari* (Prof. Meletti—

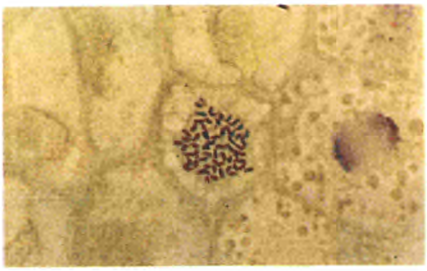


Figure 1: A set of chromosomes in a root-tip cell of African Violet. In the normal diploid variety, there are 32 chromosomes, which together contain about 20-40 thousand genes.

Figure 2: Colour mutation in "Baccara" rose. Acute X-ray irradiation of young plants produced this type of mutation from red to pink. With a suitable asexual propagation method a shoot leading to a wholly pink flower could be obtained. This mutant could then be propagated by the usual methods and compared with the original variety to check whether this colour mutation was not accompanied by mutations of an unfavourable nature.

Figure 3: Colour mutant and normal plant side by side (African Violet).

embryo transplantation), the *Comitato Nazionale per l'Energia Nucleare*, Casaccia Centre (Prof. Scarascia-Mugnozza—basic research) and the *Institut National de Recherche Agronomique* at Dijon (Dr. Dommergues—vegetatively propagated plants such as roses, pears, apples, etc.).

Besides, as early as 1958, a contact group had been formed, now known as the *Mutation Breeding Contact Group Wageningen*. The members of this group, for which both the chairman and the secretariat are provided by the Association, include most of the persons in the Netherlands and in the other Euratom countries actually engaged in mutation breeding research. The contact group meets once a year for three days, during which results are discussed, information is exchanged and programmes are reviewed.

The institutions who have sub-contracts with the Association are not the only ones to have a seat on the contact group. The membership includes several other public or semi-public organisations which are engaged in mutation breeding in co-operation with the Association; they thus have an opportunity of submitting their programmes and any problems they may have to their colleagues.

Finally a number of private firms interested in mutation breeding have links with the Association. Most of them have no seat on the contact group nor, owing to the strictly practical nature of their work, are they interested in the group. On the other hand they depend on the Association for advice.

Co-operation with breeders ...

In most cases, co-operation between a breeder and the Association comes about in the following way. The breeder discusses his problems with the author and it is ascertained which of them might possibly be solved by mutation induction and which are incapable of such a solution.

In addition to defining his problem, the breeder must be able to provide information of a general nature, especially on the genetics of his crop, for instance on the number and types of genes on which the required characters are based. This is usually a difficult matter and a certain degree of feeling for the potentialities is needed before final advice can be given.

The decision as to whether mutation breeding would be worth while or not obviously depends on knowledge of the latest possible results and experiments. Great help is afforded in this connection by an up-to-date card-index system of literature references.

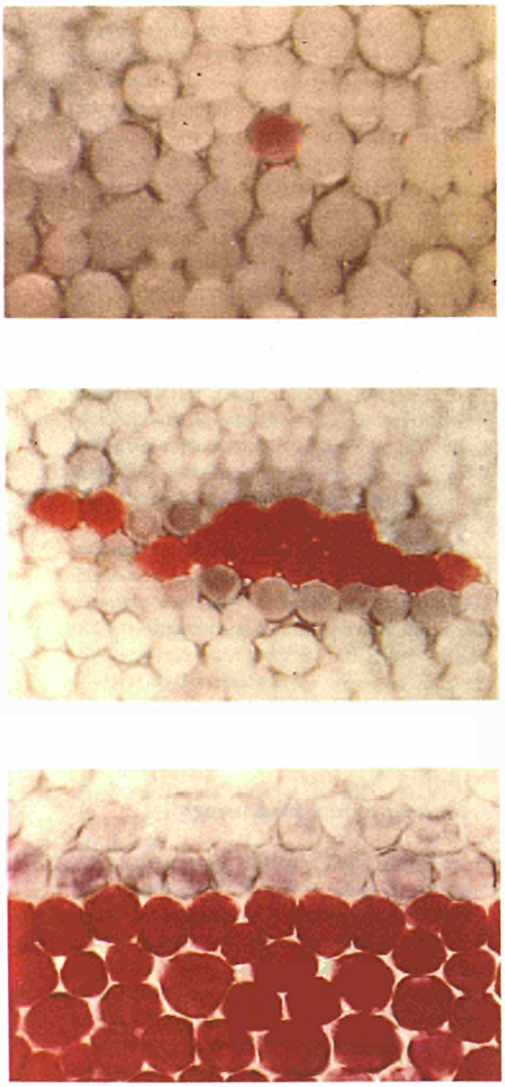


Figure 4: A mutation is a one-cell event. Irradiation induces a colour mutation in one cell of an apex of a white-flowering Dahlia plant. In some cases this cell will not win its fight against the competing unchanged cells (diplontic selection). However, if its division rate is sufficiently high, it will win the day and in due course lead to the formation of a whole layer of cells, which will become visible (Brookhaven National Laboratories, U.S.A.).

. . . deciding for or against mutation breeding . . .

Generally speaking, mutation breeding is not recommended when there are still plenty of possibilities of achieving the aim through conventional cross-breeding methods, unless there are clear indications that mutation breeding can save time. However, in the more highly developed countries, the new method has definite prospects, on the whole, because most crop varieties are the end-result of perhaps as much as a century of assiduous cross-breeding and can hardly be improved yet further by conventional means.
Mutation breeding is also pointless when the required characters depend on one or more dominant genes; there are hardly any cases of mutations from recessive to dominant genes.
The question whether a good selection method is available, or is capable of being developed, may also be decisive. If the character cannot be selected with certainty from the induced variability, mutation breeding is advised against. This can be particularly true of micro-mutations, such as those which affect disease-resistance and yield.

. . . deciding on a plan of action . . .

Before a mutation breeding project is started, the nature of the plant must be carefully borne in mind. According to whether it is a self-pollinator, a cross-pollinator or a vegetatively propagated plant, different decisions have to be made as to the particular strategy to be adopted in order to discover useful mutations and to select them. In almost all cases the required procedure is protracted and involves growing many successive generations.
In the case of vegetatively propagated plants, attention must be paid to diplontic selection, a process which sets normal cells in competition against mutated cells and tends to work out to the advantage of the former. However, mutated cells can be afforded abundant opportunities for development if special techniques are used (fig. 4, for instance, presents the history of a winning group of mutated cells). The vegetative apices and other reproductive organs should usually be irradiated at the earliest possible stage, if possible at the unicellular stage. This has proved possible with Saintpaulia (African Violet) and Begonia and has had a good effect on both the mutation spectrum and the mutation frequency (see fig. 5).
One of the advantages of mutation induction through irradiation is that, starting from good vegetatively propagated plant varieties obtained by conventional breeding, it is possible to alter just one character or a few only, without interfering with the others. As the simile of the marble-filled barrels, quoted in the introduction, was destined to show, this is practically impossible, statistically, with the conventional cross-breeding methods. On the other hand there is a good chance that mutation breeding may effect a considerable time-saving in the case of fruit, potato and ornamental plants, for example.
For some attractive plant varieties, such as triploid tulip, triploid roses and hybrids obtained from different species, conventional breeding methods are completely out of the question because the varieties are sterile. The use of mutation induction is then the only way of making them accessible to selection.

. . . following the plan through

Mutation breeding is not a simple task; it requires a great deal of time, space and material, and wrong advice leads to disappointment. This is always stressed in the course of discussions with breeders, as all possible steps must be taken to ensure that mutation breeding does not acquire a bad name because of ill-conceived projects.
This is particularly true of co-operation with private persons, who are often entirely dependent on the Association for advice. The Association therefore makes a deliberate choice among a small number of leading growers for work on plants considered particularly suitable for mutation breeding. Organisations with university-trained staff are, of course, responsible for their own mutation breeding programmes, although they are glad to avail themselves of the literature, knowledge and experience of the Association.
The actual irradiations are carried out through or by the Association, as far as possible under accurately fixed and therefore reproducible conditions.
Costs are not charged to subcontract part-

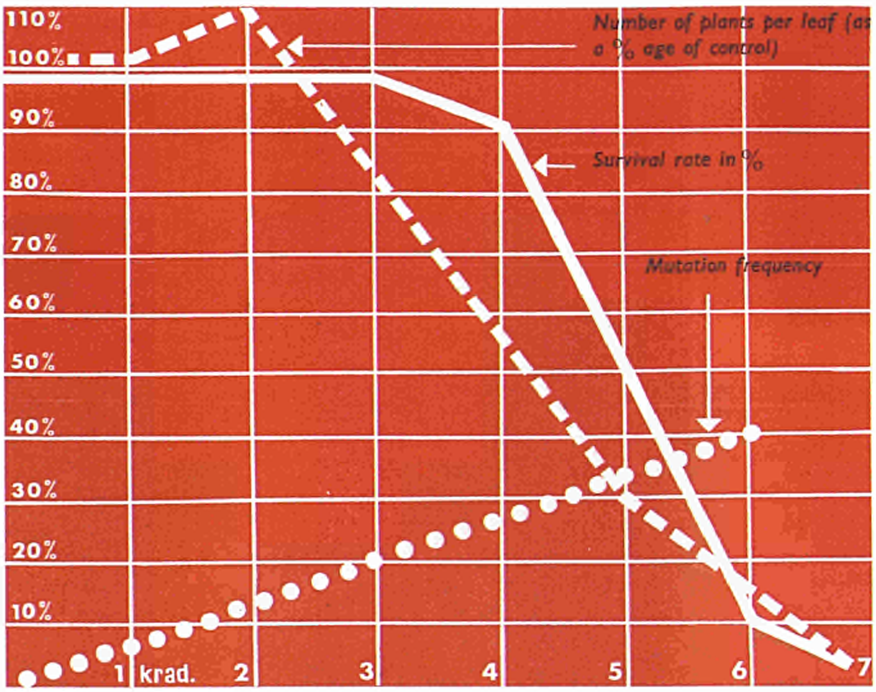


Figure 5: Dose response curves for "African Violet".

The well-known indoor plant "African Violet" is propagated asexually: if a leaf is placed with its petiole in a suitable medium, for instance a mixture of peat and soil, roots will form and in due course anything from 10 to 15 young plants will start growing at the base of the petiole (see figure 6).

If the leaf is irradiated, mutations can be expected (see figure 3), but the rate at which they occur varies according to the dose received. It can be seen from the graph that, as the dose increases, so does the mutation rate. On the other hand the survival rate drops, as well as the rate of production of young plants (except in the 1-2 krad region, where this production is actually stimulated).

The rate at which the radiation dose is applied is also an important factor. The graph shown only covers the case of acute X-ray treatment, i.e. a dose rate of over 200 rads per minute.

One of the aims, when planning an experiment, is normally to obtain the highest possible number of mutations, in order to improve the chance of hitting on useful changes. It is clear that an optimum compromise must be made in each case between the different factors involved.

ners. Other public institutes only defray direct costs, unless their work fits into the framework of the Association's programme. As for private organisations or persons, they pay both direct costs and overheads, but only as soon as the proper treatment can be recommended; no charge is made for the development work, for instance the establishment of the optimum dose, the correct irradiation time and the method of dealing with the material.

The material is supplied by the co-operating organisations themselves, who are also responsible for the actual growing and breeding work. It is however a condition of co-operation that the scientific data be made available to the Association, which can use them for advising others in turn. For each project, an "irradiation card" is filled in by the Association, showing details of the irradiation treatment administered; a duplicate of the card is then sent to the breeder, who has to enter data on the subsequent behaviour of the treated plants. On completion of the project, the card is incorporated in a card-index system.

Some of the projects carried out with the help of the Association have produced mutants which proved suitable for commercialisation, so that problems have arisen in connection with the attribution of rights over these good mutants. As the cost of the research work involved is borne by the Dutch state and by the Community, profits arising out of it should not accrue to a few persons. Decisions have up till now been made from case to case in accordance with this principle.

Mutation breeding projects . . .

The number of practical mutation breeding projects in the Netherlands has steadily grown: on 1st January 1967, 63 different crops had been the subject of 100 mutation breeding projects.

The diversity of the crops covered by these projects is large. The asexually propagated plants on which work is being done include *bulbs* (Tulip, Narcissus, Hyacinth, Iris, Lilium, etc.), *florist crops* (Azalea, Begonia, Chrysanthemum, Dahlia, Carnation, Saintpaulia, Streptocarpus, etc.) and *ornamental shrubs* (Azalea, Clematis, Potentilla). In most cases the aim is to obtain new flower colours as well as other characters that are important for their ornamental value, for instance flower form and size, growth habit of the plant, etc. Besides, a number of other crops are being investigated, such as *fruit* (apple, pear, cherry), with the aim of inducing colour mutations and creating dwarf varieties, and *potatoes*, in order to induce disease resistance, improve skin colour, etc. Work on self-pollinated plants includes projects on pea, tomato, canary seed, cucumber, colza and leek, the principal aims being to increase variability and disease resistance and improve yield.

In cross-pollinated plants similar work is under way with lettuce, spinach, onion, sugar beet and two grass species.

The first project started in 1959, although no irradiation facilities were yet available and the buildings were in the very first stages of construction. In 1960 *ITAL* was allowed to use the X-ray machine at the Wageningen hospital and seeds were sent to the *Brookhaven National Laboratory*, U.S.A., for neutron irradiation. Soon, however, the Association's own equipment, including a specially designed reactor (*BARN*), was put into service and the co-operation

Figure 6: Rooted African Violet leaves producing young plants.

Figure 7: Four mutants of the Dahlia variety "Salmon Rays". Below: the original variety. Middle row left: a mutant with a larger flower and a better flower form but the same flower colour. Middle row right: larger flower, better flower form and changed flower colour (apricot). Top left: completely different flower form and flower colour. Top right: larger flower, better flower form and deep pink colour.
These varieties were commercialised in 1966 under the names of "Selection", "Ornament", "Gracieuse" and "Rotonde" (co-operative programme between the Association Euratom/ITAL and a private breeder, Ballego & Sons, Leiden).

Figure 8: History of a colour mutation in the pot-grown Chrysanthemum variety "Hortensien Rose".
This variety is one of the best pot-grown Chrysanthemum varieties, but it was originally only available in the colour shown on the left of the middle photograph.
After irradiation treatment of rooted cuttings a small yellow sector appeared on a flower (left-hand photograph). The shoot carrying this flower was cut into several pieces which were then rooted to give new shoots. Some of these gave completely yellow flowers (right of middle photograph) and further propagation gave rise to a number of wholly yellow-flowering plants (right-hand photograph).
By following this method, a large number of mutants with different flower-colours and flower-forms were obtained and are now being propagated to find out which ones are suitable for commercialisation.

programmes with other institutes were launched.

. . . and their results

In 1963, the growing interest of private plant breeders became noticeable. After a low in 1964, this interest was rekindled and it has been becoming keener ever since. This can be explained by the increasing use of mutation induction in many parts of the world and by the first results yielded by a joint programme between the Association and a private breeder, namely four new Dahlia mutants which were commercialised in 1966 (see fig. 7). In the meantime other projects have shown promising prospects. It is likely that a new variety of onion will shortly be available, possessing increased resistance against neck-rot and therefore better keeping properties. It will perhaps also be possible to put on the market shortly new Chrysanthemum varieties (see figs. 8, and 9).
A number of projects were discontinued, sometimes simply because the crop turned out to be unsuited to mutation breeding. However, in a number of cases, failure was due to a lack of enthusiasm or perseverance on the part of the breeder. This is perhaps quite understandable: nuclear energy is regarded as one of the most powerful forces of nature and is expected to produce spectacular results, whereas its action, in this application, is extremely subtle. The actual irradiation treatment is in any case only a beginning; it must be followed up, as we have already pointed out, by years of painstaking work. (EUBU 6-8)

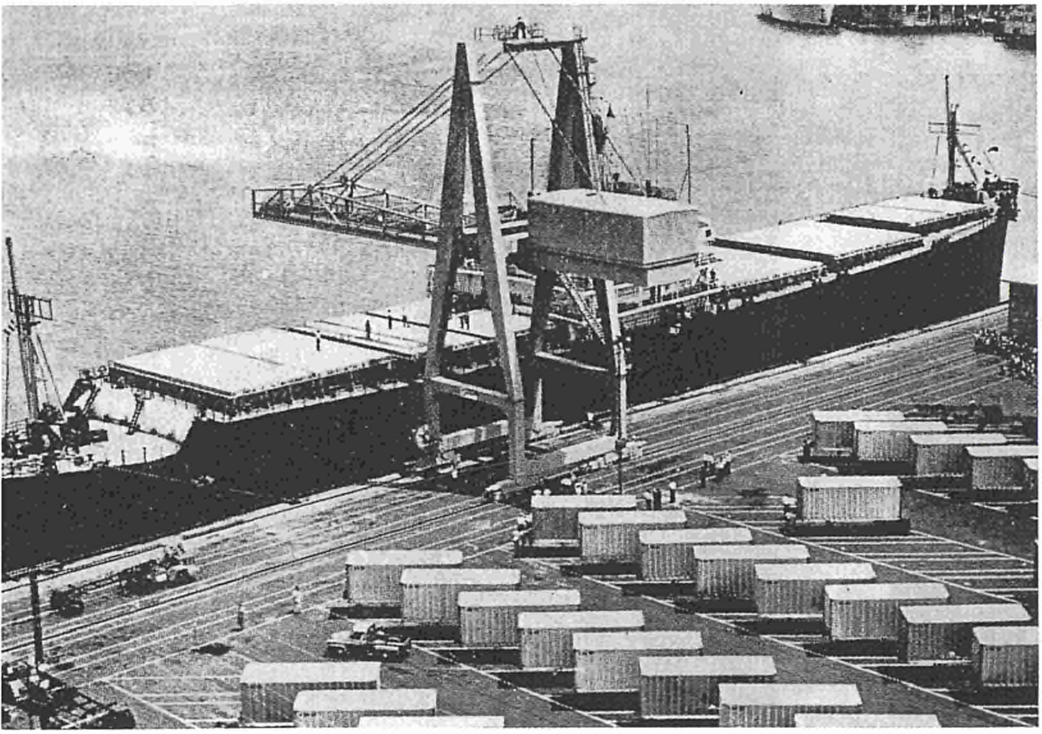
Figure 9: "Hortensien Rose" mutant showing a new flower shape.

Container transportation - a boost

MICHEL GIBB, *editor*

ABOUT TWENTY years ago the initial enthusiasm aroused by nuclear energy pointed to its ever increasing use both on land and at sea. Man's dream of plentiful and cheap electricity supplies from power reactors has not come about as sensationally as was perhaps originally imagined, but we are nonetheless experiencing its realisation almost without our noticing it.

On sea, there has been a major increase in the use of atomic energy to drive military vessels but at the same time the dream of a nuclear-driven merchant fleet plying over all the seas of the globe has remained as unattainable as ever. In some circles, the fact that the *Savannah* is to be taken out of commission in August 1967 will appear to constitute striking confirmation o



this, although it should be pointed out that the *Savannah* is primarily a demonstration ship, and that its success in this capacity is irrefutable.

It is common knowledge that purely economic factors are responsible for this state of affairs. Admittedly, reactors have certain inherent advantages over the boiler-turbine units used in modern high-power ships. They take up less space for a given output, even as technical developments stand at the present, the amount of space taken up by the fuel is virtually negligible and, in addition, the "proportional" operating costs, the main item in which is the fuel cost, are lower in the case of a nuclear reactor. For all these advantages, the competitive nature of nuclear-powered ships is by no means clear-cut.

The main reason for this is the fact that reactor capital costs are still high. The majority of land-based power reactors also suffer from this handicap but can be put on a competitive footing provided they can operate on the base of the load diagram, thus ensuring high annual utilisation times, of the order of 7,000 hours a year. It may surprise some people to learn that a conventional cargo vessel does not, on average, spend more than 145 to 160 days a year at sea. The rest of the time, i.e., 220-205 days, is spent in port. Expressed in hours, these figures give an annual utilisation time of less than 3,000 hours.

The reasons for this are outlined by Mr. Hans Boos, of Euratom's Directorate-General for Industry and Economy, in a study just published entitled "Evolution du transport océanique de con-

to nuclear marine propulsion

tainers par des cargos rapides, conduisant à de meilleures perspectives pour l'utilisation de la propulsion nucléaire—EUR 3.285 f" (Development of ocean transport of containers in fast cargo ships, leading to better prospects for the adoption of nuclear propulsion). At the same time he draws attention to a current trend in the transportation of mixed cargoes which promises to act as a boost to nuclear propulsion.

According to this study, the situation facing shipping companies operating conventional cargo vessels is very briefly the following: the growth in world trade has led to an increase in the amount of merchandise transported from one port to another, but has not been paralleled by any basic change in the methods used for loading and unloading mixed cargoes, i.e. cargoes consisting of a large number of different articles. Since a great deal of manual labour is involved in these operations, there has been a marked increase in the amount of time which ships must spend in port. As shown above, the result is that a cargo vessel is only at sea for about 40 days out of 100.

This being so, is it worthwhile building larger and faster ships? Obviously not, for the larger a conventional cargo vessel is, the longer it takes to load and unload it, thus bringing about a further reduction in the vessel's productive time, i.e., the number of days during which it is actually transporting cargo at sea. Assuming that the speed of the ship was increased, it will be seen that a conventional cargo vessel could indeed carry out one more trip a year, but in that case one would have to add on the extra days spent in port as a result of this crossing, so that in the final analysis the difficulty to be overcome is precisely the same.

Hence, calculation of the annual productivity increase—expressed in tons transported multiplied by the distance covered—to be obtained by increasing the size or speed of the ship reveals that it is minimal and does not warrant the additional investments entailed.

This is why the present trend among shipping companies is toward the increasing use of fast cargo vessels converted or built for the transportation of mixed cargoes in containers. These are crates of standard dimensions which can be filled *before* a ship arrives in port. The economic advantages of this technique are considerable, provided, of course, that special port facilities are available, so that the containers can be loaded, unloaded and dispatched to their final destination in as short a time as possible.

It is not the impact of some recent invention which is responsible for this trend, but quite simply competition. An American company, Sea Land Service, was the first to start a container-service on the transatlantic route. Despite the additional investments which it had to make in order to convert some of its ships and certain port facilities and to buy the containers themselves, its gamble came off, and as a corollary other companies were forced to come to terms with this new development.

Through a considerable reduction in the number of days spent in port, it is estimated that container-ships might be able to reach a sea-going time of 300 days a year. In order to benefit further from this advantage, it is economically justifiable to raise the cruising speed so as to cut down the number of ships required to transport a given tonnage over a given route, despite the fact that the required shaft horse power is a cube function of the speed, and hence the increase in installed power becomes appreciable.

Now that several shipping companies have started up container services, it must be assumed that the savings achieved by reducing the number of ships will enable profits to be made despite the extra costs involved.

In the United States numerous ports are already fitted out to receive container-ships, as are the ports of Rotterdam, Amsterdam, London, Bremen, Hamburg, Antwerp, Le Havre and Gothenburg in Europe.

It is to be expected that the trend outlined above, which has gathered momentum over the last few years, will continue. As a result, the annual utilisation time of the drive-units employed in ships transporting mixed cargoes will tend to be stepped up substantially; hence the fuel cost is an item which will assume increasing importance when the balance is drawn up for the operation of a ship at the end of the year. Furthermore, the trend towards higher cruising speeds will ultimately lead to higher output of drive-units. These two factors are to the advantage of nuclear propulsion, so that it may be concluded that the case for the efforts now being devoted to the development of this technology will become even stronger. (EUBU 6-9)

Automatic language translation

its possibilities and limitations

SERGEI PERSCHKE, *CETIS*[1], *Ispra Establishment of Euratom's Joint Research Centre*

RIGHT FROM ITS conception about fifteen years ago, automatic language translation aroused a great deal of interest even in non-specialised quarters. Although the first experiments carried out, which date back to 1954, received very optimistic appraisal, fundamental difficulties soon arose which indicated that there was no likelihood of perfect machine translations being obtained in the near future. Even now the final word has not been said on the extent to which a computer can translate competently. A fact which is frequently not given sufficient consideration here is that, for all their imperfections, machine translations can be of practical use. For the past five years or so, for example, all the translations from Russian used at Euratom's Ispra Nuclear Research Centre have been made by computer. Before an account is given here of the experience thus acquired, it would be worthwhile devoting some attention to the methods employed in automatic translation and the fundamental difficulties encountered.

Linguistic problems

In automatic language translation the task of the computer is comparable with that of a human being who has to translate a text which he does not understand from a language he does not know into another language which he does not know either, the following aids being at his disposal:

— *a bilingual dictionary* containing for each entry a word in the input language, its grammatical description and one or more corresponding terms in the output language; the meaning of the word remains unknown;

— *the grammar of the input language* containing the rules by which individual words are inflected, information as to the function of individual word forms and the rules for the formation of syntactical relations between individual words;

— *the grammar of the output language* containing rules as to how the syntactical relations used in the input language are translated and how the individual words are to be inflected.

The traditional grammar can be used for such purposes only to a limited extent, since it is built up on different principles and its task is not the same. In it, the essential criterion for the systematic coverage of a linguistic phenomenon is the information content of the sentence treated, and the user must, in particular, understand the meaning of the examples given in order to recognise the linguistic laws. If comprehension is precluded, as in the case of the computer, the grammar must contain all the information relative to the translation and, in particular, the rules in accordance with which these phenomena can be recognised.

The following difficulties arise in translation work:

— Many words have various meanings, and the particular meaning in a specific case and the correct translation can only be determined from the context. To take an example, the German word "*verschieden*" can either be an adjective, being translated into English as "*different*", or it is an inflected form of the word "*verschieden*" and must be translated by the corresponding form of "*decease*".

— In many cases a word may have only one meaning, but the output language does not possess a word which corresponds to it completely. The English word "know", for example, has only one meaning, but in German it can sometimes be translated by "*wissen*" and sometimes by "*kennen*".

— The syntactical methods of expressing relations are frequently very different and these relations must first be recognised before they can be translated. A construction such as the English "*he was given a book*" must be transformed in German into "*ihm wurde ein Buch gegeben*".

The way in which such difficulties can be solved with formal means is illustrated below using as an example the translation into English of the simple German sentence "*Er hätte seiner Frau die Wahrheit nicht gesagt*". It will be shown what data the dictionary and the grammar must contain in order to ensure a correct translation.

Fig. 1 reproduces the information to be

1. *Centre européen de traitement de l'information scientifique* (European Scientific Data Processing Centre).

found in any ordinary dictionary on the words making up the sentence. With the aid of morphology, the following formal data can then be derived for automatic translation purposes:

ER	Personal pronoun, nominative singular, masculine	HE/IT
HÄTTE	Verb 1st and 3rd person singular preterite subjunctive	HAVE
SEINER	Possessive pronoun, genitive and dative singular feminine or genitive plural	HIS/ITS
FRAU	Noun, feminine singular	WOMAN/WIFE
DIE	Article, nominative and accusative plural or feminine singular	THE
WAHRHEIT	Noun, feminine singular	TRUTH
NICHT	Adverb, negative	NOT
GESAGT	Verb, past participle	SAY/TELL

For reasons of brevity, certain possible translations, such as the use of "*die*" as a relative pronoun or "seiner" as a genitive of "er", have been omitted from this table and in the rules given below.

Even if the individual English words are correctly inflected, a word-for-word translation is not satisfactory:

"*He/it would have his/its woman/wife the truth not said/told*"

In order to determine the correct English word order and also in order to decide which of the possible variations is to be used, the sentence must first be parsed. The sentence contains the following syntactical relations:

a — *hätte* + *gesagt*
analytic form of "sagen"
(pluperfect subjunctive)

b — *hätte gesagt* + *nicht*
negation of verb

c — *seiner* + *Frau*
adjective plus noun

d — *die* + *Wahrheit*
Article plus noun

e — *hätte gesagt* + *die Wahrheit*
verb plus accusative object

f — *hätte gesagt* + *seiner Frau*
verb plus dative object

g — *er* + *hätte gesagt*
subject plus predicate

In order to recognise these syntactical relations, the following rules are necessary:

ad a — in analytical verb forms the personal form of the auxiliary verb in German (*haben* or *sein*) comes second in the sentence and the remainder at the end of the sentence.

ad b — the negative particle is placed before the impersonal verb form.

ad c — the adjective comes before the noun and agrees with it in case, gender and number. For this reason the case of "*seiner*" and "*Frau*" is limited to the genitive or dative singular.

ad d—the article comes before the noun and agrees with it in case, gender and number.

ad e—"*sagen*" is a transitive verb; the only part of the sentence which could be the accusative object of the verb is "*die Wahrheit*".

ad f—"*seiner Frau*" can therefore only be the dative object, there being no other syntactical possibility.

ad g—because of its case and its position in the sentence, "er" must be the subject; in addition, the verb agrees with the subject in person and number.

The system of relations in this sentence can be represented graphically as follows:

er – – g – – *hätte* – – a – – *gesagt* – – b – – *nicht*
– – e – – *Wahrheit* – – d – – *die*
– – f – – *Frau* – – c – – *seiner*

This example contains only subordinative syntactical relations. In the diagram the superordinate term of the relation is always to the left and the subordinate term to the right. It is the purpose of parsing to include every word in the sentence in a system of relations. The extent to which the individual relations must be differentiated depends essentially on how far the output language requires transformation of the sentence in certain cases. In order to translate the sentence given as an example, the following rules are necessary:

ad a — the arrangement of an analytical verbal form is: personal form of the auxiliary verb—impersonal form of the auxiliary verb—verb. The pluperfect subjunctive is formed with the auxiliary verb "*would*" and the infinitive of the auxiliary verb "*have*".

ad b—the negative particle comes after the personal form of the verb.

ad c—the adjective comes before the noun

ad d—the article comes before the noun

ad e—the direct object follows the verb and is used without prepositions.

ad f—the indirect object (dative) can precede or follow the direct object. If it follows it, it must be preceded by the preposition "*to*".

ad g—the subject precedes the predicate.

If the above rules were applied, the translation would run as follows:

"*he/it would not have said/told his/its woman/wife the truth*"

In order to decide which of the possible variants are to be employed, the following rules are necessary:

ad *he/it*—in an isolated sentence it is not possible to decide to what the pronoun "er" refers. However, it forms the subject of an activity which can only be carried out by human beings (*sagen*). We are therefore fairly safe in deciding for "*he*".

ad *woman/wife*—the word "*Frau*" must be translated as "*wife*" if it is related to a male person. This condition is fulfilled by the word "*seiner*".

ad *his/its* — according to the above rule "*seiner*" can only refer to a male person and must be translated by "*his*". Another point influencing this decision is the fact that two pronouns appearing in the same sentence, such as "*er*" and "*seiner*", usually refer to the same thing.

ad *say/tell*—the crucial point here is that the verb is complemented by a dative object referring to the receiver of the information. In addition, the expression "*tell the truth*" is common in English. In view of this the word "say" can be excluded. In line with the above rules the final translation is as follows:

"*He would not have told his wife the truth*"

With individual examples it is almost always possible to draw up adequate rules for correct parsing and translation. The big difficulties occur when a complete system has to be built up for a multitude of rules and the necessary detailed data concerning each word. The semantic classification problems are by no means beaten yet, especially in cases when it is not the characteristics of an individual word which are concerned but rather its relations to other words, such as the relations "part and whole" or "activity and instrument".

Since there was no adequate theoretical basis for solving the linguistic problems posed, empirical methods were used in an attempt to arrive at usable translations as quickly as possible. The first efforts were mainly directed at drawing up a sufficiently large mechanical dictionary and the elaboration of procedures for analysing the text syntactically, at a formal level at first as far as possible, and solving ambiguities. At the time the dictionaries were drawn up it was not known which information might later be used and work was at first limited to the purely formal, morphological and syntactical classification of each word. The linguistic procedures which make use of the information in the dictionary must therefore be largely restricted to the purely formal criteria, which are frequently not sufficient. As a result of the overestimation of the empirical methods adopted, the automatic dictionaries and syntactical rules were taken almost entirely straight from actual texts. In actual practice this time-consuming approach yields results which are less complete and reliable than those obtained by drawing the information required from traditional grammars and dictionaries. This method has been criticised in particular by Bar-Hillel, who wrote in 1960: "But grammars have in general not wholly been dreamt up, nor have dictionaries been compiled by some random process. Russian is not Kwakiutl, and with all due regard to the methods and techniques of structural linguistics and to the insights this science has given us with respect to the deficiencies of the traditional grammars, I do not think that all existing codifications of languages with a highly developed literature should be totally disregarded".

Fig. 1: Extract from Langenscheidt Pocket German-English Dictionary showing the words used in the model sentence.

er *pers. pron.* he; ~*selbst* he himself; *er ist es* it is he, F it's him; *von Dingen*: it; *vom Mond*: she.

'**haben** *v/t.* have; (*besitzen*) *a.* possess, be in possession of, own, hold; *es hat* there is, there are; ~ *zu inf.* have to *inf.*, be obliged (*od.* compelled) to *inf.*; ~ *wollen* (*wünschen*) wish, desire, want; (*fordern*) ask for, demand, require, *stärker*: exact; *sich* ~ put on airs, (*Aufhebens machen*) (make a) fuss; *etwas* (*nichts*) *auf sich* ~ be of (no) consequence, (not to) matter; *hinter sich* ~ have experienced (*od.* undergone), have gone through *a th.*; *vor sich* ~ await, face, be in for; *unter sich* ~ be in charge (*od.* control, care) of, (*befehligen*) command; *es im Halse* ~ suffer from (*od.* have a bad) throat; → *gern, recht, unrecht*; *es bequem* ~ have a comfortable (*od.* easy) life; † *Ware*: *zu* ~ obtainable, to be had, for sale, on the market; *zu* ~ *bei* (*dat.*) sold by; *ich hab's!* I have (got) it!; *da hast du es!* there you are!; *was hast du?* what is the matter with you?, what ails you?,

sein[2] **1.** *gen.* his; *er war* ~*er nicht mehr mächtig* he had completely lost control of himself; **2.** *pron.* ~(e) his; *e-s Mädchens*: her; *Sache*: its; *von Ländern, Schiffen oft*: her; *mein und* ~ *Vater* my father and his; *mit inf.*: ~ *Glück machen* make one's fortune; *all* ~ (*bißchen*) *Geld* what (little) money he had, his little all; *es ist* ~ it is his, it belongs to him; *Se Majestät* His Majesty; *es kostet* ~*e hundert Dollar* it will cost (at least) a hundred dollars; ~*er m,* ~*e f,* ~*es n, der* (*die, das*) ~(*ig*)*e* his (own); his property; *er und die* *S*(*ig*)*en* he and his family (*od.* people, *Am. a.* folks); (*gebt*) *jedem das S*(*ig*)*e* give everyone his due; *das Sige tun* do one's duty (*od.* part, share, best, F bit).

'**Frau** *f* woman; female; (*Herrin*) mistress; (*Edel2, Dame*) lady; (*Ehe2*) wife; *vor Namen*: Mrs.; *gnädige* ~! madam!; *m-e* ~ my wife, *förmlich*: Mrs. X; *wie geht es Ihrer* ~? how is Mrs. X.?; *Ihre* ~ *Mutter* your mother; *eccl. Unsere Liebe* ~ Our (blessed) Lady; *zur* ~ *begehren* ask in marriage; *zur* ~ *geben* give in marriage; *zur* ~ *nehmen* marry, take in marriage; ~*chen n* little woman; F wifey, old girl.

die → *der*.

der *m*, **die** *f*, **das** *n*, *pl.* **die I.** *art.* the; *der arme Hans* poor John; *die Königin Elisabeth* Queen Elizabeth; *die Oxford Straße* Oxford Street; *die Chemie* chemistry; *das Fernsehen* television; *ich wusch mir das Gesicht* I washed my face; *zwei Dollar das Pfund* two dollars a (*od.* the) pound; **II.** *dem. pron.* that, this, he, she, it; *pl.* these, those, they, them; *der Mann hier* this man; *der* (*od. die*) *mit der Brille* the one with the glasses; *nimm den hier!* take that one!; *sind das Ihre Bücher?* are those your books?; *das sind Sie* it is you; *das, was er sagt* what he says; *das waren Chinesen* they were Chinese; *zu der und der Zeit* at such and such a time; *es war der und der* it was Mr. So-and-So; *der und baden gehen?* go bathing?, not he!; → *dem*; **III.** *rel. pron.* who, which, that; *das Mädchen, mit dem* (*mit dessen Vater*) *ich sprach* the girl to whom (to whose father) I spoke; *das Material, dessen Eigenschaften* the material, whose properties (*od.* the properties of which); *ich, der ich Zeuge davon war* I who witnessed it; *der Bezirk, der e-n Teil von X. bildet* the district forming part of X.; *er war der erste, der es fertigbrachte* he was the first to succeed; *keiner* (*jeder*), *der* no one (any one) that; *alle, die davon betroffen sein können* all that may be concerned.

'**Wahrheit** *f* truth; *in* ~ in truth, in fact, in reality; F *j-m die* ~ *sagen* (*schelten*) give a p. a piece of one's mind; *um die* ~ *zu sagen* to tell the truth.

nicht *adv.* not; *beim v/aux*: *er darf nicht* he may not; *sonst mit* do: *er geht* ~ he does not (*od.* doesn't) go; *gingst du* ~? did you not (*od.* didn't you) go?, *nein, ich ging* ~ no, I did not (*od.* didn't); *er kam* ~ *a.* he failed to appear; *ich verstehe* ~, *warum* I fail to see why; *der Apparat wollte* ~ *funktionieren* refused to work; *vor comp.*: no, *z.B.* ~ *besser* no better; ~ *mehr,* ~ *länger* no more, no longer; *oft a.* in..., *z.B.* ~ *einlösbar* inconvertible; non..., *z.B.* ~ *abtrennbar* non-detachable; un..., *z.B.* ~ *anziehend* unattractive; *a. miß..., z.B.* ~ *glücken* = *mißglücken* fail, be unsuccessful; *gar* ~ not at all; *ganz und gar* ~, *durchaus* ~ not in the least, by no means; ~ *doch!* (*laß doch*) don't; ~ *wenige* not a few; ~ *einmal* not even, not so much as; *nur das* ~! anything but that; ~ *daß ich wüßte* not that I know of; ~ *daß es mich überrascht hätte* not that it surprised me; *ich kenne ihn auch* ~ I do not know him either; *sie sah es* ~, *und ich auch* ~ she did not see it, nor (*od.* neither *od.* no more) did I; *du kennst ihn* ~? *Ich auch* ~! you don't know him? Nor do I!; ~ *wahr*: is it not so?, F isn't that so?; *er ist krank,* ~ *wahr?* he is ill, isn't he?; *Sie tun es,* ~ *wahr?* you will do it,

'**sagen** *v/t. u. v/i.* say; *j-m et.* ~ tell a p. a th., say a th. to a p.; → *Dank, Meinung, Wort usw.*; *j-m et.* ~ *lassen* send a p. word; *sich* ~, *daß* tell o.s. that; *et.* (*nichts*) *zu* ~ *haben bei* have a (have no) say in; *du hast mir nichts zu* ~ I won't be ordered about by you; ~ *Sie ihm, er soll kommen* tell him to come; *er sagt nur so* he doesn't mean it; *was willst du damit* ~? what do you mean by that?; *sagt dir das etwas?* does that mean anything to you?; *wie sagt man ... auf english?* what is the English for ...?; *das hat nichts zu* ~ it doesn't matter, it makes no difference, never mind; *das will* (*nicht*) ~ that is (not) to say; *das will viel* ~ that is saying a lot; *das sagt man nicht* that's not the proper thing to say; *das kann man wohl* ~ you may well say so, *Am.* you can say that again; *ich habe mir* ~ *lassen* I have been told that; *er läßt sich nichts* ~ he won't listen to reason; *laß dir das gesagt sein* let it be a warning to you, F put that in your pipe and smoke it; *laß dir von mir* ~ take it from me; *man sagt, er sei tot* they say he is dead, he is said to be dead; *was Sie nicht* ~! you don't say!; *wenn ich so* ~ *darf* if I may say so; *ich muß schon* ~ I daresay; *wem* ~ *Sie das?* you are telling me!; *es ist nicht zu* ~ it is incredible, it is fantastic; *wie man so sagt* as the saying (*od.* phrase) goes; ~ *wir zehn Stück* say, suppose; *sage und schreibe* no less than, as much as, to the tune of; *sage und schreibe e-e Stunde lang* for a solid hour; *es ist nicht gesagt, daß* that does not (necessarily) mean that; *unter uns gesagt* between you and me (and the bedpost); *wie gesagt* as I said; *gesagt, getan* no sooner said than done.

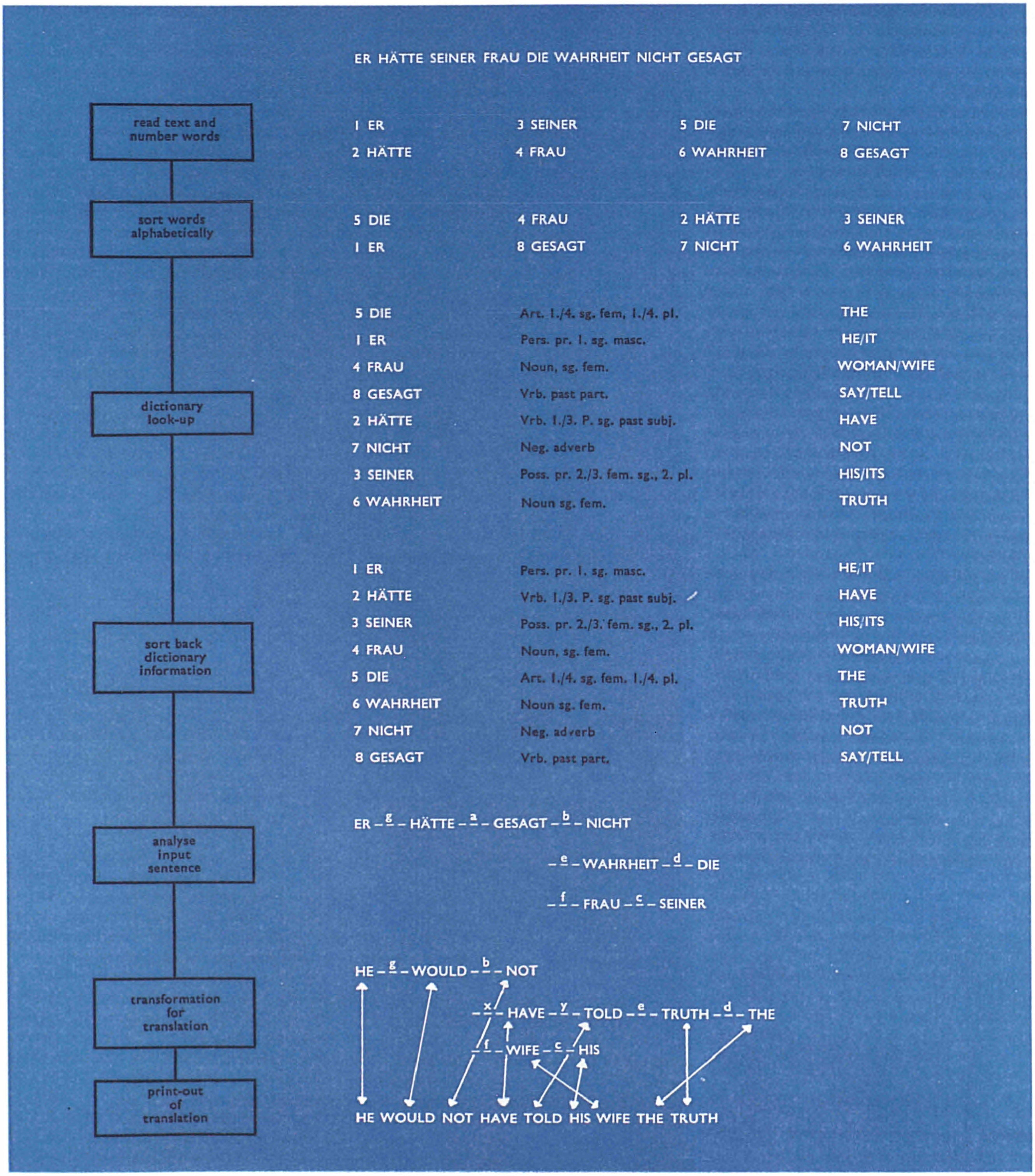
It is indeed true that the existing translation programmes do not make full use of all the useable information contained in a good grammar. From the linguistic point of view these programmes offer largely a word-for-word translation which is refined by a number of individual rules. If automatic translations are nonetheless perfectly useable in actual practice, this is due to the fact that they have so far been limited to the translation into English of Russian scientific texts, the style and syntax of which are very limited and uniform. At the same time, Russian and English are both Indo-European languages and apply very similar means for the display of the thought.

The call for a formalised description of language also inspired researchers in other disciplines, particularly mathematicians, to apply their methods to linguistics. An independent discipline of mathematical linguistics has developed, but so far the methods applied have not been able to meet the requirements of automatic language analysis because mathematical linguistic models such as transformational grammars, meta languages, etc. in their present form reduce rather than increase the amount of information contained in the description of the language, when compared with traditional grammars.

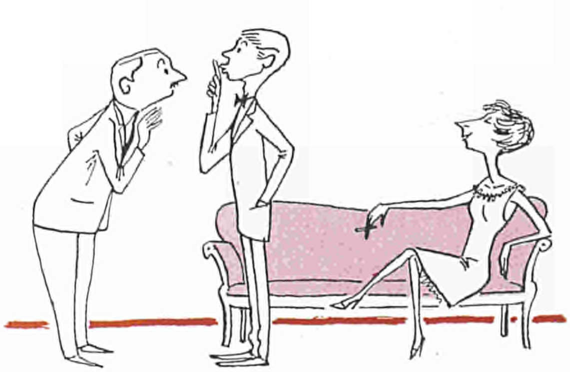
The translation process

While linguistic research into automatic translation is still in its infancy and a solution to all the problems involved is not yet in

Fig. 2: Flow chart of automatic translation process. The result of each stage is illustrated next to the diagram with the aid of the example.



sight, generally recognised procedures for the technical handling of linguistic data have been developed in the few years in which intensive work has been carried out in this field.
Each word of the input text must first be read and looked up in the automatic dictionary, the text to be translated being transferred to punched cards or tape. The look-up procedure used depends largely on the design of the computer and its input and output media. As technical developments stand at present, the dictionary, which can cover more than ten million alpha-numerical characters, must be stored either on a magnetic tape or on magnetic discs. These storage media do not permit the words to be looked up in the dictionary in the same order as they occur in the text, because too much time would be lost moving forwards and backwards the magnetic tape or the access arm of the disc storage. For this reason a large portion of the text is first read in and each word numbered, after which words are alphabetically sorted and looked up in the dictionary. The information found in the dictionary is then sorted back in the original text order.
From the linguistic point of view, this procedure has the drawback that the words must be recognised according to purely formal criteria. Therefore with this system it is not possible to analyse composite words, since only the first component would be found after the alphabetical look-up. For instance, in looking for the German word "*Witwenrente*", the word "*Witwen*" would be found, a second retrieval operation being necessary for "*rente*". In addition, idiomatic expressions such as "*solid state physics*" can not be identified during the dictionary look-up but in the course of the syntactical analysis, which often entails considerable codification problems. The increasing sophistication of computer design, however, indicates that sufficiently fast mass storage systems will be available in the forseeable future with which it will be possible to look up words in the order in which they occur in the text without appreciable loss of time.



After the dictionary look-up, the text is processed sentence by sentence. Each sentence is first parsed. The analysis methods used depend largely on the linguistic concept and are of two types. With the one, the sentence is regarded as a sequence of elements and an attempt is made to determine the relations between these elements. This method is normally combinatory in the sense that one takes two elements in the sentence (usually two words) and examines whether a relation can be established between them in accordance with the syntactical rules. If this proves possible, the product is used as an element in further relations until all the words in the sentence have been connected up. With the second system, the sentence is regarded as a unit and the aim is to define its structure by comparison with a number of model sentences. This models method has numerous advocates among the theorists in the automatic linguistics field, such as Yngve and Chomsky, but, owing to the multitude of possible structures, an operational model which could be used for practical purposes has not yet been developed.
The subsequent steps in the translation process depend on the thoroughness and reliability of the parsing. The first thing to do is to find a corresponding relation in the output language for every syntactical relation. The following situations are possible:
—There is a precise corresponding relation, and only the word order and the inflectional forms are defined.
—For translation purposes the relation, which is unambiguous in the input language, must be divided up into several subgroups since there is no precise corresponding term. For example, the German expression "*mit Kreide schreiben*" must be translated by "*to write with chalk*" in English, whereas "*mit Kreide werfen*" is constructed without a preposition: "*to throw chalk*".
—There is no corresponding relation in the output language and the sentence must be structurally transformed in order that the content can be reproduced faithfully. For example, the German sentence "*ihm wurde das Auto gestohlen*" must first be transformed into "*sein Auto wurde gestohlen*" in order to be subsequently translated as "*his car was stolen*", "*the car was stolen to him*" being incorrect English.
The decision as to one of several possible translations of a word is taken when the necessary information is available. Since the conditions for this must be determined individually in each case, it is a help if they can be codified in the dictionary together with the particular word. The conditions can be purely formal or they can necessitate information concerning the syntactical structure, the semantic environment, etc.
Once the syntactical structure of the sentence in the output language has been defined, the individual words must be inflected. The dictionary contains details concerning the inflections for each word. Should an analytical form be required, it is best to carry out a syntactical transformation corresponding to this form in order to avoid possible errors in word order. After the linguistic operations have been performed, the translation of the sentence—or what will ultimately be the translation—is printed out and the next sentence processed.

Automatic translation at Euratom

As part of its research in the field of automatic documentation, the Ispra Scientific Data Processing Centre (*CETIS*) from early on devoted its attention to problems related to automatic translation. When the installation of a large computer (IBM 7090) in 1961 provided it with the technical equipment for practical work on machine translation, it could base on the experience which had hitherto been acquired in the United States. By that time two Russian/English translation systems had been developed to such an extent that they were in a position to provide translations of scientific texts which could be put to practical uses.
The first system was developed in the *IBM* Research Centre at Yorktown Heights, New-York. This involves the use of a special purpose computer in which a photoscopic storage is used for the dictionary. This device was developed under US government contract and has been in operation since 1963 with the *FTD (US Air Force Foreign Technology Division)*. However, this system is not suitable for the require-

К теории каскадов для разделения многокомпонентных изотопных смесей

Р. Я. Кучеров, В. П. Миненко

Рассмотрен стационарный процесс разделения многокомпонентных изотопных смесей в каскадах произвольного профиля. Теоретически исследованы предельные случаи нулевой и бесконечной относительной скорости изотопного обмена. Получено решение системы уравнений переноса для прямоугольного ступенчатого каскада и разработана методика расчета таких каскадов.

THEORY OF CASCADES FOR SEPARATING MULTI-COMPONENT ISOTOPE MIXTURES

(UDC 621.039.31)

R. Ya. Kucherov and V. P. Minenko

The article discusses a stationary process for the separation of multi-component isotope mixtures in cascades of arbitrary profile. It includes a theoretical investigation of the extreme cases in which the relative rate of isotope exchange has values of zero and infinity. A solution is obtained for a system of transport equations for a rectangular stepped cascade, and a calculation procedure for such cascades is worked out.

TO THE THEORY OF CASCADES FOR THE SEPARATION
OF THE MULTICOMPONENT ISOTOPIC MIXTURES .

R. YA. KUCHEROV , V. P. MINENKO .

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WORKED OUT THE METHOD OF CALCULATION OF SUCH CASCADES .

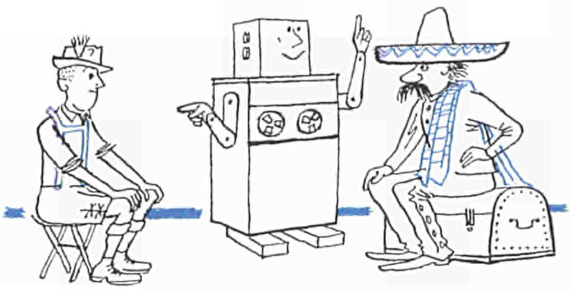
Fig. 3: Example of Russian-English translation.
A normal translation of the same text is given together with the machine version for illustration purposes.

ments of *CETIS*. Quite apart from economic considerations—the system costs several million dollars—such a system tends to hamper independent further development work since the translation logic is fixed and any alteration of it would necessitate redesigning the computer. From the linguistic standpoint the system provides a word-for-word translation which is then edited before use.

The second system was developed at Georgetown University, Washington. It was particularly suitable for Euratom, because by the time it was finished it had been programmed for the IBM 7090. A further advantage with this system was the fact that it was also eminently suitable as a tool for use in independent linguistic research. The system is built up in two stages. Those procedures which, while being very complex, do not constitute linguistic problems, such as input and output, alphabetical sorting, dictionary look-up, sorting-back and the control over the processing of each sentence, are fixed and permit very rapid processing. For the linguistic procedures, such as syntactical analysis, transformations, etc., and for the codification of the necessary data, a symbolic programming language has been developed with which the linguist can programme new procedures and data with a minimum of time and effort, subsequently checking them for their efficiency.

The first contacts were established between *CETIS* and Georgetown University in 1961, and in the following year this system was made available to *CETIS* so that it could be used for experimental purposes to provide an experimental automatic translation service at the Ispra Research Centre and to check its practical efficiency. After the initial experience acquired, which was quite favourable, a short-term research contract was concluded with Georgetown University in 1963 for improving the system and adapting it to Euratom's own requirements. Since 1963 this system has been in use at Ispra for the automatic translation into English of all Russian-language documents required there. The users of the system, whose number is constantly increasing, receive the translation as it is produced by the computer without any post-editing.

It is impossible to ascertain the precise value of an imperfect translation. One tries to define translation accuracy of 90%, for example, which would mean one mistake for every ten words in the text, but the



extent to which these mistakes impair comprehension of the text or falsify the information contained in it depends on a number of factors which may have nothing to do with the text translated, such as the specialist knowledge of the reader, the purpose for which the translation is used, the author's style, etc. No notable differences have emerged from tests carried out, in an attempt to check the reliability of the translation, by having a number of people read texts translated by both human translators and by computer and then quizzing them on the contents.
The experience acquired at Ispra shows that the scientists are satisfied with the quality of the automatic translation of scientific texts. The users do not avail themselves of the facility for obtaining more accurate translations by a human technical translator, although they sometimes consult *CETIS* in order to clear up points of difficulty in the translation. Comprehension of the text does not appear to be impaired to any major degree by stylistic and grammatical irregularities in the translation, although the observation has been made that readers who have English as their mother tongue are more bothered by this than others.
Automatic translations can satisfy the immediate information requirements of a scientist, but human editing work is necessary before such a translation can be published. In this connection the rough translation supplied by the computer can save considerable time and money. Even editors with no knowledge of Russian should be capable of transforming the automatically translated text into a smooth and correct translation.
The present cost of automatic translation is around $ 7 per thousand Russian words. From the economic angle automatic translation could even be defended if some of the texts had to be retranslated again later by a human translator. The cost of human translations is between $ 13 and $ 40, depending on the organisation. The question, however, is how much the quality depends on the price paid.
The Georgetown University translation system is not only being used by *CETIS* but is also being improved and developed. The starting point for this work was a detailed analysis of the computer programmes and of the linguistic data and procedures forming the basis of the system. This work, which was extremely laborious and time-consuming (for example, the instruction lists provided the only available documentation concerning the computer programmes), was necessary in order to acquire as rapidly as possible the know-how obtained over a ten year period as a result of intensive research by a large team, and hence to catch up the head start enjoyed by the American groups. Analysis of the translation system showed that it cannot be fundamentally improved by local corrections and additions to the individual linguistic rules. The basic linguistic concept was fixed and programmed very early on by empirical methods, and the work carried out by Georgetown University over the last years had essentially consisted in ad hoc improvements on the basis of test translations. As a result of this approach, the individual steps in the linguistic operations are so intertwined that it is now no longer possible to determine what effect one individual modification might have on other operations.
In order to achieve some major progress on the linguistic level, a start has been made at *CETIS* on reformulating the basis used for the parsing process. The aim here is a complete definition of the syntactical structure of each sentence, say, on the model of the example given above. The formal data already contained in the dictionary are first used for the syntactical rules. It goes without saying that these data alone are not always sufficient to provide an unambiguous definition of a syntactical structure which is adequate for translation purposes. But this work is necessary so that the mistakes and gaps in the analysis can be utilised as a basis for semantic research.
A further field for the improvement of the translation quality is the dictionary. This contains at present about 30,000 entries and in the technical and scientific field this is frequently not sufficient, so that sometimes there remain Russian words in the translations. The work required in order to extend a dictionary is very time-consuming and requires highly specialised personnel, who, in addition to knowing the languages concerned, must possess training in linguistics and be acquainted with the translation system, and in particular, the specialised field covered by the new words. This work could be avoided because the computer dictionary, containing about 180,000 words, which is used in conjunction with the above-mentioned special installation developed by *IBM*, was made available to *CETIS* in connection with an information exchange. The adaptation of this dictionary into the Euratom system is admittedly a vast job owing to the differences in the linguistic concept and in the retrieval strategy used but it is considerably less expensive.
The installation of a new computer at *CETIS* (IBM 360, Model 65) at the beginning of 1967 posed a further pressing task, namely, that of adapting the system to the new computer. It is not sufficient to rewrite the existing programmes, because, firstly, they would not make use of the potential offered by technological progress and, secondly, the present dictionary look-up strategy would, on economic and scientific grounds, not be defensible in the case of a far greater dictionary.
The two-stage structure is retained in the planned system, but both the set-up of the computer programmes and the symbolic programming language for the codification of the linguistic data and procedures are to be entirely reformulated so that they can make best use of the new computer. In addition, the new version of the programming language is also to take account of the requirements of the new syntactical analysis strategy and other applications of the system, such as automatic key-word assignment in documentation.
It is expected that the new system will be able to translate about 300,000 Russian words an hour and thus, despite the larger dictionary, will be able to work roughly five times as fast as the present one. This will also lead to a reduction in the cost of automatic translations. During the development stage the translation service is ensured by the IBM 360 with the aid of a special feature, which can process, though not optimally, programmes written for the IBM 7090. (EUBU 6-10)

EURATOM NEWS

Euratom looks beyond 1967

When, last February, the Euratom Commission presented proposals for the course Community action should follow after its second five-year plan expires on 31 December 1967, it initiated a procedure which should ultimately lead to the adoption of a programme by the Council of Ministers during the course of the year.
In formulating its proposals, the Commission made allowance, first, for technical progress, which augurs for an even faster expansion of nuclear power than was envisaged in the first target programme published in 1966, and secondly, for the need to face increasing and world-wide competition. It considers, therefore, that the immediate fundamental problem is to rationalise the use of available resources.
The obligations laid down by the Treaty imply utilising the means of action it provides, the research programme being only one of such means. Nine years' experience of implementing the Treaty has enabled the Commission to analyse the pros and cons of the methods it has employed and, in certain cases, to modify them for the sake of greater efficiency or to make them less difficult to apply.
The starting-point of any programme is the selection of the tasks to be performed by the Community; inter-governmental agreement on this selection must be obtained before the ways and means of achieving it can be worked out.
The Commission is proposing an action programme covering a period of five years (subject to amendment in the third year) and comprising three categories:

1. *Direct action, based on a joint programme* financed by all the Member States (Art. 7) and carried out mainly by the Joint Research Centre and the Information and Documentation Centre.

a) *Joint Research Centre and ORGEL Project*
The Centre's four establishments have at their disposal expensive equipment and "integrated" teams of research workers who have already proved their mettle.
The programme drawn up for the *Ispra* establishment includes, in the heavy-water reactor field, work in furtherance of the *ORGEL programme* (mainly on the fuel-element and the channel) using the *ESSOR* reactor; in the field of solid- and liquid-state physics, the construction of a pulsed reactor (*SORA*) to be used in conjunction with the very-high-flux reactor at Grenoble —in which Euratom participation is desirable—and in the field of direct conversion of nuclear energy into electric power. The European Transuranium Institute at *Karlsruhe*, which is devoted to research on the use of plutonium in fast reactors, the recycling of plutonium in thermal reactors and work on the transplutonium elements, would also be further developed. The same applies to the Central Nuclear Measurements Bureau at *Geel*, where it is proposed to install an accelerator, and the *Petten* establishment, whose programme will cover studies on materials in the high-temperature gas reactor field and more sophisticated operation of the HFR materials-testing reactor.

b) *Other direct activities*
These include:
—dissemination of information, which is undertaken by the Information and Documentation Centre. The Documentation Department already has a semi-automatic retrieval system which should be brought up to date and constantly improved as to efficiency;
—health and safety;
—supplies;
—technical and economic studies;
—training, particularly by means of organised working courses.

2. *Participation* in certain national projects from which it is desirable that the entire Community should benefit. These projects would include the development of *CIRENE* fog reactors, high-temperature gas reactors, fast breeders and nuclear marine propulsion, the development of uranium-prospecting techniques and radioactive waste storage methods, research on thermonuclear fusion, the study of low-energy nuclear phenomena, operation of the Grenoble very-high-flux reactor, research into radia-

tion effects on living matter, and the use of nuclear techniques in biology, medicine and agriculture.

In this connection, and particularly as regards reactor development, the Commission makes a distinction between:

—"basic" research and development programmes, aimed at fairly long-term applications, which afford a wide dissemination of information and are generally carried out in public research centres, and

—specific development work, as a preliminary to the construction of industrial installations.

Depending on the particular case, various participation formulas can be adopted, if intelligent use is made of the flexibility offered by the Treaty.

3. *Industrial Promotion.* The Commission proposes that an industrial promotion fund be set up to provide financial backing for industrial-type activities aimed more especially at improved reactor operation and a concerted approach to fuel management. Lastly, it puts forward various formulas for the construction of power reactor prototypes with particular recourse to the facilities afforded by the joint enterprise system.

RAPSODIE reaches full power

The *RAPSODIE* (*RAP*ide *SOD*ium) reactor, which went critical at Cadarache (France), on 28 January 1967, reached its full power of 20 MW(th) on 17 March 1967, i.e. in an extremely short time.

RAPSODIE is cooled by liquid sodium. It is the first reactor in the world to operate on a mixed uranium oxide/plutonium oxide fuel under conditions representative of those that will obtain in the fast-neutron power reactors of the future. It will be used intensively for the development of these fuels and for acquiring operating experience with sodium cooling on a semi-industrial scale.

The reactor was built under a contract of association concluded on 1 January 1962 between the *French Atomic Energy Commission* (CEA) and Euratom.

ESSOR has gone critical

An important milestone in the *ORGEL* project was passed on 19 March 1967 when the *ESSOR* test reactor at Ispra went critical. The *ESSOR* reactor, the only one of its kind in Europe, will enable the main components of an *ORGEL* power plant to be studied thoroughly; this means that the fuel-elements, channels, coolant liquid, pumps and various instruments will be tested under conditions closely approximating to those of a large atomic power station.

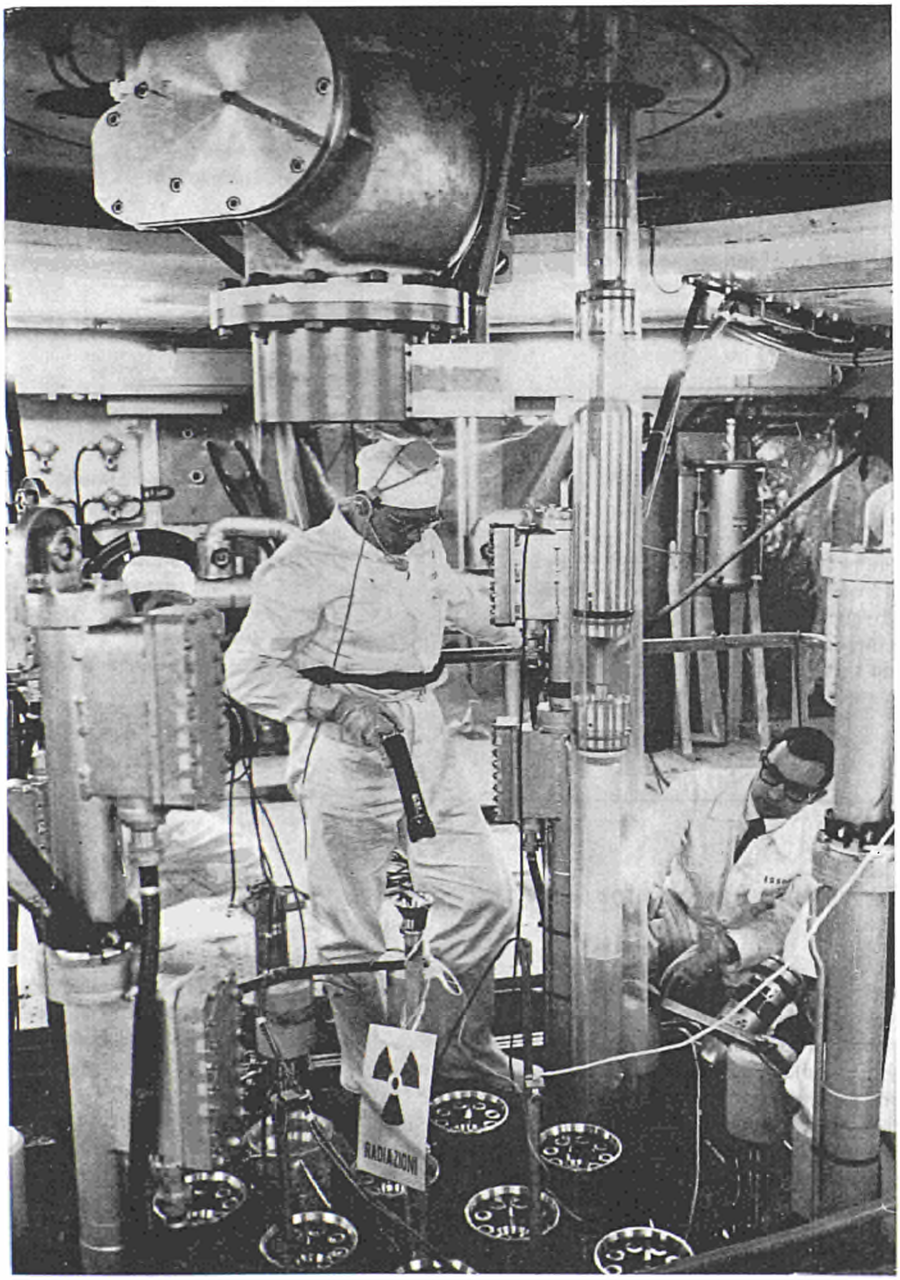
The experimental zone of the reactor comprises twelve channels in which are inserted the fuel-elements to be irradiated. The requisite neutron flux is produced by a "feeder" zone composed of a ring of sixteen enriched-uranium fuel-elements. The feeder zone is moderated and cooled by heavy water. The experimental zone, which is likewise heavy-water-moderated, is divided into two sections. The major *ORGEL* section is cooled by organic liquid; the other is a section used for the Italian *CIRENE* project, in which cooling is provided by light water in "fog" form (for a more detailed description of *ESSOR* see *Euratom Bulletin* 1963, No. 2, pp. 12-17).

ESSOR is a striking example of community achievement. From specifications drawn up by Euratom, a preliminary design was produced jointly (1961) by a French firm, the *Groupement Atomique Alsacienne Atlantique (G.A.A.A.)*, and a German firm, *Interatom*. The decision to build the reactor was taken by the Euratom Commission in October 1962 and at the same time the co-ordination of all structural work was assigned to a European industrial architect unit consisting of *GAAA*, *Interatom* and *Montecatini* (Italy) and directed by *GAAA*. Site preparation started in March 1963. Works supervision was carried out by a special *ORGEL* team, using the most up-to-date methods of management. Over fifty firms were engaged to construct the plant, including:—

—in Germany: *Mannesmann* (organic circuit), *Interatom* (loading and unloading casks), *Siemens* (instrumentation), *AEG* (emergency electricity plant);

—in Belgium: *Ateliers de constructions électriques de Charleroi* (electric power distribution systems);

—in France: *GAAA* (core components and part of handling gear), *Alcatel* (nuclear instrumentation and control), *Fives-Penhoët* (heavy-water circuits), *Chantiers de l'Atlantique* (reactor block);



View of upper platform of ESSOR reactor. This platform, accessible only during shutdown, is used for supervising reactor loading operations. Here two technicians are watching the insertion of a "feeding fuel" element, which slides down through a hole in the rotating shielded cover into one of the reactor channels.

—in Italy: *Montecatini* (hot laboratories), *Gavazzi* (general electrical installations), *Marelli* (ventilation), *Fergal* (conventional liquid circuits), *Selo* (radiation protection). European firms formed groups for certain specific tasks:—

—*Dingler* (Germany), leading the group, *Chantiers maritimes de Provence et des Ardennes*, and *Fives-Penhoët* (France) for the leaktight containment;

—*Nukem* (Germany), *Métallurgie et mécanique nucléaires* (Belgium) and *CERCA* (France), for manufacture of the feeder fuel elements;

—*Farsura* (Italy), *COGEFRA* (France) and *Montecatini* (Italy) for the civil engineering;

—*Montecatini* (Italy), leading the group, and *GAAA* (France) for the hot laboratories.

Eighth Euratom information meeting on power reactors

Under the auspices of Euratom, 114 nuclear firms and organisations of the six Community countries met in Brussels, on 13 and 14 April, to discuss the experience they had obtained from the construction and operation of seven nuclear power stations with which the Community is associated in several capacities. The plants in question are the Italian Garigliano and Latina stations, the Franco-Belgian station at Chooz, the German stations at Gundremmingen, Lingen and Obrigheim, and the Dutch station at Dodewaard, representing a capacity of some 1,400 MW. The first four are already in operation, whilst the three others are due to be commissioned this year or next year.

This eighth technical information meeting organised by the Commission amply fulfilled its purpose, which was the wholesale pooling of the knowledge that power station constructors and operators had gained through experience. Its success is borne out by the fact that with each previous meeting attendance has increased, to such an extent that this latest meeting attracted over three hundred and fifty people.

EURATOM NEWS

Euratom issues "technical notes" to industry

Euratom has recently started issuing "technical notes" containing highlights of patented inventions and proprietary information developed during the execution of its research programmes. Industries of the Community will thus be able to ascertain to which extent they can use the technical results obtained by Euratom and whether they should apply for a non-exclusive licence according to the Euratom Treaty.
The information given in each technical note, which includes descriptive drawings or photographs, is condensed on two sheets of paper in order to facilitate distribution to technical staff of laboratories, design offices, etc.

Interested firms who do not yet receive these notes may obtain them on request by writing to:

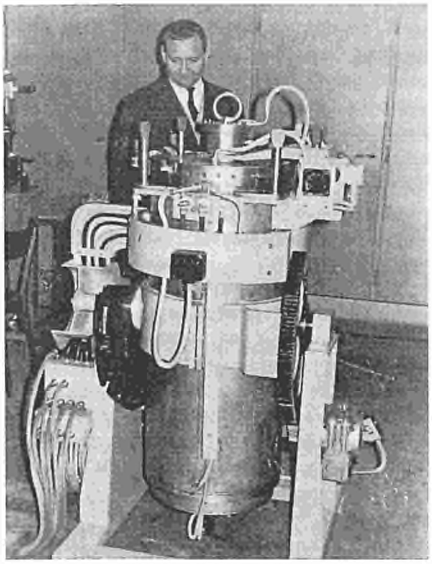
Euratom
Directorate General for
Dissemination of Information,
51 rue Belliard,
Brussels 4, Belgium.

It is intended to publish periodically lists of distributed notes.

Pumping in to pump out

When the working atmosphere has to be replaced in a glovebox or hood, there have hitherto been difficulties due to the fact that the necessary flushing of the spaces with large quantities of gas is expensive and time-consuming.

The problem is now being solved by means of a device which is attached to a lock in the glovebox and includes a large balloon which is introduced empty into the working space and then blown up, so that the atmosphere in this space is driven out completely by the increasing volume of the balloon. The desired gas can then be introduced into the working space while at the same time air is pumped out of the balloon.
The device can then be removed from the lock and used elsewhere.
The method was developed in a Euratom laboratory at Petten Nuclear Research Centre.



Swivelling furnace for fuel reprocessing invented at Ispra.

Swivelling furnace for fuel reprocessing

Some technical difficulties arise during the reprocessing of irradiated nuclear fuels by means of pyrometallurgical processes in which liquid metals are used as solvents and precipitants, particularly in work in hot cells and with remote control.
A new furnace contains a crucible of fireproof material, such as graphite, elongated and slightly conical in form, so that it can hold a complete fuel element. The crucible is tapered at the bottom rather like a pointed pipette for microchemical work, so that after the furnace contents have hardened and the ingot has been withdrawn, the lower end of the ingot, containing the desired deposit, usually fuel, in concentrated form, can be mechanically separated.

The furnace can be swivelled, so that in the horizontal position a complete fuel element can be inserted, and it also possesses a special cover system—an inside graphite cover which seals the graphite crucible tightly, and an outer, also tight-sealing and lockable cover—which makes it possible to mix the contents thoroughly by swivelling the furnace from the horizontal to the vertical position. The inner cover can be ventilated by remote control before the outer, thus enabling fission gases to be removed in vacuo. The furnace is also suitable for work with fused salts.

This invention was made at Ispra.

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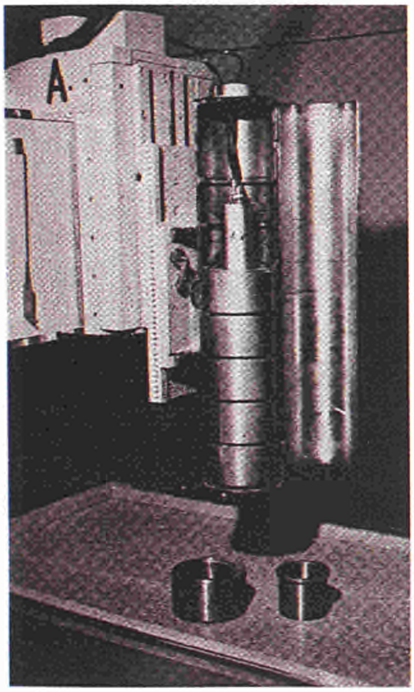

Several collimators in one

Lead collimators are used in nuclear measurement techniques in order to limit the field of high-energy radiations. With frequently changing measurement problems the conversion of the lead filling of collimators is a tricky problem.
A new collimator has been constructed in which the lead filling consists of units which can be placed in a cladding tube like drawers. The cladding tube opens into two half-cylinders on a hinge which runs along a generatrix. The collimator parts rest on support ribs fitted inside the tube around the circumference. The collimator parts themselves fit concentrically into one another, so that the aperture can be adjusted easily, quickly and simply.
This invention was made under a Euratom research agreement with the University of Pisa.

Forthcoming Euratom conferences:

June 16, 1967
Merano (Italy)
"Demonstration and working meeting on gas analysis by radiometric methods".
Write to: Bureau Eurisotop, 51, rue Belliard, Brussels 4 (Belgium).

July 3-5, 1967
Baden-Baden (Germany)
"Applications of radiochemical methods and of irradiation techniques in the textile industry"
Write to: Euratom, Bureau Eurisotop, 51, rue Belliard, Brussels 4 (Belgium)

September 4-8, 1967
Eindhoven Technical University (Netherlands)
"International symposium on the dynamics of two-phase flow"
Co-sponsor: *Technical University of Eindhoven*
Participation by invitation only.
Write to: Euratom, attn: Mr. Colling, 51, rue Belliard, Brussels 4 (Belgium)
or
Technische Hogeschool Eindhoven, attn: Prof. Bogaardt, Eindhoven (Netherlands)

September 18/19, 1967
Liège (Belgium)
"Third meeting on accelerator targets for the production of neutrons"
Co-sponsor: *Liège University*
Write to: Euratom, attn: Mr. Godar, 51, rue Belliard, Brussels 4 (Belgium)

September 21/22, 1967
Liège (Belgium)
"Practical aspects of activation analysis with charged particles"
Co-sponsor: *Liège University*
Write to: Euratom, attn: Mr. Godar, 51, rue Belliard, Brussels 4 (Belgium)

November 7/8, 1967
Brussels (Belgium)
"Information meeting on prestressed concrete reactor vessels and their thermal insulation:
- —Fundamental studies in the field of concrete-technology (resistance to heat and behaviour under irradiation);
- —New vessel prototypes;
- —Fundamental studies on vessel insulation;
- —Practical demonstration of insulation devices."

Write to: Euratom, attn: Mr. Benzler, 51, rue Belliard, Brussels 4 (Belgium)

January 10-13, 1968
Frascati (Italy)
"Conference on physics of quiescent plasmas"
Co-sponsor: *CNEN* (Italy)
Write to: Quiescent Plasmas, Laboratorio Gas Ionizzati, C.P. 65, Frascati, Rome (Italy), till Oct. 1, 1967

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