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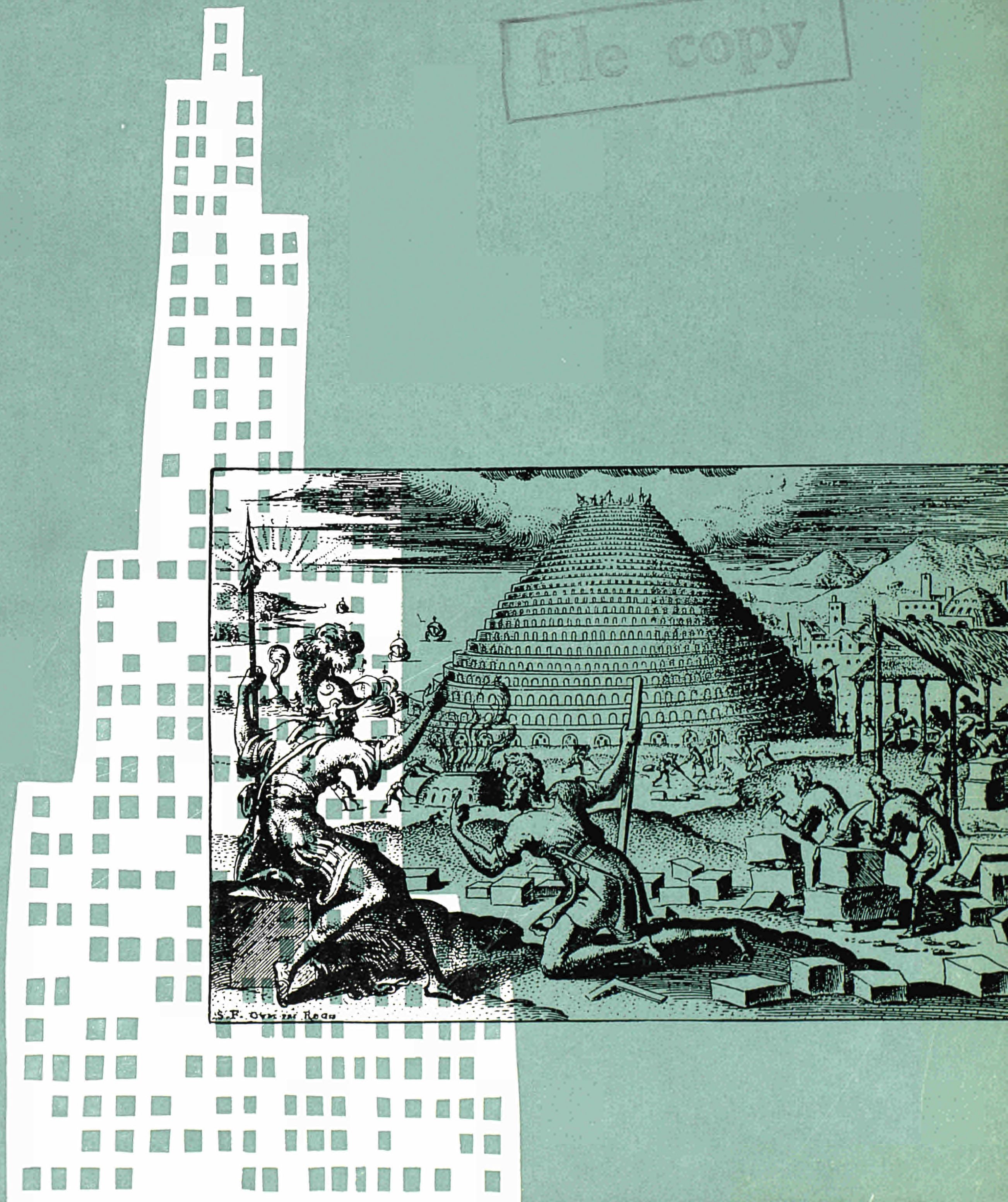

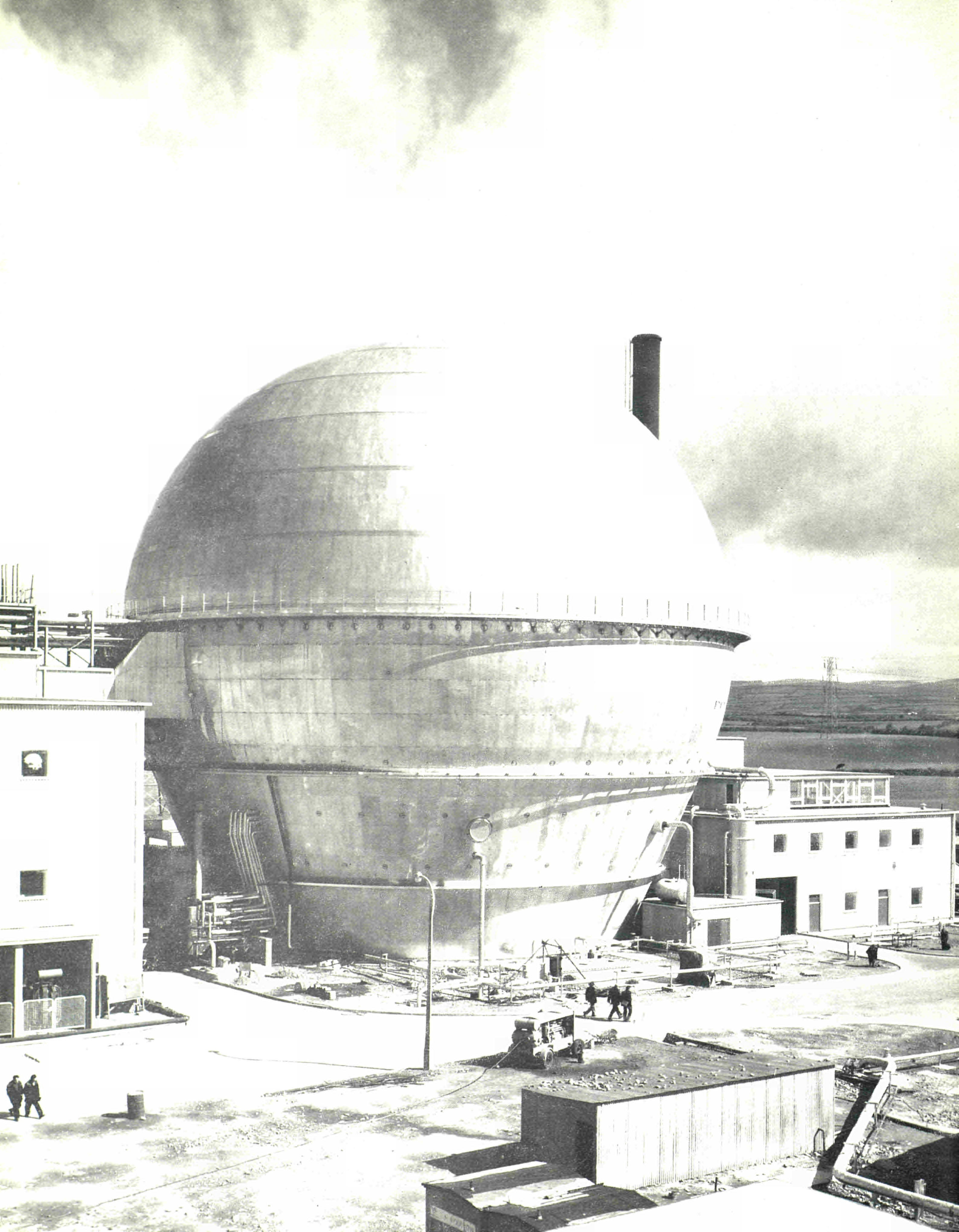

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1965-4

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It is both an honour and a pleasure for us to present in this issue of Euratom Bulletin an article by Sir William Penney, Chairman of the United Kingdom Atomic Energy Authority.

A year ago exactly, we launched a series of articles devoted to the nuclear programmes of the European Atomic Energy Community's Member States. Although Sir William's article cannot strictly speaking be considered as part of it, since the United Kingdom is not a Member State of Euratom, there can be no doubt that in spirit it holds a place in this series.

There are two main links between the United Kingdom and the European Community in the field of nuclear energy. One is afforded by the O.E.C.D. Dragon project, in which both are major partners, and the other by an Agreement for co-operation, signed in 1959, covering a wide range of exchanges.

Some three years ago, negotiations over the United Kingdom's entry into the European Atomic Energy Community were under way and it was assumed by all that they would succeed. However, the failure early in 1963 of the negotiations over the United Kingdom's entry into the Common Market, which had been proceeding at the same time, entailed that the Euratom negotiations had to be broken off.

Far from weakening the links between the United Kingdom and Euratom, this event gave renewed significance to the 1959 Agreement and led to a gradual expansion of the areas of co-operation.

The arrangements which are being made at the moment to extend the Agreement to exchanges of information on fast reactor physics are evidence that this process is still continuing. Our sincere hope is therefore that the future will reserve opportunities for ever closer contacts.

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

EUBU 4—15

The British atomic programme

SIR WILLIAM PENNEY, *Chairman, United Kingdom Atomic Energy Authority*

The Atomic Energy Authority Act of 1954 recognised the need for a large and concerted effort on the development of nuclear power for civil use. The Act created the U.K.A.E.A. as a body financed by the Government and subject to Ministerial direction, but free of some of the day to day restrictions on a Government Department. The Authority have therefore had considerable freedom in choosing the direction of much of their research and development work on the civil side.

The Atomic Energy Authority have capital assets of some £250m. and the civil research and development programme employs nearly 3,000 graduate and professional engineers and scientists. The cost of this programme is about £50m. a year. Half of this is spent directly on the development of reactors for nuclear power production to meet the requirements of the U.K. electricity generating programme and of export markets. The rest is spent on more general research related to this objective, on isotopes and on fusion research. The Authority is also continuing to examine nuclear reactors of lower power output, including their use for nuclear marine propulsion, although the economic prospects of the present concepts of marine reactors are not good.

The Authority, in addition to its research function, is a major production organisation in the fields of nuclear fuel fabrication and reprocessing, enriched uranium production and radioisotope preparation.

More recently, the Science and Technology Act 1965 has widened the powers of the Authority to conduct research work not in the nuclear field. The intention is to work for the exploitation of skills and hardware developed for or closely associated with nuclear matters. The first task given under this Act by the Minister is the development of desalination techniques, in conjunction with British industry.

The Authority's organisation

The Atomic Energy Authority is constituted as a Board of some 15 Members, of whom about half have full-time executive posts. The organisation comprises several Groups responsible respectively for research, reactors, production, engineering and weapons. The following are the main sites at which our work is carried out:

Harwell (Research Group): Founded in 1946, Harwell is responsible for research work, largely concerned with materials, their properties (particularly nuclear properties) and the effects on them of radiation. Its programme covers nuclear as well as theoretical physics, and physics of the solid state, nuclear chemistry, radiation chemistry and irradiation damage studies, physical metallurgy and certain specialised lines of chemical engineering. Harwell, of course, have a number of reactors and particle accelerators which are the essential tools of their work.

Culham (Research Group): A laboratory near Harwell and Oxford where we are carrying out research into controlled thermonuclear reactions, plasma physics and the feasibility of using nuclear fusion of light isotopes as a source of industrial power in the longer term. The work at Culham is at present aimed at understanding and controlling the many instabilities which prevent magnetic fields from confining extremely hot ions and electrons (i.e. plasma) for more than a relatively brief moment. Culham has also been concerned in aspects of the U.K. space programme including the first stages of a study of the solar corona and the chromosphere.

Aldermaston (Weapons Group): The Weapons Group is, in the main, outside the subject of this article. However, Aldermaston is also doing substantial research and development work in aid of the civil programme.

Risley (Production Group): Risley in Lancashire is the Headquarters for our Production Group which directs the operation of our factories:—at *Springfields* for the manufacture of nuclear fuel for the electricity power stations; at *Windscale* the Chemical Separation Plant for the reprocessing of irradiated fuel from the Authority's power and research reactors, from the U.K. nuclear power programme and from various types of reactors in other countries; at *Capenhurst* where the gaseous diffusion plant for the enrichment of uranium is situated. The Group also manages the two power-producing nuclear stations of *Calder Hall* and *Chapelcross*. This Group conducts large commercial operations with sales of the order of £ 30 million a year, mainly of fuel elements from Springfields but including the sale of electricity from Calder Hall and Chapelcross.

Also at Risley are the Headquarters of the Engineering Group, responsible for the design and construction of our complicated and sophisticated plant and for some work for other organisations, and of the Reactor

U.K.A.E.A. establishments

- *Research Group*
- *Production Group*
- *Weapons Group*
- *Reactor Group*
- *Engineering Group*
- *Other establishments*

C.E.G.B. and S.S.E.B.

- *Nuclear power stations*

Group, who are primarily responsible for the design and development of new types of power reactors. The Reactor Group operates four R. & D. laboratories (at *Windscale*, *Springfields*, *Risley* and *Culcheth* near Risley) and two sites where reactor experiments take place—*Winfrith* in Dorset and *Dounreay* on the north coast of Scotland. More will be said about reactor development later in this article.

Amersham: The Radiochemical Centre sells and distributes isotopes and now does considerable business of nearly £2m. a year. Over half of Amersham's output is exported: recently the Centre has notably extended its range of labelled compounds.

High energy physics

An important element in the national facilities for research in high energy elementary particle physics is the *Rutherford High Energy Laboratory*, one of the establishments of the newly formed Science Research Council. Established on a site adjacent to Harwell it is used mainly by scientists from British Universities.

Work at the Laboratory is centred on the use of two proton accelerators—a 7 GeV synchrotron, *NIMROD*, and a 50 MeV proton linear accelerator (*P.L.A.*).

Operation of the *P.L.A.* began in 1959 and 50 nuclear physicists now use the machine. *NIMROD* has been in use for high energy physics since February, 1964 and about 120 physicists are involved in the experimental programme. The full range of techniques which are needed to investigate the properties of fundamental particles is found in this Laboratory. Bubble chamber experiments have recently begun, using an 80 centimetre hydrogen chamber, on loan from the Saclay Laboratory near Paris.

Eventually three large chambers (a 1.5 metre hydrogen, a 1.4 metre heavy liquid and an 80 centimetre helium) will be used with *NIMROD*.

A further large high energy project in the U.K. is that for a 4 GeV electron synchrotron, *NINA*, at Daresbury in Cheshire, not far from Risley.

The U.K. nuclear power programme

The electricity generating stations of the U.K.'s industrial nuclear power programme are owned and operated by the national electricity boards of the country and are built by British industry.

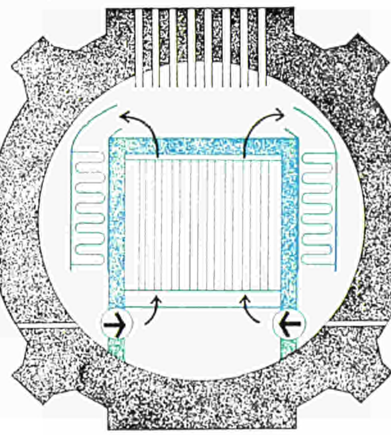
The relationship between the Authority and industry was defined in 1955 as one of close partnership. In order to ensure the maximum practicable use of existing facilities, research and development would be the responsibility of the Authority, who would place contracts with industry in suitable circumstances, while industry would be responsible, with appropriate support from the Authority, for the commercial exploitation of the results of the Authority's nuclear research and development programme.

The Authority have encouraged the growth of a strong nuclear engineering industry capable of putting the results of the Authority's research and development work to good use. The Generating Boards, the Authority and industry work in close association on the development and construction of prototype power reactors. The Authority also makes design studies, in collaboration with industry, on concepts of full-scale power stations, thus giving industry an early opportunity of applying the developing techniques to the best economic advantage. The nuclear consortia of private industrial firms have as a result successfully collaborated with the electricity generating boards in the United Kingdom and with the Authority in establishing the largest national nuclear power investment in the world. The first phase of the national nuclear power programme consists of the construction and commissioning of 5,000 MW of nuclear power by 1969—all magnox stations, based on the design of the Authority's Calder Hall and Chapelcross stations which were the prototypes. The programme consists of nine stations: Hunterston in Scotland; two in North Wales and the remainder in the South of England. There are good reasons for this distribution: coal stations are at their cheapest when situated near the coalfields, and nuclear stations therefore are of most advantage in areas which are furthest from coalfields but near to large load centres.

Table 1 shows the capital costs and the design performance for each station.

You will see that as the programme pro-

Figure 1: Vertical cross-section of an A.G.R. *Dungeness 'B' type of station*



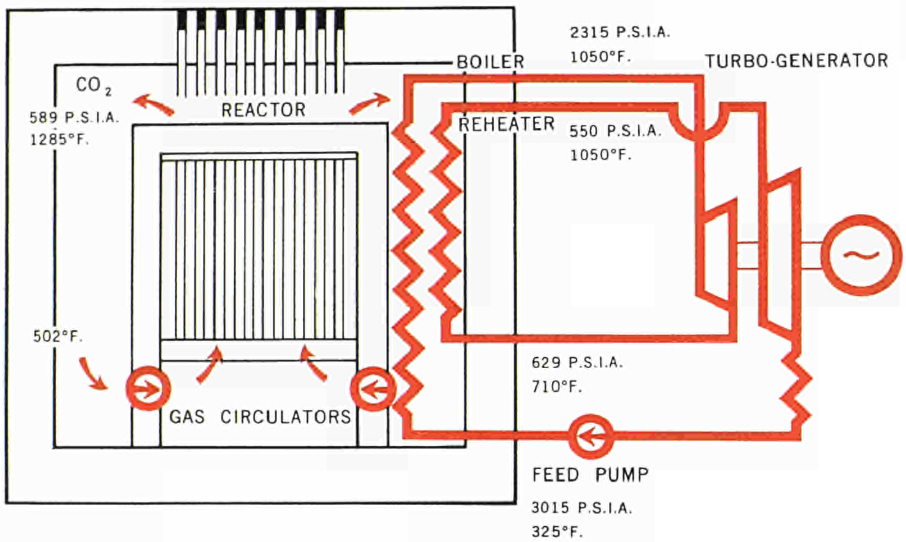


Figure 2: Temperature and steam conditions of a 600 MWe A.G.R. reactor

gressed there has been a very big increase in size of stations. Each of these stations has twin reactors. The first two at Bradwell and Berkeley have reactors of 150 MW or less; the last at Wylfa consists of 2×590 MW reactors. The last column shows the fall in capital costs per kW of the stations. These falls are in part due to the effect of increases in size; and in part, as can be seen from the costs of the middle group of stations, as the result of improvements in design. The 4th and 5th columns show improvements in performance, with thermal efficiency rising from around 24% for Berkeley to over 33% for Oldbury, and in fuel rating (which gives the electrical output for each tonne of uranium) rising from 0.6 MWe to over 1.0 MWe per tonne of uranium.

Already five of these stations are on power and two more are now loading. The U.K. nuclear stations have already generated over 36,000 million units and by the end of this year there will be over 3,000 MWe on power. The early stations, Bradwell and Berkeley, have now been on power for three years and the reactors have performed satisfactorily with high availabilities; over the six months' period December to May covering last winter these stations had load factors of over 90%. The Scottish station Hunterston came on power early in 1964 and appears to be capable of generating at perhaps 25% above its design output.

Magnox stations have also been constructed by British industry in Italy and Japan.

With the first 5,000 MW programme now well under way, the Authority's role in the magnox programme is now limited to the manufacture and reprocessing of the fuel. Further improvements in the design and construction of the magnox reactor are now the task of the consortia.

Table 1: Civil magnox stations capital costs and performance data

(a) i.e. Total station cost including tender price, site costs and Generating Board engineering charges.
(b) Under negotiation.
(c) Actual output is above 320 MWe.

Station	Date first reactor on power	Guaranteed output MWe	Thermal efficiency %	Fuel rating MWth/teU	Gas pressure p.s.i.g.	(a) Capital cost £/kW
Berkeley	1962	275	24.4	2.4	125	186
Bradwell	1962	300	28.2	2.3	132	176
Hunterston	1964	300(c)	28.3	2.3	150	—(b)
Hinkley Point	1965	500	26.4	2.55	200	150
Trawsfynydd	1965	500	29.4	2.9	240	137
Dungeness	1965	550	32.9	2.8	268	114
Sizewell	1965	580	30.5	2.96	279	107
Oldbury	1966	600	33.6	2.85	364	108
Wylfa	1968	1180	31.5	3.2	400	100

The reactor development programme

The Authority's work in the last few years has been concentrated on developing more advanced systems. Here again, the Authority work closely with the industrial consortia and with the electricity generating boards. The main aim is to reduce the capital costs.

A.G.R.

In this development work the Authority first sought to exploit further the potential of the gas-cooled graphite-moderated system, building on our experience of the magnox system. This led to the development of the advanced gas-cooled reactor (*A.G.R.*). The *A.G.R.* has CO_2 cooling and graphite moderation. The fuel is slightly enriched uranium oxide canned in stainless steel, as opposed to the uranium metal rods canned in magnesium alloy of the magnox station. The *A.G.R.* prototype, built at the Authority's Windscale establishment, went on power two-and-a-half years ago. Notable features of the *A.G.R.* system are high thermal efficiency, on-load fuelling giving high availability and excellent safety characteristics.

This prototype has worked well with a high availability and electricity generation. It has averaged 85% since it went on power excluding shut-downs for experimental purposes. The fuel has behaved excellently. Its task has been to demonstrate on the actual reactor the technical soundness of the system. The Windscale *A.G.R.* is also a valuable testbed for improved fuel elements developed to achieve better performance (e.g. higher gas temperatures) and lower fabrication costs.

reactor systems of proved design (in practice *B.W.R.* or *P.W.R.*) to be judged on a comparable basis. They received seven tenders; three for *A.G.Rs*, and four for U.S. designs. The detailed and thorough tender assessments carried out by the C.E.G.B., with the Authority's assistance on technical aspects, in the early part of this year showed that the *A.G.R.* tendered by Atomic Power Constructions Ltd. had clear advantages both economically and technically over the other systems, and the contract has been awarded accordingly.

The details and costs of this station were released by the C.E.G.B. in July, 1965 in a full and precise form. The station will have a 41% efficiency. Assuming 20 year life, 75% lifetime average load factor and 7½% discount rate, C.E.G.B. assess the generating cost at 0.457d/u.s.o. This is some 10% below the nearest competing water-moderated system.

a high load factor (above 75%) for many years.

Figure 1 shows a diagram of a Dungeness 'B' type of station with the concrete pressure vessel, which, among other features of the *A.G.R.*, can refer to the full-scale experience of the magnox stations. Amongst the advantages for this are the small size of the reactor leading to less construction costs, and simplicity of construction with little requirement for special equipment. The attractive safety features of the Dungeness 'B' station are also in part due to the use of concrete pressure vessels. These in turn should open up a greater range of sites for future *A.G.R.* stations. Dungeness 'B' will also have on-load refuelling with high availability, will meet standard conventional steam conditions and will use completely standard turbines and associated equipment.

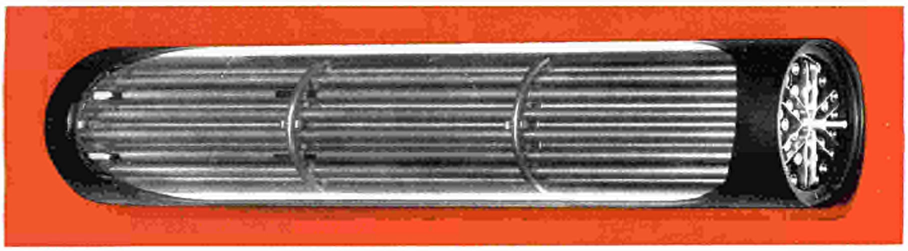


Figure 3: A cutaway model of a 36 pin A.G.R. *fuel assembly*

Our hopes for the *A.G.R.* were confirmed in mid-1965 when the Central Electricity Generating Board placed an order for a 1200 MW power station of this design, comprising 2 × 600 MW reactors each linked to a single standard 600 MW turbine, called the Dungeness 'B' station. (Dungeness 'A' is a magnox station—see Table 1).

In 1964 the British Government announced in a White Paper that, all the stations of the first 5000 MW power programme having been ordered, there should be a second nuclear power programme of stations to be commissioned in the period 1970-75. For planning purposes this was put at 5000 MW, with the possibility of subsequent review. Under the terms of the White Paper, the Central Electricity Generating Board in 1964 invited tenders for an *A.G.R.* station and indicated their readiness to consider also tenders from British industry for water

If less conservative assumptions are made, the *A.G.R.* generating costs are still further improved. With a 30 year life and 75% load factor they fall to just over 0.41d/u.s.o. With 30 year life and 85% load factor, they become just under 0.38d/u.s.o. The C.E.G.B's tender assessment also referred to the particularly good development potential of the *A.G.R.* It was estimated that the reduction in total generating costs below those of Dungeness 'B' which might be achieved within a five-year period is about 20%.

Thus, with the *A.G.R.*, nuclear power in the U.K. is now established as cheaper than conventional methods of generation for stations operating at high load factors. In the U.K., with our integrated generating systems, nuclear stations will, even with a large nuclear programme, be able to enjoy

Now that the *A.G.R.* has proved itself for the power programme, the Authority will be concerned in consultation and advice on the construction of the industrial power stations, and in continued development particularly of the fuel to improve both performance and economics.

S.G.H.W.

The Authority have always maintained an active interest in water reactor systems. After careful consideration of the possibilities we decided a few years ago to select for major development the *Steam Generating Heavy Water Reactor*. We are at present building a prototype *S.G.H.W.R.* of 100 MWe output at Winfrith, to be commissioned in 1967 and on power in 1968.

The *S.G.H.W.* is an advanced boiling water reactor of pressure tube construction (similar to the Canadian *Candu*, except that the tubes are vertical, not unlike the U.S. pressure-vessel *B.W.Rs*) with facilities for the development of nuclear superheat. The light water boiling or superheating takes place in the fuel channel pressure tubes. Moderation is effected partly by the heavy water in the tank surrounding the pressure tubes and partly by the light water coolant. The fuel is in the form of long clusters of pins containing ceramic uranium dioxide pellets. The canning material is Zircaloy for the boiling channel fuel and stainless steel for the superheat fuel.
The *S.G.H.W.* fuel could be low-enrichment UO_2, natural uranium dioxide or metal or natural uranium dioxide enriched with plutonium. There are thus several possible routes to select. The design also offers the promise of combining low enrichment requirements, low capital costs and low generating costs. These advantages are likely to apply over a wide range of station outputs.

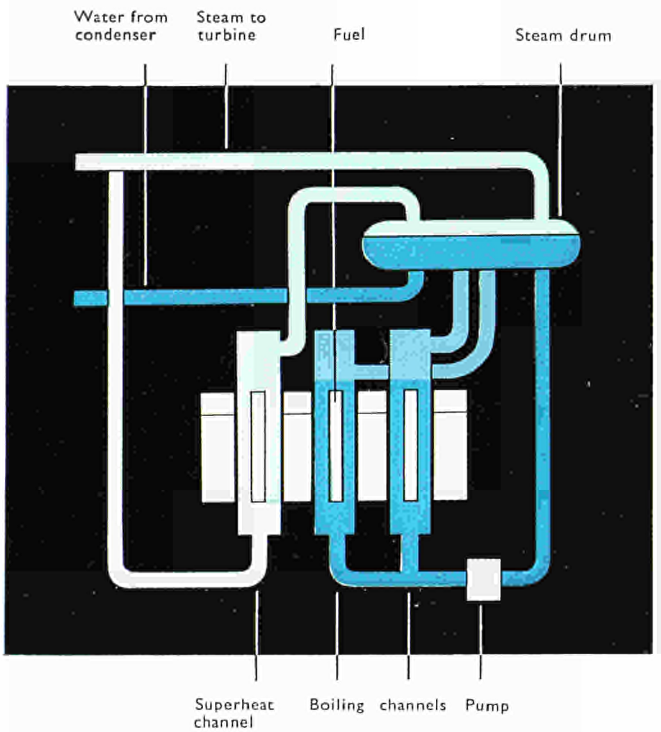


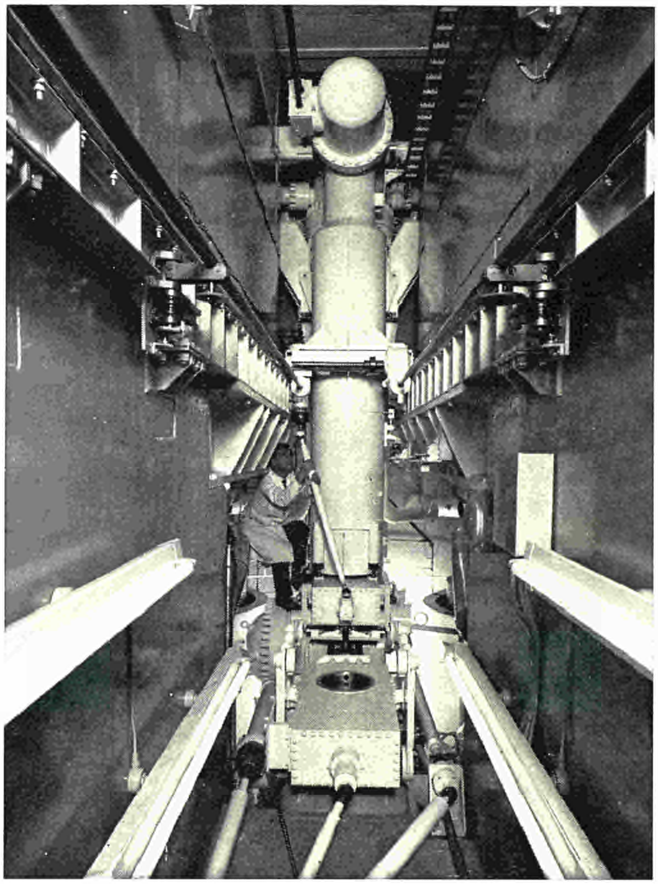
Figure 4: Flow diagram of the Steam Generating Heavy Water Reactor

Dragon

A reactor system in which the Authority has a shared interest with other Western European countries is the *High Temperature Gas-cooled Reactor*.
The 20 MWth *Dragon* reactor became critical a year ago. Although built on British soil at the Authority's Winfrith establishment, *Dragon* is a European Nuclear Energy Agency project in which Britain is a partner with the six Euratom countries and with Austria, Denmark, Norway, Sweden and Switzerland. The objective of the *Dragon* Project is to provide the participants with information and experience to enable this reactor concept to be assessed for large competitive nuclear power plants.
This is a very advanced system and we do not yet know its exact economic prospects, but—as stated in the Project's sixth annual report—it is thought that the most appropriate size for a *Dragon*-type power plant would be based on a 500-600 MWe reactor unit in a pre-stressed concrete pressure vessel. This system could well be the culminating point of the development of gas-graphite reactors which has been pursued with such success in both Britain and Europe. It is still an open question how large a place we can see for the *H.T.R.* in the power programme of the U.K. When the *Dragon* reactor has operated at full power for a year or so it should be easier to make forecasts of the future of the *H.T.R.*

Fast reactor

Finally I come to the fast reactor on which the largest single part of our development effort is now concentrated. This promises to be the most economic system because of the hope it offers from the costs angle, and because of its breeding characteristics. The fast reactor is the best user of plutonium as a fuel. During the 1970's increasing supplies of plutonium will become available from the magnox and *A.G.R.* stations of the U.K's electricity programmes. By using this as a fuel the fast reactor should help to improve the economics of the whole British nuclear power programme. In the long run an even more important aspect of the fast reactor will be its potentiality for breeding more plutonium than it consumes. Ultimately this could enable us to extract 30 or 50 times more energy from uranium than would otherwise be possible, which should remove any fear of the growth of nuclear power being restricted by the economics of uranium supplies. It is interesting to note that with such nuclear fuel conservation reasons in mind several other leading industrial countries, e.g. the U.S.A., Russia, France and Germany are all working energetically on fast reactors.
The Authority have a growing confidence that the fast reactor offers promise of lower power costs as well as much improved utilisation of natural uranium. Our work has convinced us that fast reactors can operate at substantially lower fuel costs than any other system. The capital costs, by the time that the Generating Boards are ready to build commercial fast reactor stations, should be similar to those of advanced thermal neutron stations built at the same period.
Our experimental 60 MWth fast reactor at Dounreay has operated at full power for long periods since July 1963 and supplies electricity to the grid. It is the first fast reactor to have produced electricity for



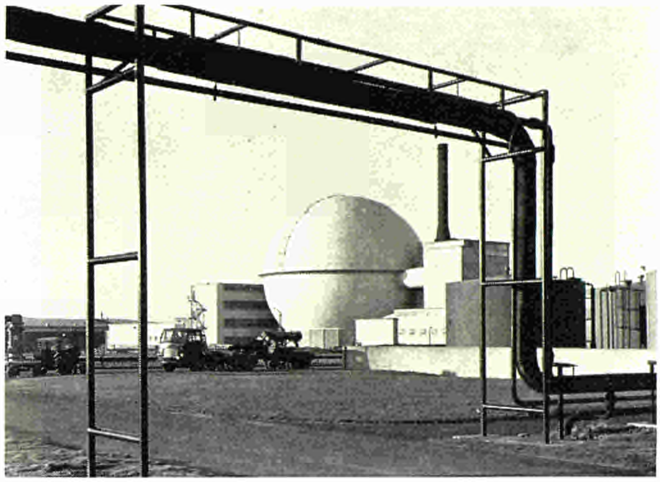


Figure 6: The Fast Reactor Experiment, Dounreay, Caithness. The Fast Reactor Experiment at Dounreay attained its full power of 60 MWth in July 1963 and since then has been used primarily as an irradiation test facility for future fast reactors, though it is generating about 15 MW of electricity, some of which is fed to the grid.

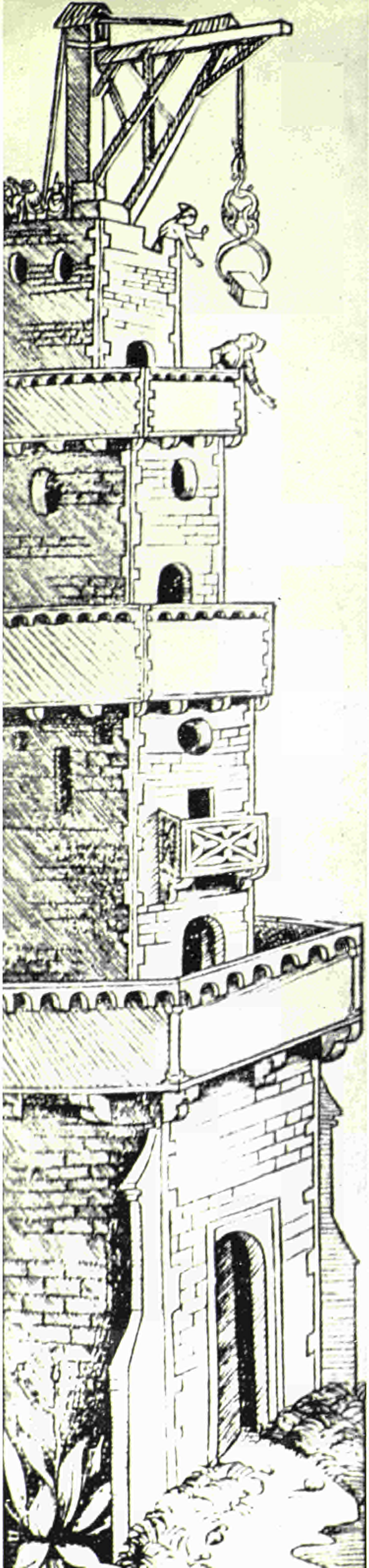
Figure 5: Fuel element transfer flask in the upper loading facility of the O.E.C.D. Dragon *reactor, Winfrith, Dorset, England*

public use and to have operated at such high power levels. It is being used as a test facility and for the development of fuel. We have now decided on the main design features of a much larger prototype power producing reactor and the Authority hopes shortly to submit proposals to the Government for the building of this prototype to come on power around the end of the present decade. This is the next major step towards the installation of commercial fast-reactor power stations of 500 or 1000 MW in the later 1970's.

Conclusion

A large effort and large sums of money are being spent by the United Kingdom in developing economical forms of nuclear power. Several other highly industrialised countries are also now planning to increase very sharply their construction programmes of nuclear power stations. Estimates suggest that there may be between 100,000 and 200,000 MWe installed nuclear power capacity in the Western World by 1980. In the U.K. there is much speculation on the future rate of growth of electricity demand and on the trend in nuclear power programmes by the time that we have completed our second national programme in 1975. I myself am convinced that the U.K. and other developed countries will rather rapidly increase the rate of building nuclear stations. The continuing work I have described above will prove of great benefit in helping to meet future needs for economic power.

I am honoured that I should have been given the opportunity to describe our national effort in the nuclear field in Euratom's official bulletin. Although the United Kingdom is not a member of Euratom, we are partners in the *Dragon Project* and we are enabled to keep in close touch on matters of common interest through the U.K./Euratom Continuing Committee set up under the Agreement for Co-operation signed in February, 1959. All of us, whether members of the Community or not, have much in common where nuclear power is concerned. We are all highly-industrialised densely-populated countries with a rising demand for electric power. We have a common interest in helping each other in this exciting work.



The tower of Babel (15th century woodcut)

EUBU 4—16

Nuclear slang and nuclear terminology

HEINRICH KOWALSKI, *Head of the Terminology Bureau at Euratom, Brussels*

From a lecture given to the International Congress of Translators and Interpreters (CITI), held in Gürzenich Hall, Cologne

Of all the scientists and technologists who have ever walked the earth, more than 90% are living in our own time. All over the world they are assiduously extracting new knowledge and describing new discoveries in such an enormous range of different fields and on such a vast scale that we are justified in speaking of an "information explosion". All these branches of science have their own peculiar vocabulary or specialised jargon.

The time is long past, and probably for ever, when there was a uniform physical or technical, or even a universally intelligible and generally recognised, scientific terminology. In the laboratory, on the test-rig or in a reactor no difficulties arise. The people engaged in these activities are all birds of a feather and if necessary, they can even make themselves understood with slang expressions: e.g. 'a bit more juice!', 'up one notch!', 'back to zero!'. It is only at the next higher level that problems begin to crop up, i.e. in the summarising of results and in the drafting of reports with the object of passing on information, especially when this is intended for the uninitiated, who may be experts working in other fields. For this purpose there is a need for a fixed terminology with clearly-defined concepts and a carefully chosen nomenclature, just as the Eskimos, for example, have a specific ice terminology which contains some 20 designations to distinguish between the various kinds of ice.

From Confucius to Hertz

The terminology problem in the widest sense has been with us since time immemorial. We need only think of the tower of Babel or of Confucius who, when asked 2,400 years ago what he would do first of all if he had to rule the country, replied:

"I should first improve the use of language. If the language is not used correctly, then that which is said fails to reflect the speaker's meaning. Art and morality cannot thrive, justice is not done and the people do not know which way to turn. Let us therefore tolerate no arbitrariness in words."

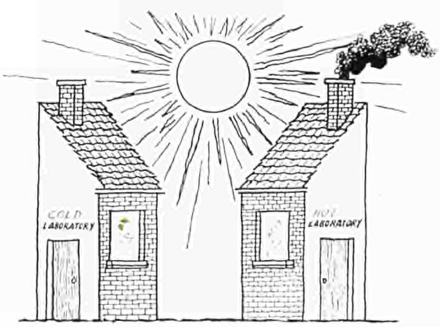
In our labours in the field of terminology we are concerned primarily with solving the problems of technical language in everyday practice and with clearing a frequently impenetrable linguistic jungle, in which laboratory slang is hopelessly entangled with technical jargon, and legitimate scientific terms with the parlance of popular science. Our object is to help establish a technical terminology which,

— is sufficiently correct to serve as a medium of communication;
— wherever possible assigns a particular designation to a particular concept and vice versa;
— is practical and clear—or as Wilhelm Grimm said: "sensuous and evocative" (otherwise it will not survive);
— and is so constituted that it does not unduly offend the purist (a requirement which, as we know, is almost impossible to fulfil).

Heinrich Hertz, the discoverer of the waves which are named after him, expounded the relationship between the research scientist and the outside world. In this connection he speaks of inner images, of basic notions that we build up from external objects and processes. Our reasoning faculty sets to work on these images and we may possibly draw inferences and even make "predictions": we need only think how Leverrier deduced the existence of the planet Neptune or Yukawa that of mesons, or Einstein the possibility of converting mass into energy; in each case the concept existed in the scientist's mind as a "deductive necessity" before any proof was ascertained.

These inner images and concepts, says Hertz, must therefore be so constituted that the *inescapable deductions* to which they lead always reflect the *inescapable physical consequences* of external phenomena.

Thus to impart information is to evoke the right images and basic responses in the mind of the recipient. And how can this be done if the information vehicle is defective? Language—in this case technical language—is, in the words of R. W. Jumpelt, "the basis of all scientific thought, even though we may be aware of it merely as a means of communication".



Considering the exponential increase in the number of scientists and technologists, and in view of the many specialised fields with all their new and complicated research objectives, apparatus and theories, it may be doubted whether language is at all capable of keeping pace with this sudden development.

E. Wüster wrote: "The complexity and fertility of scientific and technical thinking is such that unregulated natural selection is no longer adequate for the establishment of a uniform and efficient linguistic usage".

For this purpose a high degree of standardisation is necessary: language must be frozen, as it were, in order that words may not take on different meanings from one moment to another and from place to place.

Danger: linguistic contamination!

In future, when you hear somebody using such words as *hot*, *black*, *fast* or *bare*, or speaking of *age*, *dollars* and *cents*, ask him what his profession is. If he is a nuclear engineer he will mean by *hot* either "excited" (e.g. a hot atom) or "radioactive" (e.g. a hot laboratory). To him a *black* body could easily be white or red, since by black he means opaque to certain radiations. A *fast*, *bare* reactor usually has no velocity at all, that is to say it is stationary, but the neutrons causing nuclear fission in its fission zone possess an extremely high energy, which in this case is synonymous with fast, and *bare* denotes that it is not surrounded by a reflector. The *age* of neutrons is given not in years but in units of surface: you may perhaps remember that a light-year, too, is not what it seems, i.e. a unit of time, but a measure of astronomical distance. Finally, *dollars* and *cents* may, of course, refer to money but in this context it is more likely that reactivity is meant.

These terms are not rare specimens of "contaminated laboratory slang"; they have become established in standard scientific language, appear in specialist literature and are used both in research centres and at conferences. In this case, moreover, the situation is comparatively harmless because we are still entirely within the sector of nuclear technology. It deteriorates when a number of scientific and technical disciplines are involved and becomes really complex when, in addition, the subject matter is in several languages, and has to be translated or interpreted. It is a case of the devil take the hindmost, and this is the extremely challenging terminological situation which prevails, for example, in the Linguistic Division at Euratom, which every year has to translate some 50,000 pages of mainly scientific and technical texts from the entire range of developments connected with nuclear energy—a field the scope of which is barely hinted at by the subjects dealt with in *Euratom Bulletin*.

Furthermore, the translations must not only be accurate and readable but must also smack of authenticity. To the terminological difficulties and ambiguities of one's own native tongue which I have already outlined, are now added those of other languages. Moreover, scientists of different countries often look at the same problem from totally different points of view, so a translation in the true sense is impossible.

On the boiling of water

Let me give a seemingly simple example—*the boiling of water*. Nothing could be easier, you may think. For when the vapour pressure of the water reaches the external pressure the water starts to boil, at a temperature, as we all know, of 100 degrees Centigrade at atmospheric pressure.

If, however, you pour water on to a hot-plate which has been heated to several hundred degrees, you will be surprised to find that although part of the water rapidly evaporates in the normal way, some of it gathers into separate drops which continue to roll about wildly for quite a while without boiling. The solution of the puzzle is this: between the hot-plate and the water drops a protective cushion of vapour is

formed which considerably reduces the further transfer of heat. This phenomenon is known as the "spheroidal state" (German: *Leidenfrost'sches Phänomen*; French: *caléfaction*).
Incidentally, in the Middle Ages some of the unfortunate women who were made to walk over red-hot coals in trials for witchcraft were saved from burning their feet severely by this vapour film. From the present-day standpoint this gruesome test was based on false premises insofar as it could tell us more about the relationship between the perspiration rate and combustion temperature of human feet than about the necromantic proclivities of the ladies concerned.

In the hot zone of a water-cooled reactor this phenomenon can be dangerous. The great quantities of heat evolved as a result of nuclear fission processes in the atomic fuel must be evacuated from the fuel-element walls. However, the untimely formation of such a vapour film at certain points causes an accumulation of heat and the wall becomes so severely overheated locally that destruction of the heating surface may occur; this is known as *burn-out* (German: *Durchbrennen*; French: *brûlage*).
As is so often the case, these conditions can best be illustrated by means of a graph, the so-called *Nukiyama curve*. But it is also necessary to describe them in words—and here is where the trouble starts: in Germany the basis is usually taken as *the thermal load on the heating surface (Wärmebelastung der Heizfläche)*, whereas in France it is the *vapour film effect*, and in Britain and the U.S.A. the *theoretical boiling curve;* consequently, one and the same quantity, namely the thermal flux at which burn-out occurs is termed respectively *kritische Heizflächenbelastung*, *flux de caléfaction* and *DNB-flux*, in which connection it is also necessary to know that *DNB* stands for *departure from nucleate boiling*, that is to say the transition from bubble- to film-boiling.
There are about a dozen more confusing terms for this; they are all the more confusing because they are frequently used indiscriminately to denote both the *phenomenon* itself and the *physical value*, as is the case, for example, with radioactivity: strictly speaking, *radioactivity* refers only to the phenomenon, while the correct term for the corresponding physical value is *activity*.

The jungle of nuclear terminology

In such cases, as in a thousand and one others, even good technical dictionaries are of no help; the only solution is to compare appropriate technical publications in the original languages. A useful indication will then often be obtained from the physical units in which the quantity is expressed, i.e. what appears in square brackets after a figure. An example of this is the word "power" with its various meanings of force, energy, output, etc.; frequently the correct meaning can only be ascertained from the units quoted.
The energy released per unit of mass by nuclear fuel is called *burn-up* in English and *Abbrand* in German. The French exasperated us for some time with such expressions as *taux d'irradiation*, *taux d'épuisement*, *combustion massique*, *durée d'irradiation* and *niveau d'intégrité* until it turned out that all these terms referred to the number of megawatt-days per tonne, i.e. they always meant "burn-up".
Nuclear engineers are fond of using elliptical forms on the pattern of "longhaired dogowners", especially in reactor designations—a practice of American origin. Thus besides the previously mentioned *fast reactor*—or, more correctly, fast-neutron reactor—we have the *thermal breeder* which operates with thermal neutrons and produces, or "breeds" more fuel than it consumes (although it is by no means an example of perpetual motion!), the *enriched converter reactor* in which enriched fuel is present, and so on. One can therefore

sympathise with the interpreter who, to the astonishment of the assembled experts, spoke of a *tail reactor (Schwanzreaktor)*. In point of fact the term that had been used was not, as he thought, *réacteur à queue* but *réacteur aqueux*, that is to say a reactor in which the fuel takes the form of an aqueous solution.
In some languages use is often made of metaphorical designations which have to be paraphrased, since a literal translation would sound either unduly morbid or somewhat comical: to quote some examples from English, *mortuary facilities* are *equipment for the handling of radioactive waste*, a *coffin* is a *transport container*, and a *burial ground* or *graveyard* is a *storage site*.
The English term "*rabbit*" which denotes a small pneumatically or hydraulically propelled container used in a reactor, becomes *furet* (i.e. ferret) in French and *Rohrpostbüchse* (one of the gadgets used in department stores which push money about through tubes) in German. The apparatus known as "cutie pie", which was thus christened by its American inventor in honour of his wife, whom he used to call by that name, can unfortunately not receive such an affectionate designation in other languages; the translator will have to keep his feet to the ground and render the equivalent of "portable radiation monitor".
Even such apparently innocuous words as "*fissionable*" and "*fissile*" must be treated with caution, since, strictly speaking, the former means capable of undergoing fission in the general nuclear sense, whereas the latter refers to material in which fission can be produced by thermal neutrons; in German these terms are properly rendered by *spaltbar* and *thermisch spaltbar* respectively.
French, too, gives us many a hard nut to crack: for instance, it is not always easy to ascertain whether by "*diffusion*" a Frenchman means *diffusion* or *scatter* or *propagation*.
For a time we were puzzled by the expression "*les zones périphériques dégavées d'un réacteur*", and it was only by wading through the proceedings of the Geneva Conference that we found the answer to the riddle. At first sight "gaver" and "gavage" will no doubt suggest to you—as it did to us—the practice of cramming, or forced feeding, e.g. of geese; here, however, it means in the peripheral zones of a reactor core the fuel is less tightly "crammed" i.e. less highly

enriched than in the central zone.
The term "*vache à radio-éléments*" refers not to a cow that yields radioelements instead of milk, but to a so-called "milking" system consisting of a column with a tap at the bottom for drawing off radionuclides; and in this connection it would be wise to take a closer look at the confusion frequently encountered in the use of the words *element*, *isotope* and *nuclide*.

Nomen est omen

To conclude this chapter of examples I should like to mention a not uninteresting trend that is discernible in some countries as regards the naming of nuclear installations. Abbreviated names which may seem quite arbitrary very often have a logic of their own and convey more information than would appear at first sight, and it can doubtless be assumed that, like so many other apparently fantastic designations, they are based on mnemonic principles.
For instance, there is a sodium-cooled fast reactor in France called *RAPSODIE*, the name being formed from the first few letters of "*rap*ide" and "*sod*ium" respectively. In the same way a breeder mock-up at Cadarache which is a further development of this type is known as *MASURCA*, the letters in this case standing for "*ma*quette *sur*régénératrice *Ca*darache" and the next stage of development—which is being carried out on a basis of harmonious European collaboration —is called the *HARMONIE* project, because in Greek mythology Harmonia was Europa's sister-in-law.
A zero-power reactor designed by the Argonne Laboratories in the U.S.A., i.e. the Argonne Naught Power Reactor, was dubbed *ARGONAUT*. There are also other members of this reactor family in Britain; like the Argonauts of old, these have crossed the sea and consequently bear such names as *JASON*. To give a further example, *JANUS* is, of course, a reactor with two faces, or, more accurately, two experimentation surfaces, one for low- and one for high-flux irradiations. And if I now tell you that *KIWI* is a reactor which was designed for space research but which—like the New Zealand bird after which it was named —is still incapable of flight, you will easily guess the characteristics of the *GODIVA* reactor. You need only picture Lady Godiva on her legendary ride through the streets of Coventry to conclude that the reactor is bare and fast!

A technician of the HARMONIE *reactor staff*...

Standardisation—or else

Whereas in other fields there is already a high degree of terminological stability, in nuclear science there is still a need for vigorous pruning of the fertile but frequently over-abundant linguistic outgrowth in order to prevent uncontrolled proliferation of terminology in our own language and a Babylonian confusion of tongues among translators and interpreters.
Standardisation must be carried out wherever possible and any term that is ambiguous or superfluous must be eradicated, even though this may mean that many words will become ossified into formulae and many concepts be represented purely by symbols, e.g. α-particle, ν-factor, k-capture.
This task is being tackled at a national level by the Terminology Committees of the official standardisation bodies, whose publications—although for the most part unilingual—are certainly the most reliable documents available. Unfortunately, the work of terminology standardisation progresses comparatively slowly. This is due on the one hand to inherent difficulties of formulation and on the other hand to the fact that for some time now steps have been taken, chiefly through the International Standardisation Organisation (ISO), to achieve international uniformity of terminology, and this, of course, entails further delay.
In this standardisation work the accent for the most part is not so much on purist activity or the coining of the new words—although this too is done—as on the definition of words and expressions in current usage. And this is where opinions frequently differ on opposite sides of the Atlantic; for what is current usage on one side may sound like hideous laboratory slang on the other. However, the discoverer of a new star or a new chemical element has always been privileged to christen his own discovery, and since—in the past at any rate—most of the inventions and developments in nuclear *technology* were of transatlantic origin, we in the Old World must in many cases give way and, whether we like it or not, allow the nuclear inventors to give their "babies" whatever names they choose.
The European Atomic Energy Community with its four official languages, namely French, German, Dutch and Italian, is particularly interested in such attempts to

arrive at a well-defined nuclear terminology, i.e. at an adequate measure of correspondence between the technical vocabularies of the various languages; indeed, as long ago as 1957 the Euratom Treaty expressly stated that one of the tasks of the Community's Joint Nuclear Research Centre should be to "... ensure the establishment of uniform nuclear terminology..."

Consequently it is only natural that at Euratom the terminologist has been working side by side with the translator and the interpreter from the very outset. Since the Terminology Bureau is attached to the Linguistic Division it must also be equipped to answer queries from our own translation sections or from other sources both inside and outside Euratom.

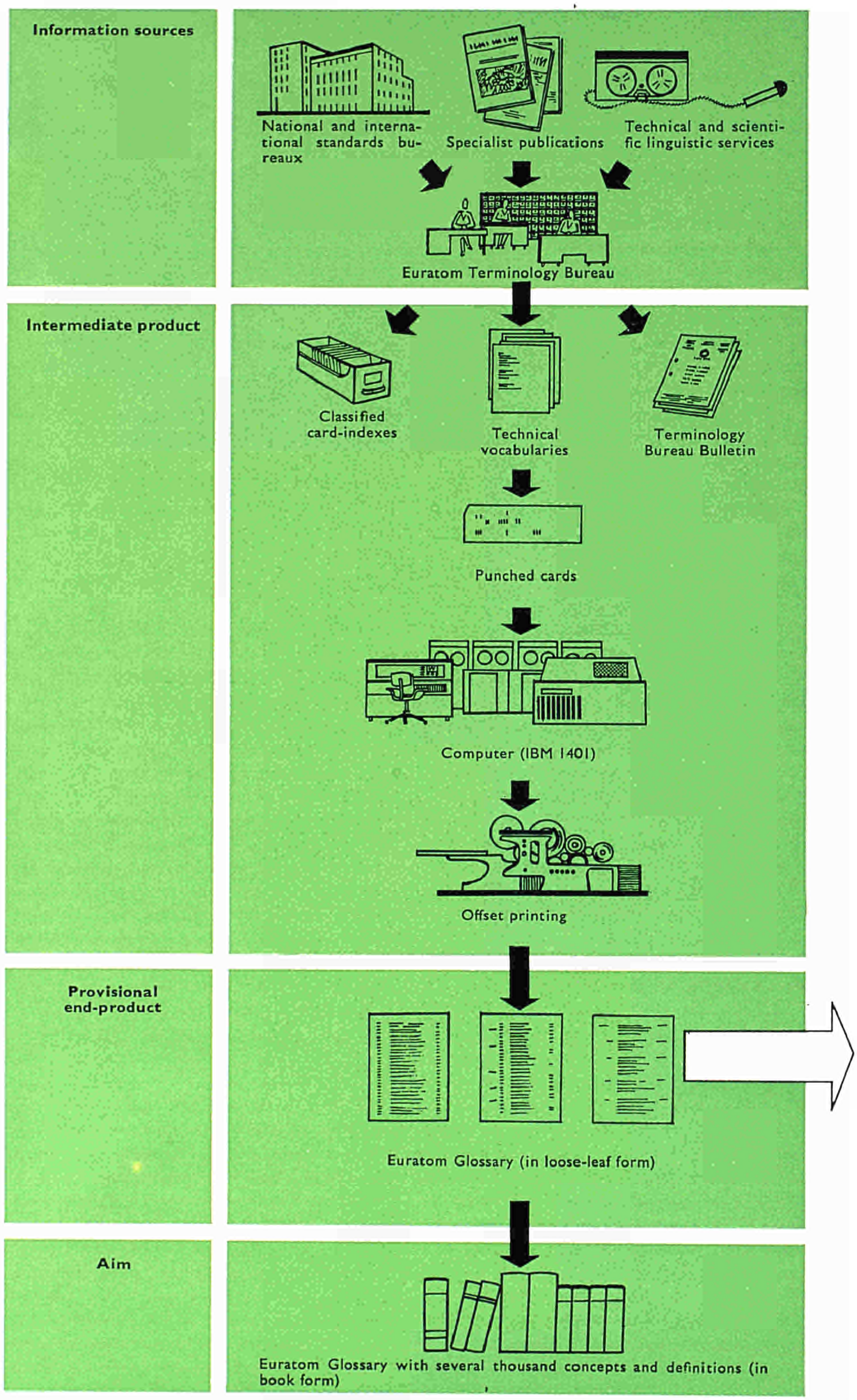
To this end we have compiled a central card-index and built up a specialised library adapted to our specific requirements, in addition to which we have established, either directly or via terminology correspondents, contacts with research centres and other useful sources of terminology.

As far as our terminology work in the strict sense is concerned, I must say at once that there is, of course, no question of setting up in competition with the existing standardisation bodies: in the first place we should not have enough staff to do so, and secondly this would entail the risk of overlapping and duplication of effort. What we can do—and are doing—is, wherever possible, to co-operate actively with the existing national and international standardisation organisations, to submit proposals and express wishes—and to take what steps we can to ensure that the standardised designations are in fact used. Moreover, we consider it a success if in a given case we have managed to persuade the standardisation authority of this or that country that certain concepts should be dealt with as a matter of priority.

First and foremost, therefore, we collect what has been defined in one, or occasionally two languages by the various standardisation authorities working in the fields of particular concern to us, set these definitions side by side in the languages in which we are primarily interested, and see to it that the gaps are filled.

Secondly—and I have already mentioned the inevitable time-lag in the standardisation process—we also endeavour to fix provisional nomenclature for concepts for which no official terminology has yet been established, and for this purpose we

The Euratom Glossary in the making



naturally rely mainly on original publications in the languages concerned.

In this connection the card-indexes compiled by individual translators are another valuable aid, since in order to keep abreast of developments the translators read numerous technical journals and—according to their temperament—evaluate the information they contain.

The results obtained are filed in the previously mentioned *central card-index*. From time to time we also compile smaller technical glossaries on various subjects, for instance on the use of radioisotopes, or on nuclear ship propulsion, or on the basic standards for radiological protection.

A *Terminology Bureau Bulletin*, which at present contains some 25 pages, is issued monthly and serves for the information of the translators and other circles interested in our activities, besides providing a sort of forum for discussion.

The Euratom Glossary

As a long-term objective we have undertaken the compilation of a five-language technical dictionary entitled "*The Euratom Glossary*". We are quite aware of the fact that this will be approximately the 5507th technical dictionary to have appeared since the turn of the century, but R. W. Jumpelt's complaint about the inadequate cataloguing of technical language to date is valid in our field too, and we therefore believe that this project is justified, the more so in view of our own particular needs and the task entrusted to us.

In addition to the four official Community languages the Euratom Glossary also covers English, which in many cases is the working language and *ultima ratio* of scientists and technicians. The Glossary is issued in loose-leaf form in separate unbound instalments of format DIN A4. The first two of these have so far appeared; they contain about 3.000 terms and 400 definitions from nuclear technology, nuclear physics and related subjects. For each term we have given what seemed to us the most reliable source, i.e., wherever possible, publications by standardisation bodies or appropriate technical literature. Terms which are defined in the reference cited are indicated by a cross; useful definitions which are less easily accessible are quoted in full—if possible, in all five languages—in the *definition section* of the Glossary, and the relevant term is then identified by an asterisk in the actual *dictionary section*.

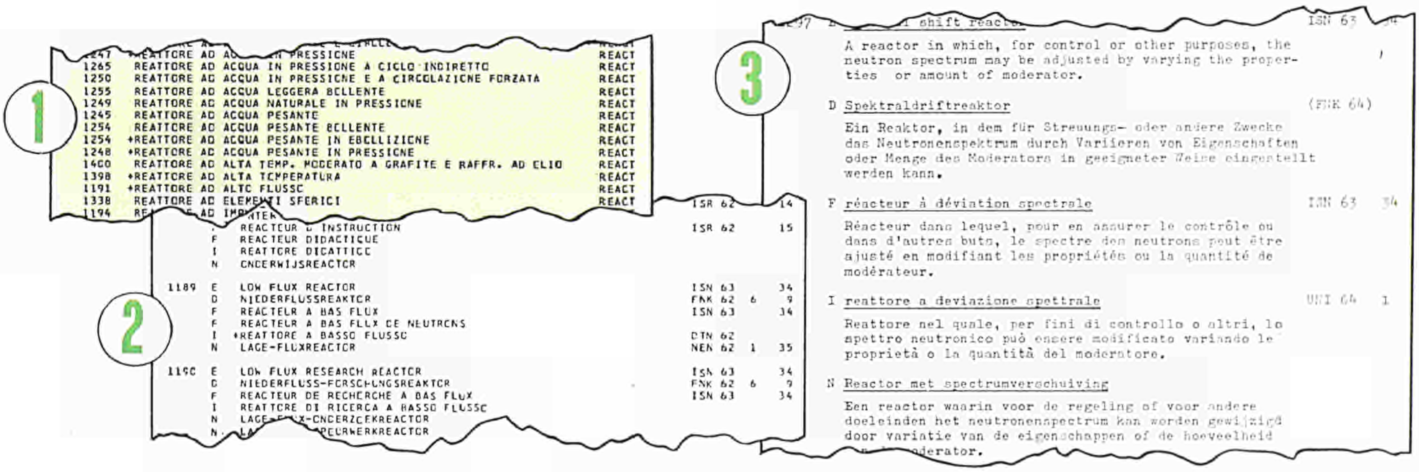
Lexicographical projects are notoriously time-consuming and attended by an excessive amount of drudgery. Think of the alphabetical indexing alone! To cover 1,000 compound terms in five languages, at least 10,000-15,000 entries are necessary. Fortunately, we are aided by a device which some people call an "electronic brain" and others a "mechanical moron with special gifts". The vocabulary is recorded on punch-cards and transferred to the magnetic tapes of an IBM 1401 computer, which then sorts the material and prints the five-language main section and the five alphabetical indexes. The computer programme was drawn up in accordance with our requirements by the Scientific Data Processing Centre (*CETIS*) of the Euratom Joint Nuclear Research Centre at Ispra.

The continuously numbered main section of the Glossary remains unchanged—except insofar as errors may necessitate the replacement of individual pages—and is supplemented from issue to issue. With each new issue—and this is an important point—the machine turns out five entirely new, consolidated indexes which supersede the previous ones.

It will be several years before the Euratom Glossary assumes its final form; in the meantime, however, thanks to the procedure adopted, the translators of the three European Communities can benefit from the various instalments compiled and from the alphabetical indexes, as and when they appear.

Since the number printed is very small, only a few copies can at present be made available to outside parties, and these are confined to establishments which collaborate with the Euratom Terminology Bureau, for example on an information-exchange basis.

Later on, when this Glossary has attained a certain size, it is planned to publish it under the Euratom imprint, and we hope that we shall thereby have made a modest contribution to the harmonisation of nuclear terminology in five languages and to the facilitation of its use, and thus to have fulfilled our obligation under Article 8 of the Treaty of Rome.



1

1247 +REATTORE AD A[illegible] PRESSICNE REACT
1265 REATTORE AD ACQUA IN PRESSIONE A CICLO INDIRETTO REACT
1250 REATTORE AD ACQUA IN PRESSICNE E A CIRCOLAZICNE FORZATA REACT
1255 REATTORE AD ACQUA LEGGERA BOLLENTE REACT
1249 REATTORE AD ACQUA NATURALE IN PRESSICNE REACT
1245 REATTORE AD ACQUA PESANTE REACT
1254 REATTORE AD ACQUA PESANTE BOLLENTE REACT
1254 +REATTORE AD ACQUA PESANTE IN EBOLLIZICNE REACT
1248 +REATTORE AD ACQUA PESANTE IN PRESSICNE REACT
1400 REATTORE AD ALTA TEMP. MODERATO A GRAFITE E RAFFR. AD ELIO REACT
1398 +REATTORE AD ALTA TEMPERATURA REACT
1191 +REATTORE AD ALTO FLUSSO REACT
1338 REATTORE AD ELEMENTI SFERICI REACT
1194 RE[illegible] AD IMP[illegible]

2

[illegible] REACTEUR D INSTRUCTION ISR 62 15
F REACTEUR DIDACTIQUE
I REATTORE DIDATTICO
N CNDERWIJSREACTCR

1189 E LOW FLUX REACTOR ISN 63 34
D NIEDERFLUSSREAKTOR FNK 62 6 9
F REACTEUR A BAS FLUX ISN 63 34
F REACTEUR A BAS FLUX DE NEUTRONS
I +REATTORE A BASSO FLUSSO DIN 62
N LAGE-FLUXREACTOR NEN 62 1 35

1190 E LOW FLUX RESEARCH REACTOR ISN 63 34
D NIEDERFLUSS-FORSCHUNGSREAKTOR FNK 62 6 9
F REACTEUR DE RECHERCHE A BAS FLUX ISN 63 34
I REATTORE DI RICERCA A BASSO FLUSSO
N LAGE-[illegible]X-ONDERZOEKREACTOR
N LA[illegible]PEURWERKREACTOR

3

[illegible]97 E [illegible] shift reactor ISN 63 [illegible]

A reactor in which, for control or other purposes, the neutron spectrum may be adjusted by varying the properties or amount of moderator.

D Spektraldriftreaktor (FNK 64)

Ein Reaktor, in dem für Streuungs- oder andere Zwecke das Neutronenspektrum durch Variieren von Eigenschaften oder Menge des Moderators in geeigneter Weise eingestellt werden kann.

F réacteur à déviation spectrale ISN 63 34

Réacteur dans lequel, pour en assurer le contrôle ou dans d'autres buts, le spectre des neutrons peut être ajusté en modifiant les propriétés ou la quantité de modérateur.

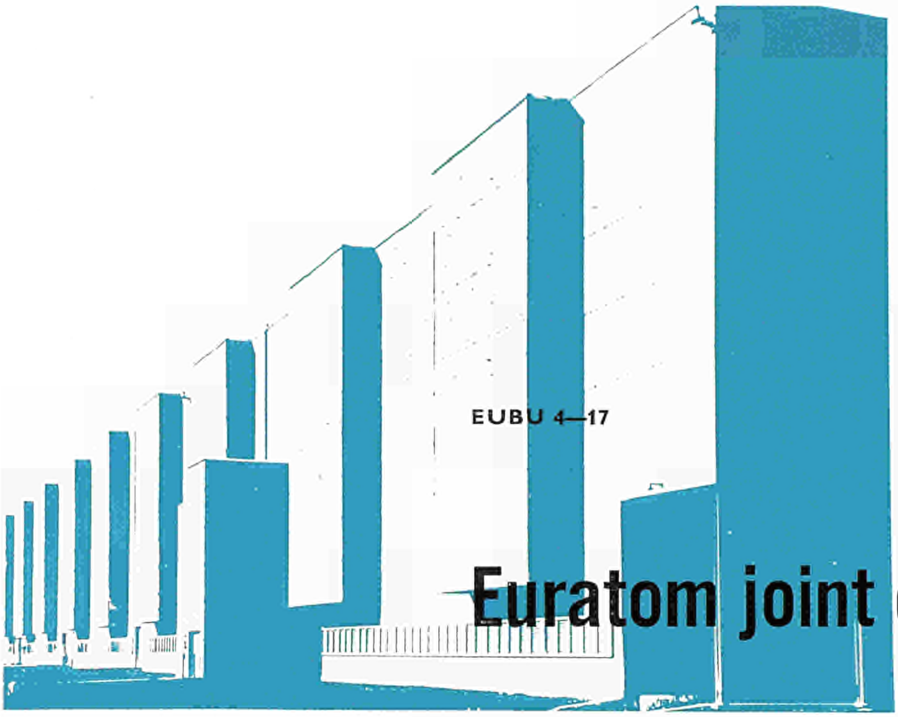
I reattore a deviazione spettrale UNI 64 1

Reattore nel quale, per fini di controllo o altri, lo spettro neutronico può essere modificato variando le proprietà o la quantità del moderatore.

N Reactor met spectrumverschuiving

Een reactor waarin voor de regeling of voor andere doeleinden het neutronenspectrum kan worden gewijzigd door variatie van de eigenschappen of de hoeveelheid [illegible]derator.

The nuclear power plant at Gundremmingen on the Danube. The Kernkraftwerk RWE/ Bayernwerk GmbH (KRB) *received joint enterprise status on 18 June 1963.*



A view of the gaseous diffusion uranium isotope separation plant at Portsmouth, Ohio, U.S.A. According to present estimates, the Community will require enriched uranium to the tune of over 25,000 tonnes (in natural uranium metal equivalent) during the period 1970-1979.

EUBU 4—17

Euratom joint enterprises

HUBERT TOURNÈS, *Directorate-General for Industry and Economy, Euratom*

At a time when a European Community industrial policy on nuclear energy is taking shape, closer attention is being paid to the means which Euratom has at its disposal for the creation of "a powerful nuclear industry". In general, this attention relates to Euratom's power to constitute as joint enterprises those undertakings which are of fundamental importance to the development of nuclear industry in the Community, and to confer substantial advantages on them.

The concept of the European joint enterprise in the nuclear field was born at the same time as the European urge to set up a powerful nuclear industry. It was formulated more or less simultaneously in the Euratom Treaty and in the statutes of the *European Nuclear Energy Agency (ENEA)*. Thus, ever since 1957 a need has been felt for "the emergence of enterprises on a European scale": this need has recently been strongly emphasised by the EEC Commission, among others, and has induced the Commission to press on vigorously with the work aiming at the harmonisation of company law.

It was within the framework of the *ENEA* that the first joint ventures were launched, the most important of these being *Eurochemic*, an international undertaking in which twelve countries participate and in which more than half the capital is owned by Member States and enterprises of the Community. Its object is the chemical reprocessing of irradiated fuel elements.

As far as Euratom is concerned, the authors of the Treaty intended that the joint enterprises should occupy a central position in the construction of a nuclear community. The nuclear common market, common nuclear policies and the joint enterprises can be said to constitute the three bases of such a community.

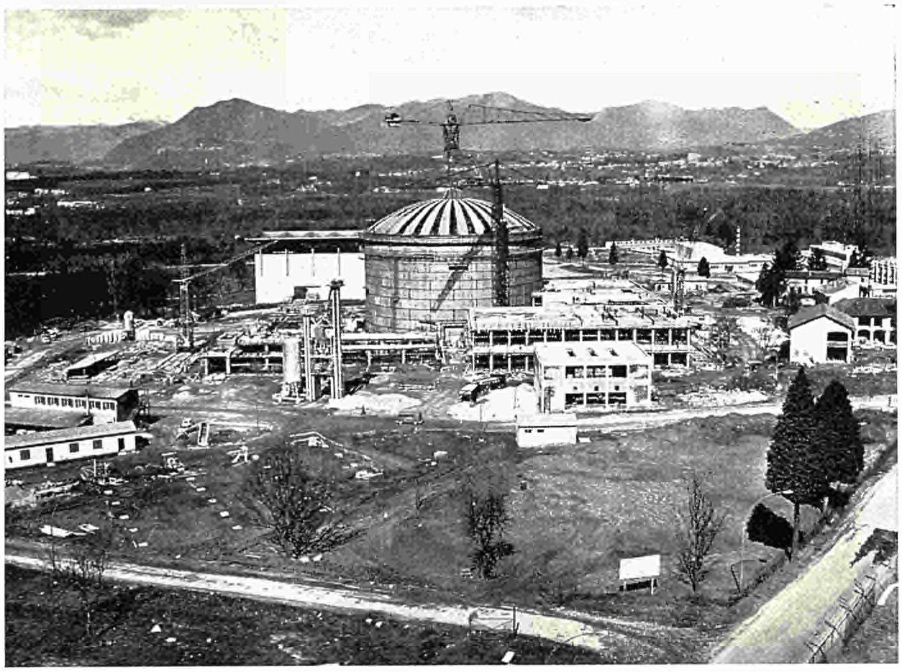
The joint enterprise: instrument of an industrial policy?

Nuclear energy, now within an ace of attaining competitivity with conventional sources of energy, will shortly begin to assert itself. The consequences of this evolution are adumbrated in Euratom's first target programme: 4,000 MW of installed nuclear capacity in 1970, 12,000 MW in 1975, 40,000 MW in 1980. In order to keep pace with this expansion the nuclear industries will have to develop rapidly and immediate consideration must therefore be given to the pertinent question of how the creation of joint enterprises can facilitate their growth.

First of all, what are "joint enterprises" in the sense of the Euratom Treaty?

A European statute

Joint enterprises come into being through a decision of the Council of Ministers by virtue of which they acquire legal personality, that is to say they constitute juridical persons in Community law. Nowhere in the Community do they have alien status: in each of the member states they enjoy the

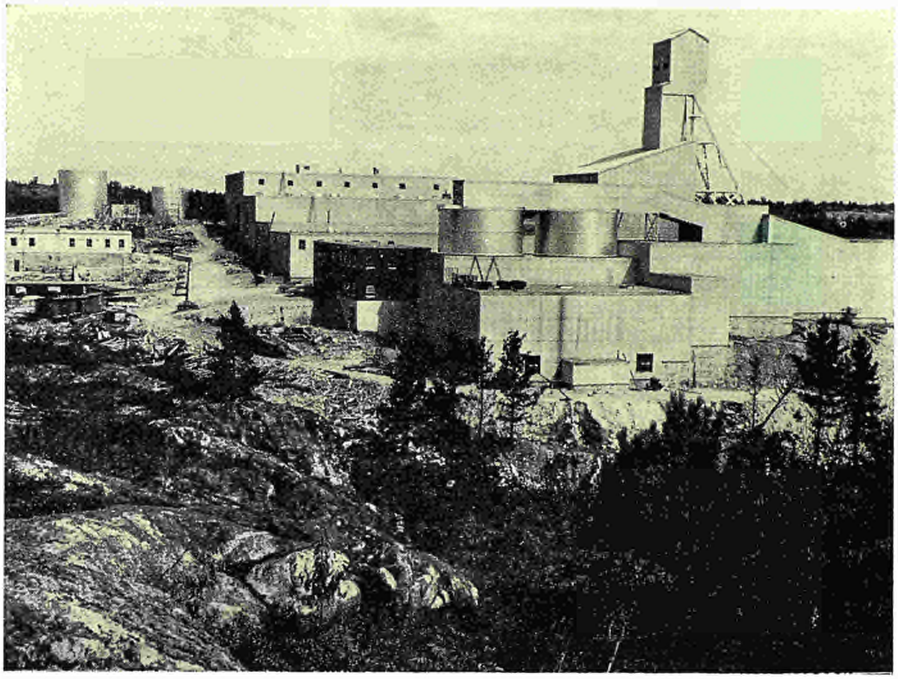


The ESSOR *reactor (ESSai ORgel) under construction at Euratom's Joint Research Centre, Ispra. As the name suggests, this reactor is intended to serve as the test rig for the* ORGEL *reactor string (organic-liquid-cooled and heavy-water-moderated) which belongs to the advanced converter class.*
Two or three advanced converters with capacities of 200 or 300 MWe should come into operation between 1970 and 1974; one of these might be an ORGEL *industrial prototype.*

fullest recognition granted to juridical persons under national law, including the right to call upon the capital market in each member state on the same terms as the juridical persons of that state; in particular, throughout the Community the joint enterprises are entitled to bring civil actions before the courts and to acquire and transfer movable and immovable property.
Joint enterprises are only secondarily, and to be more precise, to the extent laid down by the Council of Ministers, subject to the regulations applying in each Member State to industrial and commercial concerns. Their statutes, which the Council must approve, may therefore contain any original provisions with regard to the organisational setup which is considered necessary. This applies, for example, to a joint enterprise taking the form of a commercial company of a member country, which is the case for the joint enterprises set up to date. Thus it is possible, to visualise joint enterprises possessed of the widest possible diversity of juridical forms, ranging from the commercial company to the corporation under public law. This flexibility makes it possible to cover the wide variety of purposes which may be involved. However, the activities of joint enterprises as well as their relations with third parties, remain in principle subject to the provisions of national law.
Apart from having a utility value in keeping with the extent of the barriers which still exist between the economies of the member countries and to the diversity of national legislation in those countries, joint enterprise status can entail considerable practical benefits, e.g. in the case of undertakings for which an international statute would otherwise have to be drawn up by means of a convention between the states concerned. The Community procedure is an internal one and is consequently much simpler: every joint enterprise project is examined by the Euratom Commission, and it is on the Commission's proposal that the Council of Ministers gives its ruling, in principle by a qualified majority, though on certain points unanimity is required. Thus joint enterprise status constitutes a Community seal and warranty serving to facilitate the recipients' access to the capital market.

The "advantages"

Hitherto the interest of industrialists has been aroused mainly by the "advantages" that can be conferred on joint enterprises.
Among the chief advantages enumerated in Annex III to the Euratom Treaty is "exemption from all direct taxation to which Joint Enterprises and their goods, assets and income would otherwise be liable". The resultant easing of the financial burden obviously varies from one member state to another according to the fiscal regulations in force, which at present differ widely. For instance, exemption from taxation on goods and assets is of interest primarily to German firms, which are subject to a tax on capital. On the other hand, the tax relief is hardly of importance to public undertakings, whose liabilities in respect of capital yield can be much less onerous than those of private enterprises; they frequently enjoy exemption from national taxes and, above all, do not operate for profit.
However, any enterprise, whether public or private, is interested in "exemption from all customs duties or charges with equivalent effect and from any import or export prohibitions or restrictions, whether of an economic or fiscal character". Such exemption can cover "scientific and technical material" as well as "any substance that has been or is to be subjected to processing by the Joint Enterprise", i.e. a range of materials to be determined from case to case.
As regards intra-Community duties, the advantage will retain a certain practical importance during the transitional period of the general Common Market insofar as it applies to products other than those pertaining to the nuclear common market, which has not undergone any transitional period. This advantage, in conjunction with others (such as freedom to employ nationals of any Member State), means that as far as the joint enterprise is concerned the



The mining plant at Blind River, Ontario, Canada. Present estimates predict that the Community will require 54,000 tonnes of natural uranium during the period 1970-1979 and 122,000 tonnes during 1980-1989. The Community's known reserves do not suffice to cover more than half of the consumption expected up to the end of 1979, so that prospecting activities will have to be stepped up for the discovery and exploitation of fresh resources. The Community's enterprises should also make an effort to acquire their own sources of supply in non-member countries.

common market has been fully achieved.
Exemption from external import duties—and this is the most important factor—enables Community protection to be adapted so as to accommodate activities involving co-operation with non-member countries. In the case of the first nuclear power plants this made it possible to reduce the cost of reactor components which the Community's industry was not in a position to manufacture, as well as that of the first cores for these reactors.

These advantages call to mind the facilities which the states grant to enterprises which are in the public interest or which facilitate the achievement of precise aims of economic policy, such as the development of a particular region. This character of public interest can in point of fact be attributed, in conformity with national legislation, to the acquisition of such immovable property as is necessary for the installation of joint enterprises.

By alleviating the burdens of the enterprises these advantages also have an effect on competition. In each case it is the responsibility of the Community institutions to gauge them and to fix their conditions and duration, these being decisions which arise out of industrial policy.

A framework for vast achievements

Joint enterprise status offers Member States and firms within the Community a framework within which to marshal all the means required for undertakings of the greatest magnitude. There are no restrictions on their initiative as regards the submission of projects for joint enterprises. The Commission itself has the power to draw up such projects.

Given a unanimous decision of the Council, participation in a joint enterprise can be made open to: the Community, non-member states, enterprises in non-member states and, finally, to international organisations. Both private and public participation are permitted; in fact it can scarcely be seen what type of participation the Treaty excludes. For that matter, it makes no stipulations on the subject: it does not require, for instance, that, in order to be admissible, a project must emanate from a multi-national group. As far as outside participation in finance and management is concerned, this opens the widest possible door to industrial co-operation with non-member countries.

Joint enterprise status therefore constitutes not only a framework for concerted action but also an incentive to that end.

In the nuclear field

The spheres in which joint enterprises can be established is not expressly defined in the Treaty, which lays down as the basic condition that the undertaking must be of "outstanding importance to the development of the nuclear industry in the Community". It therefore sets not a field but an aim, which allows of much greater flexibility. Annex II to the Treaty specifies the branches of industry the investments of which must be declared to the Euratom Commission, but the authors of the Treaty also had in mind other activities such as the production of radioisotopes and specialised apparatus; furthermore, they left open the possibility of joint enterprises in the field of research and training.

The Treaty does not lay down any criteria of "outstanding importance"; it leaves to the Community institutions the responsibility of deciding whether an undertaking which applies for joint enterprise status does in fact possess the fundamental importance required. This decision has to be taken according to the circumstances and, in particular, from the standpoint of industrial policy. At all events, therefore, it follows from the concept of "outstanding importance" that the status of joint enterprise was devised with the object of promoting ventures which make a significant contribution to the development of nuclear industry in the Community, whereas the harmonisation of company law undertaken by the EEC aims at providing a common legal framework for private initiative.

Site of the Franco-Belgian nuclear power plant in the Ardennes, at Chooz (France). The reactor and its cooling circuits are installed in two caves hollowed out of the hillside. The Franco-Belgian SENA (Société d'Energie Nucléaire Franco-Belge des Ardennes) *received joint enterprise status on 9 September 1961.*

The joint enterprise and current problems relating to the development of a European nuclear industry

The accelerated rate of expansion generally forecast for nuclear energy production in the Community, as in all the major industrial countries, might give rise to the impression that the main problem that industrial policy will have to face in the nuclear sector is a quantitative one of investment. However, the magnitude of the problem should not be overestimated, since the nuclear investments will dovetail into the entire complex of investments for the development of energy production. To an increasing extent it is acknowledged that the main accent in the Community's industrial policy should be placed on the rapid "industrialisation" of nuclear techniques if European enterprises are to gain a foothold in the home market as well as abroad.

The joint enterprise in the reactor field

The "industrialisation" of a reactor type, by which is meant its transition to the stage of series production, presupposes the previous construction of experimental installations and subsequently of prototypes, both for the development of the techniques and for the training of qualified teams. Such ventures entail considerable financial burdens and risks for the constructors and operators. They call for large-scale co-operation between firms as well as for public aid.

Thus three nuclear power plants are at present being built under the joint enterprise arrangement: one at Chooz in the French Ardennes, a few miles from the Belgian frontier, another at Gundremmingen in Bavaria, and a third at Lingen in Lower Saxony. In addition, a fourth proposal, submitted by the Obrigheim power plant undertaking in Baden-Württemberg, is currently under study.

These plants are being equipped with "proven-type" light water reactors which, judged by the standards of the installations already in service when work was started on their construction, can be considered as high-capacity units, and each of which presents a technical advance as compared with its predecessors. Furthermore, the proportion of orders placed with firms inside the Community has increased greatly from one plant to another, ultimately accounting for very nearly all components of the plant. In view of the foregoing considerations these plants, which benefit from other forms of Community or national aid, are deemed to be of "outstanding importance" to the development of the nuclear industry in the Community. One of the aims of the Community's industrial policy at this stage was to encourage the building of full-scale power plants which would make use of the research results and enable reactor constructors and nuclear fuel manufacturers, as well as electricity producers, to acquire technical and economic experience.

Owing to the non-profitability of these plants they have been granted most of the advantages enumerated in the Treaty, but in order not to distort the competitive situation it is intended that these shall be withdrawn as soon as the enterprises become profitable and have made good the losses incurred since their inception.

Moreover, with a view to ensuring that the experience gained during the design, construction and operation of the plants is widely and rapidly circulated in the Community's industry the advantages were granted only on condition that the know-how acquired be communicated to Euratom for dissemination within the Community.

As regards advanced-type and breeder reactors, the commercial success of the European techniques will clearly depend on how soon they attain industrial maturity, i.e. the stage at which they become attractive to operators. What is true of supersonic commercial aircraft applies also to tomorrow's nuclear reactors. The commercialisation of these reactors at a reasonable cost and an adequate pace in the face of outside competition calls for the concentration of effort on the smallest possible number of types, these being selected against the background of a common industrial policy.

In the case of *ORGEL*, for example, which is being developed by the Euratom Joint Research Centre and is therefore a joint reactor project, the economy in time and money spent on the construction of the one or more prototypes required will depend on the degree of concerted effort by the operators and constructors. Joint enterprise status offers various means of facilitating implementation of the projects.

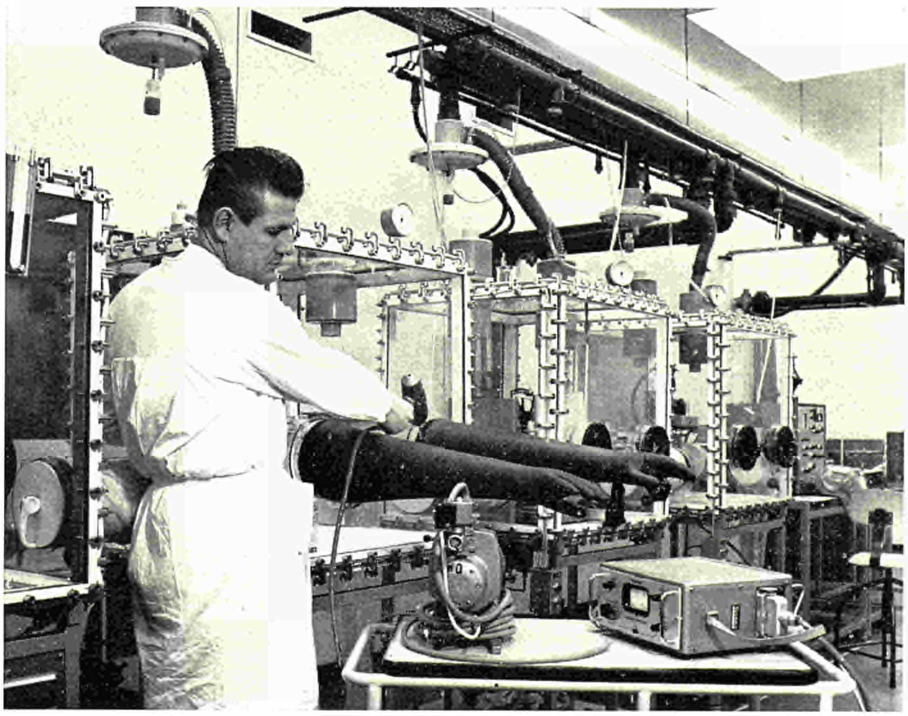
The joint enterprise in the production of nuclear fuels and other reactor materials

We are concerned here with a chain of activities ranging from the extraction of ores, via numerous transformation processes, to the final burial of radioactive waste. The transformation industries make use of physical, chemical and metallurgical techniques: uranium enrichment, heavy-water production, reprocessing of irradiated fuels, fabrication of fuel elements.

The problem of industrialising these techniques involves effecting the transition from the pilot plants, or at any rate small-capacity units, now in existence in the Community to installations of a size as near as possible to the economic optimum. In fact safety and nuclear quality requirements entail a high-

level of investment, and installations that meet such demands are only economic when they have a high capacity.
Consequently, in several of these sectors the transition to the industrial stage will involve building plants with an output which in many cases (e.g. fuel reprocessing) will exceed the entire national demand and which sometimes (e.g. in the case of uranium enrichment) will even outstrip the national investment capacity. This may apply not only in the short but also in the medium term.
If the Community's industry for the production of nuclear fuels and other reactor materials is to reach economic maturity at a satisfactory rate in relation to that of nuclear power-plant construction in the Community and to the growth of the nuclear sector in other countries—and this is vital if it is to be in a position to meet outside competition—then it is manifest that Community enterprises must strive towards an increasingly rational division of labour. To do otherwise would amount to allowing the mammoth foreign firms to reap the entire benefit of the vast and attractive market opened up by the European Community. This distribution of effort could take the form of joint projects such as the construction of a uranium enrichment facility or a heavy-water plant. It could also lead to specialisation on the part of the enterprises concerned. The granting of joint enterprise status and of the advantages that this can entail is calculated to encourage Member States and Community enterprises to follow the path of co-operation while still leaving room for healthy competition.
In addition, two activities forming the two ends of the industrial chain involved in the production of nuclear fuels and reactor materials could be carried out on a co-operative basis by joint enterprises possessing as decentralised a structure as is desired and charged with the task of co-ordinating and encouraging activities rather than of carrying them out.
The first problem is that of uranium extraction. The increased civilian demand for uranium which can be expected, as from the beginning of the next decade, will require of the industry an immense effort in exploration and prospection which, in the opinion of the experts, must be undertaken without delay. However, the fact that the market has already been depressed for several years and the prospect of four or five more slack years make it difficult to finance the essential operations. Moreover, the larger the scale on which they are carried out the greater is the chance of discovering new deposits. Concerted action by Community firms in the shape of a joint enterprise can therefore be envisaged. In the case of exploration activities in non-member countries this would be bound to facilitate the granting of favourable operating conditions.
At the other end of the chain are the processing and final disposal or storage of radioactive waste, activities which are indisputably in the public interest.
It is conceivable that, in collaboration with the Member States and the enterprises concerned, the Community may assume responsibility for these operations and possibly take over part of the cost, a move which would make it easier to find the funds required. Community management of the installations, especially of the storage sites, would contribute to a high degree of uniformity in the safety standards as well as to a geographical distribution satisfactory from the public health angle.

In conclusion, the joint enterprise framework can provide an essential but unprofitable undertaking with a measure of assistance which, slight though it may be, is nonetheless vital. It also enables the Community to supply the impetus, if necessary, and even to take the initiative in accomplishing certain major tasks of nuclear development. It is seen, so to speak, as an all-purpose instrument which, given a vigorous determination to work on the scale of a large economic unit, will evoke a commensurately satisfactory response to the problems that beset the rapid development of the European Community's nuclear industry.



A technician in the process of testing the leaktightness of a glove-box at the European Transuranium Institute, Karlsruhe. One of the main tasks of the Institute is to develop for European industry fabrication techniques for plutonium-based fuel elements. During the period 1970-1979, the Community's proven-type and advanced reactors will produce 34,000 kg of plutonium, while for the period 1980-1989, a production of 177,000 kg is expected.

The story of a piece of fundamental radiobiological research, which not only threw light on the events which lead up to the death of an irradiated cell, but produced a new method of measuring the dose received by a person exposed to radiation.

EUBU 4—18

How radiation causes cell death

JAMES F. WHITFIELD, *Department of Biology, Ispra Establishment of Euratom's Joint Research Centre*

With the increasing use of nuclear power, the potential hazards of radiation have assumed great importance in people's minds. Much has been written about the unpleasant death which follows irradiation with high doses of radiation. In addition, there is a general anxiety about the long-term hazards to the future generations from the ingestion of the radioactive waste-products of nuclear explosions. In this article, an attempt will be made to assemble some facts and hypotheses into a general picture, showing how radiation damages the most radiosensitive cells of the body and how this damage leads to the death of these cells.

After having received a fairly large dose of radiation (a few hundreds of *roentgens*), a man will die after first suffering from nausea, vomiting, diarrhoea, depletion of his bone marrow and blood cells, loss of the ability to resist infections, and destruction of the intestinal epithelium. Much lower doses will produce no obvious symptoms, but more insidious changes will have been unleashed which can lead to leucemia or other tumours in the man himself and can spell deformation and tragedy for his descendants.

The death of a man is the last event in a complex series of cellular changes. If we examine the changes in those large social groups of cells called *tissues*, we will find that the most striking change has been a cessation or deformation of the process of cell division. In irradiated bone marrow for instance, the inhibition of cell division will reduce the number of cells which can replace the worn out cells of the circulating blood and the distortion of the process of cell division will prevent those cells which do manage to divide from reaching a functionally normal maturity.

For many years now, there has been a very great effort expended on the study of the effects of radiation on mitosis (the name given to the process of cell division) and the structure of the chromosomes which are the filing cabinets of the cell and contain the genetic information for the construction of new cells and tissues. In particular, there has been a vast amount of research energy spent on the effects of radiation on the structure and synthesis of desoxyribonucleic acid (DNA) which is the compound into which is built the genetic information. This mental fixation on DNA has relegated another, perhaps equally vital, phenomenon to the background.

When certain cells such as lymphocytes (a type of white blood cell which makes antibodies to fight diseases) and the younger, immature cells of the bone marrow population are irradiated with relatively low doses of radiation, a surprisingly large fraction of them will actually die in a couple of hours (Figs. 1, 2, 7, 8). *This death is not related in any way to mitosis (cell division) nor is it likely that damage to DNA or its synthesis plays any role in it.* Conversely, other cell types such as fibroblasts may have their ability to divide and multiply completely destroyed by radiation, yet they will continue to live and grow in size for several days.

If we divorce ourselves from the "everything is due to mitotic-DNA-chromosome damage" theology and heretically consider this immediate death as well as the other forms of damage, we will be able to achieve a much more balanced view of radiation damage to the man or animal. The immediate killing of cells of the bone marrow or lymphatic tissues will seriously deplete the reserves of cells which would otherwise be able to fill the needs created by the reduction of the mitotic capacities of the stem cells, which by their division and maturation constantly generate functionally active cells. Bone marrow collapse will be a delicately balanced function of the degree of mitotic inhibition and actual cell death. Again, the loss of the ability to resist disease is possibly largely due to immediate cell death since the production of antibodies against invading bacteria or viruses depends on the lymphatic cells, which are particularly radiosensitive.

To study this type of swift death (which is called *interphase death* since it occurs in cells which are in the phase between two mitoses), we have resorted to using a particular type of lymphocyte, called the thymocyte, which forms the major part of the cell population of the *thymus* (a large lymphatic gland lying over the heart in the chest cavity). Since this gland reaches its maximum size in very young animals and regresses with increasing age, we have chosen the thymus of the very young (3-week-old) Sprague-Dawley rat as our main material. Cultures of thymocytes can be very easily obtained by simply removing the thymus and mincing the gland in a few millilitres of a nutrient solution (medium). During mincing, the gland simply dissolves into a homogeneous suspension and very concentrated cell cultures are thereby produced. These cultures can then be irradiated and there are more than enough cells to carry out any biochemical or cytological determinations.

The most striking symptom of radiation damage displayed by the thymocyte, and cells like it, is the complete loss of nuclear structure (Figs. 5, 6). In the normal nucleus there is a group of DNA-containing granules lying against the nuclear membrane and these, in turn, are connected by finer filaments to a central granular aggregate. These granules are concentrations of heavily condensed chromosomes (Fig. 3). The intense chromosomal condensation is probably due to the concentration in these regions of the basic proteins called *histones*. DNA is a large, negatively-charged, helical molecule and if histone attaches to the DNA, the charge will be neutralised, the DNA molecule will coil up and the chromosomal region which contains the DNA-histone complex will appear condensed when examined under the microscope. The specific pattern of granules in the nucleus of any given type of cell is probably a negative picture of the operational genetic regions of the particular cell type, since it is known that the combination of histone with DNA will inhibit the DNA from synthesising, and hence transferring its instructions to *informational ribosenucleic acid* (RNA) which in turn directs the synthesis of specific proteins. These points are pictorially summarised in Fig. 3.

The disaggregation of the granules in the nucleus of the irradiated cell would be expected to be due to a dissociation of the histone from its combination with DNA and the consequent uncoiling of the DNA. H. Ernst working in Germany confirmed this expectation when she showed that during the first hour after irradiation the histone content of isolated thymocyte nuclei decreased. Direct evidence was then found in our laboratory at Ispra when we observed that very shortly after the loss of nuclear structure large amounts of histone left the nucleus and accumulated in the cytoplasm (see Fig. 3 for the location of the cytoplasm). This could only mean that histone had dissociated from DNA since the normal cells contained no demonstrable histone in their cytoplasms.

The liberation of histone should have a very grave effect on the cell since free histone can inhibit many nuclear as well as cytoplasmic metabolic processes. The normal thymocyte nucleus accumulates phosphate, respires (i.e. consumes oxygen), makes protein (Fig. 3) and ribosenucleic acid and, unlike the cytoplasm, accumulates sodium along with the intermediates needed for protein and RNA syntheses. The liberation of histones will reduce, or inhibit these activities. Therefore we may conclude that irradiation causes some metabolic alteration which releases histone from DNA and the liberated histone then depresses nuclear metabolism: radiation kills the cell via a normal component which in the free state is a metabolic poison.

We may even go one step further and suggest that the probability of a cell suffering interphase death may very well be a function of its histone content. This would explain the fact that cells with very little cytoplasm in relation to the nuclear volume seem to be the types which are very radiosensitive and suffer this death. The amount of cytoplasm (which consists largely of protein) in a cell is a function of its protein synthesis which, in turn, is related to the activity of the nucleus in sending out informational RNA. If the genetic material be saturated with histone (and the histone content be therefore very high), then little informational RNA will be synthesised and sent out to establish a large protein synthetic machinery and the cytoplasm will be sparse.

What causes the dissociation of histone? The first clue came when we studied the effect of changing the phosphate concentration of the medium. The rate of nuclear changes (both the loss of structure and seepage of histones into the cytoplasm) varied directly with the phosphate concentration; the higher the phosphate concentration, the more rapidly did the nuclei lose their structure after irradiation. It has been well established by other workers that isolated nuclei lose their structure when exposed to phosphate compounds. Along with this loss of structure, there is a loss of metabolic activity. The basis for the action of phosphate is its ability to competitively

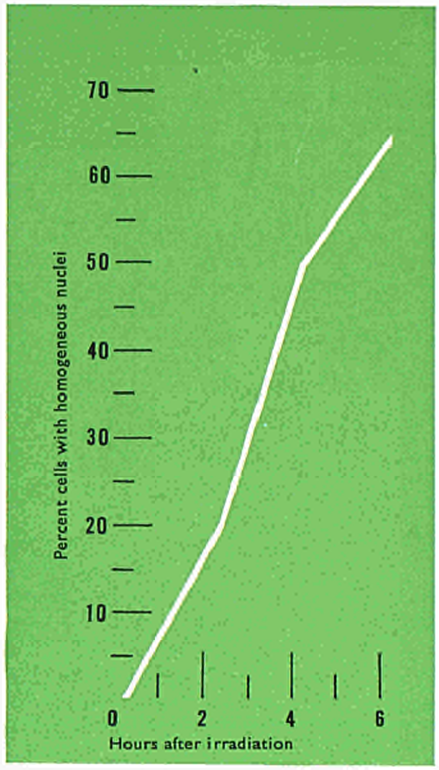


Fig. 1. The effect of 500 r of x-radiation on the nuclear structure of rat thymocytes. Radiation causes the nuclei to lose all of their normal granular structure and they become structurally homogeneous. This graph shows the speed with which the cells of an irradiated population develop structureless nuclei.

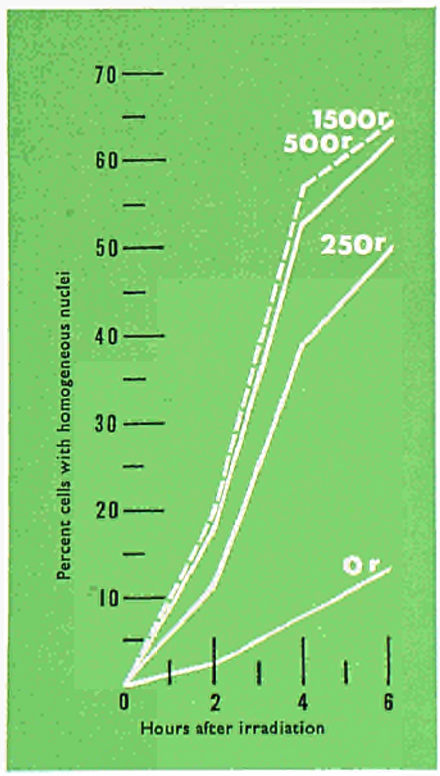
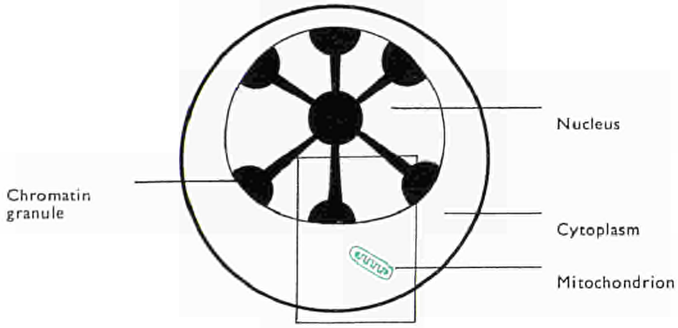


Fig. 2. The powerful effect of various doses of x-rays on the rate of appearance of damaged, structureless nuclei in the younger cells of the bone marrow. The older cell types which were nearer to being ready to enter the blood and carry out their mature tasks were much less affected during this short time after irradiation.



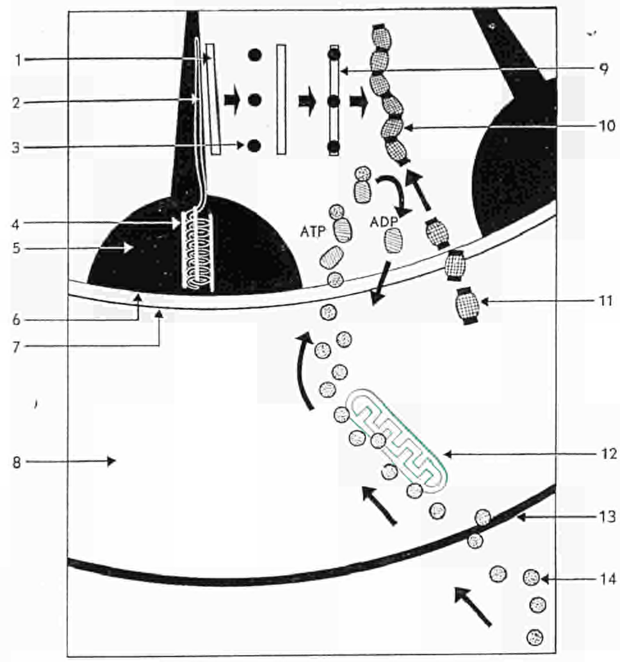


Fig. 3. This is a diagrammatic representation of some of the metabolic activity occurring within the nucleus of a thymocyte.
A part of a thymocyte is cut out and is magnified. We see the phosphate entering into the nucleus through the double membranes where it is mated with adenosine diphosphate (ADP) to make adenosine triphosphate (ATP). Meanwhile, amino acids enter the nucleus and they are assembled into proteins according to plans sent out from the DNA via its agent, RNA. The energy needed to do this work is provided by the ATP which is converted to ADP. It should be noted that the DNA which is held tightly coiled by histone is not able (because of this coiling) to send out information; only the histone-free DNA can do this.

1) RNA (information from DNA) 2) DNA 3) RNA' (ribosomal) 4) Histone 5) Chromatin granule 6+7) Nuclear membranes 8) Cytoplasm 9) RNA + RNA' (protein-making RNA) 10) Protein (chain of many amino acids) 11) Amino acid 12) Mitochondrion 13) Cytoplasmic membrane (cell boundary) 14) Phosphate

remove the histones from their salt-like linkages to the phosphate groups of DNA.

However, we are still not at the crucial point in the chain of events which result in the "nuclear disaster". We have merely pushed the events back one step to implicate phosphate. However, before we go any further we must outline the relations between respiration and phosphate uptake by the cell. The primary source of energy for the cell is the sugar called glucose. The glucose is gradually broken down in many stages into several molecules of carbon dioxide. At these stages, the energy contained in the molecule is released in the form of electrons which pass along a chain of enzymes (large molecular catalysts) located in the walls of membranous structures such as mitochondria (see Fig. 3) and the nuclear boundary. The electrons are eventually united with hydrogen ions and oxygen to form water. During the passage of electrons along the respiratory chain, molecules of inorganic phosphate are drawn into the cell from the medium and concentrate in the regions of respiratory activity (mitochondrion or nuclear membrane). The energy is trapped by attaching a molecule of this phosphate to another compound called adenosine diphosphate (ADP); the new energy-rich compound thus formed is called adenosine triphosphate (ATP). When ATP enters into various reactions in the cell, it gives its phosphate to other molecules and thereby imparts the energy to them and this permits the reactions to proceed.
Normally, the uptake of phosphate is closely tied to the transport of electrons along the chain of respiratory enzymes. Also, the system is adjusted so that the phosphate which is taken up from the environment is bound into adenosine triphosphate (ATP) and is put to good use in building and repairing the cell. Biochemists say that the processes of respiration and phosphorylation (binding of phosphate to ADP to form ATP) are coupled. However, if respiration and phosphorylation should be uncoupled, respiration (comsumption of oxygen by the formation of water) and its associated uptake of inorganic phosphate will continue, but the phosphate will not be joined to adenosine diphosphate (ADP) to make adenosine triphosphate (ATP). Therefore, the accumulating phosphate will be free to attack the histone-DNA complex (see Fig. 4). The only thing which could possibly blunt such a phosphate attack on the histone-DNA complex is calcium. Calcium ions are passively pulled into the cell along with phosphate. If there be a lot of calcium in the medium, then the accumulating phosphate will probably be combined with calcium to form insoluble, and therefore harmless, calcium phosphates. We have indeed found that the rate of appearance of damaged cells in irradiated cultures depends very much on the calcium concentration of the medium; a lot of calcium reduces nuclear structural changes. Even more striking is the fact that increasing the amount of calcium in the bone marrow of the irradiated animal by injecting a certain hormone (parathyroid hormone) can reduce

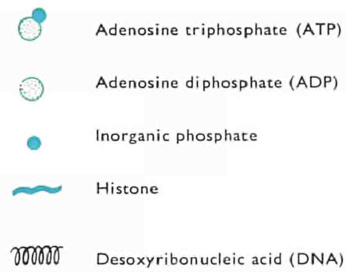
the number of animals which die.

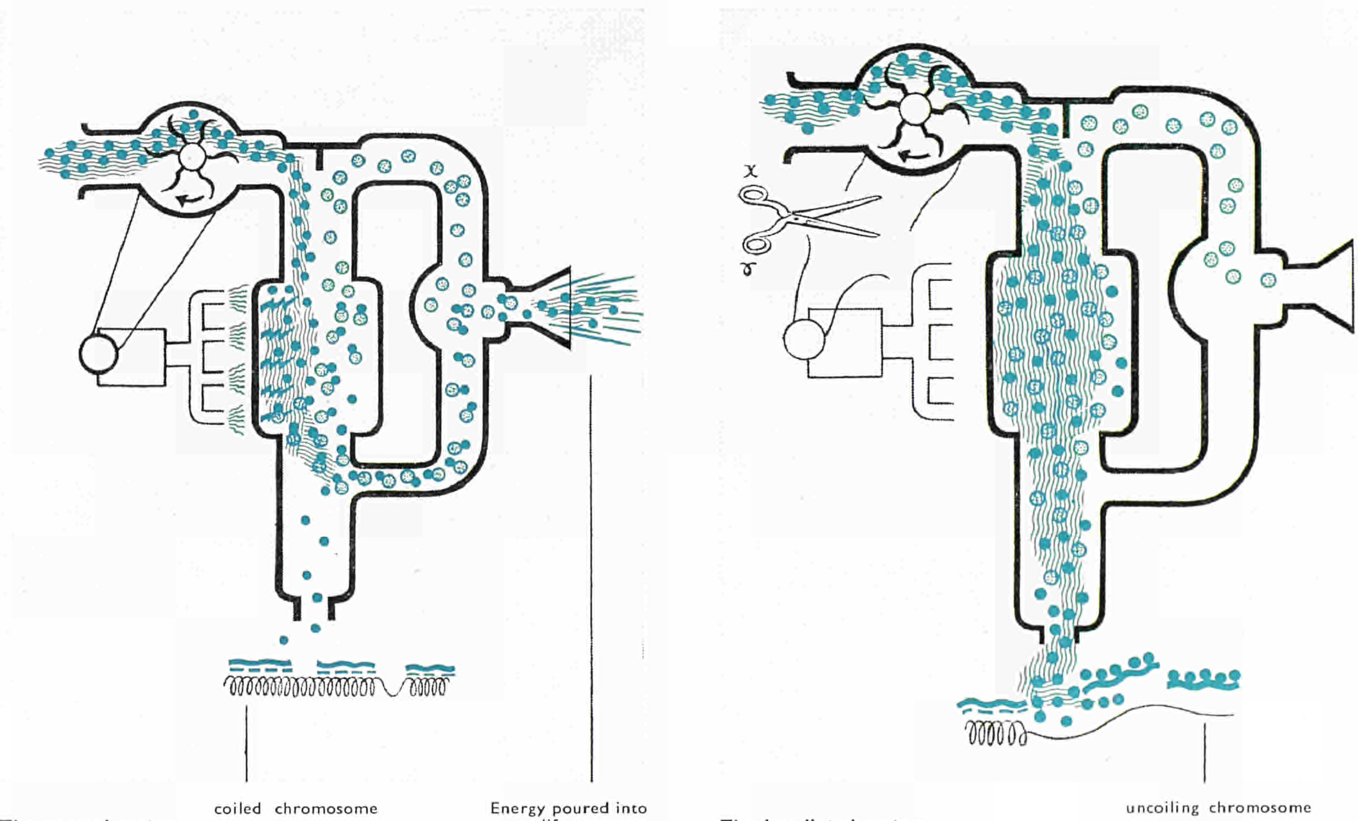
One of the very earliest changes consistently observed shortly after irradiation is the inability of the cells to mate inorganic phosphate with ADP. However, we have found that the respiration of the cells remains perfectly normal until the nuclei lose their structure (which would be expected since only when histones are released will respiration be stopped). We have further found that high concentrations of nicotinamide (a vitamin) prevent all symptoms of radiation damage in the thymocyte populations and nicotinamide at such levels strongly inhibits respiration. Cyanide, which is a classical inhibitor of respiration, also strongly inhibits the nuclear changes after irradiation. Curiously enough, very high doses of radiation (doses above 5000 r) *inhibit* rather than cause the loss of nuclear structure; such doses, like nicotinamide and cyanide, cause the immediate depression of the respiration rate. These facts are all perfectly consistent with the hypothesis that the first change to occur after irradiation is the uncoupling of the formation of ATP from respiration which, in turn, causes an accumulation of free phosphate which attacks and breaks the association between DNA and histone (Fig. 4). It is also clear that if this dangerously unbalanced situation of a normally functioning respiratory machinery with an inhibited phosphorylation system be corrected by reducing respiration (and therefore phosphate uptake), the cell can be saved from the ravages of nuclear metabolic paralysis resulting from histone release.

We also might be able to prevent nuclear

Fig. 4. The Model I nuclear homogeniser. This strange machine illustrates our concept of the relation between oxidative phosphorylation, phosphate uptake and histone-DNA complexes. Normally phosphate is pumped into the cell by the movement of electrons along the chain of respiratory enzymes to their final combination with hydrogen and oxygen to form water. This movement of electrons is also accompanied by the union of the phosphate with the compound ADP to give ATP (see text). Therefore, not much phosphate is free to disturb the histone-DNA complex. However, radiation (represented by the scissors) cuts out the system which binds the phosphate to ADP. However, phosphate is still pumped in. This phosphate is now free to accumulate around the histone-DNA complexes. Soon the complexes are split and the histone murderously diffuses into the nucleus stopping essential reactions.

This machine in the living cell is a system of enzymes which probably operate in the double membranes which surround and enclose the nucleus (see also Fig. 3).





The normal system **The irradiated system**

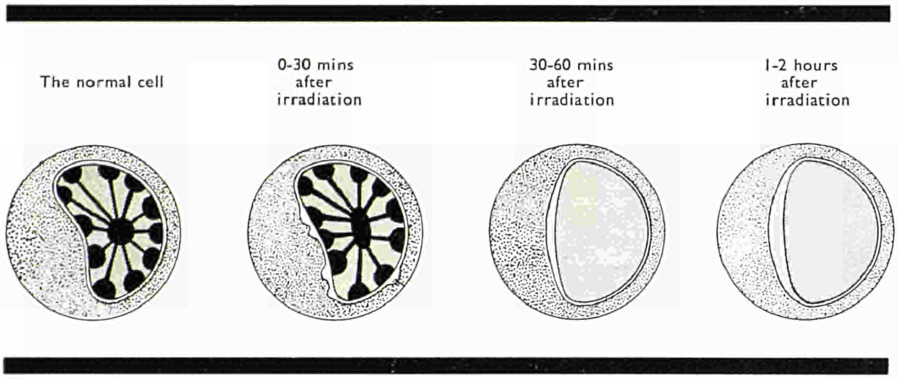
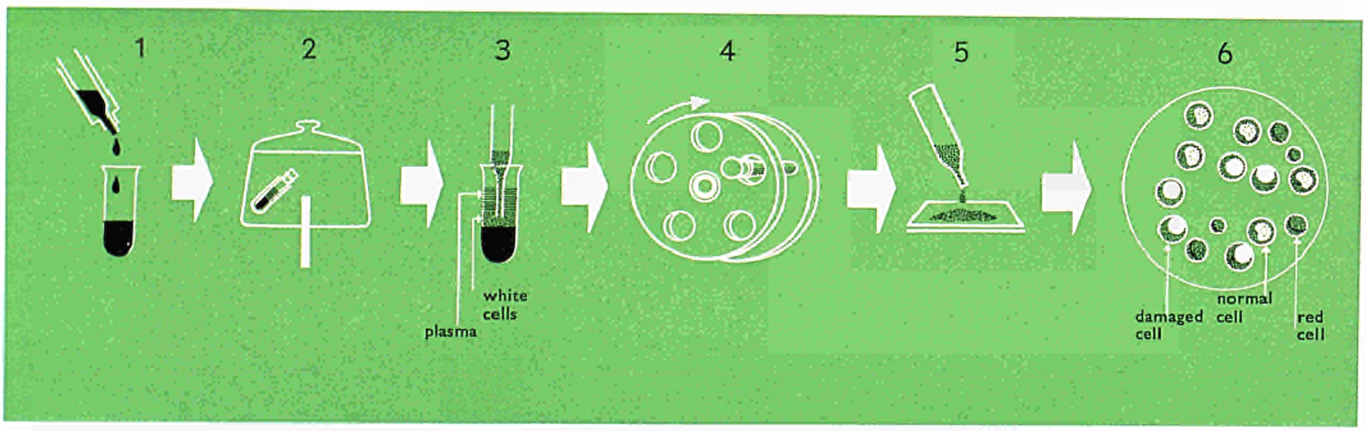


Fig. 5. The cytological and chemical events known to follow irradiation of the thymocyte. Major changes after irradiation:
0-30 minutes after irradiation: *vacuolation of nuclear membrane; inhibition of the reaction ADP + P → ATP; respiration normal.*
30-60 minutes after irradiation: *nuclear structure disappears; respiration still normal; loss of histones from nucleus and decrease of histone/DNA ratio; evidence of weakening of protein DNA bonds.*
1-2 hours after irradiation: *histones appear in cytoplasm; respiration falls; coenzyme NAD is destroyed; lactate is produced.*

changes if we could find some chemical which could directly inhibit phosphate uptake instead of indirectly via inhibition of respiration. Such a chemical is 2,4 dinitrophenol (DNP). Low concentrations of DNP stop phosphate uptake and, like radiation, stop the making of ATP. However, such concentrations of DNP actually *increase* respiration. Under these conditions, DNP very strongly inhibits the development of nuclear damage. Since the only difference between radiation and DNP is that the latter inhibits phosphate uptake (they both inhibit phosphorylation of ADP while leaving respiration intact), it is clear that phosphate is the vilain of this nuclear tragedy.
However, we are *still* not at the beginning of this lethal chain of events. What causes this crucial destruction of the cell's ability to mate phosphate with ADP? It is probable that the nuclear site of respiration and phosphorylation is to be found in the double membrane which surrounds and encloses the nuclear material. This can be shown cytologically by exposing cells to particular stains (Janus Green B and neotetrazolium) which colour those structures which are active in electron transport (i.e. structures active in respiration). These compounds colour the nuclear membrane (and, of course, the very active mitochondria in the cytoplasm). It is known that the co-ordinated processes of electron transport and phosphorylation of ADP require the combined efforts, structural integrity and close association of the two lipoprotein sheets which form the double membrane of the nucleus and the mitochondrion (these double membranes are illustrated in Fig. 3). The cause of the paralysis of phosphorylation of ADP in the irradiated nucleus is probably due to the formation of blisters or bubbles (technically called vacuolation) in the nuclear membrane and the consequent separation of its two layers which H. Braun (working in Germany) has found to appear immediately after irradiation.
In conclusion, I should like to give a factual-hypothetical sequence of events which follow the irradiation with 25 to 1500 r of x-rays of a rat thymocyte (also summarised in Fig. 5). During the first 15 minutes, the lipoprotein sheets which form the double membrane of the nucleus are so affected

Fig. 6. A pictorial summary of the way we determine the amount of radiation which an animal has received.

1. *Irradiated blood*
2. *Centrifuge*
3. *Separation of white cell layer from red cell layer*
4. *Incubation of white cells while rotating at 40 rpm at 37° C in salts-glucose medium for 6 to 7 hours*
5. *Fixation and staining of culture sample*
6. *Microscopic examination shows that 5 out of 10 white cells are damaged in this case*



that vacuoles develop between them. As the vacuoles increase in size, they separate the sheets. When the sheets are separated, the processes of phosphorylation and electron transport are uncoupled. However, since electron transport is not affected, phosphate uptake continues and the phosphate accumulates around the histone-rich granules lying against the nuclear membrane. The histones begin to slip away from their anchorage on the phosphate groups of the DNA and the nucleus begins to lose its structure by 45 minutes after irradiation. The liberated histones now start to leak into the cytoplasm and to diffuse throughout the nuclear space. Between 1 and 2 hours after irradiation, the histones do their lethal work by stopping nuclear function. The joyously normal respiration which has been killing the cell begins to feel the grip of the histones, which combine with the cytochrome enzymes of the respiration chain, and even it starts to slow down. The suffocating cell now signals its metabolic desperation by a violent outburst of lactic acid production. However, the struggle for life has ended and previously well-controlled enzymes go wild and start to destroy the structures of DNA and vital coenzymes such as nicotinamide adenine dinucleotide (NAD) The cell is dead.

Practical applications

We have just gone on a very hypothetical voyage through the intricacies of cell death. The research required for this study is very fundamental. However, it is the duty of the radiobiologist who carries out his work in a nuclear centre to contribute to the practical needs of that centre. The phenomenon of interphase death can be the consequence of irradiation with very low doses of radiation and the loss of nuclear structure which is such a vivid symptom of this death is a very simple thing to demonstrate and quantitate. Therefore, we have devised a type of biological dosimeter which uses the proportion of lymphocytes from circulating blood which contain structureless nuclei as an indicator of the amount of radiation received. Since blood lymphocytes circulate rapidly throughout the body, this dosimeter will average the dose received by any part of the body over the whole body and it is pictorially summarised in Fig. 6. Briefly, the white cells in irradiated blood are separated from the red cells by centrifugation. These cells are then cultivated in a glucose-salts medium for 6 or 7 hours. The cells are then fixed in neutral formalin, stained with haematoxylin and the fraction of cells with structurally homogeneous nuclei is determined. From Fig. 7 it is clear that there is a linear relation between dose and nuclear homogenisation between 25 to 100 r. If we use our standard thymocytes and grow them in a medium with very high phosphate concentration to accelerate the nuclear changes, then there is a linear relation between the rate of homogenisation of nuclear structure and dose within the very low range of 10 to 30 r (Fig. 8).

It might well be asked why no one has used this before. The answers to this are rather simple. The change cannot be seen to any extent in the circulating blood of the whole animal because the damaged cells are eliminated by being collected in certain organs where their débris is eaten by scavenger cells. The method we use preserves the irradiated cells from the scavenging mechanisms of the body by taking them out of the body and putting them into a test-tube culture and accelerates the rate of nuclear homogenisation by cultivating the cells in the presence of a high concentration of phosphate and a low concentration of calcium (it should be remembered that these are the most deadly conditions we can use to stimulate the development of nuclear damage).

I hope that I have shown that a combination of fundamental biological research and practical development can yield valuable fruit. That fruit is the understanding and eventual prevention of cell death and the biological evaluation of dose received either by accident in the peaceful halls of a reactor or in the turbulent chaos of war.

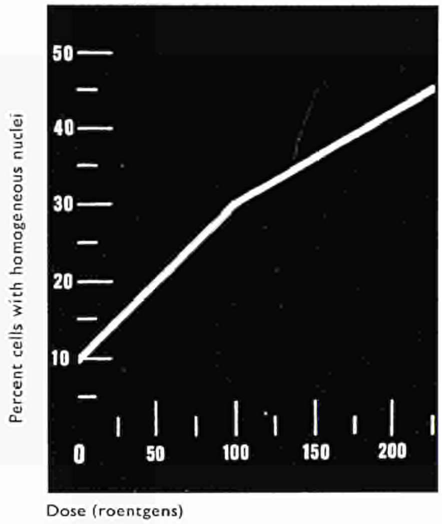
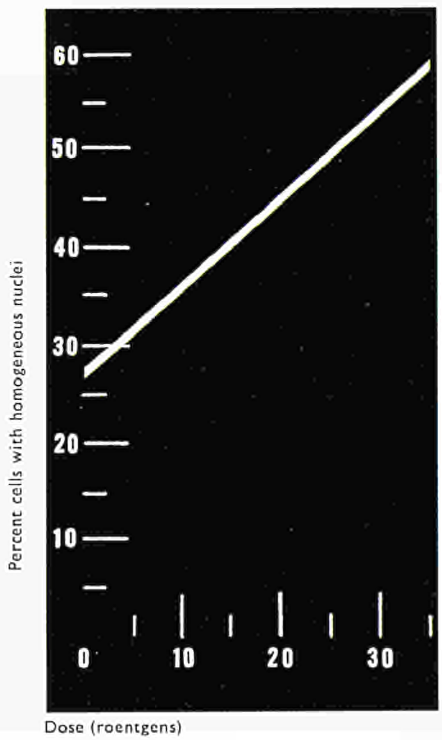
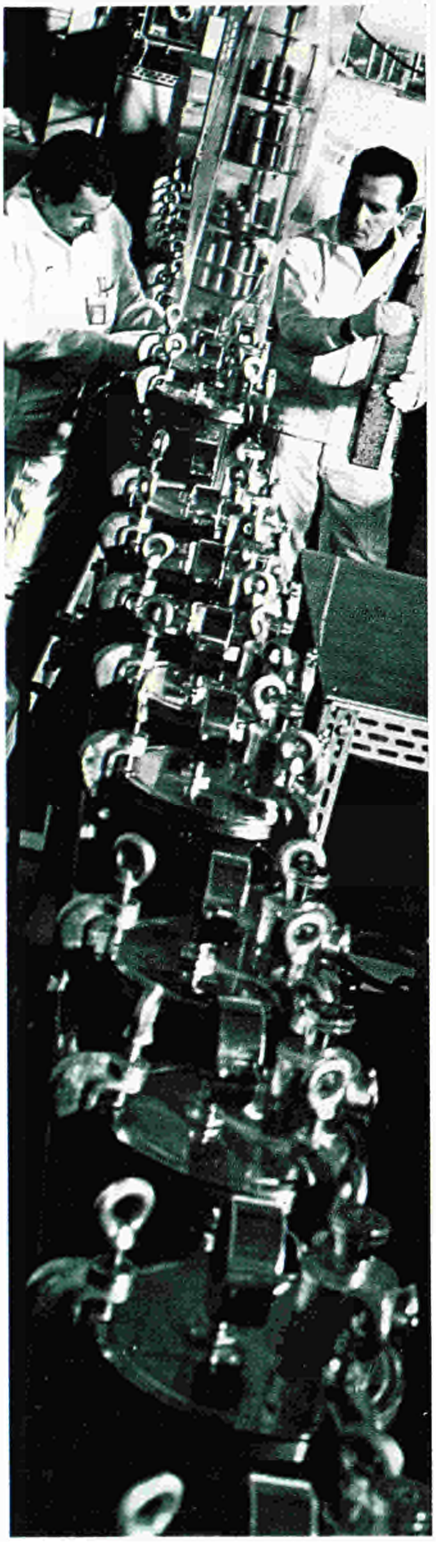


Fig. 7. The relation between dose of radiation and cellular damage sustained by rat lymphocytes. The cells were removed from irradiated blood, cultivated in a glucose-salts medium containing a high concentration of phosphate (30 mM Na_2 HPO_4) and a lowered concentration of calcium (0.63 mM $CaCl_2$). The promise extended by the type of experiment described in Fig. 8 was finally realised when we studied blood lymphocytes in experiments such as this one.

Fig. 8. The relation between dose of radiation and cell damage in cultivated rat thymocytes. The thymocytes were irradiated and cultivated in glucose-salts medium containing 60 mM Na_2 HPO_4 and 0.62 mM $CaCl_2$. This sort of experiment with the thymocyte gave us the idea of using the frequency of cells with structurally homogeneous nuclei as an indicator of absorbed radiation dose.





Towards an ORGEL prototype

JEAN-CLAUDE LENY, *Director of the* ORGEL *project, Ispra Establishment of Euratom's Joint Research Centre*

At the moment there is a great deal of discussion in European nuclear circles of the "*ORGEL* prototype". The study of the heavy-water-moderated and organic-liquid-cooled reactor concept was launched in 1960 by Euratom. Thanks to work which has gone on in the Community since then, the main difficulties facing this concept have been overcome and the body of information already obtained may now be considered as sufficient to justify planning the construction of a prototype.

The decision-making responsibility on this subject rests with the Euratom Council of Ministers. The Commission has therefore submitted to it a paper setting out the technical, economic, industrial and financial problems raised by the construction of an *ORGEL* prototype; this paper should constitute an adequate basis for a useful discussion.

We thought it desirable to clarify here the main considerations which will underlie this discussion. The fact that we have now begun to think in terms of a prototype proves clearly that *ORGEL* is no longer merely a matter for research laboratories, but is ready to embark upon the transition to the industrial stage. The future of *ORGEL* will therefore come to depend more and more on private initiatives, which will develop favourably to the extent to which they are based on precise and complete information. It was in this spirit that a colloquium was held towards the end of October at Ispra, during which the industries, electricity producers and certain state authorities of the six countries were informed of the results of the current research projects, and were able to judge the possibilities of the reactor.

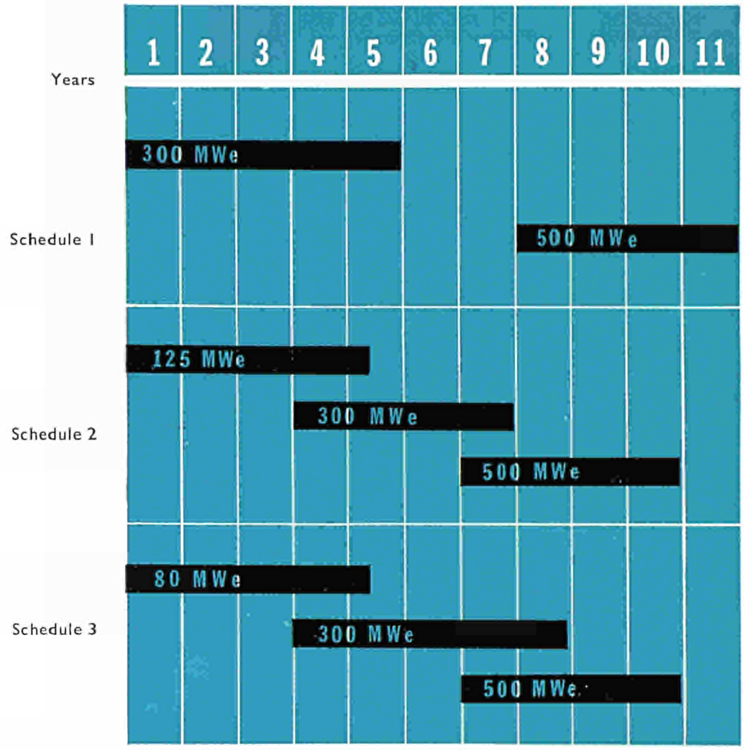
In fact—and that is the main justification for the construction of a prototype—the task henceforward is to reap the fruits of past efforts and to enable European industry to consolidate a position acquired after five years of unremitting labour over *ORGEL*.

These efforts have sometimes been of an isolated nature, particularly from the day in 1962 when the United States announced its decision to abandon its research work on reactors moderated and cooled by organic liquid. But a spectacular change in this situation has taken place with the fairly recent American decision to reconsider an organic liquid as coolant, this time in combination with heavy water as moderator; thus making a reactor type identical to *ORGEL*. Since the *USAEC* has announced its intention of allocating substantial funds to its development, and in particular to the construction of prototypes, we may expect very rapid progress on the other side of the Atlantic.

In these circumstances, if the construction of the prototype is not rapidly decided and

Storing uranium carbide, to be used in ORGEL *fuel-elements.*

begun in Europe, the Europeans will first find their position weakened and will then fall behind.
In addition, the research and development projects at present under way in the Community, and particularly at Ispra, will not be able to converge as they would normally do at the present stage of their progress. In fact the construction of a prototype should have the effect of channelling the projects in hand towards a set of concrete solutions.
The outlook for the reactor is extremely promising as regards power production, desalination, the conservation of fissile materials, the use under good conditions of new fertile materials such as thorium, and lastly the production of the plutonium necessary for fuelling fast reactors. It therefore seems probable that large numbers of *ORGEL* reactors will be built as soon as a prototype has been put through its paces.



From the site preparation for an ORGEL *prototype up to the commissioning of the first 500 MWe reactor, how many years will it take? Above are three possible timetables.*

What size prototype ?

What should be the size of the prototype? It seems that the choice must be made in the light of two main considerations: first of all the prototype must be big enough to give information which can be easily extrapolated to larger units; in other words, it must be "representative" of the *ORGEL* concept, and must consequently be built on an industrial scale. On the other hand, a reasonable desire to save money dictates the choice of a solution offering the least hazard from the economic angle.
If a comparison is made with the industrial development of proven-type reactors, it emerges that after the construction of low-capacity prototypes (e.g. 37 MWe for the *G2* and *G3* graphite-gas reactors, 35 MWe for *Calder Hall*, 5 MWe for the *EBWR* boiling water reactor and 60 MWe for the *Shipping Port* reactor), there was only a gradual transition to the 500 MWe plants which may be considered as the final industrial stage of these concepts. The principal steps were 150 MWe, 250 MWe and 300 MWe.
Furthermore, there was a long time-lag between the commencement of work on the first prototype and on the competitive 500 MWe plant, and the necessary technical level was reached only after construction had started or in some cases after a number of plants had already been commissioned.
With *ORGEL* not only is there a wider range of general knowledge available at the outset, but a research and development programme has already been completed and the *ESSOR* (*ESSai ORgel*) reactor constitutes a large-scale facility for studying the behaviour of fuel elements and channels. All these factors should make it possible to make slightly faster progress.
In practice there should be an interval of about 6 years between the start of work on the *ORGEL* prototype and on the 500 MWe plant. It remains to decide the best method of setting about the development of this reactor.

Three hypotheses

One might immediately construct either a large power plant, e.g. 300 MWe, or a medium-capacity power plant, e.g. 80 MWe or 125 MWe. It should be noted that in the last two hypotheses it would still be necessary to construct a 300 MWe plant before proceeding to a 500 MWe plant. Let us compare the advantages and the drawbacks of these three possibilities, examining first of all the respective timetables.
On the first hypothesis a 300 MWe plant is constructed, followed by a 500 MWe plant. It is reasonable to assume an interval of at least five years between beginning work on the first plant and commissioning it. Before constructing the first in the 500 MWe series, it will be necessary to let the prototype operate for a year or two. A minimum period of seven years must therefore be left between the decision to construct the prototype and the start-up of the 500 MWe reactor.
On the second hypothesis there is first a 125 MWe plant, followed by a 300 MWe plant, and later by a 500 MWe plant. Here it is necessary to allow at least four years for constructing the prototype, but, during this

period—let us say three years from the start of work—a 300 MWe plant might be begun; the head of the 500 MWe series could be launched about one or two years after the commissioning of the prototype. Thus 5 or 6 years in all are required to pass from the prototype to the first-of-series plant.

The third hypothesis is essentially the same as the second, except that the reactor output would be 80 MWe instead of 125 MWe. Approximately the same timetable therefore results.

Cost

It is not easy to make economic comparisons between the three hypotheses. However, a few ideas may be clarified at the outset by quoting some capital costs. Taking into account the results of certain economic surveys and other data, the following estimates are obtained:

- 80 MWe *ORGEL* prototype: 60 million u.a.[1] or 750 u.a./kWe
- 125 MWe *ORGEL* prototype: 80 million u.a. or 640 u.a./kWe
- 300 MWe *ORGEL* prototype: 150 million u.a. or 500 u.a./kWe

these being of course tax-free costs, i.e. without direct duties on investment capital or indirect taxes, such as the added value tax or the turnover tax. The justification for quoting these tax-free prices is that the first *ORGEL* plant might be exempted from taxation in the same way as the Franco-Belgian plant in the Ardennes *(SENA)* or the Gundremmingen plant *(KRB)*.

Whichever solution is preferred, it is clear that it will result in the supply of a certain number of megawatts, which will be included in the overall construction plan for new electricity generating plants. In other words a prototype, although by definition more expensive than a conventional installation, produces a certain amount of electricity. In all cost estimates, therefore, attention should be directed primarily to the *additional* expenses entailed by a prototype as compared with a plan making provision only for conventional plants or proven-type nuclear plants. For a conventional plant for example, the investment cost has been calculated at 125 u.a./kWe.

in millions of u.a.

	Investment	Total actual expenditure
ORGEL	150	193
Conventional power plant	38	113
Difference:	112	80

First hypothesis: to begin with a 300 MWe prototype
In this case it must be borne in mind that the initial outlay would be very high, at least 500 u.a./KWe, and the fuel cost would also be high, at least 1.5 mills/KWh.

		Investment	Total actual expenditure
ORGEL	125 MWe	80	98
	300 MWe	105	120
total		185	218
Conventional power plant	125 MWe	16	47
	300 MWe	37	95
total		53	142
Difference:		132	76

Second hypothesis: to build a 125 MWe power plant first, followed by a 300 MWe plant
The initial outlay for the 125 MWe plant would be 640 u.a./KWe, and the fuel cost 1.5 mills/KWh. The subsequent 300 MWe plant would reap the benefit of experience with the first one; this would be quite substantial from the technical and industrial standpoint. The initial outlay would therefore be no more than 350 u.a./KWe, the fuel cost being 1.2 mills/KWh.

		Investment	Total actual expenditure
ORGEL	80 MWe	60	72
	300 MWe	120	133
total		180	205
Conventional power plant	80 MWe	10	30
	300 MWe	37	95
total		47	125
Difference:		133	80

Third hypothesis: to build an 80 MWe plant first, followed by a 300 MWe plant
The initial outlay for the 80 MWe plant would be 750 u.a./KWe plus fuel cycle cost of 1.5 mills/KWh. As the 300 MWe plant would benefit less from technical progress than under hypothesis 2, its initial cost would be 400 u.a./KWh but the fuel cost would still be 1.2 mills/KWh.

But the plant costs are only one aspect of the question. The variable costs must also be taken into account, i.e. the fuel cost and the operating and maintenance costs. As with the plant costs, the important quantity to bear in mind is not absolute cost but additional cost. As regards fuel charges, the *ORGEL* consumption characteristics are such that the situation is reversed. Whereas a figure of 4 mills/kWh was adopted for a conventional thermal plant, it proved possible to take 1.2-1.5 mills/kWe for an *ORGEL* prototype, and it should be added that these figures are very much on the cautious side.

Any fair comparison must therefore be based on total expenditure, including the financing of both capital costs and variable costs, and assuming a certain working life and annual output.

A figure of 5,000 hours per year for 20 years was taken as a basis for this last computation.

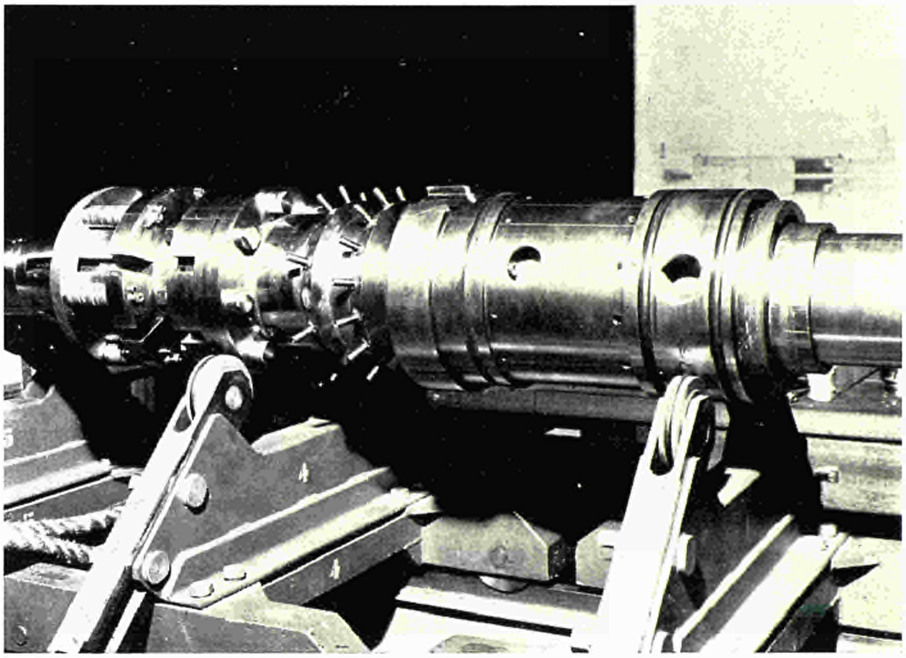
If the three initial hypotheses are appraised in this light, no single one of them appears to have any edge on the others from the economic standpoint (see tables). In fact they all entail extra costs of the order of 80 million u.a. as compared with the conventional-plant-only possibility. On the other hand, if only the cost of the first prototype is taken into account, the 80 MWe plant obviously entails the lowest additional expenditure (42 million u.a. as against 51 million for the 125 MWe and 80 million for the 300 MWe prototype).

Technical considerations

From the technical standpoint, however, there is something to choose between them.

1. 1 u.a. = 1 US dollar.

Prototype ORGEL *channel head*



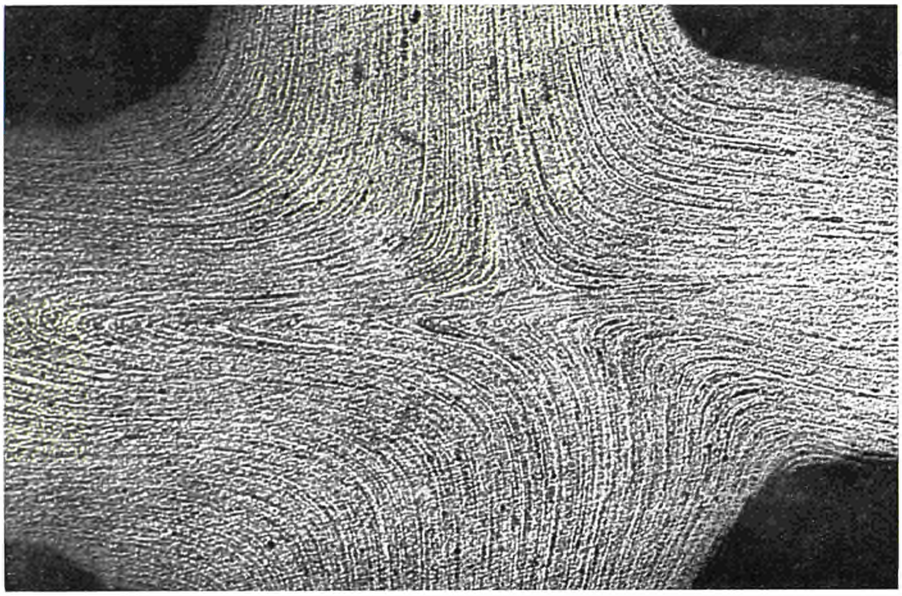
It seems that the first solution, namely the immediate construction of a 300 MWe plant, will be the one which the *USAEC* will choose for the *ORGEL* prototype which it intends to build. However, the object there is only to perfect the techniques involved in the heavy-water-organic-liquid combination, while using fuel elements already proven in other reactors. In the Community, on the other hand, the aim would be to exploit knowledge obtained under the *ORGEL* programme, which has related primarily to the development of new materials, such as sintered aluminium-alumina powder *(SAP)* and uranium carbide, to permit the use of natural or nearly-natural uranium fuel.
In these conditions the 300 MWe project would be a considerable risk, for we do not at present possess all the data necessary to be certain of putting into practice in the prototype stage what might be called the "*ORGEL* reactor philosophy".
Moreover, it would be necessary to develop practically full-scale versions of a range of equipment of which as yet only small models have been built, for example the *ORGEL* channel, the organic liquid pumps etc. This entails a risk of postponing the prototype commissioning date, and in consequence, the finalisation of the concept.
Furthermore, the need to gain operating experience with this prototype before launching the construction of a 500 MWe plant would interrupt the work going on in the design offices and in industry, while with the two other hypotheses continuity of work is assured.

From the technical standpoint therefore, it seems preferable to decide in favour of a smaller prototype. The 125 MWe plant, for example, would be a good point of departure. It makes possible the design of equipment which could easily be extrapolated even to reactors of more than 300 MWe. As for an 80 MWe plant, it undoubtedly offers the minimum risk. However from the technical and industrial standpoint, it would be a less valuable reference than a plant of about 125 MWe, and would provide less useful information for the development of the concept; it would therefore entail an increase in the cost of the subsequent 300 MWe plant.

How is the prototype to be built ?

A prototype, by definition, is not an end in itself; its whole purpose is to start a new technique on the road to practical success. Thus the judicious choice of characteristics for the *ORGEL* prototype is not, alone, enough to guarantee the reactor's success, for the basic aim is to achieve power plants capable of competing not only with the traditional thermal plants but with other nuclear plants. Without underestimating the peculiar advantages offered by heavy-water power plants, and *ORGEL* in particular, as regards plutonium output and the use of natural uranium, the fact remains that production costs must be cut to a competitive level. Hence the parties most directly interested in development of the reactor are the public authorities, the electricity producers, and the constructors.

In these circumstances the proper course is to push on with *ORGEL* development side by side with the construction of the prototype and, indeed, after it is completed. This



Section of a SAP-SAP (sintered aluminium powder) flash weld. SAP will be playing an important part in ORGEL-type reactors.

Micrograph of a specimen of stoichiometric natural uranium carbide. Uranium carbide is the reference fuel for the ORGEL concept.

implies continuity of technical work; for the lowered construction costs that technical progress can achieve depends intimately on keeping the design offices together.

In consequence, the procedure adopted for constructing the prototype should be able to call on a powerful, competent and lasting organisation, capable of spotting likely markets, financing the prototype and the research and development work on which the future of the reactor depends, and providing the financial backing essential for later constructions. Furthermore, whatever type of organisation is adopted, one condition is imperative—it must be a Community enterprise, that is to say, access to it must be open, under equal terms, to any Community concern with serious intentions.

The Euratom Commission has submitted to the Council of Ministers several possible schemes which try to allow for all these requirements.

For example, one of these schemes envisages the simultaneous creation of two companies, possibly in the form of "joint enterprises" within the meaning of the Euratom Treaty[2]. One of them, operating as an engineering office, would be responsible for preparing plans and, later on, as industrial architect, would be in charge of the construction work; the other, composed basically of power producers, would own and operate the reactor, which it would order from the first company. Euratom would participate in both companies. Its role in the first would be considerable in technical matters; in the second, it would cover any operating deficit by comparison with a conventional installation; it would probably diminish and finally disappear after a certain time.

Conclusion

It is difficult to predict how the Council will react to the Commission's proposal. It is probable, and natural, that so important a move will give rise to heated arguments; but we must hope for a positive decision, within a reasonable time, if we are to make an honourable showing in the competition over this type of reactor that has recently started with the United States.

2. Mr. H. Tournès gives more precise information on the status of "joint enterprise" on pages 111-115 of this issue.

EURATOM NEWS

First criticality of HARMONIE reactor

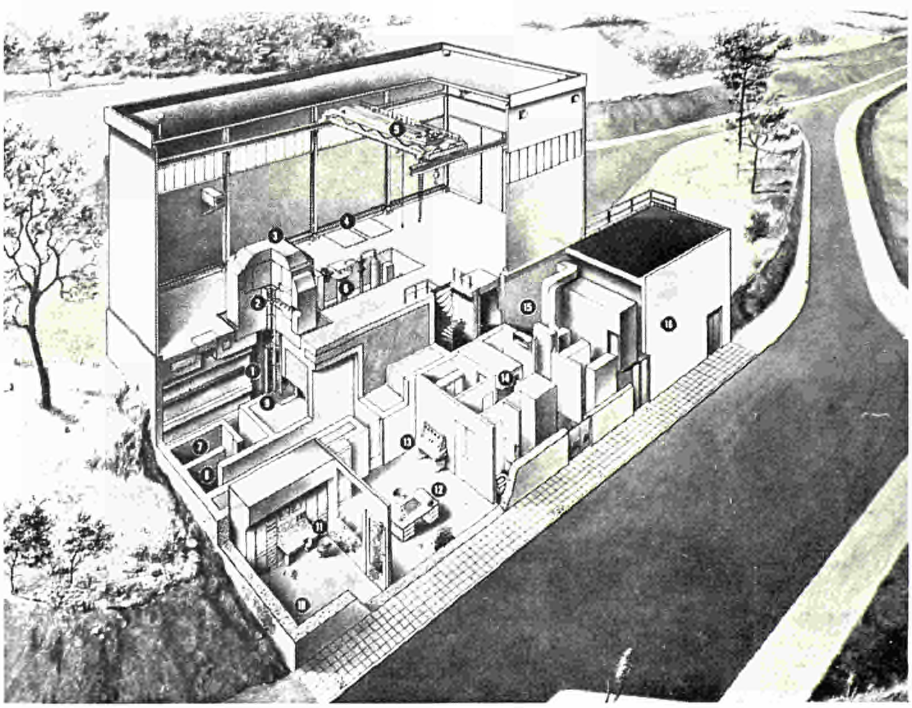
The *HARMONIE* source reactor went critical during the night of 25-26 August 1965. This reactor, the name of which has faint European associations, (Harmonie, or Hermione in Greek mythology being the wife of Cadmus, brother of Europa) forms part of the installations set up at Cadarache, near Aix-en-Provence, France, under a Contract of Association concluded between Euratom and the French *Atomic Energy Commission (C.E.A.)*. These are intended for use in the design and development of fast-neutron reactors, and, in addition to *HARMONIE*, include the *RAPSODIE* reactor and the critical assembly *MASURCA*, both of which are under construction, together with liquid-sodium-cooled test loops and various experimental mock-ups.

HARMONIE is a low-power (2 kWth) pile, the purpose of which is to supply not energy but, mainly, stable neutron fluxes of various spectra, ranging from very hard spectra, near the core, to thermal spectra (by means of the graphite thermal column), via degraded spectra (by means of the intermediate steel column). These neutron fluxes can be used for adjusting and calibrating nuclear detectors, such as fission chambers, and also for supplying neutrons to exponential masses whether surrounded by shielding or not.

In the case of this second kind of experiment a special feature of the reactor is that it can be removed from its biological shielding with all its control devices, so that parasitic neutron reflections are reduced to a minimum.

In other respects, however, *HARMONIE* is fairly similar to the *AFSR (Argonne Fast Source Reactor)*, which has been in operation at the Arco centre since 1960.

The core of the reactor consists of a stock of three cylindrical slugs of 93% enriched uranium clad in stainless steel. It is 123 mm in diameter and has a total height of about 129 mm.



The upper slug is itself made up of a pile of thin discs of enriched uranium, the exact number of which was determined during the experimental research on the critical mass, plus a number of discs of depleted uranium. The run-up to criticality is in fact carried out as follows: initially, all the discs in the upper slug are made of various thicknesses of depleted uranium, in the manner of a set of weights. They are gradually replaced, one by one, by enriched uranium discs of uniform thickness, the reactivity in the different configurations of the control system being measured after each replacement operation.

When criticality was reached, the height of the pile of enriched uranium discs necessary for criticality was found to be 31 mm, which corresponds to a total mass of about 25 kg of enriched uranium in the core.

The core is surrounded by a blanket of depleted uranium, which is in turn enclosed by a stainless steel reflector. The entire core-blanket-reflector unit makes up the core.

Fourteen experimental channels provide access to various parts of the core. In particular, there is a central channel going right through the core. The heat produced in the reactor is removed by air circulated at underpressure and passed through absolute filters.

Reactor control is effected by displacement of the axial blanket and the lower reflector (the whole unit being known as the safety block) and two safety rods, two shim rods and a depleted uranium control rod. All these rods are led into the blanket. The mechanisms for them and the safety block are housed in a kind of cage, which also supports the core and can be moved together with it.

Exponential masses of a maximum weight of 20 tonnes can be placed on top of the core, which can be set in two positions above its normal one (0.25 and 1.75 m above the low position). A 400 kV electrostatic accelerator can be connected up to the reactor to act as a modulated or pulsed neutron source.

The unit is installed in a 26 × 14 m hall

fitted with lightweight walls. The control and experimental rooms are in the basement and are suitably shielded in anticipation of experiments in which the reactor has to be extracted from its biological shielding. For the same reason the reactor is surrounded by a forbidden zone 300 m in radius.
Construction work on the reactor, which was in the hands of the *C.E.A.* Pile Construction Department, was started at the beginning of 1964 and ended in July 1965.
The Belgian company of *BelgoNucléaire* acted as the industrial architect, while the draft design of the reactor was drawn up by the Fast Neutron Critical Experiments Section of the Euratom/*C.E.A.* Association, which is also in charge of operation.

A glandular extract helps to cure radiation damage

Among many other scientific results of outstanding importance revealed at the 11th World Congress on Radiology, which took place in Rome from 22 to 28 September 1965, was the information that to all appearances mastery has been achieved over a "nuclear" disease which had hitherto been considered incurable. The disease in question is the radiation damage which usually occurs as a consequence of the therapeutic use of radiation in the treatment of cancer. For example, patients with brain tumors could in many cases be saved by external irradiation of the tumor. Unfortunately the rays produced festering ulcers on the skull surface, which often made it impossible for the patient to carry on normal activity.
Prof. Susanne Simon of the University of Brussels read a paper to the Rome Congress in which she reported 100 cases of radiation damage which had been cured in the course of the last five years. It is particularly noteworthy that in the majority, if not all, of the cases treated, there was found to be a complete recovery. These results are the fruits of observations made by Prof. Simon after the Medical Service of the Euratom Commission under the direction of Dr. Massart had discovered a new application for a glandular extract which had already been known since 1945 for its cicatrising properties but had not hitherto been considered for use in connection with radiation damage, because it was generally believed that "nuclear" diseases could only be treated by specific methods.
In order to examine all possible further developments in the new therapy and to ascertain the underlying mechanism, Euratom has financed experimental researches the chief of which are being conducted at the University of Strasburg by European research groups under the direction of Prof. Mandel.

Prestressed concrete vessels for water reactors?

Present-day boiling-water reactors are equipped with steel pressure vessels. As a result, the greater the size of the reactor, the more intractable are the problems that arise, in particular those relating to transport when the vessel has to be transferred *en bloc* from workshop to construction site. If, on the other hand, in order to circumvent this difficulty the vessel is assembled on site, the welding operations have to be carried out in extremely awkward conditions.

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Virtually identical problems were encountered in the case of gas-graphite reactors developed in France and the United Kingdom. As is known, the solution has been found in the form of prestressed concrete vessels.
It has accordingly been considered desirable to extend this technique to boiling-water reactors, which, as well as enabling large units to be constructed in better conditions, would offer additional advantages, such as the possibility of trying out natural circulation. Hence the conclusion of two recent contracts under the United States/Euratom Agreement, one with the *Société d'études et d'équipements d'entreprises (SEEE)*, Paris, and the other with *General Electric* in the United States.
As boiling-water reactors operate at appreciably higher pressures than those hitherto applied in gas reactors and their working conditions are different, it is necessary to make a detailed study of the technical and economic consequences of adaptation. This is precisely the subject of the two contracts, which are to be carried out jointly. The final phase in the studies would consist in drawing up a design for the construction of and experimentation with a small-scale mock-up.

An interexecutive for scientific research

On 14 October 1965 the three European Communities (Coal and Steel Community, Common Market and Euratom) created an interexecutive for scientific research, under the chairmanship of Prof. De Groote, Member of the Euratom Commission. This decision contributes to meeting the need, voiced for some time with increasing urgency in the six countries, to lay the foundations of a common scientific research policy.

LETTERS TO THE EDITOR

Dear Sir, Having read the very interesting article by Mr. Leopold Van Wambeke in the Euratom Bulletin *(Vol. IV, No. 3), may I draw your attention, and the author's, to a fact which, we believe, can be added to the information given in the published text. On page 84 the author mentions that aerial prospecting is usually carried out with light aircraft equipped with a very sensitive scintillometer, and that it is advisable to use a gamma spectrometer in order to distinguish which element is emitting the radioactivity detected. An instrument already exists—developed by the* C.E.A. *(French Atomic Energy Commission) and manufactured by the* Saphymo *Company, which* simultaneously *detects deposits and identifies the gamma emitters by means of discriminators.*

J. Fort, Brevatome, Paris

Dear Sir, I have always read the Euratom Bulletin *with great interest and eagerness. This is due to the fact that at the Technische Hogeschool (Technical College) in Delft Nuclear Chemistry is one of the courses offered by the Chemical Engineering Department.*
It is a laudable practice in Delft to allow a certain discount on periodicals, books and other such requisites, which naturally applies to students only. This may suggest to you the possibility of introducing a special reduced price for the Euratom Bulletin *in the case of students.*
I am convinced that such a decision would meet with a response in student circles.

A. H. J. M. de Mönninck
Vlaardingen

We have recently received several letters in which it has been suggested that we should introduce a special reduced subscription rate for students. This letter has been selected at random.
We are pleased to inform you that we have acceded to these suggestions. Henceforth, students may take out subscriptions to the *Euratom Bulletin* at a special rate of 12/6 or $ 2.50.

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