1962 No. 4

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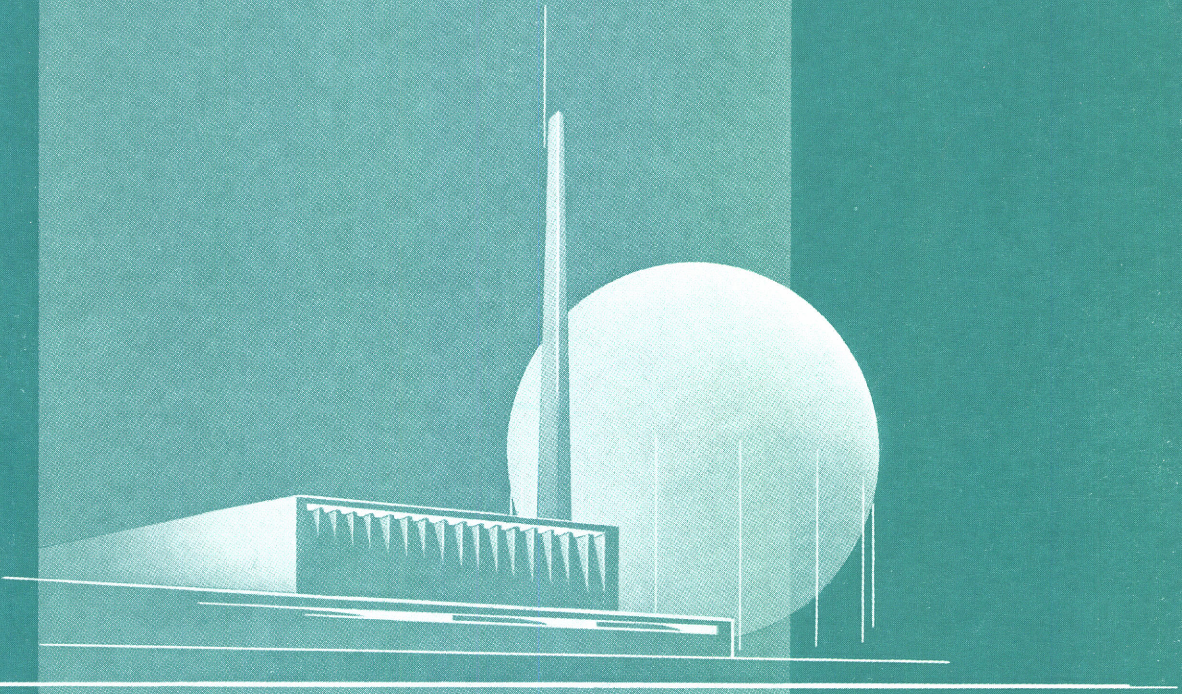
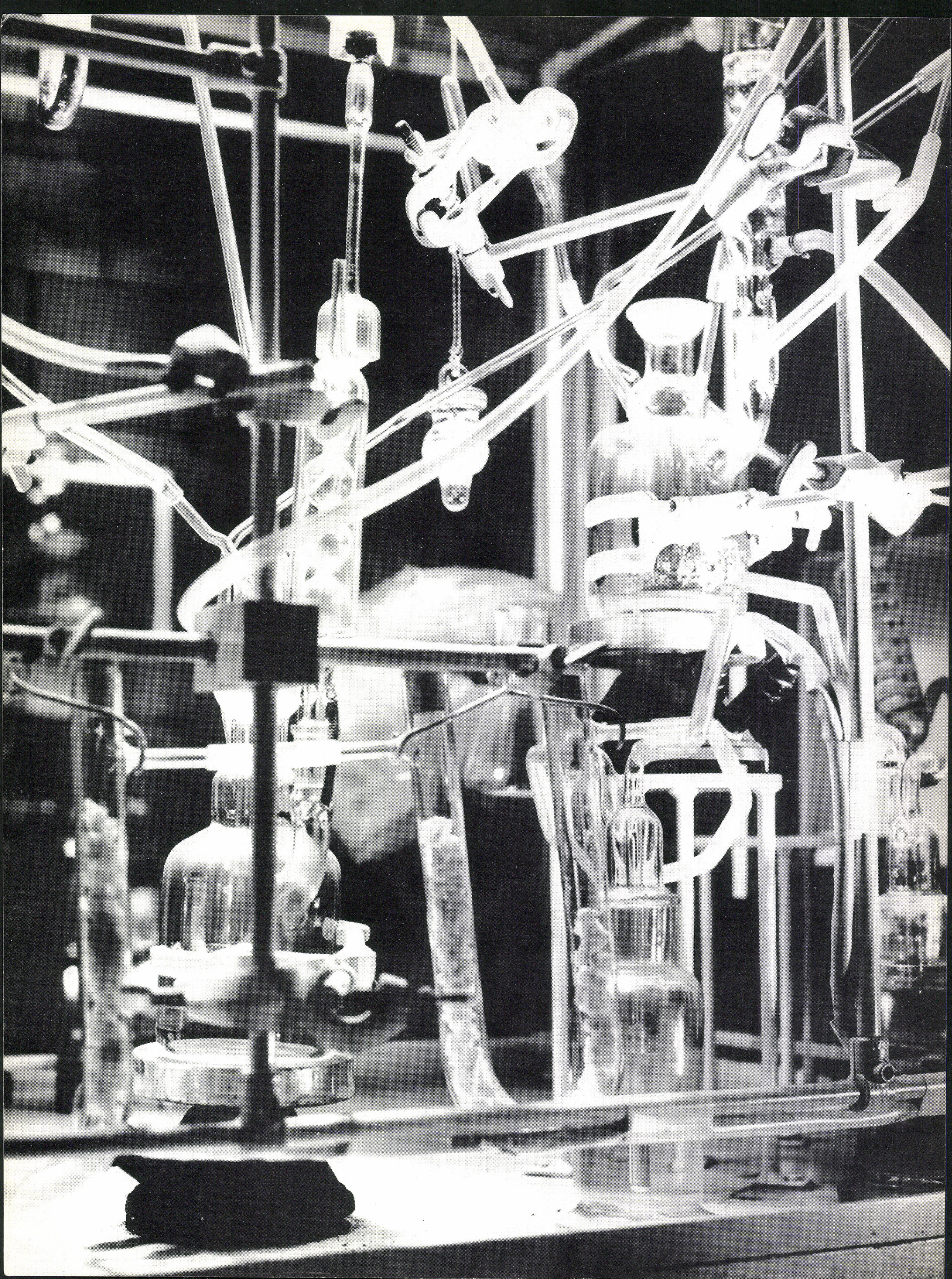


euratom
BULLETIN

EUROPEAN ATOMIC ENERGY COMMUNITY



euratom

Information Bulletin of the European
Atomic Energy Community

1962
No. 4

On the 25th March 1957 in Rome, six States, namely:

THE KINGDOM OF BELGIUM
THE FEDERAL REPUBLIC OF GERMANY
THE FRENCH REPUBLIC
THE ITALIAN REPUBLIC
THE GRAND DUCHY OF LUXEMBOURG
THE KINGDOM OF THE NETHERLANDS

signed the treaty which instituted the European Atomic Energy Community (Euratom).

Power reactors

Nuclear Physics

Reactor Technology

Nuclear Fusion

Radioisotopes

Mineralogy and Geochemistry

Ship Propulsion

Biology

Automatic Information Methods

Health Protection

Law

Insurance

Economics

Education and Training

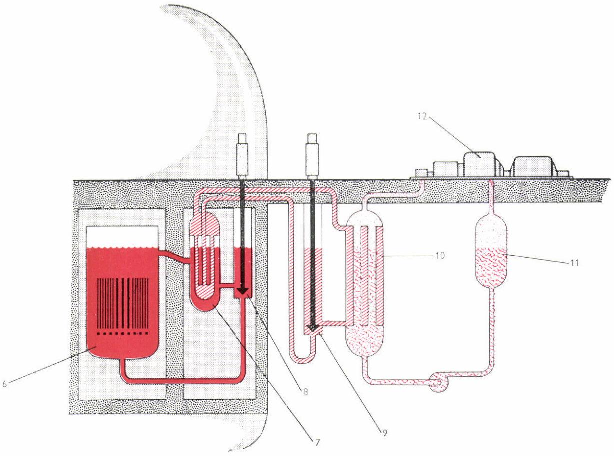
The European Atomic Energy Community will soon be five years old. A five-candle anniversary is not so much an occasion for reminiscences, as for a determined and hopeful look into the future. That is indeed the attitude which is reflected in the following pages.

Fast reactors for instance. Part of Euratom's future will be closely tied to the development of this strange family of reactors—strange because of their remarkable ability to make full use of uranium. This is of vital importance to long-term planning, since the world's uranium reserves, which seem so abundant at present, are in reality too small to permit extravagance in their use.

Then there is the question of the price we shall have to pay for nuclear energy. Indeed it is sometimes forgotten that we are not harnessing the inner forces of the atom simply because it is rather fun, but because we aim at making it produce material benefits at a reasonable cost. The immediate future of nuclear energy, especially in the context of power generation, rests on its ability to compete on equal terms with the forms of energy we have come to consider as "conventional". Some years ago the economic "breakthrough" of nuclear energy was discussed, certainly with enthusiasm, but in a spirit of speculation. The technical improvements already yielded by research, coupled with the fruits of practical experience, have now made it possible to combine optimism with cold calculation.

Fig. 1. Schematic diagram of a fast reactor power plant

1 🟥 primary sodium circuit
2 ▨ secondary sodium circuit
3 ▨ water
4 ░ steam
5 ☐ cover gas (inert gas)
6 = reactor
7 = intermediate heat exchanger
8 & 9 = sodium pumps
10 = boiler
11 = condenser
12 = turbine-generator



Fast neutrons and

Nuclear Fission

The nuclei of certain heavy elements, such as uranium, have the interesting property of being fissile: in other words, they can be split, by a neutron colliding with them, into two smaller nuclei. It is well known that what is of still greater interest about this reaction is the fact that these two parts, when taken together, are not exactly as heavy as the original nucleus, and hence the difference in mass reappears in the form of a considerable amount of energy —and we want to use this energy.

Of course, splitting a uranium nucleus is easier said than done, although a particular phenomenon comes to our rescue: when fission occurs, the colliding neutron is absorbed, but several others are actually produced: the number varies, but on an average 2.5 neutrons are emitted by a split uranium nucleus.

It is clear that this leaves the way open for a chain reaction: if we can arrange, every time a fission occurs, for an average of one out of these 2.5 neutrons to cause further fission, we can indeed claim to have obtained a self-sustaining chain reaction.

In a nuclear reactor, full use is made of this phenomenon in such a way that the "neutron population" of its core can be made to renew itself continually and therefore remain constant.

Should there be a wish to increase the output of the reactor, it will merely be necessary to arrange for the net production of slightly more than one fresh neutron per neutron usefully absorbed. Once the neutron population has reached the desired level, a return can then be made to steady conditions. Should a decrease in the output of the reactor be necessary, the same process can of course be made to occur in reverse.

What happens then to the neutrons which are not being used to cause further fission? They *leak out* of the system altogether or are absorbed by the atomic nuclei of various structural materials present in the reactor (so-called *parasitic* capture). Even a fissile nucleus can sometimes absorb a neutron without reacting; there then occurs a kind of nuclear "misfire" (so-called *non-fission* capture). There is yet another possibility which is capture by a *fertile* material. More will be said later about this important process.

Thermal neutrons

The neutrons produced by a fission reaction are *fast* neutrons. Yet the power reactor concepts which have been most widely developed to date are those systems in which the neutrons are deliberately brought down to much lower energies, to so-called "thermal" energies. They are actually slowed down several thousands of times from their original velocity.

This is achieved by inserting into the reactor a sufficient quantity of light material (e.g. water or graphite), which is best able to degrade the energy of neutrons by successive elastic collisions. This slowing down material is usually called the "moderator".

fast reactors

Most of the nuclear power reactors operating at the present time make use of "thermal" neutrons, i.e. neutrons which are deliberately slowed down. Although there are good reasons why this should be the case, the arguments in favour of developing "fast" reactors are strong. Not least among them is the remarkable capacity these reactors have for "breeding" new fissile material.

Wilhelm Sahl

Directorate-General for Research and Training, Euratom

It may seem odd that so much trouble should have been taken to turn fast neutrons into thermal neutrons; it even sounds like quite a waste. But the desire to create moderated systems is not without its reason.

This reason is that neutrons are most likely to find their way into a fissile nucleus, and thus cause fission, when they are at thermal energies. Hence, there is no need for a large inventory of fissile material. The utilization of neutrons can be made so good that it is possible to design reactor systems capable of maintaining a chain reaction by using *natural* uranium, which contains only about 0.7% of the fissile isotope U-235. Where the design actually requires a greater concentration of fissile material, enrichment of the fuel in U-235 can still be limited to a few percents.

This advantage definitely helped to make all those interested in reactor development give priority to moderated systems. The reactor types having reached a stage where they can be run on an industrial scale are for example:

- the CO_2-cooled, graphite-moderated natural-uranium-fuelled reactors;
- the heavy-water-moderated natural-uranium-fuelled reactors;
- the light-water-moderated and -cooled reactors using slightly enriched uranium.

Fuel utilization in thermal reactors

U-235 is the only fissile uranium isotope which is found in nature and, as already mentioned, it accounts for only about 0,7% of natural uranium, the rest being U-238, which cannot be fissioned directly by the absorption of neutrons having low or intermediate energies only.

However, the fuel utilization is slightly improved by the fact that a small fraction of the inert U-238 present in the fuel is being exploited:

- *directly*, by fissions due to the impact of fast neutrons, before they have been slowed down underneath the fast fission threshold of U-238;
- *indirectly*, since a U-238 atom can absorb a neutron and be converted into a plutonium 239 atom, which is fissile.

These two phenomena bring it about that, in reactors losing relatively few neutrons to parasitic absorption and leakage out of the system, there can be burned 0.5 to 1 atom of U-238 for each atom of U-235 burned. The result is still far from brilliant, since this means that only 1% to 1.5% of the total natural uranium quantity can be utilized for the production of energy by fission.

A small improvement can be made by reutilizing the plutonium which is left over in the burned-up fuel, since by far not all of the plutonium produced in the fuel by conversion of U-238 is burned again during the same cycle in which it is produced. The plutonium extracted from the burned fuel can then be added as additional fissile material to the fresh fuel and "recycled" in the reactor. By this method—in an equilibrium cycle where all the plutonium contained in the used fuel is constantly reinserted in the fresh fuel—the fuel utilization can at best be improved to about 2.5%.

This relatively poor utilization of fuel in thermal reactors of the type developed so far is due to their inherently low neutron economy. It has already been seen that a neutron absorbed by a U-235 nucleus, and causing fission, produces 2.5 further neutrons on an average. One of these is earmarked for the maintenance of the chain reaction through *fission capture* by the fuel material. As for the rest, it was seen that their fate could be:

- leakage out of the system,
- parasitic capture in structural materials,
- non-fission capture by the fissile material,
- capture by a fertile nucleus.

In thermal reactors, it is usually the case that few neutrons are left over for the last of these processes. Yet capture by a fertile nucleus, such as U-238, is of great interest since it generates new fissile material in the form of plutonium-239.

Improving the neutron economy

Already in thermal reactors one tries to improve the neutron economy by reducing the quantity of structural materials inside the reactor core to a minimum compatible with mechanical and thermal requirements, thereby reducing parasitic absorption of neutrons.

However, if parasitic absorption must be reduced *radically*, this can only be done by using fast neutrons instead of thermal neutrons. This solution has three advantages:

a) The tendency of all structural materials to absorb neutrons is more or less inversely proportional to the velocity of the incident neutrons; the faster the latter become the less chance they have of being absorbed.

b) It was seen above that U-238 could be fissioned by high energy neutrons. Thus in a fast neutron system U-238 can make a more direct contribution to the fission process. This contribution can reach 20% of total direct fission, whereas in a thermal reactor it is only of the order of 3%.

c) There is a reduction in the importance of non-fission capture by fissile nuclei, and hence a saving of both neutrons and fissile nuclei. Indeed the relative probability of fission as against capture increases with the speed of the absorbed neutron, especially in the case of plutonium 239.

It was essentially these three aspects which led scientists to conceive the idea of reactors running on fast neutrons and on plutonium already in the early days of reactor design.

The principle of fast reactors

No moderator

The principle of fast reactors is as simple as one can imagine. Whereas the moderator is an essential part of a thermal reactor, a fast reactor possesses none; hence, for instance, the use of liquid metals having a high atomic weight rather than water as coolants. This is not to say that the neutrons retain their maximum energy throughout: they are still subject to some degradation in energy because of inelastic collisions with the atoms of the surrounding materials. However the average energy level remains high (in the region of 100.000 to 1.000.000 electron-volts, as opposed to 0.25 electron-volts in a thermal reactor).

Material conservation

Before giving a description of the principal design features of fast reactors it is perhaps interesting to point out their material conservation properties, which earned them the name of breeders.

It was found that if a fast neutron core was surrounded with "blankets" of fertile material, such as U-238, good advantage could be taken of the excellent neutron economy. In a thermal reactor, neutrons tend to be wasted because of absorption in the structural and moderating materials. On the other hand in a fast reactor, conditions are such that most of the neutrons which are not needed for maintaining the chain reaction can be made to find their way into the U-238 material and thus convert it into plutonium. It is actually possible to design reactors where, in a given fuel cycle, more new fissile material is produced than is consumed. This would be impossible in a thermal reactor because of the high rate of capture by structural materials and the moderator.

The so-called "breeding ratio" associated with this very high rate of conversion can, in representative reference systems, reach a value of about 1.35. This figure by definition indicates the number of newly produced fissile atoms per atom of fissile material consumed. In other words after burning less than three initial core inventories, an amount of fissile material equivalent to four cores will have been produced.

Thanks to these inherent properties, fast reactor systems can be made not only to provide themselves with their own fissile material demands, but at the same time to be producers of new material, which can be used to satisfy demands elsewhere. Under these conditions fast breeder reactors offer the really stimulating outlook of being, in the long run, a power-producing system which not only burns uranium fully but produces additional fissile material, possibly at a pace corresponding to the increase in power demand.

In view of these inherent features it is generally recognized that the long range objective should be to develop the full potential of fast breeder reactor systems, as they would be capable of making full use of natural uranium reserves.

Design of fast reactors

The initial development work on fast reactors has been essentially carried out in the United States, followed by the United Kingdom, Russia and France. The reactors built or planned so far contain the fuel either in metallic or in ceramic form (e.g. oxides) and are cooled by liquid sodium. There is of course no moderator in order not to slow down the neutrons unnecessarily. Since the sodium of the primary cooling circuit becomes highly radioactive it is usual to envisage an intermediate carrier of the heat between the reactor circuit and the working medium, the latter being usually water and steam. Figure 1 gives a general impression of the circuit lay-out. The intermediate heat exchanger between the primary and secondary circuit is in principle housed, together with the reactor, in an airtight building. This containment of the radioactive parts of the system is extremely important because of safety considerations. The philosophy behind this is that no radioactivity should be released to the environment in the case of a primary system rupture, should this occur. Practically all important efforts to develop a fast power reactor have revolved around this general concept. Considerable variations are of course possible within such details as the arrangement of the core, the choice of fuel material and the fuel design, but there are a number of features which are common to all designs developed so far. Besides the core region proper, there are blanket regions which wholly envelop the core region. The core region essentially contains the fissile material and as such represents the main source of thermal power. The blanket

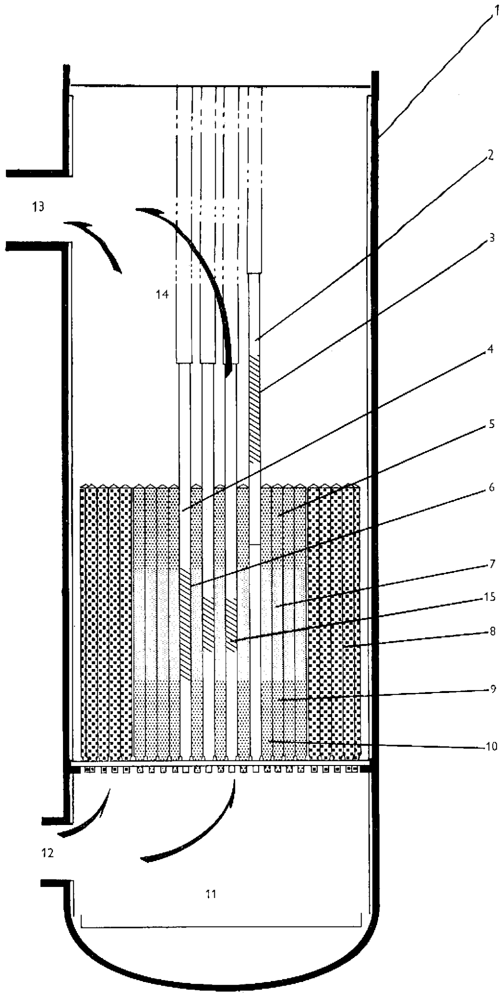
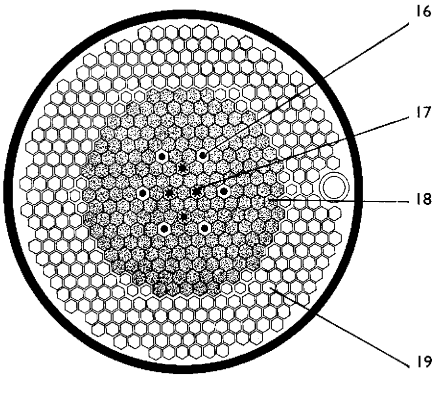
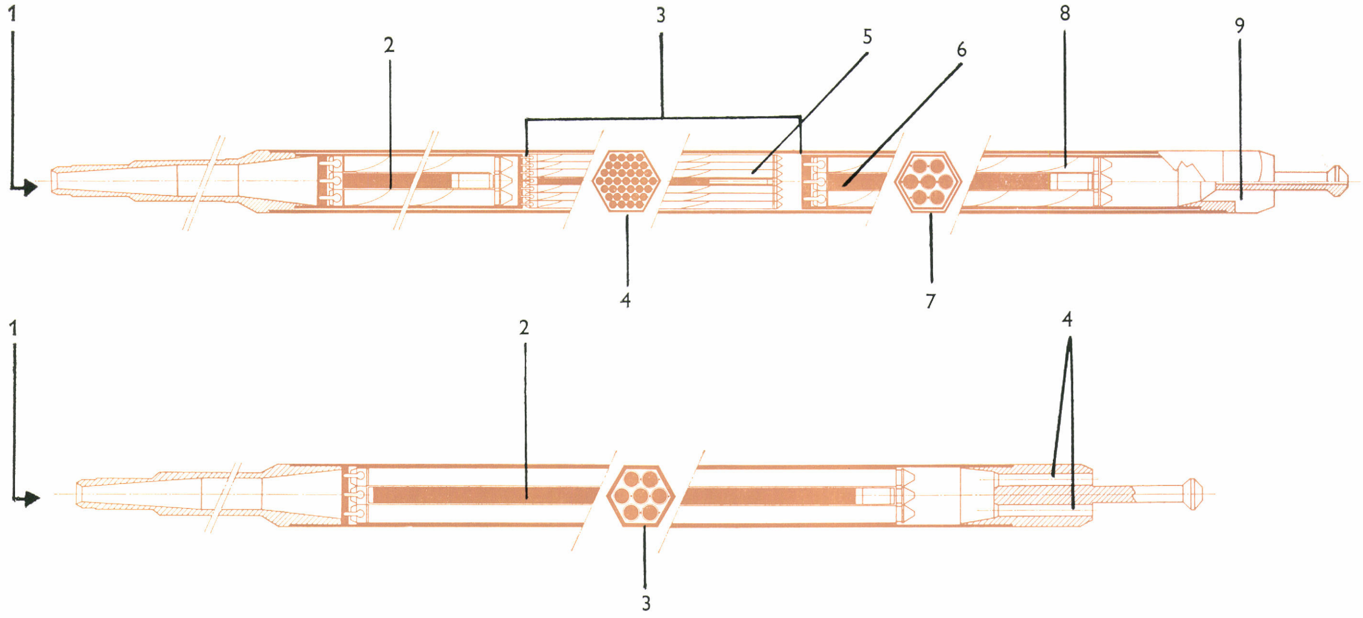


Fig. 2. Schematic views of a sodium-cooled fast reactor

1 = reactor vessel
2 = safety rod (operating position)
3 = poison
4 = safety rod (shut-down position)
5 = upper axial blanket
6 = poison
7 = core
8 = radial blanket subassembly
9 = core subassembly
10 = lower axial blanket
11 = high pressure plenum
12 = sodium coolant in
13 = sodium coolant out
14 = low pressure chamber
15 = control rod
16 = safety rod
17 = control rod
18 = core subassembly
19 = blanket





regions contain fertile material (U-238, for example), and absorb the neutrons leaking from the core and exploit them for the production of plutonium.

Figure 2 gives a schematic impression of the reactor arrangement. In the case of fast reactors fuelled with solid fuel (this is the most developed concept so far) both fuel and fertile material are usually contained in steel plates or tubes to form individual elements. These elements are always grouped together in so-called subassemblies, which are square or hexagonal tubes serving at the same time as ducts for the liquid sodium coolant.

The fuel

It has already been pointed out that the need for a good neutron economy marked out plutonium as the best fuel for fast reactors. Beside this need there are others, the most important of which affects the "burn-up" of the fuel. Good burn-up characteristics spell long life for a fuel element and hence a reduction of reprocessing and re-fabrication costs. This requirement would not be satisfied if fissile material only, for instance plutonium, were used in the core, since reactivity would die down quite quickly until an insufficient concentration of plutonium was left in the core to keep the chain reaction going. The career of the reactor, under these conditions, would be split into a series of short cycles where plutonium produced in the blankets had to be reprocessed and introduced in the core. This can be avoided by diluting the core fissile material with fertile material, with the result that a good part of the breeding happens inside the core itself. For instance, for a reactor with a dilute core designed for a 1.35 *overall* breeding ratio, the *core* breeding ratio can amount to 0.9, the remainder of 0.45 being bred in the *blankets*.

A fuel element thus designed for long service will have to be able to cope with an accumulation of changes within its structure. This is why the idea of using ceramic plutonium and uranium compounds, such as oxides, in preference to the metals has been receiving considerable attention. It indeed seems likely that experience will demonstrate these compounds' better behaviour under irradiation.

A typical reference design for core and blanket assemblies of rods containing mixed oxide fuel is shown in fig. 3. It will be noted that the "blanket rods" can be permitted to be much larger in diameter than the actual fuel rods, because their power production is very low and therefore creates no heat conduction problems from centre to surface.

The helicoidal wire wrapped around each fuel rod is designed to keep the fuel rod at a minimum distance from its neighbours and thereby ensure sufficient coolant flow.

Control and safety

The safety of fast reactors was the cause of much discussion in the initial years of the development of this concept. After an accident incurred by the first reactor experiment in the world (EBR I in the United States) it was even believed that there was something inherently wrong about the concept from the safety point of view. The same qualms had not been experienced in the case of thermal reactors because it was quickly realized that they could be designed to be inherently self-regulating. This fact stems in particular from their strong negative temperature coefficient; i.e. a rise in temperature automatically leads to a reduction of reactivity. Thus if for some reason there is an abnormal increase in reactivity, the consequent release of energy will raise temperatures and hence check the reactivity. It was feared, at the time

Fig. 3

Below: **Fertile material assembly**

1 = sodium inlet
2 = fertile rod
3 = cross-section
4 = sodium outlet

Above: **Fuel assembly (U-Pu-Mo-alloy type)**

1 = sodium inlet
2 = fertile rod
3 = fissile region (core)
4 = cross-section of core
5 = fuel rod (U-Pu-Mo)
6 = fertile rod
7 = cross-section of fertile region
8 = helicoidal wire
9 = sodium outlet

the EBR I accident occurred, that reactivity coefficients were inherently positive in the case of fast reactors. Fortunately it was found that the accident was purely due to thermal bending of the fuel elements, which of course can be avoided by means of adequate mechanical design. Nevertheless much care is being devoted to the safety features of the fast reactor concept because, in a fast reactor (and this is not the case in a thermal reactor), any melt-down and compacting of the fuel can lead to a considerable increase of the reactivity of the system and thereby cause vehement energy releases and serious damage to the more or less immediate environment of the reactor.

It has been seen that early fears were disproved; indeed the temperature coefficient of fast reactors can in fact be made negative. In metal-fuelled cores the phenomenon of thermal expansion in itself leads to a considerable negative temperature coefficient. On the other hand in large oxide breeders thermal expansion is slow-acting and of insufficient importance. One is therefore wholly left with the so-called "Doppler effect". This effect is positive in the fissile material (more fission) and negative in the fertile material (more capture), but an overall negative Doppler coefficient can be obtained by arranging suitably the ratio of fertile to fissile material.

Theoretical studies carried out so far seem to indicate a reasonably large negative Doppler coefficient, which would render the reactor sufficiently stable. However these theoretical results will have to be confirmed by adequately conceived experiments.

As far as operational control is concerned, it is based, as in the case of thermal reactors, on the use of control rods containing neutron absorbers. In the type of reactor using large dilute cores (i.e. where a considerable amount of fertile material is mixed with the fissile material), the previously mentioned Doppler effect promises to be negative to an extent that it provides an extremely quick-acting inherent shut-down mechanism against all imaginable power-excursions. Hence core melt-downs become very improbable, even if the control apparatus should fail to operate satisfactorily. Thus the final conclusion under this heading is that fast reactors, against former belief, can be designed in such a way as to be completely safe.

Fast Reactor Programmes

The most important programme is doubtless that which is under way in the USA since 1946, when the Americans started operating their fast plutonium reactor "Clementine", which was essentially a low power reactor designed to study the general characteristics of a fast neutron system.

Subsequently extensive physical and technological development programmes were carried out, and this led to both EBR I and EBR II, which are both already experimental power reactors. EBR II, which will be brought to criticality within this year, is an integral fuel cycle experiment, which includes an on-site re-processing and fuel fabrication plant.

The first 100 MWe fast power reactor prototype in the world was also built in the USA, and that completely by a group of private utilities. It is the famous "Enrico Fermi" plant, which has been constructed near Detroit and will probably become critical at the end of this year or at the beginning of 1963. As early as 1956, Belgium was associated with this project thanks to an agreement between the sponsors of the Fermi reactor and the Belgonucléaire company.

Apart from these projects, considerable efforts are being devoted in the USA to the development of fast ceramic breeders, especially those using mixed oxides as fuel material.

The United Kingdom Atomic Energy Authority has been operating its first fast reactor experiment since the beginning of 1961 at Dounreay, Scotland. Although it is recognized that this reactor is not very representative of an industrial prototype from the specific design point of view, it nevertheless yielded very important basic technological and physical experience. The UKAEA, in continuing this programme, is also envisaging the development of a large dilute fast oxide breeder.

About five years ago the French Atomic Energy Commission started a programme whose first step is the construction of "Rapsodie", a small and flexible experimental power reactor and breeder, which should come into operation early in 1965. Rapsodie will run on plutonium from the very beginning. Ceramic fuel, sodium cooling, large dilute cores—those are the guiding lights of the development programme, and it is hoped the way will be clear for the construction of a much larger prototype.

In the German Federal Republic, preliminary evaluation studies were started about two years ago. The Germans are looking to a reactor concept which is complementary to and possibly more advanced than Rapsodie. The scope of the studies includes steam-cooling and systems coupling fast and thermal neutrons.

Finally Italy has not long ago launched investigations aiming at the use of the uranium-233/thorium cycle and paste fuels.

The Euratom Commission's Programme

In 1959, the Commission included the study of fast plutonium reactors in its official research programme ("Journal Officiel des Communautés Européennes", 6 June 1959). In 1960, realizing the advantage of having in the Community a fast-neutron critical assembly capable of giving the experimental information necessary to the design of reactors of the future, the Commission entrusted Belgonucléaire with a first contract, covering literature searches and preliminary design work. In 1961 and 1962, the same company was awarded further design contracts, in which the French Atomic Energy Commission (CEA) soon decided to cooperate closely, contributing its own resources. These efforts resulted in the definition of a critical assembly capable of utilizing plutonium, which it has since been decided to construct at Cadarache. It may be mentioned in passing that regular contacts were maintained between the Belgonucléaire, CEA and Euratom technicians and those working on the design of a critical assembly for the Karlsruhe Nuclear Centre. About the same time, certain activities were started at the Ispra establishment of the Community's Research Centre, more particularly in connection with fundamental research on liquid metals, research on non-aqueous fuel reprocessing and fundamental physics research.

But the Commission had no intention of confining itself to such partial measures. It had long considered that the scale of the resources needed for the development of fast reactors, coupled with the fact that all efforts at the national level in this field were at a relatively early stage, opened up an ideal field for concerted action. Thus in 1959, it had already proposed that fast reactor studies should be the subject of associations; the enterprises of a national character would be converted into broader-based enterprises in which the National Centre and Euratom would undertake together the financing, management and maintenance of the joint working teams. A favourable response to this proposal came in 1961, first from the CEA in France, with whom negotiations were immediately started for a contract of association covering a large-scale programme, and then from Germany. A "fast-reactor" group was set up for this purpose at the end of 1961 by the Consultative Committee on Nuclear Research which, after examining all aspects of the problem, recommended the adoption of the policy advocated by the Commission as soon as 1959 concerning the latter's association with the national programmes.

The Commission will accordingly devote to this end the greater part of the funds (73 million EMA units of account) and manpower appropriated for its fast reactor activities.

The negotiations with the CEA recently led to the conclusion of a first contract of association[1] relating to the design, construction and operation of the "Rapsodie" reactor and a fast neutron critical assembly installation at Cadarache. This contract is likely to be followed in the near future by another, dealing with the research and development work recently started in connection with a prototype reactor of a capacity of about 100 MWe.

The negotiations with the Karlsruhe Nuclear Centre began a short while ago and in the normal course should be concluded before the end of the year. This association will cover the whole of the activities which had been decided upon by the German authorities, and in particular the research and development work on a prototype

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[1] See Euratom Bulletin No. 3, 1962, p. 32.

power reactor of a different type from that which is the object of the CEA-Euratom association. It will also extend to a plutonium critical assembly to be set up at Karlsruhe for the special investigations conducted there.

Up to the end of 1967, the two European critical assemblies are scheduled to have a single plutonium stock of 300 kg, the disposal of which will probably be determined in accordance with the provisions of a utilization programme to be worked out jointly.

Finally, negotiations should shortly be opening with Italy, which earlier this year announced its intention of embarking upon fast reactor studies and expressed its desire that the Commission should associate itself with them on the same lines as with the CEA and Karlsruhe Centre projects.

The Commission will gradually adjust its own activities, and in particular those at the Ispra Establishment, to those pursued under associations which have been or are subsequently concluded. In this way, it will be in a position to maintain independence of judgment, a factor essential to the success of the policy of coordinating national activities.

This opens up prospects for wide-scale international cooperation. There are already very close relations with the UKAEA and the USAEC in the field of critical assemblies. The USAEC is further prepared to collaborate very openly with the Commission, and organized in September 1962 a preliminary exchange of views between European experts and their American colleagues. In addition, both these institutions are willing to enter into negotiations with the Commission for the supply of plutonium, which is not yet available in Europe and without which all the projects referred to above would be liable to suffer delays.

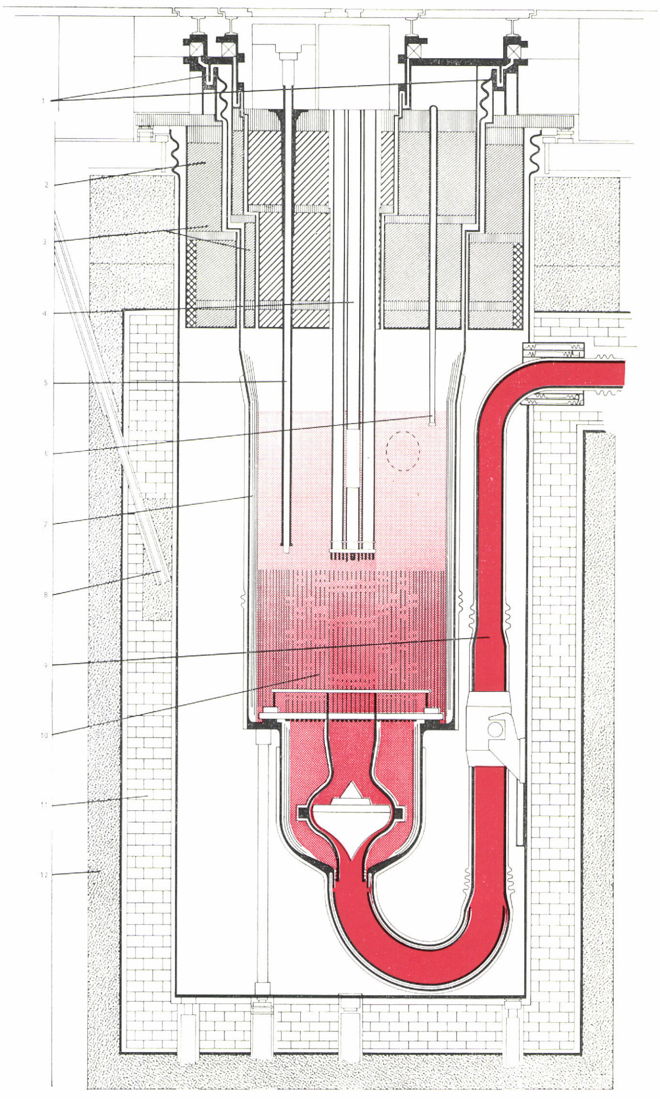

Fig. 4. Reactor cross-section (Rapsodie)

1) meltable joint
2) fixed plug
3) rotating plugs
4) control rod system
5) handling channel
6) level indicator
7) thermal shielding of reactor vessel
8) neutron detector
9) sodium inlet
10) fuel and fertile material assemblies
11) graphite shield
12) concrete shield

The European economy, as it expands, is making greater and greater demands on electricity producers. Many of the primary sources of energy, such as coal and water-power, which are the "raw materials" of this electricity, will not be able to cope on their own with the rise in demand. Among the other sources which have to be called in to close the gap, nuclear energy is destined to play an important part—if it can compete with its rivals.

Nuclear Energy—a Competitive Sourc

The Energy Needs of the Six

Energy consumption in the Community Countries in 1961 amounted to 500 million tons of coal equivalent; by 1970, this figure will have risen to 700 million, and by 1975, to 800 million. These are some of the statistics in a new memorandum on energy policy which was submitted to the Council of Ministers by the ECSC High Authority, the EEC Commission and the Euratom Commission towards the end of June 1962. It is thus seen from this document that the power requirements of the Six are likely to increase even more than had been anticipated.

In 1961, demand had been met as to nearly half by the Community's indigenous coal. In 1970, only a little more than 50% of the quantity thus mined may be expected to be still competitive, which means that, in the absence of protective measures, not only will coal production fall off, but the rate of increase of overall primary energy needs will cause the share of coal in the satisfaction of such needs to shrink to about one-sixth.

Meeting Requirements

To ensure the supply of power at minimum prices, the memorandum is in favour of an open market in energy. In the case of coal, a system of subsidies and protection is contemplated. These measures should ensure the necessary continuity in supply and obviate the danger of economic and social strains. In the case of oil, free access to the European market must be given, but during the transition period a decreasing consumer-tax should be applied to fuel-oil, which would not be more than four EMA units of account[1] per ton in 1966 and would come down to two units of account per ton by 1970. But, even with protection measures, there is little chance that output will maintain its present level, and the probability is that in 1975 it will cover no more than a quarter of the overall primary energy requirements. It will therefore be necessary to rely on the abundant sources of coal and oil which exist outside the Community. Imports, says the report, involve risks which are limited to the extent that there is judicious diversification as to geographical origin and that sufficient stocks are available.

Is a New Source of Energy Warranted?

This being so, it is natural that there should be some doubts as to the expediency of developing a new form of power, to wit, nuclear energy, at the cost of considerable financial sacrifices. Isn't the available energy already sufficient? And won't the development of nuclear energy have precisely the effect of making the situation in the coal ector worse? These are questions which call for an ans swer. In many respects, nuclear energy is worth while developing: firstly in the short and medium term, for producing electric current, heat and isotopes and for assisting marine propulsion, and again in the longer term, because of its direct applications to various chemical and metallurgical processes. But from the economic angle, accurate forecasts are only possible in the case of the outlook for large-scale nuclear power plants.

Primary Energy and Secondary Energy

The progress made by energy consumption finds expression not only in its overall expansion but also in the fact that the primary forms of energy (particularly coal and oil) are being increasingly superseded at the final utilization phase by secondary forms of energy which are easier to use, and can consequently claim greater "no-

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[1] EMA unit of account = 1 US dollar.

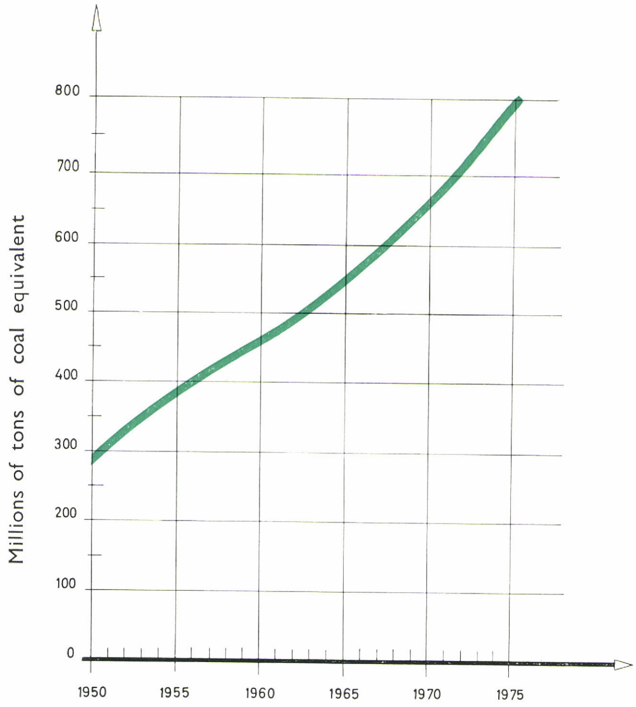


Fig. No. 1: Total energy consumption in the Community from 1950 to 1975

# of Electricity?

Hans Michaelis

Director, Economics Division, Euratom

bility", such as coke, oil products and electricity. For the period 1950-1960 alone, the share of the secondary forms of energy in the total consumption at the final stage rose from 60% to 75%.

Electricity, the "Noblest" Form of Energy

The ease with which it can be transported and distributed and the wide range of its potential applications, to mention only its chief advantages, have won for electricity the leading place among forms of energy. In 1961, the Six's electricity output (290,000 million kWh) absorbed nearly a quarter of primary energy availabilities.[2] As a result of the overall economic expansion, which has found expression in an increase in industrial production, and the substitution process referred to above, electricity consumption has almost doubled over ten years. In 1970, it will be about 540,000 million kWh, and by 1975, it will have risen to about 750,000 million kWh, thus absorbing a third of the primary energy. It may be pointed out that, even with this rate of growth, per capita consumption in the Community will be no greater in 1975 than that of the United States at the present time.

Needs are covered partly by thermal power plants and partly by hydroelectric generators. The primary sources used by the former are lignite, coal (both high grade and low-grade), blast-furnace gas, natural gas, fuel oil and geothermal energy. Nuclear energy's share is at the moment still extremely small—in 1961, it was less than one-thousandth.

The "Privileged" Sources of Electricity

But the energy sources referred to above will not all develop at the same rate as needs. Thus the calculations show that capacity for production of electricity derived from *lignite*, *blast-furnace gas*, *coal by-products*, *hydraulic energy and geothermal heat* will take about 20 years to double. On the other hand, these various primary sources are "privileged" in that they admit of relatively low costs. And the general opinion is that electricity of nuclear origin has no chance—for the time being at all events—of competing with electricity derived from any of these "privileged" sources.

Nuclear Energy's Place among "Non-Privileged" Sources

In order to meet the growing demand for electric current therefore, all that is needed is to draw still more amply on the other primary sources, and in particular high-grade coal and fuel-oil, and on natural gas. Consumption of these products will at least treble over the next ten years. Nuclear electricity will be able to stake its chances entirely in this field.

In the period of energy shortage which followed the Suez crisis the accent was laid on the building of nuclear power plants so as to reduce dependence on imports and to ensure greater safety as regards supplies. This campaign has now been relegated to the background. The above-mentioned energy policy report, while conceding that excessive reliance on imports involves a risk, nevertheless states that this risk can be lessened by a judicious geographical spreading of supplies and by the creation of adequate stocks.

These are precisely the conditions that nuclear energy can

[2] Hydraulic energy being calculated at the rate of 400 grammes of coal equivalent per kWh.

satisfy. Not only does the Community possess substantial reserves of uranium, but imports are obtained from countries marked by political stability. Furthermore, its high energy content makes nuclear fuel very expensive to transport and stock. The storage of a whole year's fuel supply for a nuclear power station costs only about a third to a fifth of what it does in the case of a coal or oil fired station.

In the context of a low-price energy policy, therefore, nuclear power production must aim primarily at the attainment of a competitive position, and the question for us is whether electricity of nuclear origin can in the long run be made cheaper than that of coal or fuel-oil origin. The future of nuclear energy hinges on this question.

"Proven"-type Reactors

In more than twenty years of nuclear research a large number of reactor families have been developed. From a short- and medium-term standpoint, the proposition is to test the profitability conditions governing reactors of the "proven" types. Among these are:

— the graphite-moderated, carbon-dioxide-cooled reactors constructed in the United Kingdom and France, burning natural uranium;

— the light-water-moderated and -cooled reactors constructed in the United States, burning enriched uranium, such as "pressurised" and "boiling" water reactors (PWR and BWR).

The experience acquired concerning these types is sufficient for specialized firms to be able to offer firm prices for the construction of turnkey-basis reactors whose power and life they guarantee.

How is the Unit Cost of Nuclear Power Calculated?

The usual practice is to break down nuclear electricity costs (as in other power plants, e.g. those using fuel-oil or coal) in the following manner:

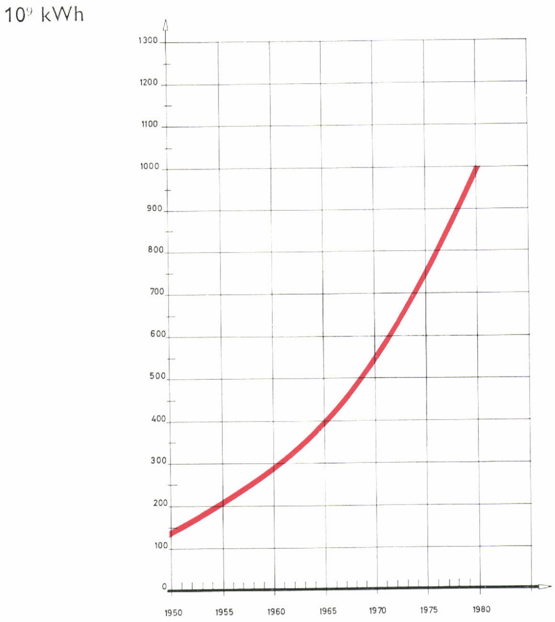
— fixed charges
— fuel costs
— operating and maintenance costs.

The fixed charges include capital redemption and interest and the various taxes on profits and capital. These expenses are spread over the total quantity of electricity produced during the entire reactor-operation period. The unit cost of power is thus basically a function of the installation's estimated life and also of the power plant's effective utilization level.

The fuel cost relates both to the initial core load and to reloadings at intervals averaging three years.

Fig. No. 3: Electricity consumption per capita for 1960 ▶

Fig. No. 2: Electricity consumption in the Community from 1950 to 1980



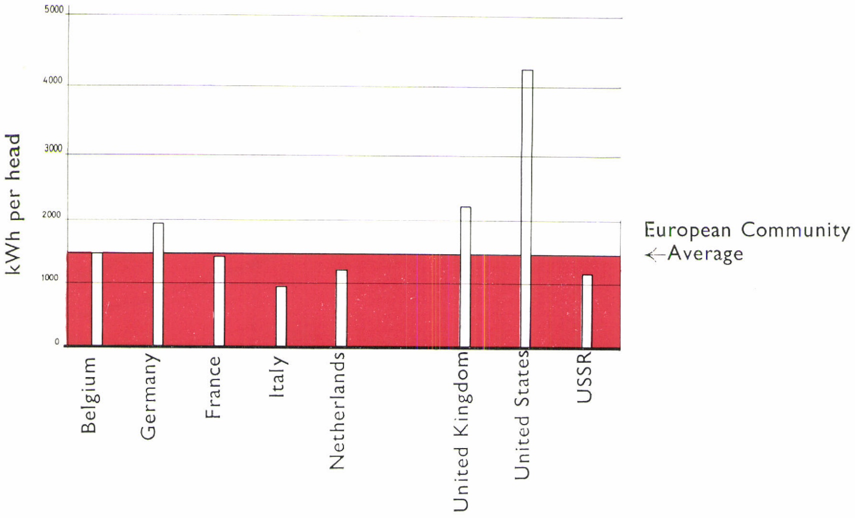
Operating and maintenance expenses, which are relatively small in relation to the fixed charges and the fuel costs are of the same order of magnitude whether for nuclear or for conventional power plants.

Fixed Charges

The minimum construction cost (with purchase price of site and interest accrued prior to commissioning) of a modern coal-fired or oil-fired power plant is at present about 125 EMA u.a. per kilowatt of electric power. That of a nuclear power plant is currently twice as much.

In the Community countries the minimum price at which light-water reactors are being offered is 250 EMA u.a./kWe. But as a consequence of the trend in construction towards increasingly "compact" types, prices are tending in the direction of 200 EMA u.a./kWe and may even drop as far as 150 EMA u.a. The US publication "Atomic Industrial Forum" has advanced the opinion, perhaps a trifle optimistic, that the capital cost of nuclear power plants in 1970 will not be more than 20% higher than that of conventional power stations.

As regards graphite-gas reactors, which are dearer to purchase but less expensive to operate, the construction cost is tending towards 300EMA u.a./kWe and there is



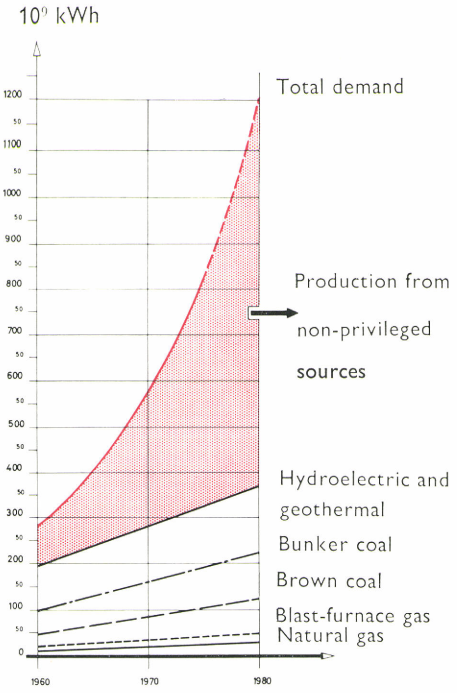


Fig. No. 5: Trend of total demand for electricity, and production from "privileged sources"

		10^9 KWh		%
1	Hydroelectric	99,3	▨	37,2
2	Geothermal and Nuclear	2,2	■	0,9
3	Brown Coal	23,5	░	11,0
4	Blast-furnace gas	13,3		4,9
5	Coal	103,1	▨	38,4
6	Oil	14,6	🟥	5,4
7	Natural gas	5,9	░	2,2
8	Total	267,9		100,0

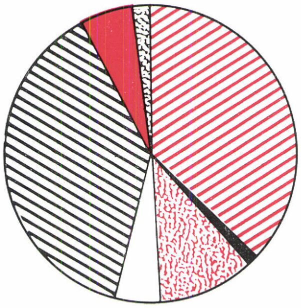


Fig: No. 4. Breakdown of electricity production in the Community for 1960 according to primary sources used

a chance that it will come down to 250 EMA u.a./kWe and even perhaps to 200 u.a./kWe.

The normal life of a nuclear power plant of the proven type is, according to the current estimate, at least 20 years, irradiation tests having established that the materials possess sufficient resistance. In the case of plants burning coal or fuel-oil, the average life is assessed at 30 years. For fiscal reasons the estimates are frequently reduced to lower rates, i.e. of the order of 15 or 20 years.

The initial outlay for nuclear power plants is high. The necessary funds are derived either from the capital market or from public sources. Rates of interest normally range from $5^1/_2\%$ to $7^1/_2\%$ according to the country.

In some Member States (France, the Netherlands, and latterly also Italy), and in the United Kingdom, production of current for the public grid is vested in a State monopoly; the enterprises concerned enjoy substantial exemptions as regards direct taxation, and in particular taxes on profits and capital. In other Member States (German Federal Republic and Belgium), as well as in the United States, the preponderant private or mixed-type enterprises do not benefit from any fiscal exemption in this respect. For them the incidence of fiscal charges takes the form of additional annual expenditure varying from 3% to 6% of the capital cost. Since capital cost is twice as high in the case of nuclear power plants (in relation to coal or fuel-oil), the fiscal charges in question have a considerable effect on nuclear energy's competitive capacity.

It is customary to calculate interest, depreciation and direct taxes in annual instalments of equal value and to express these instalments as a percentage of the invested capital. The relative amount, which varies from country to country, is shown in Graph No. 7.

Fuel costs

At the moment, natural uranium prices are, on the whole, tending downwards. Short-term uranium concentrate is selling at \$5—\$7 per pound.

As regards enriched uranium, the US Atomic Energy Commission is to all intents and purposes the sole supplier. Prices were reduced on 1 July 1961 and again on 1 July 1962, making a total out of 30% of 40% according to the degree of enrichment. The natural uranium price which forms the basis of the USAEC's current enriched uranium price scale is \$8 per pound of concentrate. This is still above the current world market quotation.

Depleted uranium is taken back at the current price. In the case of plutonium, the repayment price, which is at present only $12 per gramme, will probably be reduced to $8.50.

Uranium Reserves

Uranium deposits have been classified according to their importance from a development standpoint. At the end of 1960, a congress of experts arrived at the following estimate of the free world's reserves (probably on the cautious side):

Proved Reserves	**Potential Reserves**
(at a price of $8 to $10/lb U_3O_8)	(at a price of $10/lb U_3O_8 and over)
1 million tons of U content	at least 5 million tons of U content

According to Einstein's formula, 1 gramme of matter is equivalent to 20 million tons of large calories (kcal). With reactors of proven design, however, only 4 out of 1,000 grammes of uranium can be converted into energy. In consequence, the 1 million tons of proved reserves make it possible, with reactors of the "proven"-type, to produce about 20 billion kWh of current[3].

By employing reactors of the breeder type, which are still at the design stage, a realistic view yields the prospect of using at least 20% of the energy contained in the uranium reserves. The energy equivalent of the proved deposits is then raised to at least fifty times this value, i.e. at least 1000 billion kWh. The whole of the free world's coal deposits, workable at prices ranging up to 25% over current prices, would have to be brought in to produce this amount of electricity.

Cost of Conventional Fuel, a Determining Factor in Competitive Capacity

The forecasts concerning the competitive capacity of nuclear energy are based on a cost comparison between nuclear and coal-fired or oil-fired power stations. The major unknown here is the price at which these latter types of plant can obtain their fuel.

The present situation is marked by the concurrence of three price systems, i.e.:

— The cost of boiler-quality coal produced in the Community countries is at present about 14 EMA u.a. per ton, ex mine. The delivered cost may thus be as much as 19 EMA u.a. per ton.

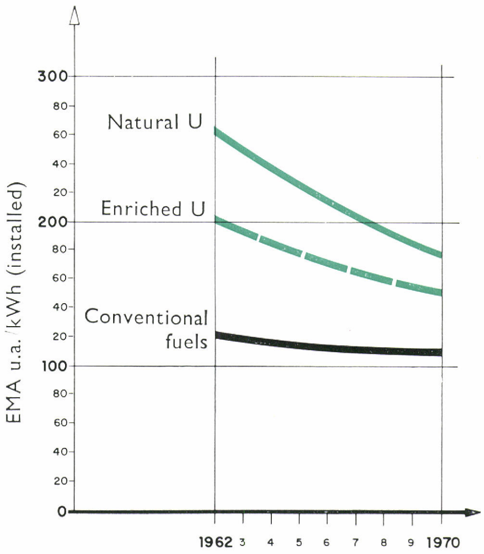


Fig. No. 6: Trends of construction costs for conventional and nuclear power plants

— US coal suitable for power-plants (bituminous slacks) is currently on offer at about 8.50 EMA u.a. delivered east coast United States; with transoceanic shipment costs added, this price comes to between 11.50 and 12.50 EMA u.a. delivered c.i.f. European ports. Taking into account the expenses involved in port handling and in carriage to power plants, the cost, except in very specific cases, amounts to at least 12 EMA u.a. For the Community countries, it may be estimated to average 13.50 EMA u.a. per ton.

— Prices of fuel-oil vary considerably. From an enquiry carried out in the Member countries for August 1961, it emerges that the range of ex-refinery prices of fuel-oil, not including taxes, is 10.50 to 19 EMA u.a. per ton, and that of delivered-user prices, including taxes, 15 to 23 EMA u.a. per ton. Converted into coal equivalent (7000 kcal/kg), the ex-refinery price, not including taxes, fluctuates between 7 and 13 EMA u.a. per ton, which means that the price to the consumer, including taxes, varies between 10 and 15.50 EMA u.a. per ton (see Graph No. 8). Since August 1961 the gap between upper and lower price-limits has narrowed somewhat. The lower limit lies in the region, without taxes, of 8.50 u.a. and, with taxes, of 12 u.a. per ton of coal equivalent. As for the upper limit, corresponding figures of the order of 12.50 u.a. and 14 u.a. per ton of coal equivalent are mentioned.

Under these conditions, it is extremely difficult to arrive at an average coal and oil supply price in the longer term, but the best solution is to apply the price for US boiler-coal, which promises to remain a satisfactory source of supply. The price of such coal will no doubt be subjected to only slight changes. Taking into account the foreseeable devel-

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[3] 1 billion = a million million.

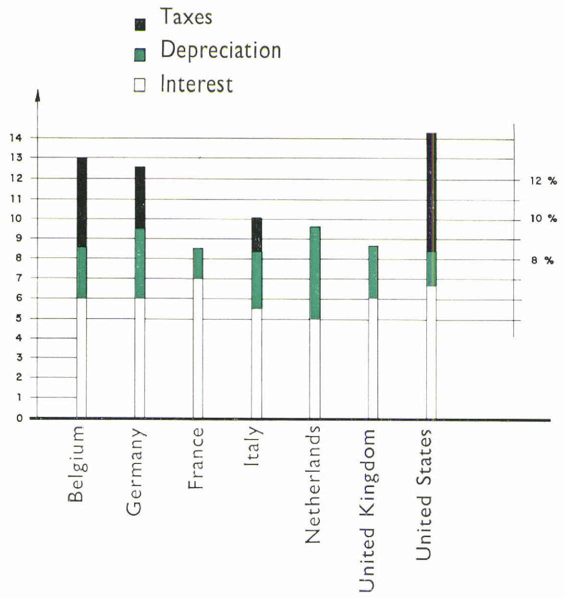

Fig. No. 7: Fixed annual charge structure for nuclear power plants

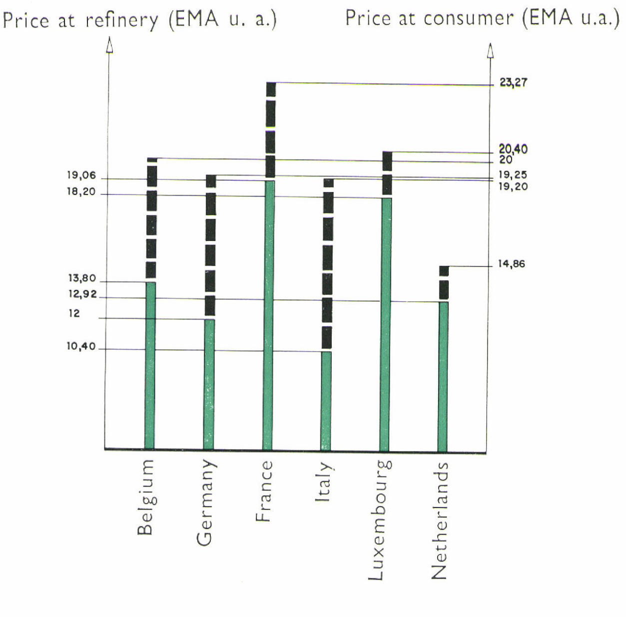

Fig. No. 8: Price of fuel-oil in the Community, with and without taxes

opment of production costs, transport costs from the mines to the coast and transatlantic freights, the memorandum on energy policy indicates that under the most favourable assumption a slight tendency towards an increase in price is to be expected; this means that the c.i.f. price will not be less than 11.50 to 12 u.a. per ton.

According to the above mentioned memorandum, the ex-refinery price of fuel-oil will in the longer term register a certain rise. It is to be expected that the lower ex-refinery price limit for heavy fuel-oil, without taxes, will be of the order of 12 to 13 u.a. per ton of fuel-oil or 8.50 to 9 u.a. per ton of coal equivalent at the end of this decade. Should a systematic consumer tax, of four u.a. per ton of oil until 1966, and two u.a. per ton thereafter, be applied in accordance with the memorandum's proposals, then under the most favourable assumption the ex-refinery prices including tax will be as follows:

— until 1966: 11 to 12 u.a. per ton of coal equivalent
— thereafter: 10 to 11 u.a. per ton of coal equivalent

Base Load and Peak Load

Demand for electric power fluctuates very widely according to the time of day and the season. The peak periods are in winter and during the evening. The rate of production capacity utilization is barely 50% annually.

An economic spreading of the load among the power plants of an interconnection system must be directed towards ensuring that the plants with the smallest variable costs deal with the slack periods, even if this means that at daily or seasonal peaks an increasing number of plants with greater and greater variable costs have to be put into service. The main item of variable expenditure is the cost of primary energy, i.e. the cost of fuel. It is therefore advisable, when changing from the base load to the peak load, to bring the power plants into operation in ascending order of fuel costs (see Graph No. 9).

At present, the base load is borne chiefly by the hydraulic, natural gas, blast-furnace gas and lignite plants. The peak load falls for the most part on the oldest plants using coal and fuel-oil and on the pumping stations. The nuclear plants' variable expenditure being more or less equal to the lignite plants', the annual utilization rate will be very much the same in each case. And thus the annual operating time averages 6,000 to 7,000 hours, or 70% to 80% of the maximum production capacity under continuous operating conditions (see Graph No. 10).

Prices of Conventional and Nuclear Power: a Comparison

With the aid of the above data, comparison of costs can be undertaken. These costs, which are expressed in thousandths of EMA u.a., or "mills", per kilowatt-hour (kWh), comprise in particular depreciation, return on borrowed or own capital and, where applicable, profits tax. These comparisons are based on firm-price tenders submitted for 250 MWe (and over) nuclear plants of the proven type, and coal-fired or oil-fired plants of the most recent type. The annual costs of the invested capital (annual instalments) are taken to be 8.6% (France and the Netherlands), 10% (estimate for Italy) and 13% (Germany and Belgium), and annual operating times 6,000 and 7,000 hours. It should be pointed out that differences in power costs calculated on this basis for various proven types of nuclear power plants (gas-graphite, boiling water, pressurized water) are only slight.

According to the information at the disposal of the Euratom Commission, the most recent figures (see Graph No. 11) are those shown below:

Power costs, in mills/kWh, of power stations to be commissioned in 1965/66

Capacity: at least 250 MWe
Utilization: 6000 to 7000 hours per year

	8.6% fixed costs	10% fixed costs	13% fixed costs
Nuclear Power Plants	6.1 to 6.8	6.7 to 7.4	7.8 to 8.8
Coal-fired or Oil-fired Power Plants			
— Supplied with coal at 18 EMA u.a./ton (present approximate "ceiling" for power plants obtaining supplies within Community)	8.1 to 8.5	8.4 to 8.8	9.0 to 9.5
— Supplied with coal at 13.50 EMA u.a./ton (current average price)	6.7 to 7.1	7.0 to 7.4	7.6 to 8.1
— Supplied with coal at 11 to 12 EMA u.a./ton (most favourable future price)	5.7 to 6.6	6.0 to 6.9	6.5 to 7.6

Thus according to the data given nuclear power stations which are ready for commissioning in 1965/66 will produce electricity at the same costs as coal-fired or oil-fired stations which pay between 12 and 16 u.a. per ton of coal equivalent for their fuel. The wide variations between figures are conditioned by the differences, from country to country, in fixed costs and utilization times for base loads.

Thus the Euratom Commission replied as follows to the question put in March 1962 by Mr. Pedini, Member of the European Parliament: "The estimates in the possession of the Euratom Commission concerning the most recent nuclear power plant projects in Germany, France, Italy, the United Kingdom and the United States are such as to confirm that the probable cost of nuclear electricity is 10% to 30% above that of conventional electricity."

The Gap is Being Closed

The Euratom Commission inclines to the view that the gap is closing. As far back as April 1960, it stated, in its Third General Report, that the competitive stage would be reached around 1970. This view has been reiterated in the two subsequent General Reports.

This calls for a word or two of explanation:

"Competitive" means that the production cost of electricity of nuclear origin will not be higher than that of electricity of conventional thermal origin, account being taken of the probable trend of fossile fuel prices. However, when the cost of nuclear electricity subsequently falls below this competitive level, this does not in itself mean that the existing conventional power plants will no longer be operated. The commissioning of more modern units will in no way cause the older ones to be closed down but will only bring about a change in their utilization (peak load rather than base load) and their profitability.

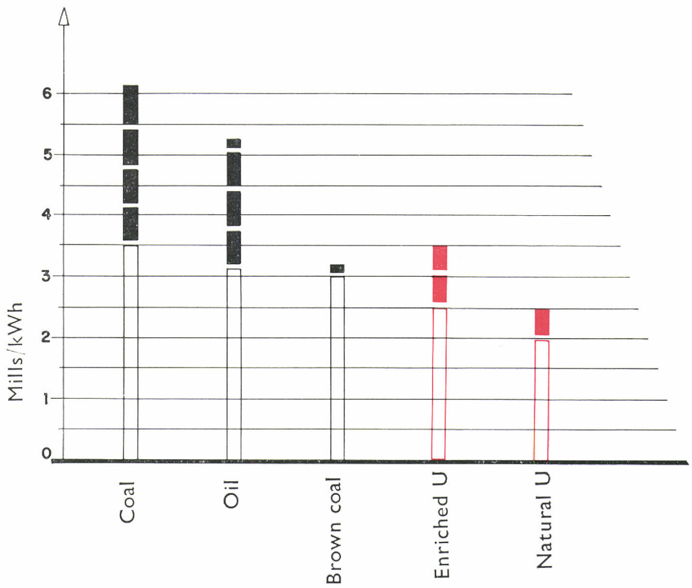

Fig. No .9: Fuel Costs per kWh

The various regions of the Community will not all attain the competitive stage at the same time. The first to do so (for base load duty) will be those which are some distance from the coast or the mining centres and hence at a disadvantage from the point of view of fuel transport costs. Thus, according to very recent information, the nuclear power plants upon which work can be started now will be competitive in some parts of the Community where fuel is dear. The "competitive" zone will thereafter progressively widen.

What are the grounds for adopting this standpoint?

As a consequence of the research and development activity in the field of power reactors, there will certainly be a further fall in the cost of nuclear electricity. In the case of the proven-type reactors, this decrease will be brought about by the following factors:

— *a decrease in the specific cost of facilities*, resulting from an expansion in capacity, an increasingly compact method of construction, industrial progress in the fields of engineering and fabrication, and simplification of safety measures to the extent warranted by the growth of scientific knowledge;

— *a stepping-up of fuel efficiency* by raising burn-up and *of thermal efficiency* by raising steam temperature. A decisive fall in the cost may be anticipated as a result of the increase in the quantity of heat derived from a ton of uranium (this increase has already been achieved repeatedly on the experimental plane) and also through improvement of the burn-up obtained to date. The same holds good for the steam temperature increase, as this implies the industrial use of the highly refractory materials currently being studied;

— *a drop in the fabrication cost of fuel elements*. The improve-

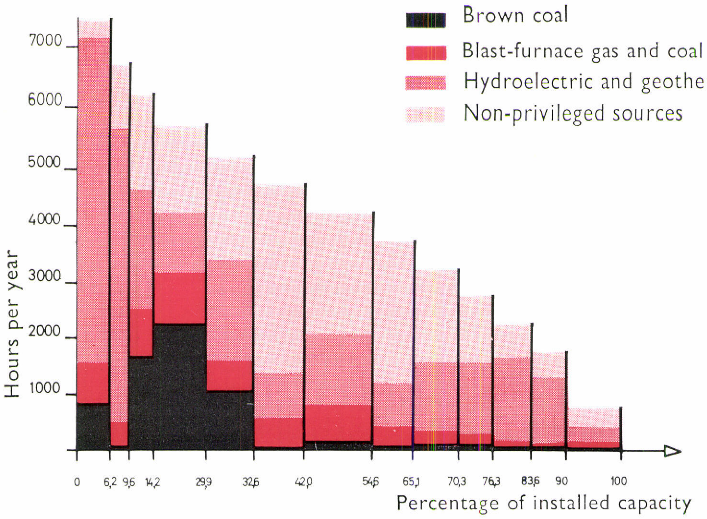

Fig. No. 10: Breakdown of electricity production in the Community for 1960 according to utilization times and sources

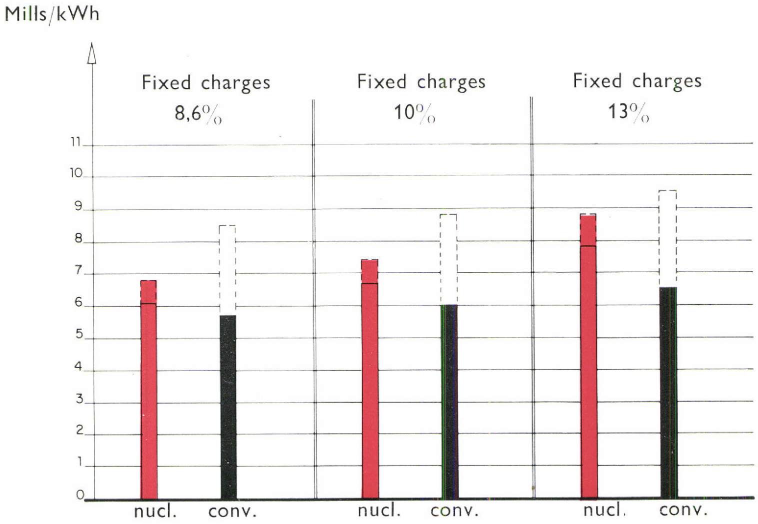

Fig. No. 11: Nuclear and conventional electricity costs (for capacity of at least 250 MWe and utilization times of 6000 to 7000 hours per year)

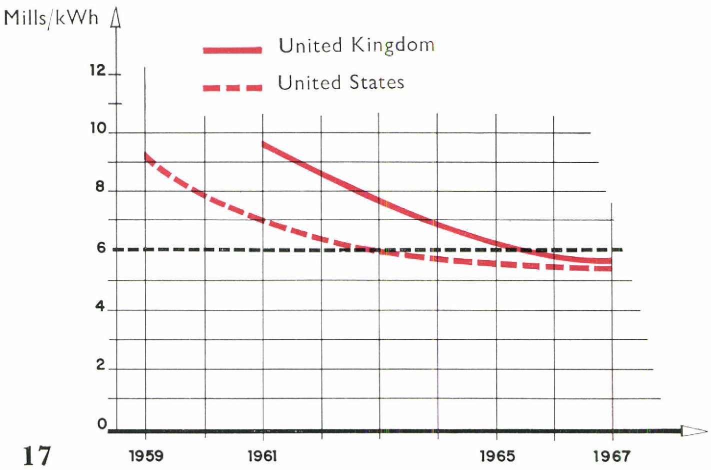

Fig. No. 12: Trends of nuclear electricity production costs in the United States and the United Kingdom

ment in technology and the transition to mass-production will result in appreciable savings.

The Euratom Commission expects that nuclear power stations with a capacity of 400 MWe or more and utilization times lying between 6000 and 7000 hours, ready for commissioning at the end of this decade, will produce electricity at the following costs:

— with fixed costs at 8.6%	between 5 and 5.5 mills/kWh
— with fixed costs at 10%	between 5.4 and 6 mills/kWh
— with fixed costs at 13%	between 6.3 and 7 mills/kWh

Under these conditions nuclear power stations will become competitive with thermal stations which are supplied with coal or oil at prices lying between 10 and 12 u.a. per ton of coal equivalent. In making this statement account has been taken of technically justifiable reductions in the fixed and variable costs of the conventional power stations used as a basis for comparison.

Convergence of Opinions

The Euratom Commission is by no means alone in its opinion regarding the attainment of competitive status. As evidence, it will probably suffice to quote several acknowledged experts on the subject.

Mr. Ailleret, Director General of Electricité de France, stated towards the end of 1961[4]:

"If one may venture a prophecy, there is reason to believe that 1970 will be the year in which we shall see the commissioning of the first clearly competitive units, which may consequently be expected to multiply rapidly."

The cost of current produced from French gas-graphite reactors will drop by at least 50% over the five years between EDF I and EDF IV.

Sir Roger Makins, G.C.B., G.C.M.G., Chairman of the United Kingdom Atomic Energy Authority, stated on 9 March 1962[5]:

"I see no reason to doubt the forecast so frequently made that for new stations at base load the cost of nuclear power in this country will fall below the cost of conventional power by the end of this decade."

Under the British nuclear energy programme, pursuance of the development of the gas-graphite family extending from Berkeley (critical in 1962) to Wylfa Head (critical in 1967) is founded on a 40% drop in the cost.

Mr. Seaborg, Chairman of the United States Atomic Energy Commission, expressed in the following terms his conviction that the United States would reach its target[6]:

"I am convinced that we now have in hand technology with which we can meet our 1968 objective of competitive nuclear power in high fuel cost areas. I refer to the technology of the water cooled and moderated systems, both boiling and non-boiling".

4. Report submitted to the 12th UNIPEDE International Congress held in Baden-Baden, October 1961.

5. Speech delivered before the North-West Branch of the Institution of Chemical Engineers in Manchester, 9 March 1962

6. Remarks presented to the "Joint Meeting of Atomic Industrial Forum—American Nuclear Society", held in Chicago, 8 November 1961.

United States forecasters are far more optimistic than those in the Community countries. The Pittman Report, issued in 1958, surmised that by 1968 nuclear power would be able to compete with thermal power plants using coal costing 10 EMA u.a. per ton (35 cts/million BTU)[7] at the power plant.

The United States Atomic Energy Commission, in accordance with the report it submitted to Congress on 25 June 1962, now expects the costs of nuclear electricity to fall off yet more steeply, quoting the figure of 4.7 mills/kWh for 1970. This forecast is based on power stations of 600 MWe with 14% capital costs and 7000 hours utilization. It is substantially more favourable than the estimates given here for the territories which are the concern of Euratom, as a conversion to European conditions will easily show.

It is therefore clear that all experts in the field of atomic energy are agreed that nuclear electricity has strong chances of becoming competitive. If differences of opinion still exist, they only concern the precise date when this will happen. At all events, this date is not far off.

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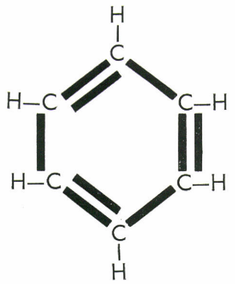
[7] BTU = British Thermal Unit = 0.252 kcal.

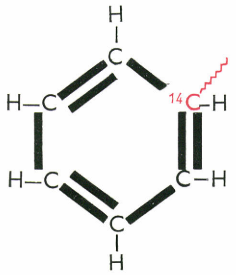
[8] as on 26 September 1962.

Power reactors in the European Community [8]
projected (P); construction decided (D); construction started (S); completed (C)

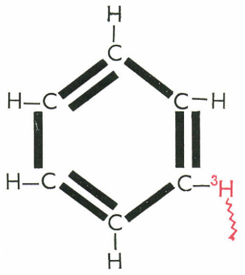
Site and designation	Country	Net power (MWe)	Type	Date of criticality	Progress
MOL - BR 3	Belgium	10,5	PWR	29 Aug. 1962	C
KAHL - VAK	German Fed. Republic	15	BWR	13 Nov. 1960	C
JÜLICH - AVR	,,	15	High temperature	1963	S
KARLSRUHE - MZFR	,,	50	natural uranium heavy water	1965	S
GUNDREMMINGEN - KRB	,,	237	BWR	End of 1965	D
OBRIGHEIM - KBWP	,,	150	OMR	1967	P
CHOOZ - SENA	France/ Belgium	210-242	PWR	End of 1965	S
MARCOULE	France				
G. 1		5	gas-graphite	7 Jan. 1956	C
G. 2		37	,,	21 June 1958	C
G. 3		37	,,	11 June 1959	C
CHINON	,,				
EDF 1		70	gas-graphite	16 Sept. 1962	C
EDF 2		170-190	,,	1963	S
EDF 3		375-480	,,	1965	S
ST-LAURENT-DES-EAUX	,,				
EDF 4		400-500	gas-graphite	1967	D
BRENNILIS - EL 4	,,	80	natural uranium heavy water	1964	S
TRINO VERCELLESE - SELNI	Italy	257	PWR	1964	S
GARIGLIANO - SENN	,,	150-230	BWR	End of 1963	S
LATINA - SIMEA	,,	200	gas-graphite	1963	S
GELDERLAND - GKN	Netherlands	50		1967	P



Benzene — non-marked molecule



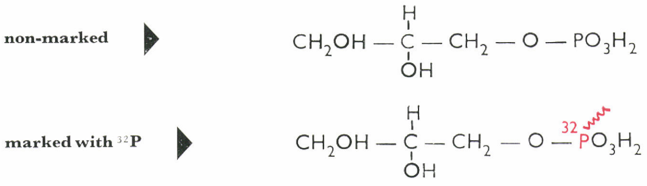
Benzene, marked with ^{14}C



Benzene marked with ^{3}H (tritium)

It is thanks to radiochemistry that scientists now have "marked" molecules at their disposal. These molecules do not differ in any way from their "non-marked' counterparts, except for the fact that some (in many cases only one) of their atoms are radioactive. They then become valuable research tools for the biochemist. Some examples of "marked" and "non-marked" molecules are shown on this page.

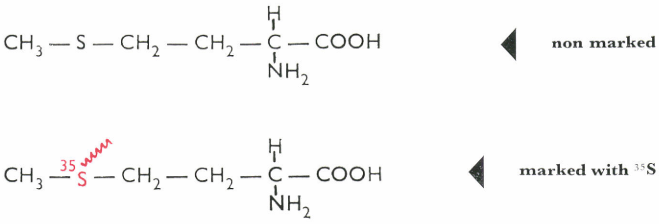
"Marked" molecules and their



$\mathrm{CH_2OH - \underset{OH}{\overset{H}{C}} - CH_2 - O - PO_3H_2}$

$\mathrm{CH_2OH - \underset{OH}{\overset{H}{C}} - CH_2 - O - {}^{32}PO_3H_2}$

Phosphoric ester of glycerine



$\mathrm{CH_3 - S - CH_2 - CH_2 - \underset{NH_2}{\overset{H}{C}} - COOH}$

$\mathrm{CH_3 - {}^{35}S - CH_2 - CH_2 - \underset{NH_2}{\overset{H}{C}} - COOH}$

Methionine, basic component of proteins.

A molecule is a combination of identical or different atoms. If one of the atoms is radioactive, the molecule as a whole also becomes radioactive. Thus it is possible, by means of highly sensitive physical measuring techniques, to detect the presence of such a molecule and to carry out a quantitative examination of its behaviour. If a molecule consists exclusively of non-radioactive atoms, this can be done only by chemical methods, which are, in general, less sensitive; therefore the introduction of a radioactive atom makes the task of detection easier.

Since it is not necessary to replace all but only some of the atoms in the molecules with the radioactive isotope, the radioactive isotope is merely used for labelling or "marking" the molecules. Thus the radiation needs only to be just strong enough to permit detection.

Since the introduction of a radioactive isotope has no appreciable effect on the chemical and physical properties of the molecules (apart from radioactivity), the molecule behaves in the same way as the non-radioactive form. Tests carried out on the marked molecules, easily identifiable because of their radioactivity, yield information on the behaviour of the accompanying non-radioactive molecules, which are identical to the radioactive ones in all other respects.

On the other hand we must bear in mind that this similarity to the non-marked molecule in fact exists when only part of the stable atoms are replaced. If all the stable atoms in a fairly large molecule were exchanged for isotopes, this would very probably lead to a perceptible alteration in the properties of the molecule. Let us compare the simple organic hydrocarbons ethane and propane in marked and non-marked form. The formula of ethane is C_2H_6 and that of propane C_3H_8. The molecular weights with the non-radioactive atoms ^{12}C and ^{1}H are 30 for ethane and 44 for propane. If we now form ethane completely from the radioactive atoms ^{14}C and ^{3}H (tritium), the compound would have a molecular weight of 46 , i. e. the molecular weight would exceed that of

by Professor H. Lettré

Director of the Institute for Experimental Cancer Research,
University of Heidelberg

applications in biochemistry

non-marked propane, which has three carbon atoms. It is clear that comparison between such a heavily marked molecule and the non-marked molecule is no longer possible.

In addition to natural radioactive elements, nuclear fission has made available numerous artificial radioactive isotopes of chemical elements. Thus marked molecules of both inorganic and organic chemicals can be manufactured and an almost inexhaustible range of applications can be found for them. They can be used, for example, to gain an insight into reaction mechanisms which are of equal importance in both inorganic and organic chemistry. If primary attention is paid here to marked molecules of organic chemicals, this is because organic compounds form stable molecules which do not split into ions, and also because the chemical nature of these organic compounds is such that they can be further developed for use in biochemistry and thus biology, agriculture and medicine.

“Marked” molecules in biochemistry

Organic compounds contain the element carbon, which consists primarily of a non-radioactive atom type having an atomic weight of 12; but there are also isotopes with atomic weights of 13 and 14, the latter being radioactive and obtainable in the form of a fission product. All the common compounds known to organic chemistry can be made up from this radioactive carbon isotope, either in

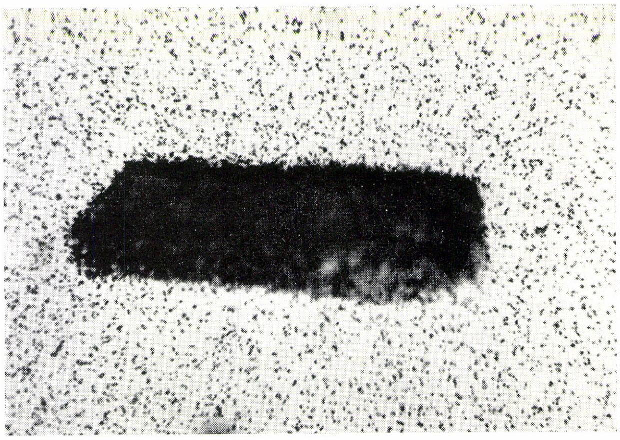


Fig. 2. Crystal of 5,6-seco-cholestan-3,5,6-triol, marked with tritium. The crystal shows very black in the autoradiograph; the separate black spots around it stem from the dissolved marked molecules, which move as much as 0.8 mm away from the crystal in 24 hours (length of crystal less than 0.1 mm). Magnification × 850.

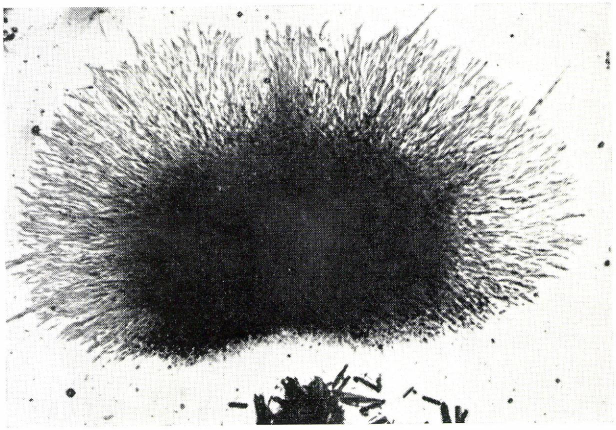


Fig. 3. Culture of chicken fibrocytes. Below the culture there are crystals of the same compound as in Fig. 2. The dissolved molecules prevent cell growth in the vicinity of the crystals. Magnification × 28.

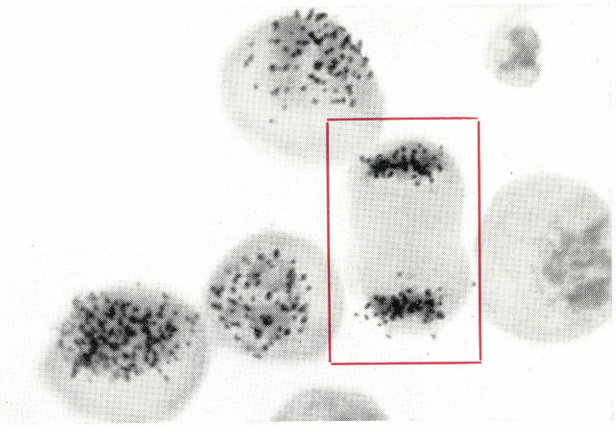
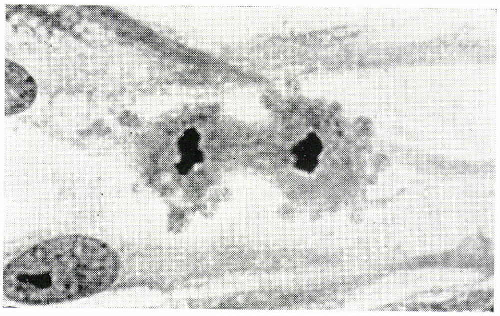
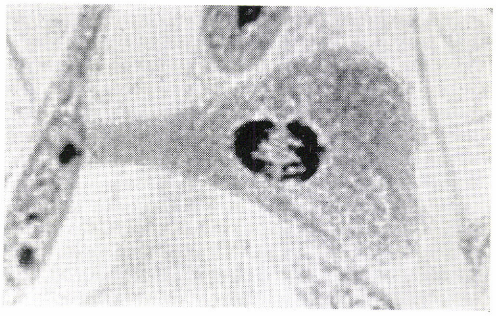


Fig. 4. Animal cells in tissue culture with addition of tritium-marked thymidine. The autoradiograph shows that the uptake of thymidine is confined to the nucleus. When mitosis (division of the cell) occurs, the thymidine is localized in the chromosomes. Magnification × 1500.

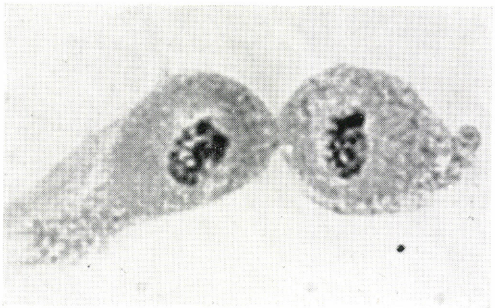


Telophase



Anaphase

Reconstruction



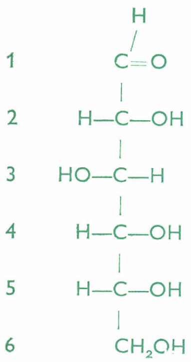
End of Anaphase

the test tube by purely chemical procedures, or by supplying living organisms with precursors containing this radioactive isotope, which they can assimilate.

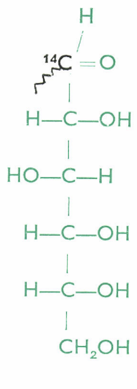
The elucidation of photosynthesis

The most important process on which all life on earth is based is that of photosynthesis, thanks to which plants in sunlight convert carbon dioxide into glucose, and hence to other organic compounds. The general equation for this reaction is:

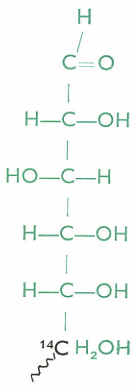
$$6\ CO_2 + 6\ H_2O \xrightarrow{light} C_6H_{12}O_6 + 6\ O_2$$



non-radioactive glucose



glucose "marked" at position 1



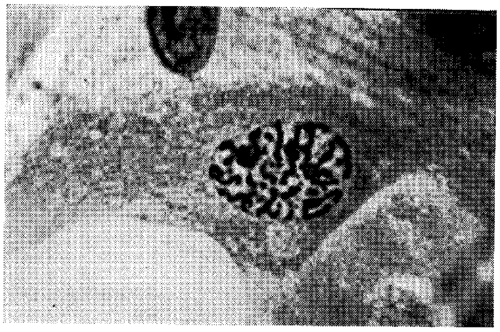
glucose "marked" at position 6

Six molecules of carbon dioxide combine with six molecules of water to form one molecule of glucose, six molecules of oxygen being released. If a plant is allowed to grow in an atmosphere where the carbon dioxide contains the radioactive isotope ^{14}C, there will be formation of radioactive glucose. By studying the intermediate products, Calvin in the USA was able to explain the mechanism of photosynthesis, which it is not yet possible to imitate outside of the plant cell. By this method radioactive glucose can therefore be produced and it is clear that other compounds in plants can also incorporate the radioactive carbon. It was in this way, for example, that the first radioactive morphine was produced.

Where should a molecule be "marked"?

In these biological processes, it is not known what particular places the radioactive atoms have occupied within the structure of the molecule. For many purposes, however, it is necessary to replace with the radioactive isotope not any atom in a molecule, but a particular one. It is here that "radiochemistry" comes in; by the use of chemical methods, both old and new, it creates "tailor made" compounds where a stable atom has been replaced by a radioactive atom at a particular point.

For example, whereas radioactive glucose molecules produced by biological means are marked in a haphazard



Prophase

Metaphase

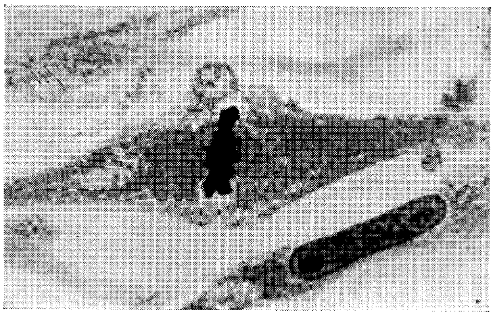


Fig. 5. *From right to left:* **Various phases of mitotic cell division (non-marked cells; the chromosomes are made visible by staining).**

manner with ^{14}C, radiochemistry can synthesize glucose molecules in which ^{14}C has replaced only one particular atom. If we number the carbon atoms in glucose 1 to 6, we can fabricate 6 radiochemically different types of glucose depending on which carbon atom is exchanged. Since there can be no doubt that this is possible, the fabrication of such different types of glucose would at first seem to constitute a purely academic verification of theory. However, these "isomers" have opened the way to new discoveries in the sphere of biochemistry. If an isomer is burned, the resultant carbon dioxide will consist of five non-radioactive molecules and one radioactive molecule, and the proportion of radioactivity must be the same, regardless of which isomer is burned. The combustion equation will be as follows:

$$C_6H_{12}O_6 + 6\,O_2 \rightarrow 6\,CO_2 + 6\,H_2O$$

This represents the reversal of the photosynthetic process which takes place in plants. This combustion reaction takes place in animals and human beings, where it is known as respiration. However in contrast to what we normally recognize as a burning process, it occurs without flame and at a low temperature, i.e. at the temperature of the body. In order to achieve this, the animal cell subdivides the entire process into numerous individual phases, made possible by the cell catalysts, or enzymes. Considerable knowledge is now available on these individual phases: by means of the Meyerhof-Embden process, the glucose is degraded to pyruvic acid, which in the citric acid cycle is further converted into carbon dioxide. This type of combustion takes place in such a way that every carbon atom of the glucose is burned up with an equal degree of probability, i.e., on the basis of these analyses it must be immaterial whether the glucose used is marked with ^{14}C at the 1st or 6th carbon atom (see Fig. 1), and there is no variation in the radioactivity of the resultant carbon dioxide. Hence up to 10 years ago, the general consensus was that there was nothing new to learn about the processes of respiration.

New facts about respiration

In 1953, however, Bloom and Stetten demonstrated that various tissues give off carbon dioxide of varying degrees of radioactivity during respiration, depending on whether the glucose used is marked at C-atom 1 or C-atom 6. Thus in addition to the reactions in the respiration process already known, others also take place, which have since been partially elucidated. The biochemical significance of these discoveries lies in the fact that the manometric method hitherto used for measuring the glucose conversion in tissues is no longer satisfactory, for a condition of its use is that the oxygen absorption should take place in line with the respiration equation shown above. However, since it is now clear that other processes are also involved, the assessment of the results has become arbitrary, and far-reaching conclusions concerning the metabolism of cancer cells, for example, have thus become suspect.

Autoradiography

We have just seen how marked molecules make it possible to follow the *breakdown* of compounds, but they are equally useful when it comes to understanding their *synthesis*. It is in this way that valuable information has been provided concerning the synthesis even of complex compounds in living organisms, such as proteins and their building blocks, nucleic acids, sterols and haemoglobin.

In such studies the radioactive element used for marking is usually detected by means of a Geiger counter. However, since the very day radioactivity was discovered, it is known that the radiation emitted by radioactive elements is capable of blackening the sensitive surface of a photographic plate or film. In this way it is the radioactive molecule itself which reveals its presence, and the method is hence termed autoradiography. As an example fig. 2 shows a crystal of a sterol derivative, in which hydrogen atoms are replaced by radioactive tritium. The crystal is imbedded in a clotted mixture of blood plasma and an extract of chicken embryo, as used for animal cell tissue cultures. Only traces of the substance are soluble in water. In addition to the heavy blackening over the crystal itself, black spots can also be seen near it, stemming from the radioactivity of the dissolved molecules. In this way, we can show that the compound is not completely insoluble, at the same time determining the extent to which the substance spreads in a given period of time. We carried out these tests in connection with studies on the effect of this substance on growing cells. Fig. 3 shows how, in a culture of chicken fibrocytes, the cells only grow on the side facing away from the crystals. The molecules which have left the crystals and gone into solution prevent cell growth. The relatively low optical magnification makes it impossible to distinguish the dissolved molecules, but the radioactivity of the crystals themselves can be clearly seen by means of the autoradiograph.

Autoradiography makes it possible to determine the distribution of marked molecules in an organism and in its organs and even in individual cells. As an example of this we may point to the study of the incorporation of thymidine into deoxyribonucleic acid (DNA) through the use of tritium-marked thymidine. As DNA is a basic component of chromosomes, and since the chromosomes are present in the nucleus, it is only here that incorporation of marked thymidine takes place. In Fig. 4 it can be seen how the radiation emitted by it is localized in the region of the cell nucleus only. When a growing cell divides, the chromosomes condense in the nucleus and are separated by the mitotic process (see Fig. 5, stages of cell division, without the use of marked molecules). In the cells containing marked thymidine, division proceeds in the same way, and it can be seen from the autoradiograph that the radioactivity is localized in the chromosomes (see Fig. 4 —framed cell). Since the incorporation of marked thymidine reveals the reduplication of deoxyribonucleic acid, we thus have at the same time a criterion for the growth tendency of cells. Furthermore, it can be used for analyzing the effect of external factors on growth.

These few examples should provide some indication of the uses to which marked molecules can be put, but while they were selected from the field of biochemistry and biology, their chemical applications should not be forgotten either. Chemistry is of basic importance for the production of marked molecules. While several hundred thousand different molecules are known to organic chemistry,—and this figure can be increased at will—the possibilities for the production of marked molecules are even greater. Radio-chemistry, as a new branch of chemistry, is opening up new fields of unpredictable magnitude, the problems and stimuli of which do not originate from chemistry itself only but from all the spheres in which marked molecules are used.

These possibilities are discussed in the book "Künstliche Radioisotope in Physiologie, Diagnostik und Therapie", published in its second edition in 1961 by the Springer-Verlag, Berlin-Göttingen-Heidelberg. This article can only be a sketchy attempt to illustrate the part played by marked molecules in making invisible processes accessible to physical measuring methods or even the human eye; at the same time an attempt has been made to demonstrate their value as a means of promoting scientific knowledge as well as leading to practical applications.

A prerequisite of their utilization is the further development of the science of radiochemistry, which makes the marked molecules available. This constitutes a task the scope of which is beyond the resources of a single institute and calls for large-scale collaboration and coordination, such as that embarked upon by Euratom in its own field.

From archaeology to automatic data processing

by J. C. Gardin,

of the French National Scientific Research Centre

Data processing and archaeology. The juxtaposition may occasion surprise, yet it serves to underline the all-embracing nature of research into automatic data processing, since even archaeology, regarded as a conservative discipline, is experiencing the need to avail itself of the advantages which computors can offer; with the aid of a few concrete references to work carried out in this field, we shall endeavour to show that this comprehensiveness characterizes not only the applications to which it can be put but also the entire range of problems involved as well as the "methods" used in the processing of data, whether archaeological, physical or sociological.

What, in fact, is meant by "data processing"? Basically, this: on the one hand, the *representation* of certain "data" by symbols which can then be stored in a "memory", and at the other hand, the automatic *handling* of these symbols on the time of conducting the "research". Such research may itself be of two types: "documentary" research, where the machine is asked to retrieve the data which show some degree of correlation with the features of a "question" which has been put; "theoretical" research, where all the data stored are subjected to a series of logico-mathematical operations designed to bring to light certain "order" phenomena (models, classifications, etc.) hitherto unnoticed.

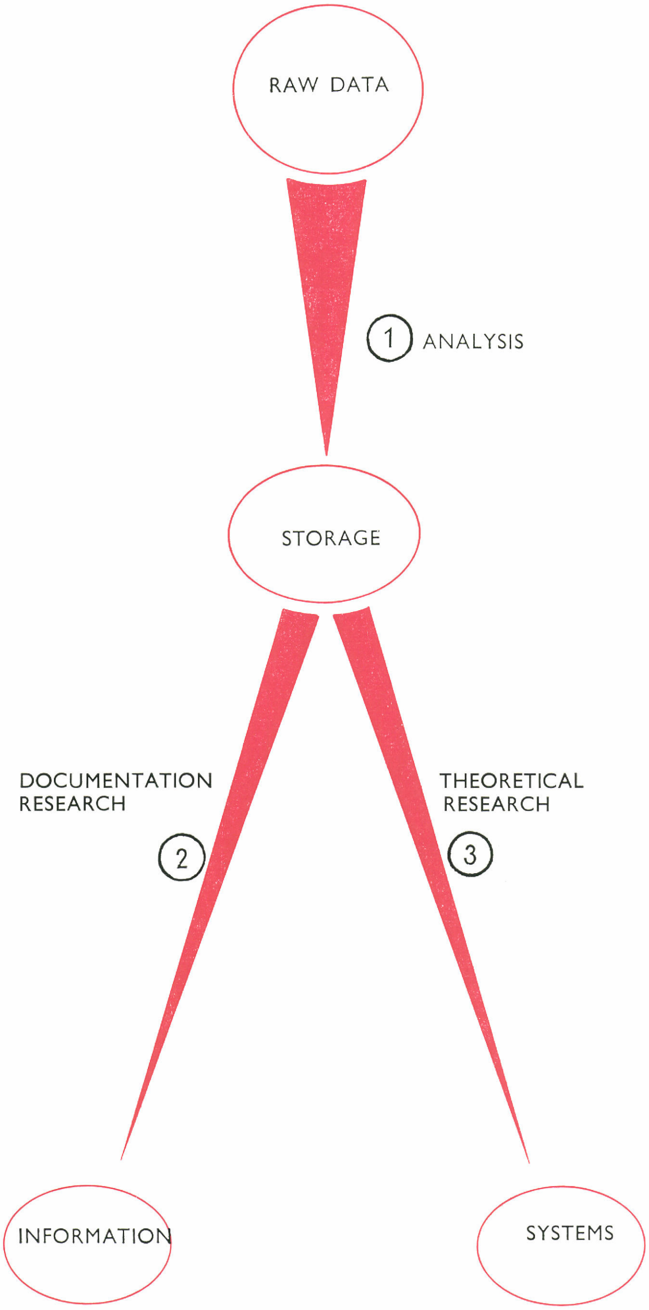
The multifarious facets of data processing are illustrated in diagrammatic form in Fig. 1. The problem is first of all to transform the raw data into a system of appropriate symbols or "codes" for storage and utilization in the machine (process 1), and then to define the rules of such utilization for documentary (process 2) or theoretical (3) purposes.

I shall leave it to those with more expert knowledge, and more particularly the members of Euratom's staff at CETIS (Scientific Data Processing Centre), to set out the *general* status of research into these three processes; it is, indeed, largely under the impulse of these specialists that work on data processing has undergone such an expansion in the European Community countries over the past few years, and it is therefore CETIS that has earned the right to present the first progress report. For my part, I shall confine myself to showing how, as regards archaeological documentation in particular, the study of the problem has resulted in a sort of overall system of data processing, in which the distinctions according to "content" have finally been superseded, giving way to methods, operations and even programmes entirely independent of any clearly-defined field of knowledge.

Archaeology and Punched Cards

1. Preliminary work

The choice of archaeology as a field for experimentation in punched-card documentation is not as strange as it may seem. Archaeology is first and foremost a *learned* science and serves excellently to exemplify the type of problems which arise in connection with documentation. "A good card-index", an authority on the subject once quipped, "is the



essential and probably the only requisite for the career of archaeologist". But what is a "good" card-index? The concept evolved by some friends and myself as far back as 1955 was marked by the need to find a more convenient form than the usual analytical indexes or tables, which are seldom accurate and invariably incomplete. This sparked off the first attempt to apply punched-card systems to archaeological documentation, sponsored by the National Scientific Research Centre; by 1956, we had compiled some 5,000 central-perforation cards (needle selection), representing almost all the "Bronze Age Implements, from the Balkans to the Indus" found in publications and collections in Europe and Asia.

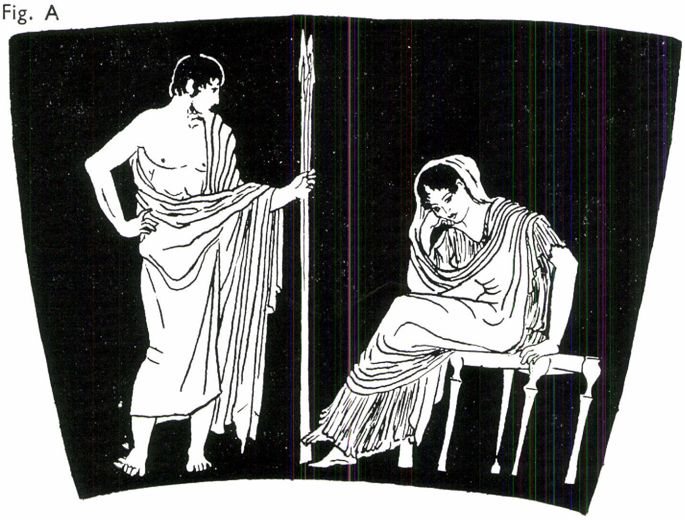
This experiment served to demonstrate that the focal problem was not of a technological—there was no lack of punched-card equipment—but of *linguistic* nature. The difficulty was to find a way of describing documents by means of a limited number of elementary symbols which, used in appropriate combinations, would satisfactorily express the complex properties of the various objects as discerned by archaeologists. Furthermore, all ill-defined concepts, however widespread their use, had to be excluded from this new descriptive language; instead of continuing to speak of "sickles", "choppers", "billhooks", etc.—which is an example of the way in which objects are labelled with descriptions which cannot measure up to any universal or objective criterion—it was necessary to resort to combinations of "discrete" terms, each denoting a distinctive feature of these implements, without prejudice to the name or the position of the latter in general typological studies.

The whole of our subsequent research was centred on this terminological aspect of the documentation problem: the replacement of the frequently inaccurate *synthetic* concepts by *analytical* expressions formed from 2, 3 . . . *n* elementary terms which were more clearly defined and more suitable for machine handling. By this means, and by "objectivization" of the analysis, the card-indexes ceased to reflect the different viewpoints of the individual authors and became a sort of pool of their combined knowledge, defined and expressed unambiguously in the terms of a new system of symbols specially designed for the purpose.

2. Current Developments

The success of the first punched-card indexes for archaeological documentation (ancient Greek and Asian weapons, implements, pottery, etc.) prompted the National Scientific Research Centre to extend the experiment in two directions: on the one hand, to develop a form of publication which would make these card-indexes available to

Fig. A



The problem involved in documentation analysis is to express all the useful data in as objective a manner as possible. This is achieved by replacing certain general designations, often vague or debatable, by a set of special attributes of a well-defined and unequivocal character. Suppose, for instance, scene C represents an episode in the Odyssey, say Penelope's vigil at Ithaca. Apart from the inscription (bottom right-hand corner) —which is frequently missing in these classical Greek painted vases—the interpretation rests essentially on the combination of a number of distinctive features: a woman seated at a loom, etc. It is only these features that will be mentioned in the analysis, in order that during the process of retrieval anybody could, as it were, "compose" the picture which he selects: group consisting of two persons—a man standing before a seated woman, with any "attributes" they may have (head-dress, clothing, objects carried, etc.) (A)—the "accessories" on the picture (loom, etc.) (B)—the ornamental motifs, the inscriptions (C), etc. By means of the punched-card processes, it will be possible to envisage any combination whatsoever of 2, 3 . . . *n* elements of this kind, without prejudicing any overall interpretations formed by the individual.

Fig. B

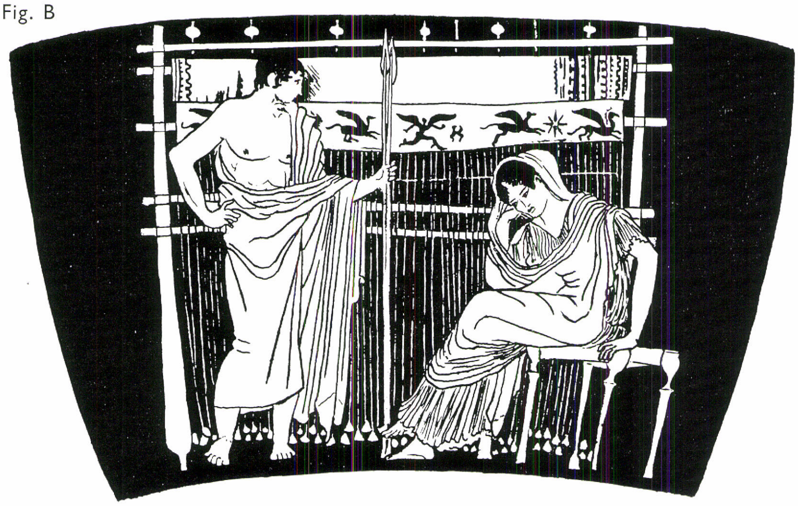


Fig. C

fellow-scientists at low cost, and on the other hand to utilize the same data for purposes not of documentation proper, but for theoretical studies involving the use of computers.

a) *Punched-Card Publications.*—In order to make punched -card material generally available, a process had to be devised which would enable such cards to by reproduced in several hundred copies without requiring the use of any complex equipment. For this latter reason, we rejected the conventional sorting machines, and also the needle devices, the awkwardness of which soon becomes manifest when the number of cards exceeds a thousand. The technique adopted was that known as "peek-a-boo", which is already being employed on a wide scale in France and the Anglo-Saxon countries. The only piece of apparatus is an inexpensive reading frame, in which the user, after having superposed the 2, 3 . . . *n* cards corresponding to the various *terms* of the question, can immediately see at which points the cards coincide, i.e. where they are perforated in the same place. The serial numbers of these common points, which are printed on the cards, refer to the documents sought.

All that now remained was to develop a machine capable of reproducing simultaneously the perforations and the titles of these "peek-a-boo" cards. This has been achieved, at least in the prototype stage and for a single index-card specimen (standard-size punched cards, capacity 5,000 documents). Three publications are now being prepared by means of this process. The first deals with the *objects* ("Catalogue of Ancient Implements", conversion of initial card-index); the second relates to *iconographic documents* (catalogue of engraved scenes of Assyrian, Babylonian, etc. origin) and the third, a *text* concerning the history of religion ("Conceptual Analysis of the Koran").

b) *Computer Work.*—It very soon became clear that the data contained in a descriptive analysis having such a high degree of accuracy could be used for purposes other than documentation research. Assuming that the "populations" studied were, to some extent at least, subject to arrangement in line with the facts of history, it was quite natural to try to find a reflection of this organization in the actual configuration of the analytical data. The attempt was made for two types of groupings to which preference was given, namely "networks" and "classifications".

In the former case, the materials consist basically of several thousands of binary relations between different points of a hypothetical network, the problem being to determine the shape which this network is to assume. We give below two examples of this:

1) The study of the economic set-up formed by a colony of Assyrian merchants in Cappadocia (now the Anatolian plain in Turkey) in the 19th century B.C., on the basis of business transactions between two merchants in each case.

2) The study of the hierarchical set-up implicit in the population of a Polynesian archipelago, in the light of the relationships observed between certain persons from island to island or from village to village.

In both cases, theminimum information unit is represented by the relationship linking two individuals, this relationship being specified as to its nature (barter of goods, rendering of services, allegiance, kinship, etc.), its "location", etc.

The aim of the exercise consists in reconstructing from this mass of data the pattern of a more or less tightly-knit organization (economic associations, dominant groups, etc.), a pattern which could not be discerned other than by computation. The first of these projects is in progress on IBM 7090; the second is still in the study phase.

Automatic classification studies similarly consist in utilizing the results of the documentary analysis as applied to a given category of objects for calculating the existence and boundaries of certain distinct groups ("cultures", "styles", "schools", etc.). The problem is, indeed, a very widespread one, from the standpoint of both its form and

The IBM 7090 machine at CETIS in Ispra ▶

its scope, in the field of data processing; our initial experiments are based on the theoretical studies carried out by Mr. Peter Ihm, of Euratom (CETIS) on the methods of automatic classification by means of computers (IBM 650 and 7090).

Extension of Data Processing to General Documentation

Thus some projects originally designed to serve practical purposes in a limited field have finally raised problems of a theoretical nature which no longer bear any relation to this field. In particular, through multiplication of the construction of "grids" or specialized combination systems for expressing and handling data of all kinds—geometric forms, abstract settings, portrayals of scenes, semantic content of certain texts—, we have witnessed the development of the rudiments of a general data processing theory, whose links with concrete content become steadily more tenuous. At this juncture, Mr. Paul Braffort, Director of Euratom's CETIS, approached us with the request that we should go into this very problem of synthesis, by means of a data processing experiment which we shall be required to prepare and complete within two years, in the least specialized and most heterogeneous field of all: the human sciences. The choice may have been an unexpected one; it was nonetheless spontaneous and stemmed from the contention that any methodology which has stood the test of texts as close to natural language as, for instance, articles on sociology, will be *a fortiori* applicable to the processing of the more arid and factual texts which deal with the exact sciences.

It is not possible, for the time being, to check the accuracy of this assumption, for SYNTOL—such being the name given to the system in question (Syntagmatic Organization Language)—has only just been finalized after protracted tests on IBM 7090. However, the fact that the body of material used for these experiments relates to more than one discipline, and that texts from the field of physiology, which is closer to the exact than to the human sciences, have been taken into consideration, gives good grounds for hoping that the objective has been achieved, i.e. we have succeeded in defining the linguistic rules, the data organization, and the logical operations without reference to any specific field of application. It remains to assess the usefulness of this general model in the widest possible range of scientific disciplines; that is the task we have set ourselves for the coming months.

Who to-day would question the usefulness of the bicycle? Although modern technology has provided us with faster and more comfortable vehicles, the bicycle is still a wonderful invention for persons of limited means or those who like exercising the leg muscles.

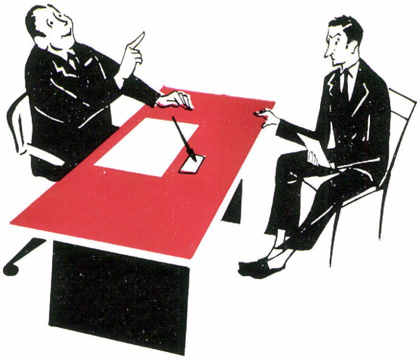
But Freiherr von Drais, who invented the bicycle some 150 years ago, was unable to reap the fruits of his invention. True, the bicycle was enthusiastically received for two years after its birth, but for Drais this marked the beginning of a desperate and even tragic struggle to gain recognition for his brain-child. In the end he died a wretched death in the workhouse, the "Draisine", as the vehicle was then called, having become the butt of narrow-minded critics. It was not allowed to be used on footpaths, and on the roads, which were in an indescribably poor state, the rider was exposed to falling under horses' hooves or having to wade up to the knees in mud. A proposal to construct special cycle tracks was torpedoed and the vehicle soon consigned to oblivion It was not to be rediscovered for another 50 years.

The connection between radioactive isotopes and the "Draisine" may not be immediately obvious. Nevertheless we should like to draw this comparison to-day, because for all their manifest advantages, the obstacles in the way of the increased use of isotopes and radiation are the same, to wit, ignorance, superficial criticism, prejudice, fear, needless restrictions and inadequate technical development.

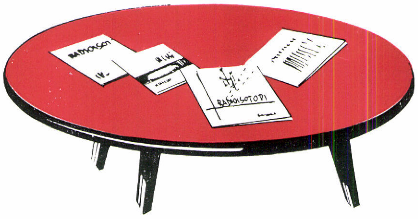
And yet there is a considerable difference after all, for whereas the 19th century could afford to ignore an important invention for 50 years, in the world of to-day this is no longer possible; industrial competitiveness would pay too great a price and the economy would suffer an irreparable loss.

For this reason even public authorities are promoting the use and dissemination of technical innovations of particularly far-reaching scope. Where necessary they are also giving active support.

In the case of isotope and radiation technology, which is of paramount industrial importance throughout the European Community, the Commission of the European Atomic Energy Community has decided to set up a publicity office known as *Eurisotop*.



EURISOTOP



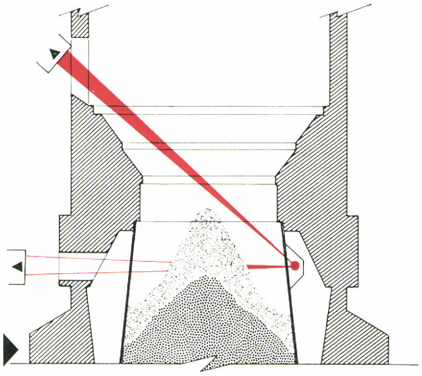
INFORMATION AND ADVICE DEPARTMENT

Eurisotop has an information and advice department on the use of isotopes which is available to all persons and organizations in the European Community. All requests are dealt with in confidence. The information and advice department covers:

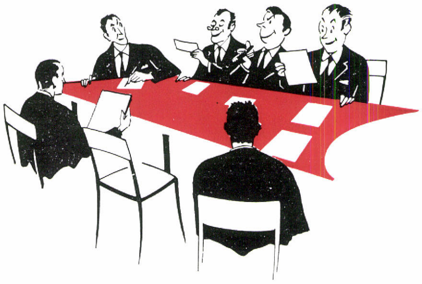
— literature searches
— assistance in the solution of problems
— advice on handling of radiation sources
— principles of application
— visits to industrial plants.

PUBLICATION OF INFORMATION BROCHURES

The most effective method of advertising in the technical and industrial sectors is by means of practical information. For this reason Eurisotop will publish for each field of industry and technology separate information brochures containing reliable material on the possibilities and advantages of isotope and radiation technology. The brochures will be written by trained scientists and engineers, selected as far as possible from the industrial sector.



Level control in cupola furnaces



FURTHERING THE DEVELOPMENT OF METHODS AND EQUIPMENT

The finest suggestion is worthless unless it can be put into practice. A considerable amount of development work is required to exploit the possibilities of isotope and radiation technology, particularly in order to adapt known methods and equipment to existing industrial conditions. Euratom is participating in the promotion of these development plans by the provision of financial and technical aid and the loan of personnel on a contract basis. The results of these developments will be made public in the European Community.

EUROPEAN CO-OPERATION

The applications of isotopes and radiation cover a wide field. Hence there exists the danger that the many efforts aimed at technical improvement and at extending their use will become too diffuse. To enhance the effect of these efforts, Eurisotop intends to act as a focal point for co-operation within the European Community. The way towards this aim is being cleared by holding specialist symposia of isotope users, a series of which is in course of preparation.

Just as the bicycle was once an entirely new vehicle, so at present is isotope and radiation technology a novelty in industry. We need only look, for example, at the indicator methods applied in production control or at the techniques for changing the properties of materials by radiation. In the European Community consignments of radioactive isotope products average only one per 10,000 inhabitants. The half-life of these consignments is often only a few hours or days, so that the materials are only in use for a brief period. But like the bicycle, isotopes will also become accepted, and just as to-day there are only a few people who know what difficulties beset the introduction of the bicycle, so will present difficulties in introducing isotope and radiation technology be forgotten.

For all enquiries concerning radioisotopes, please write to:
Eurisotop, Euratom, 51 rue Belliard, Brussels, Belgium

EURATOM NEWS

Euratom-Argentina Co-operation Agreement signed

On 4 September 1962, an agreement was signed between Euratom and Argentina for co-operation in the peaceful uses of atomic energy. Among the points in the Agreement, which is to run for twenty years, are:

- the exchange of information in fields such as research and development and health protection;
- the exchange on commercial terms of licences and sublicences and arrangements for exchanges of personnel;
- on the request of the Argentina Government, the Commission will invite Community undertakings to co-operate in prospection and research in Argentina for uranium deposits or other nuclear materials;
- raw and special fissile materials may be exchanged between the Euratom Supply Agency or other Community undertakings and Argentina;
- the two parties will aid each other, as far as they can, in the acquisition or construction of installations or equipment required for research, development or production in the nuclear energy field.

Padutine Treatment of Radionecroses – Further Encouraging Results

It was reported in Euratom Bulletin 1962 No. 2 (p. 25) that the Euratom medical adviser, Dr. Massart, had successfully treated a case of *delayed radionecrosis* localised in the fingers, the cause being accidental irradiation. The result was obtained with injections of a pancreas extract marketed under the name of Padutine-Dépôt.

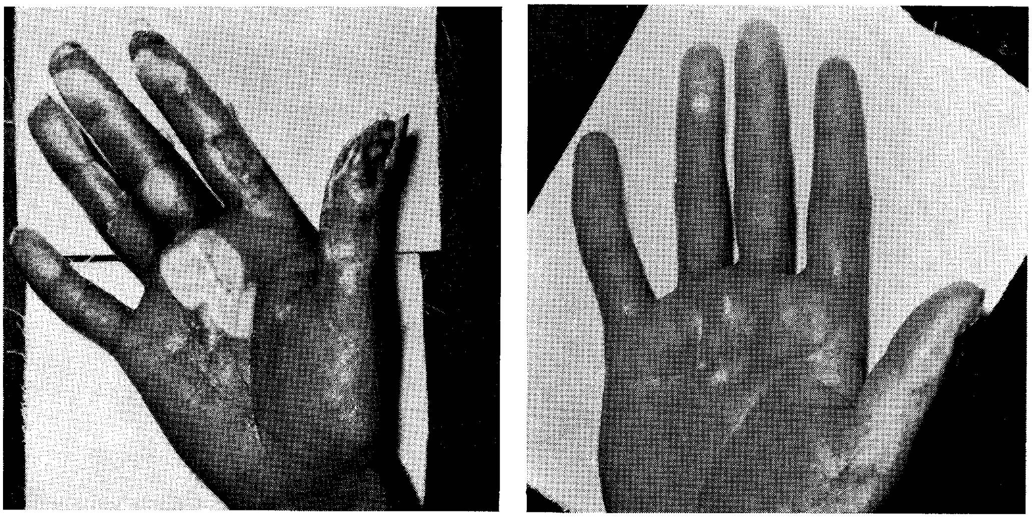
This treatment has since been applied to many other cases, including therapeutic radionecroses, notably by Professor Suzanne Simon of the University of Brussels. The results have been extremely encouraging.

The treatment has also been employed in Germany. A case in point is that of a workman whose hand was accidentally irradiated on 6 December 1961 and who became affected with *acute radiodermatitis*. The Padutine treatment effected a complete cure, which has been maintained up to the time of writing. Hence it is interesting to note that this medicament promises to be a good antidote for many kinds of radiolesions. It should also be pointed out that the injections are a sedative for the stubborn and persistent pains accompanying all radiolesion cases.

Research work is in progress on the experimental, clinical and pharmacological levels with the object of correctly analyzing the action of the medicament.

"Optimization" of the "Orgel" nuclear power plants – development of a rapid calculating method

A well-designed nuclear power plant should be able to produce electric current at the minimum price. Hence from the very outset of the designing work the economic pros and cons of a vast range of alternatives covering practically every aspect of the installation must be carefully weighed in the balance. The problem is further complicated by the interdependent nature of the majority of these features, so that a modification in the design of any one of them inevitably triggers off a whole chain reaction of alterations. Since the



Left

before treatment: As a result of accidental irradiation, this hand shows all the symptoms of acute radiodermatitis.

Right

after treatment: Six weeks later, Padutine treatment has effected a complete cure.

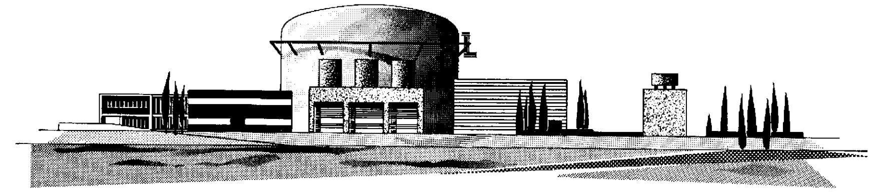
various branches of scientific activity involved, e.g. neutron physics, thermodynamics, technology, etc. often impose contradictory requirements, it will be clear that an optimal overall design can only be arrived at on the basis of an enormous number of judicious compromises.
In order to effect these compromises, a large number of calculations must be carried out which if done "by hand" are not only extremely tedious but can take up whole years of valuable time. The only way of overcoming this drawback was to resort to large-scale computers. Such machines were used in the "optimization" of the ORGEL reactor string (Organic liquid cooled heavy water moderated reactor). The Euratom departments concerned, making use of studies carried out under contract by certain industrial groups in the Community, have devised a code named "Orion I" which assembles a hundred equations showing the mathematical relationships between the various features of the power plant. On the supply of certain exact data, these equations can be solved by the machine in series (viz. by the CETIS IBM 7090 at Ispra) in less than a minute.
It is possible, in this way, to define the characteristics of an ORGEL-type power plant which, corresponding to these data, represents the most favourable compromise between the conflicting demands made by the various scientific disciplines involved and is capable of supplying electricity at the lowest possible price.

"Euratom and the Questions of Liability and Insurance in Nuclear Energy"

by Reinhart Bauer

The above-named article, published in No. 3 of Euratom Bulletin, should be corrected as follows:
Page 16, second sentence, line 3 should read: "Although any occupation which has to do with the atom in its peaceful applications tends to be considered by the layman as particularly dangerous, it is a fact that only very few nuclear incidents have occurred."
Page 17, right-hand column, lines 2 and 3 should read: "In the majority of cases, self-insurance by the operator of a nuclear installation also provides inadequate coverage against possible claims."

Euratom decides on the construction of ESSOR test reactor



The Euratom Commission has decided on the construction of a 25 MW test reactor, ESSOR (Essai Orgel). Work on this reactor is due to start in 1963, will last two years and will cost $20-25 million. The reactor is expected to be in full operation for research from 1965.

ESSOR, a specific test reactor, will be able to be used for the study of a wide range of heavy water reactors, in particular those of the ORGEL type, using natural uranium as fuel, organic liquids as coolants and heavy water as moderators. This reactor string, hitherto the object of little study, is one of the main subjects of the Euratom research programme: $57 million has been allocated to the ORGEL programme under the 1963-67 research programme.

Euratom to conclude fusion research contract with German Jülich Centre

The Euratom Commission has decided to conclude a large-scale association contract with the Jülich (North Rhine-Westphalia) Nuclear Research Centre, for a three-year controlled nuclear fusion research programme as from 1 October, 1962. Euratom will contribute 40% of the total cost of this project. The Jülich Plasma Physics Institute, which at present has 118 research staff (30 university graduates) has been at work since 1956 on the production of high-temperature plasma compression in magnetic pinch of varying configurations. This association contract, with the additional funds available, will permit the expansion of this work. The contract will take the form of a genuine co-operative effort, the two parties jointly directing the research work and jointly providing the research teams.
The Jülich Research Centre will participate in the activities of the Euratom Liaison Group in the field of controlled nuclear fusion. This Group, which consists of representatives from Euratom and other organisations and enterprises, makes periodical assessments of the advances made and the results achieved in the various tasks performed under contracts concluded or to be concluded by Euratom.

This new association is part of an overall programme of Community research into thermonuclear phenomena. As far back as 1959, a first three-year contract of association was signed between the Euratom Commission and the French Atomic Energy Commission (CEA), whose laboratories at Fontenay-aux-Roses now have a team of a hundred research workers (about 60 French and 40 from the other member countries of the Community). This European group's work is focussed on magnetic-mirror devices. A second contract, tying up with the first, was concluded in 1960 with the Italian Atomic Energy Commission (CNEN), whose Frascati laboratories are undertaking experiments based on the theta pinch method. In 1961, a third contract was signed with the new German laboratory at Garching, near Munich, which was set up on the initiative of the Max-Planck Institute in Munich and which is also working on theta-pinch devices. Earlier this year, Euratom entered into an association with the Dutch FOM (Foundation for Fundamental Research on Matter) at Jutphaas, near Utrecht, for other studies on plasma stabilisation problems, while its association with the CEA was extended for a further three-year period.