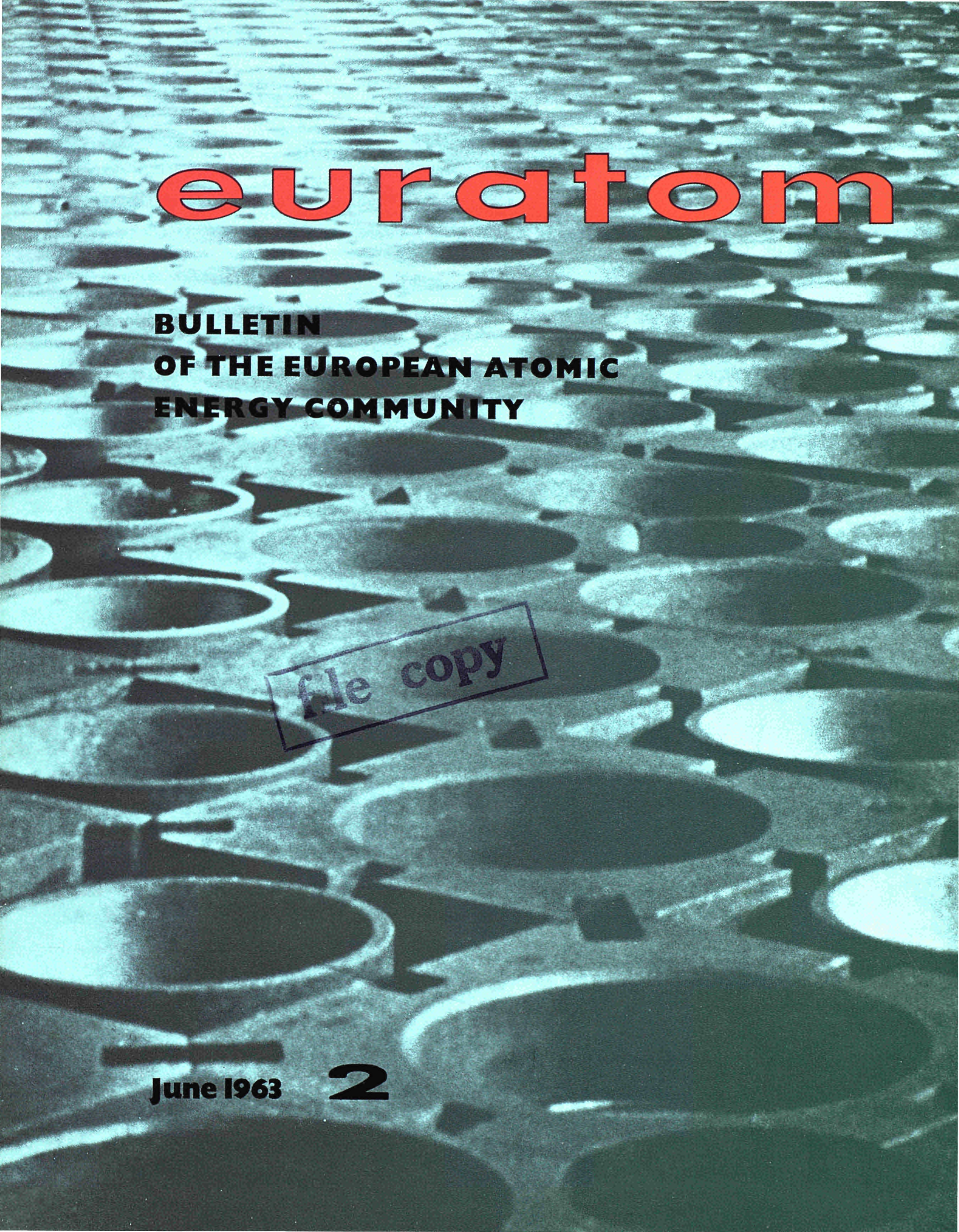
euratom

BULLETIN OF THE EUROPEAN ATOMIC ENERGY COMMUNITY



June 1963 2

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

1963 - 2

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

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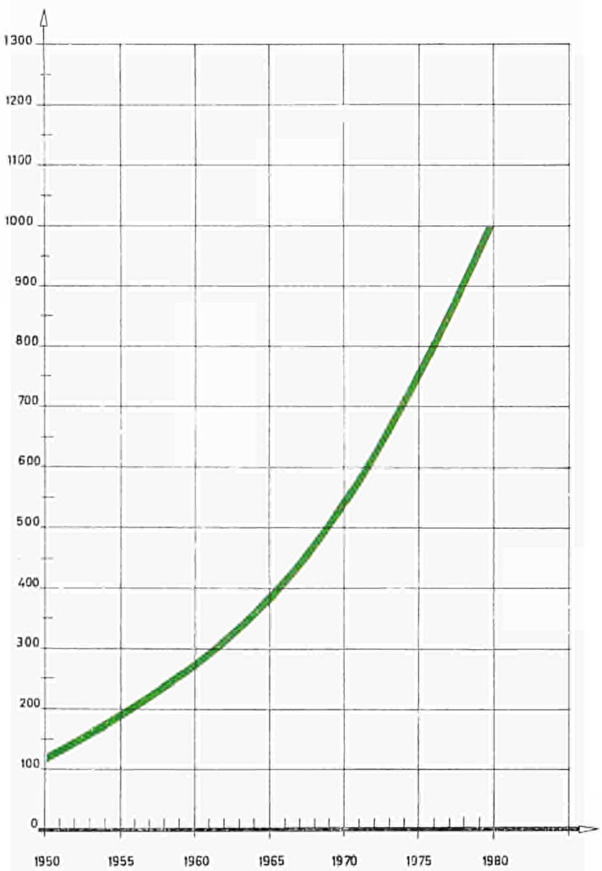
HUNTING FOR SCIENTIFIC INFORMATION IS TRADITIONALLY ASSOCIATED WITH PATIENT SEARCHES IN LIBRARIES THROUGH VOLUME AFTER VOLUME AND INDEX AFTER INDEX. THIS PICTURE IS CHANGING SOMEWHAT TODAY: THE BUSINESS OF SCIENTIFIC INFORMATION RETRIEVAL IS GRADUALLY SHAKING OFF ITS DUST AND TRYING TO INTRUDE INTO THE ASEPTIC ATMOSPHERE OF COMPUTER-ROOMS. ONE OF THE MAIN REASONS FOR THIS CHANGE IS THE WELL-KNOWN PROLIFERATION OF SCIENTIFIC AND TECHNICAL LITERATURE, WHICH, TO USE MR. BREE'S TERMINOLOGY, IS MAKING THE SEARCH FOR INFORMATION IN A SPECIFIC FIELD LOOK MORE AND MORE LIKE THE SEARCH FOR A NEEDLE IN A HAYSTACK. THE TRADITIONAL "MANUAL" METHODS ARE GRADUALLY LOSING THEIR ABILITY TO COPE ADEQUATELY WITH THIS TASK AND HENCE THE DECISION TO USE MACHINES IS BEING FORCED UPON US. THIS IS NOT TO SAY THAT THE ADOPTION OF AUTOMATIC INFORMATION METHODS WILL BE A PAINLESS PROCESS. ON THE CONTRARY IT BRISTLES WITH PROBLEMS AND DEMANDS FROM THOSE WHO TACKLE THEM A CERTAIN IMMUNITY TO DISAPPOINTMENT. A FEW ORGANIZATIONS, OF WHICH EURATOM IS ONE, HAVE DECIDED TO TAKE THE PLUNGE, IN THE BELIEF THAT THE EFFORTS INVOLVED WILL PAY OFF IN THE LONG RUN. THEY LOOK FORWARD TO A TIME WHEN INFORMATION RETRIEVAL WILL, IN SPITE OF THE TREMENDOUS UPSURGE OF PUBLISHED MATERIAL, BECOME A SERVICE COMBINING ACCURACY WITH SPEED, AND THEY WILL BE WELL SATISFIED IF, THROUGH ITS EFFICIENCY, IT IS ONE DAY ALMOST TAKEN FOR GRANTED.

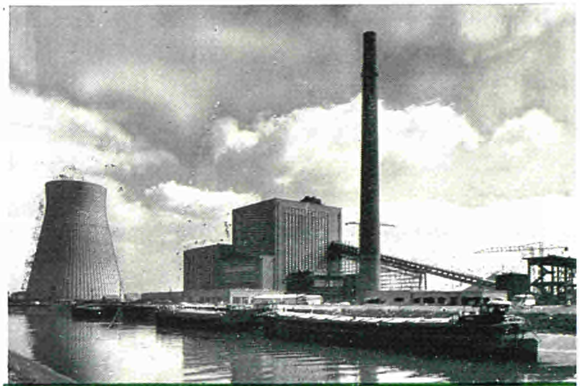
The growing need for electricity... and the means

Electricity consumption in the European Community from 1950 to 1980



The consumption of electricity within the countries of the European Community is steadily increasing; from 290,000 million kWh in 1961, it is expected to reach the figure of a million million kWh by 1980. This electricity is produced from a variety of sources, of which the main ones are water-power, coal, brown coal, fuel oil, blast-furnace gas and natural gas. Nuclear energy, which accounted in 1962 for little more than 0.1% of the Community's total production, has hardly earned a right to figure on this list. However, the several large nuclear plants which will be commissioned in the next few years should bring nuclear energy's share of production to about 3% in 1967.
It may well be asked what this percentage will be in 1980; in actual fact we *must* ask ourselves this question, not in a spirit of speculation, but with a view to taking *now* the decisions which will govern the answer. These decisions will depend on a number of factors, of which the ability of nuclear energy to compete, in the very near future, with conventional sources of energy is not the least. However, it is not a sufficiently dominating factor to make it possible to envisage nuclear energy making a clean sweep of all its competitors. The ultimate object is indeed to combine nuclear with conventional plants according to the pattern which gives the most economical overall results. This is one of the points which Dr. De Boer brings out in the following pages. Although this point has all the appearances of a reservation, it nevertheless emerges that nuclear energy ought to play a capital rôle in 1980 and that no time should be lost in launching the industrial efforts necessary to its fulfilment.

# of satisfying it



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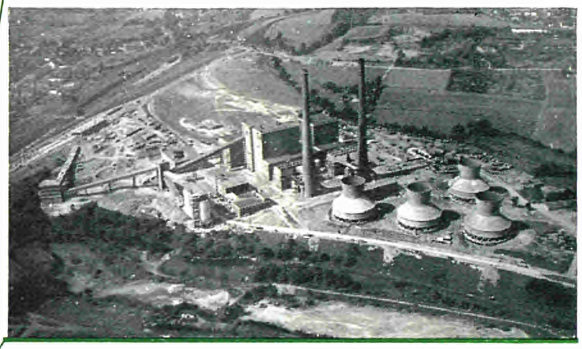
1. *Thermal power plant at Baudour (Belgium)*

2. *Thermal power plant Springorum in Bochum (Germany)*

3. *River power plant at Roßhaupten/Lech (Germany)*

4. *A barrage under construction at Roselend (France)*

Nuclear power plant of the SENN on the Garigliano River (Italy)



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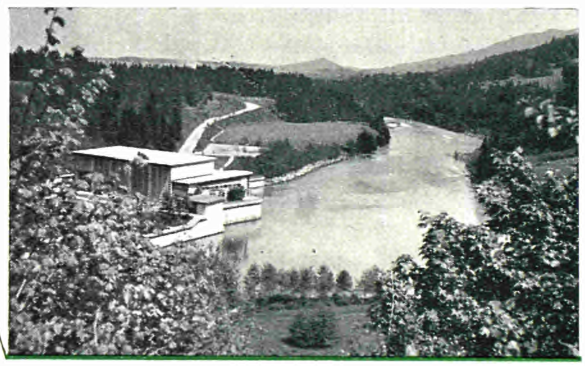

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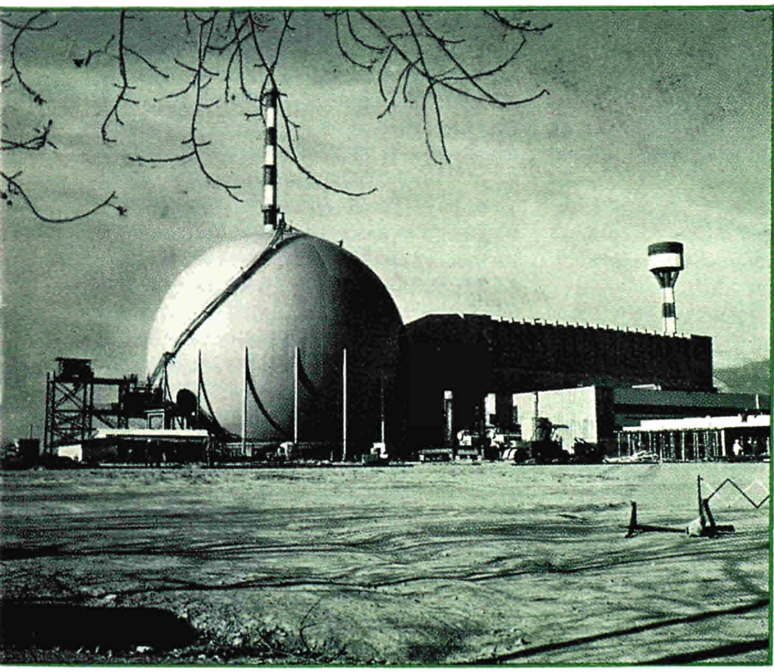

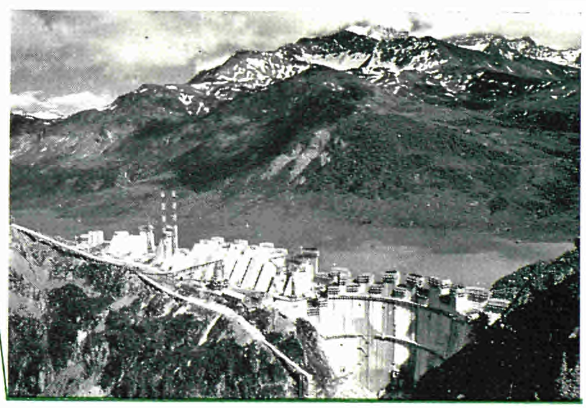

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Planning

the rôle of nuclear energy in

A. A. DE BOER, *Executive Assistant to European Commissioner*

E. M. J. A. Sassen, Euratom

The network of power plants which supplies us, at this moment, with the electricity we need is made up of an assortment of units, some of which are twenty years old or more. We can in a sense be said to have "inherited" these units, seeing that the decision to build them was not ours, but that of a previous generation. Similarly the decisions we are taking now will affect the structure of the electricity production network for most of the remaining years of this century. The task of facing this responsibility is not made easier by the advent of nuclear energy, but the author of this article hints at some of the ways we can tackle it.

In Euratom Bulletin 1962, No. 4, Dr. H. Michaelis gave a survey of the anticipated trend of nuclear energy costs, laying the accent on a cost comparison between conventional and nuclear power plants. This comparison is centred on power stations with high operating times, of the order of 6000 to 7000 hours per year (i.e. load factors of 70 to 80%), which would normally be used to supply base loads, and shows that nuclear energy will here be on an equal footing with conventional energy in the foreseeable future. It is even questionable whether conventional fuel costing in 1970 more than the current price will still be in a position to withstand its nuclear competitor for the production of electricity.

Naturally this is only one aspect of the problem of fitting nuclear energy into the general picture of electricity production. For instance, the very fact that only power plants with operating times of more than 6000 hours are covered by the above comparison stems from another aspect of the problem. As will be seen later, if we want a nuclear power plant to pay its way, it is pointless, under present conditions, to fit it into a network in such a way that it operates for less than 6000 hours.

This is however only part of the answer to the problem of fitting a nuclear power plant into a given network. The question is complicated by the fact that as soon as a new station is brought into operation, the economics of the existing stations are altered. We are therefore faced with the problem of not losing on the swings what we have gained on the roundabouts; in other words we have to keep our eye on the final aim, which is to keep the *total* production costs of the whole system to a minimum. As will be seen later, it is theoretically possible to compute an optimum distribution of capacity among nuclear and conventional plants if the cost factors are known with a sufficient degree of accuracy.

It is as well, however, to bear in mind that the structure of a given network is the result of decisions taken during the preceding twenty or thirty years. A power plant scheduled to be constructed in the immediate future must still be able to play its part in production in 1980 or 1990. This means that decisions taken *now* influence the structure of production for 1980 and subsequent years; we must accordingly ask ourselves not only what share in the total output we wish to assign to nuclear plants a few decades hence but also how we can set about achieving this optimum distribution.

It has been assumed up to this point that the development of nuclear energy is to be stimulated only in so far as this is desirable in terms of costs. However there are some other considerations, not related directly to electricity production or cost factors, which also have an influence.

Here then, we have the three main heads of this article: the most economic method of integrating nuclear power plants into the grid; the long-term planning required to approach the most desirable structure at a given future date; and the influence exerted by factors other than costs on the extent to which nuclear energy development must be stimulated.

Optimum combination of nuclear and conventional plants

Let us take an area's electricity supply as furnished by a group of interconnected conventional and nuclear power plants. The network will have a certain capacity, enabling it to carry a certain maximum load.

Of course, in view of fluctuations in demand, this capacity will not be used to the full at all times; it is therefore usual to characterize the network in terms of the average time of operation at maximum power. If the latter is, for instance, 10,000 MW and total production in a year is 5×10^{10} kWh, the average operating time is 5000 hours. This energy is generated by a number of plants which do not, of course, need to have an average operating time of 5000 hours in each case. In other words, output per installed kW varies from plant to plant.

If a new thermal plant of the conventional type is built, it has the advantage over the less modern units that it consumes less fuel per kWh. The interconnection of the various units allows the new plants to achieve a high operating time. Conversely, those units whose fuel costs are relatively high will only be brought into operation in order to cope with peak periods. Thus new power plants produce for the most part base loads.

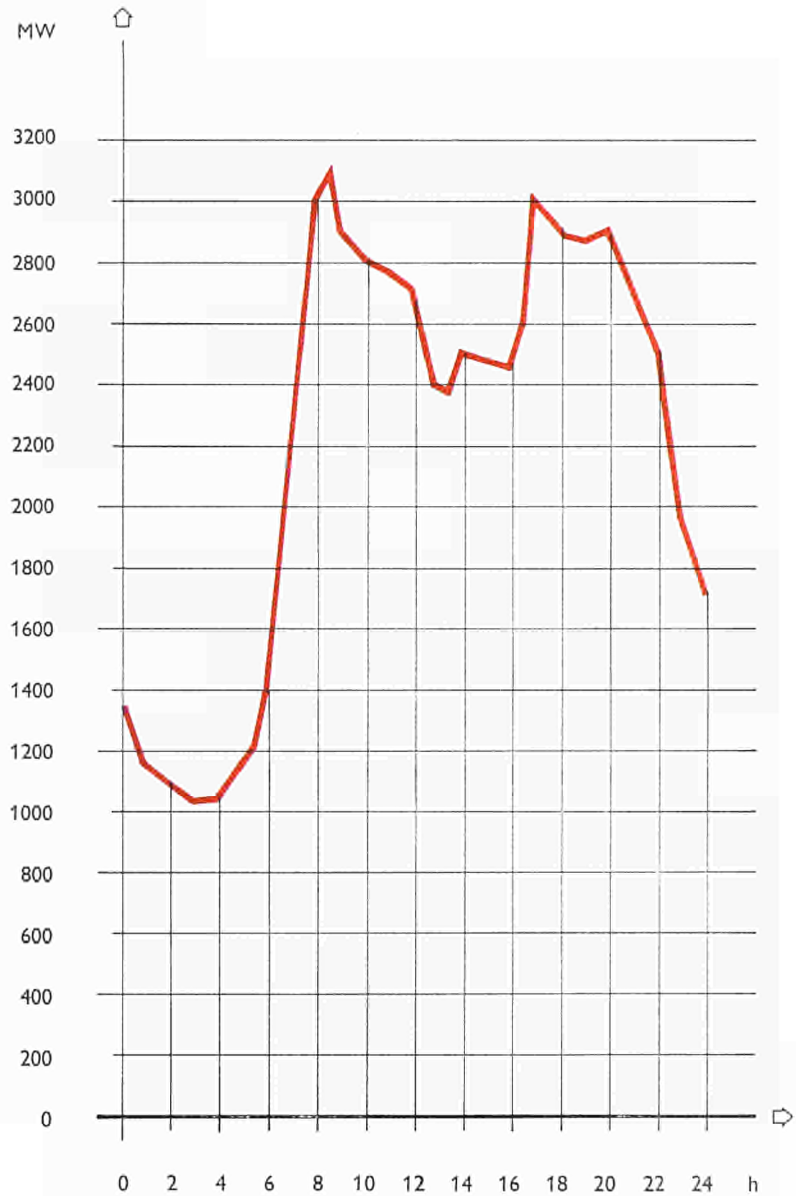
In this context, it should be recalled that a nuclear power plant of the current generation, although more expensive to build than the equivalent conventional plant, has markedly lower fuel costs. Therefore, when

electricity production

it comes to integrating it into a network, it is natural to allocate it to the base load.
The choice of a high load factor for a nuclear plant of course means a lower load factor for the other plants and consequently a relatively high level for the production costs per unit. The choice of an operating time is thus dictated not only by an assessment of the operating time at which the nuclear plant can in fact compete with a conventional plant; it is also of importance to know what influence the addition of one or more nuclear units has on the operating time, and consequently on the costs, of the other generators.
Electrical energy production in a particular area may be characterized by the *load curve*, of which a typical example is given in Fig. 1. This curve is obtained by plotting the output of the area's network as a function of time; it thus shows quite clearly peak and off-peak periods. If we have at our disposal a load curve covering a whole calendar year, we can derive another figure (Fig. 2), namely the *load-time curve* which shows how many hours (t) the network has functioned at not less than a given power level (c). This curve can be imagined as having been constructed from the load curve by dividing the latter into vertical strips and grading these strips according to decreasing power.
Let us now divide the area under this curve into two parts at a specific value of (c) by a line parallel to the abscissa. The area below this line, which is shaded in Fig. 3, represents the production by a certain number of units with a capacity (c_1) which supply the base load. The remaining area is assumed to represent the production of the other plants. The question is where the optimum dividing line is to be found.
It would take us too far out of our way if we were to go into the details of the mathematical calculations underlying the answer to this question. Some calculations of this type have been published elsewhere. [1] The optimum is *not*, however, such that the nuclear power plants' operating time is that at which costs are the same for conventional and nuclear plants. In that case, the total costs would be *just as high*, and no advantage would be taken of a possible opportunity to achieve a *lower* costs level.
This is illustrated in Figure 4, which brings

1. A. A. de Boer: Economische aspecten van de ontwikkeling der kernenergie
A. A. de Boer: Die Gesamtplanung nuklearer und klassischer Kraftwerke in einem Versorgungsnetz (Atomwirtschaft VIII, Jan. 1963)

Fig. 1
Typical load curve



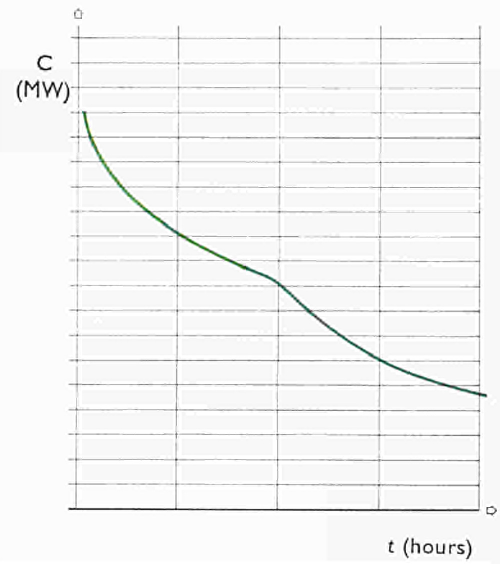
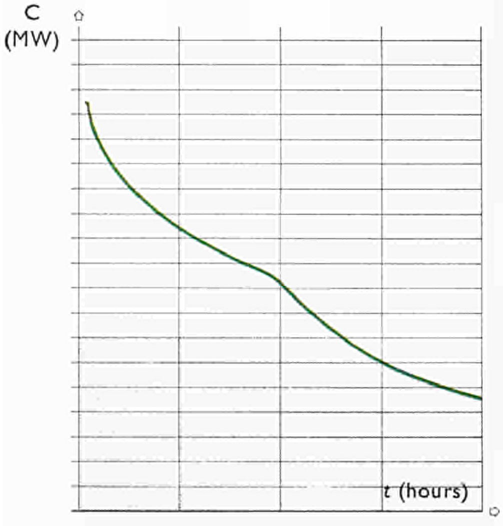


Fig. 2
Typical load-time curve. The curve shows how many hours (t) the network has functioned in one year (maximum: 8760 hours) at not less than given power levels (c).

Fig. 3
The same load-time curve as in fig. 2. The shaded area represents the production (in kWh) of the units supplying the base load.



together the results of the calculations in the form of a graph. On the abscissa is plotted the percentage of the total power (c) which is supplied by nuclear power stations, and on the ordinate the average costs (K) per kWh worked out for the whole network. Thus the curve shows the average cost of a kWh for every possible kind of network, i.e. from a network which is entirely supplied by conventional stations (on the left) to a network where nuclear power stations have ousted conventional plants completely (on the right).

There are four points of importance on this curve. The point P_1 represents the average cost in the case where the entire network is supplied by conventional plants, whilst the point P_2 represents the average cost in the case where all the electricity of the network is of nuclear origin.

At the value on the abscissa corresponding to point P_3, the load factor of the nuclear plants is such that the nuclear and conventional plants' costs are the same. In these circumstances, the replacement of one type of plant by another has no influence on the average costs, which are thus at the *same* level as P_1. But we see that between P_1 and P_3 there is a minimum P_4, which represents the optimum division between nuclear and conventional plants. Here, average costs are the lowest possible.

In this costs curve, the assumption is that nuclear energy would be more expensive for the grid as a whole. The contrary, however, is also conceivable. Fig. 5 illustrates this situation in which, for the grid as a whole, nuclear energy would be cheaper than conventional energy. It is not a situation which is likely to arise in Europe in the immediate future, except in certain areas where coal and fuel-oil are highly priced, but it certainly already exists in some developing countries. In this case, also, it can be seen that there is a possible optimum, where conventional energy is not *completely* replaced by nuclear energy. From a costs standpoint, therefore, it may be worth while to have a grid not consisting entirely of nuclear reactors, since, even where nuclear energy is more advantageous for the network as a whole, it may be possible to achieve a saving by bringing conventional plants into operation to meet peak loads.

2. M. Bruni and D. Verde: Atomwirtschaft IV, 368 (Sept. 1959)

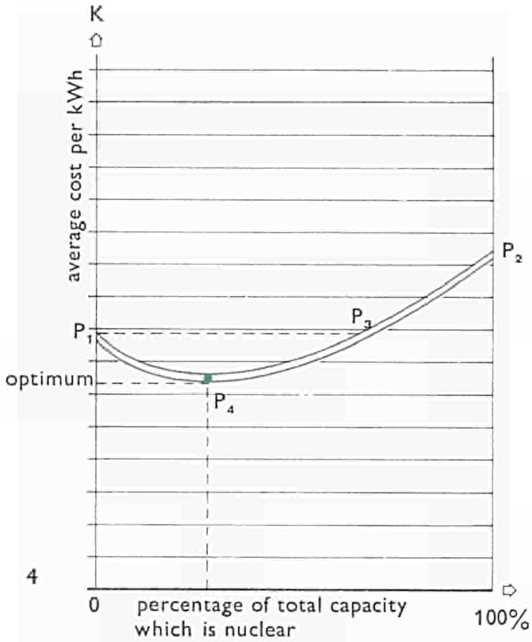
The rôle of water-power

This pattern must naturally be adapted when account has to be taken of water-power. Indeed, as there are no fuel-bills to pay in the case of hydroelectric plants, their variable costs are even lower than those of nuclear stations. This inevitably marks them out for service as base load stations — assuming, of course, that the water supply permits production the whole year round. Within the European Community, it is only in France and Italy that water-power plays an important rôle. It may therefore seem strange at first that it should be precisely in France and Italy that the development of nuclear energy is being pursued so vigorously. On the other hand it has to be borne in mind that the hydroelectric plants' dependence on climatological conditions for water supply entails variations in the power-level they are capable of maintaining. Hence, in a particular area, only a certain percentage of the total hydroelectric capacity is available the whole year round, and it is therefore only this percentage that can be allocated to the bottom of the network's load-time diagram, thus leaving space in the network for other types of generator for base load duty. We are then faced again with our original problem.

Let us take Italy as an example. At the present time, this country derives 70% of its total electrical energy from water-power. Bruni and co-workers [2] have made an approximate assessment of Italy's future energy production, separating the base load from the peak load. It emerges from this study that, after making due allowance for the contribution of water power, a substantial part of the base load requirement will have to be satisfied by other units. In view of the slightness of hydroelectricity's expansion potential in Italy, it is assumed that about 1970 or 1975 the annual production in this sector will be stabilized. In the meantime the base load requirement will increase and will thus have to be met more and more by thermal power plants; in fact it is estimated that the share of hydroelectric energy will decline from 70% in 1960 to 40% in 1975.

Influence of the growth rate

The foregoing does not mean that it will be a *practical proposition* to have nuclear capa-



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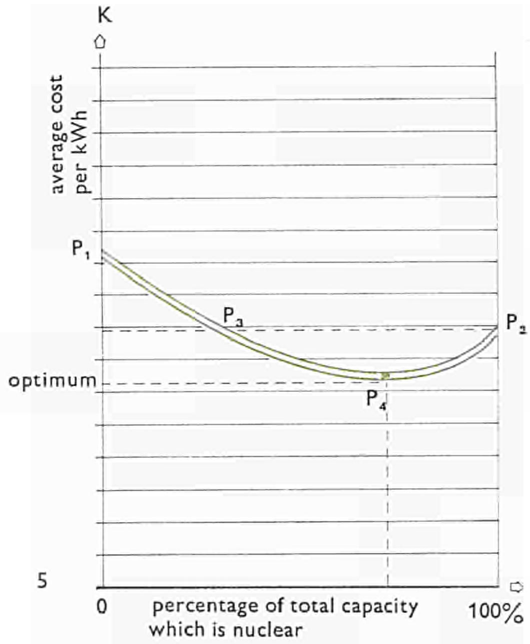

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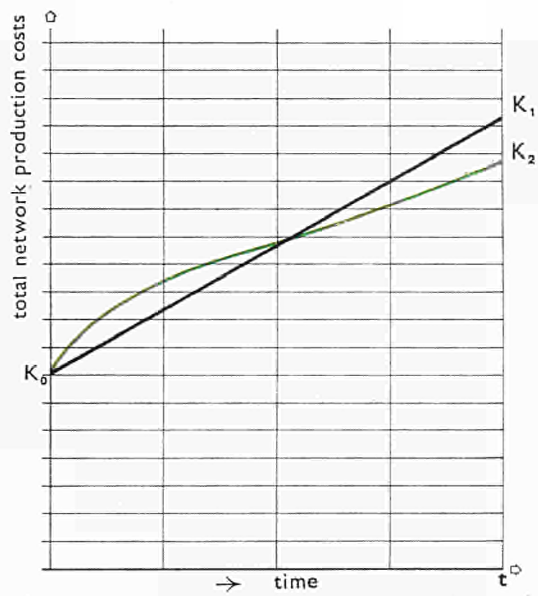


city in, say, 1975 corresponding to the theoretical optimum discussed above. The rate at which capacity is expanded will also exert an influence on the situation.
Generally speaking, it may be said that electricity production is increasing by a more or less constant percentage each year. This increase finds expression in the construction of new power plants, partly in replacement of obsolete units. It is this rate of growth that determines what proportion of capacity consists of plants which have been added over, say, the last five or ten years.
If production capacity averages an annual expansion of 6%, and 1.5% of the existing capacity is replaced, this means that, at any moment:
–over 30% has been added during the previous five years,
–over 50% has been added during the previous ten years.

Fig. 4
Average costs per kWh depending on the percentage of installed capacity which is nuclear. It is assumed in this graph that nuclear energy would be more expensive than conventional energy for the grid as a whole.

Fig. 5
A similar curve to that shown in fig. 4, but drawn under the assumption that nuclear energy is cheaper than conventional energy for the whole network.

Fig. 6
The trend of an area's total electricity production costs over a number of years. K_0K_1 *represents the trend in the case where planning of every individual step in the development process is made on a short-term basis.* K_0K_2 *indicates the trend when early sacrifices are made in order to achieve an ideal structure in the future. (No quantitative interpretation is of course to be given to this graph.)*

Allowing a further period of five years for preparatory operations, this means that, as from the time at which it is decided that *all* new power plants are to be of the nuclear type, ten years will elapse before a nuclear capacity representing 30% of the total has been created. Should it be decided to have 50% of the new plants in nuclear form, the creation of such a capacity will take more than fifteen years.

We thus have two elements in electricity production planning: the growth rate and the desirable future structure.

If the development of electricity output is only considered in the shorter term, it may be said that every new power plant must play its part in ensuring that the necessary grid expansion is carried out as cheaply as possible. However this is not necessarily the way to achieve the optimum structure. When planning for the years ahead, one must always bear in mind the long-term situation, and this involves considering the structure of the network as a whole, such as it is "inherited" at a particular time.

When a grid consists solely of conventional plants, this problem is easier to solve than when there is a choice between two entirely different types of plant, one of which–the nuclear type–presents a number of uncertainties, both technical and economic. Even, however, if these uncertainties were relatively small, it would be difficult to decide what the ratio of nuclear to conventional plants is to be in the expansion of the production network.

This may be illustrated in the following way. Figure 6 shows how, over a given period, the total electricity production costs in a specific area develop. In the year *t*, production costs will amount to K_1, which, to employ the same figurative expression again, relates to a structure that has been "inherited".

It is, however, on the cards that in the year *t* there would be a more favourable situation, in which, for example, a number of large nuclear power plants provided the base-load production. The costs corresponding to this ideal structure could be represented by K_2. The line K_0K_1 represents the planning, such that every individual step in the development process is the optimum one. On the other hand, if it can be demonstrated that early construction of larger or perhaps nuclear power plants is necessary in order to obtain a more favourable structure K_2 in the year *t*, this will involve sacrifices in the early stages. The costs trend may then be more or less that illustrated by the dotted line in Fig. 6.

It is not our intention to elaborate this subject further. We merely wish to emphasise that the construction of nuclear power plants needs to be started in good time if full benefit is to be derived from possible savings. It is, however, plain that in this field there are still a number of points to be studied.

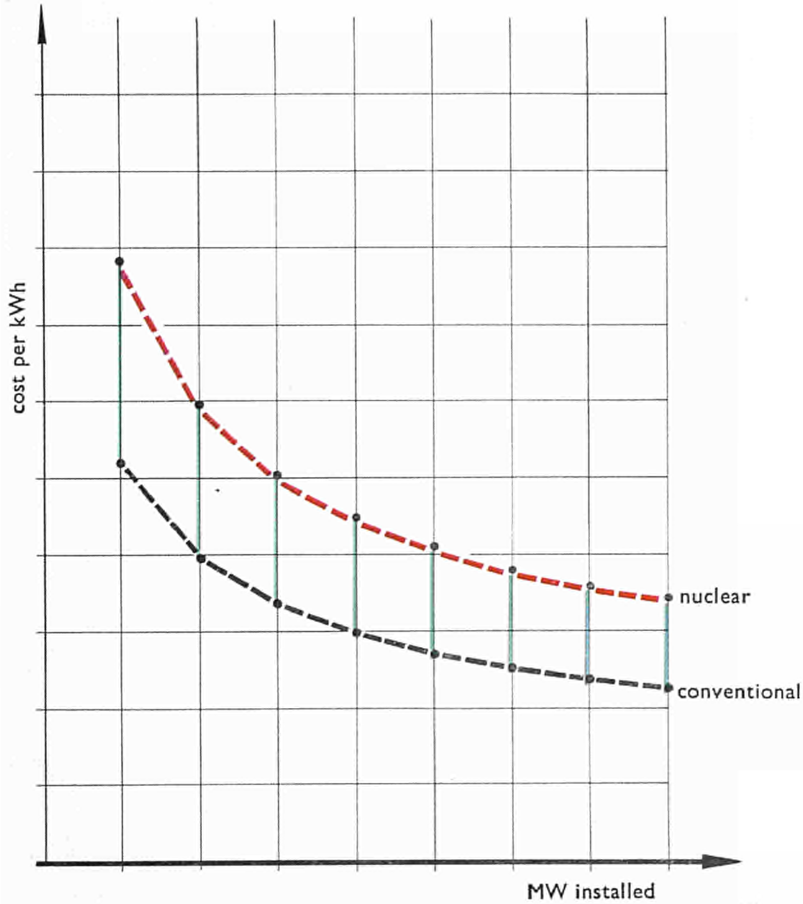
This situation is in some measure comparable with that observed in several sectors of industry. It is not impossible that in a particular sector the most advantageous expansion of the enterprise in the short term may result in a long-term structure that is not the most favourable. One can, for instance, imagine a number of small firms having apprehensions about long-term competition from either foreign or up-to-date home enterprises able to produce more cheaply on account of their size. In such circumstances, it will be necessary to carry out mergers or to prepare to meet the future by other methods involving certain sacrifices. Here too, therefore, the existing enterprises' production costs will at first follow a steeper trend than the original curve and subsequently enable savings to be effected. The only difference between this and the electricity situation is that, in the first case, industries could be driven to such action because of the *danger* of competition, whilst, in the latter case, there is no competition from other or foreign producers. Thus the efforts to achieve a more satisfactory structure for the future are prompted by concern for the public interest, i.e. the production of cheap energy.

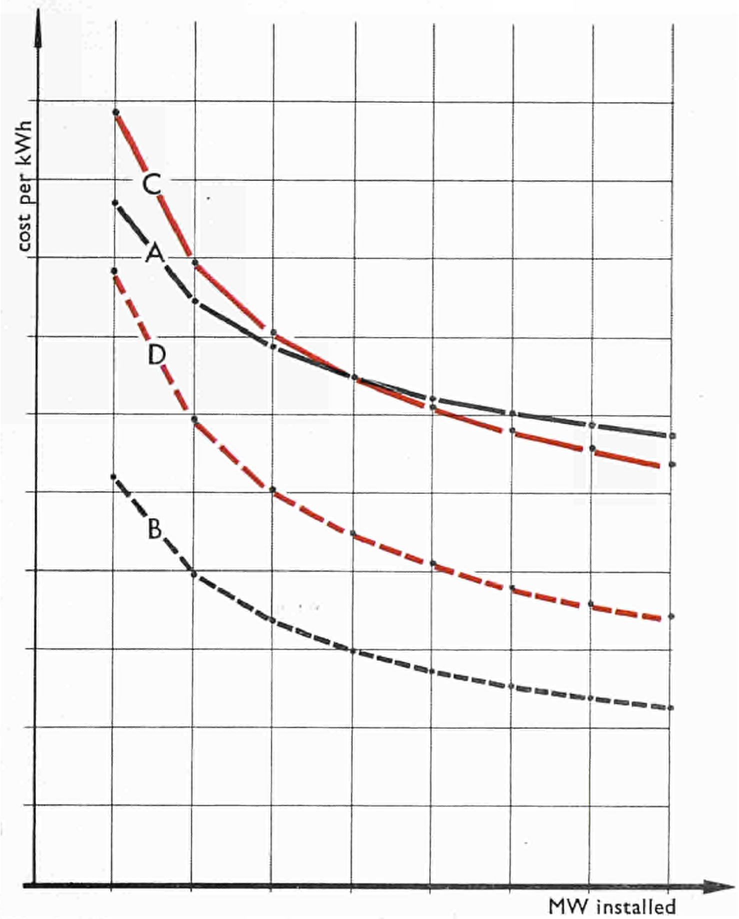
Other factors

The trend of the ideas which have just been presented is that it is in principle possible to compute the extent to which nuclear power plants should be constructed in the present launching period. There are, however, a number of uncertain factors which rule out a *precise* calculation. On the other hand, there are also a number of imponderables which militate strongly in favour of a rapid development of nuclear energy.

The building-up of a nuclear industry is of considerable importance to the economy. A stimulating influence is exerted by nuclear energy development on business in general, if only because a certain level of activity is

Fig. 7
Graphical representation of the rule of thumb according to which investment costs per kW decrease with increasing capacity by the 0.4th power of the capacity. It will be noted that, as capacity increases, this has the effect of narrowing the gap between nuclear and conventional plants' investment costs.
Fig. 8
Influence of the decreasing gap between nuclear and conventional plants' investment costs, when variable costs are also taken into consideration. Nuclear energy costs per kWh are shown in red; conventional energy costs per kWh in blue. The dotted lines take account of investment costs only (ref. Fig. 7). The full lines represent total costs, including fuel charges.





necessary in order to be able to set up a nuclear industry. If we look no further than the activity involved in the construction of nuclear power plants, we see that the high standards demanded in welding, for instance, call not only for new welding techniques but also for new measuring and testing methods. These improvements in turn have their influence on quality standards throughout industry. Failure to develop this form of energy would therefore have adverse repercussions on a far wider field than that of nuclear fission.
Furthermore, it is possible, by taking an active part in the development of nuclear energy, to establish an export position on a world market which is still expanding.
It might be asked whether the expenditure, especially that involved in development work, is outweighed by the benefits to be expected. Although nuclear energy costs will very probably be higher in the short term, which biases a costs comparison with conventional sources of energy in favour of the latter, savings will be possible in the future. Hence, if only in the light of what we have said about long-term planning, it can be asserted that the expenditure is warranted. On the other hand, account must also be taken of the fact that basic materials of mineral origin are not inexhaustible and that it will thus become increasingly necessary to switch over to nuclear energy. This being so, there is even a case to be made out, on the basis of modern replacement value theory, for having the costs occasioned by the develop-

ment of the new source of energy borne by the conventional materials now petering out. This is a factor which as a general rule has been accorded little or no consideration when appraising costs comparisons.

Anticipated trend

From the foregoing it may be concluded that, where the production structure permits, nuclear power plants, by virtue of their low variable costs, must be given prior consideration as regards the filling-in of the lower part of the area traced by the load-time curve in Fig. 2. The upper part of this area is accordingly represented by power plants of the conventional type.

Within each of these groups, new plants will be added, in every case starting from the bottom section; this is a trend that has already been witnessed among conventional plants, which are also being used more and more, as they become obsolescent, for dealing with peak loads.

In addition, the dividing line between the two areas will gradually move upwards, as a consequence of the continually growing strength of nuclear energy's competitive position. This strength is being accentuated by the existing tendency towards the construction of increasingly large production units.

Quite apart from the influence of nuclear energy, this tendency is not difficult to account for. Larger power plants produce more cheaply than smaller ones, notably because investment per installed kW decreases as the size of the production unit increases. It is therefore also advantageous from the point of view of conventional plants that per-unit capacity should be slowly but surely expanding–to the extent, of course, that this is practicable, and due consideration being given to the measure in which transmission costs are adversely affected.

We have already pointed out that the tendency towards larger power plants is boosting nuclear energy's competitive position. This can be further illustrated as follows. There is a rule of thumb which states that investment in an electric power plant increases by the 0.6th power of the capacity. This means that investment *per kW* decreases with increasing capacity by the 0.4th power of the capacity. If we assume that the same rule applies to nuclear power plants–and there is evidence that it does–, the difference in capital costs per kW between the two types of plant diminishes as the capacity expands (Fig. 7).

Figure 8 illustrates the significance of this effect when *total* costs per kWh are considered, account thus being taken of nuclear energy's lower variable costs. It will be seen, for instance, that, if nuclear and conventional energy costs are the same for a given capacity, the saving engendered by the stepping-up of capacity will have the effect of making nuclear energy cheaper than conventional energy.

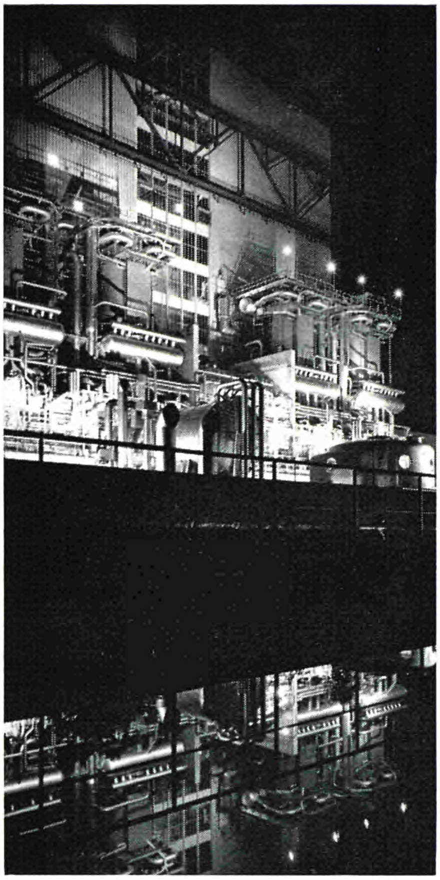
We may therefore conclude that the tendency towards larger power plants and a gradual strengthening of the competitive position of nuclear energy are two effects which consolidate and complement each other.

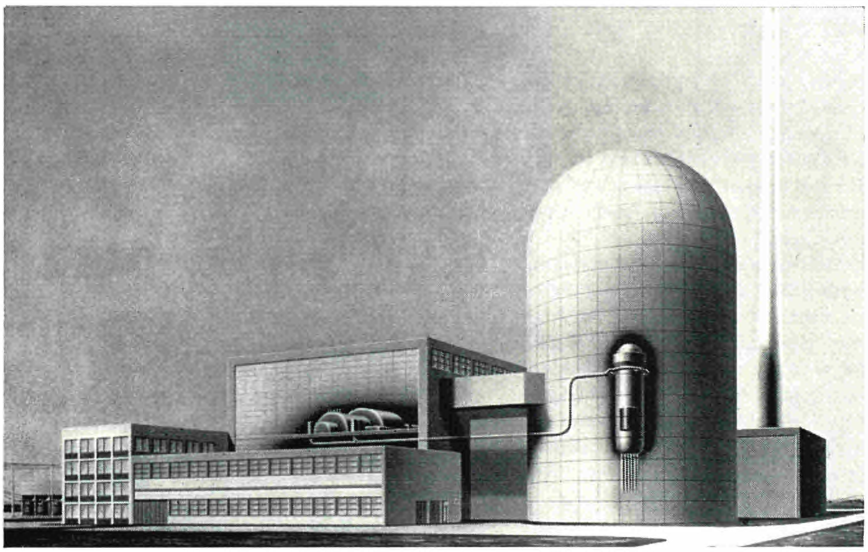
Another question which may be asked is what influence the development of new reactor types has on the picture outlined in this article. For instance, the development of fast reactors will eventually enable nuclear materials to be used with greater efficiency than at present. This improvement resides in their ability to convert non-fissile uranium atoms, which account for over 99% of the uranium found in nature, into fissile plutonium atoms. We shall not go into the technical aspects of this process here. We shall confine ourselves to mentioning that it is assumed that the breeder reactor will be operating on an industrial scale by 1975–1980.

This does not fundamentally alter the pattern of nuclear development as described above. It might be imagined that the breeder reactor, whose variable costs will in all probability be still considerably less than those of current reactor types, will breed not only fuel but also competition among the various reactor types within the lower section of the area under the load-time curve shown in Fig. 2. This, however, is not wholly correct; still less accurate is the idea that nuclear reactor contruction can be serenely suspended until the breeder reactor has been fully developed.

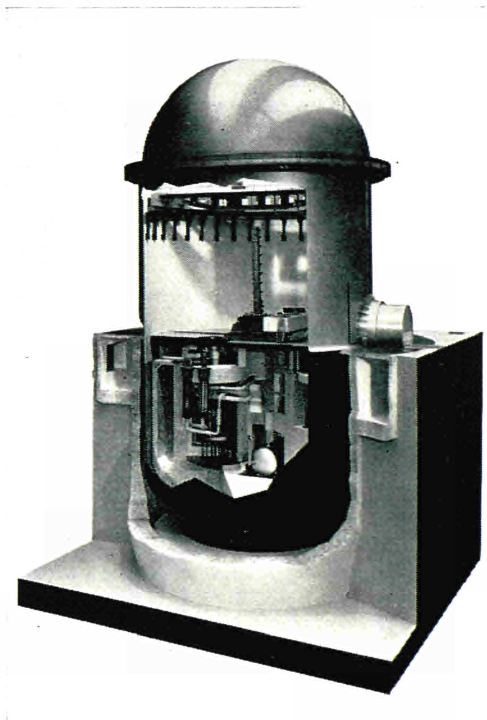
The fact is that the breeder reactor is to some extent dependent on plutonium-producing reactors, such as those which are in use now, for its supplies of fissile material. From both a supply and a cost standpoint, therefore, efficient use of fissile material calls for programming of nuclear energy production, with existing reactors of the current type providing plutonium for the first breeder reactors. This leads to the conclusion that the breeder reactor will very gradually assume a growing share in energy production, side by side with current-type reactors. The latter, which are geared to the use of natural and slightly enriched uranium, will thus for many decades to come, first of all on their own, and later alongside breeder reactors, play an extremely important part in the development of energy supplies.

To-day
Heat exchangers of the G 2 and G 3 gas-cooled reactors in Marcoule (France), which are producing electricity for the grid.





To-morrow
Model of the boiling water reactor plant to be erected in Gundremmingen (Germany). Estimated date of commissioning: 1965.



Later
Model of the Rapsodie experimental fast breeder reactor under construction in Cadarache (France).

ESSOR

CLAUDE CHASSIGNET / *Directorate-General for Research and Training, Euratom*

The name "ESSOR" is a contraction of the French words "ESSais" (tests) and "ORgel" (organic-cooled and heavy-water-moderated reactor).

To the linguist it will be clear that the name is also a symbol of the hopes which have been pinned on this test-reactor, since the word "essor", in French, conjures up the picture of a bird soaring into the sky.

On 10 October 1962 the Commission of the European Atomic Energy Community decided to go ahead with the construction of the ESSOR reactor, at the Ispra Joint Research Centre.

The elaborate piece of equipment which, in a few years' time will thus be put at the disposal of the engineers and research scientists at the Centre will enable them to push ahead with the task of developing and perfecting reactor types using cold heavy water as moderator.

The symbolic name ESSOR is a contraction of the words ESSais and ORgel. The reactor is in fact intended primarily to facilitate the further development of the ORGEL string, that is to say reactors which, besides being moderated by heavy water, are cooled by an organic liquid. Its design, however, is such that it can be used for experiments with different types of coolant. This reactor falls into the present class of reactors which are constructed for the specific purpose of designing and developing "sub-assemblies." These sub-assemblies, which will subsequently be used in a particular type of power reactor, will have to be perfected with great care since they constitute the very heart, i.e., the core, of the reactor.

Experimental reactors as a class are derived from multi-purpose reactors which, as it were, represent a sort of general-purpose test bench; nevertheless, they differ considerably from these, being more readily comparable to those special installations designed for testing a specific category of material.

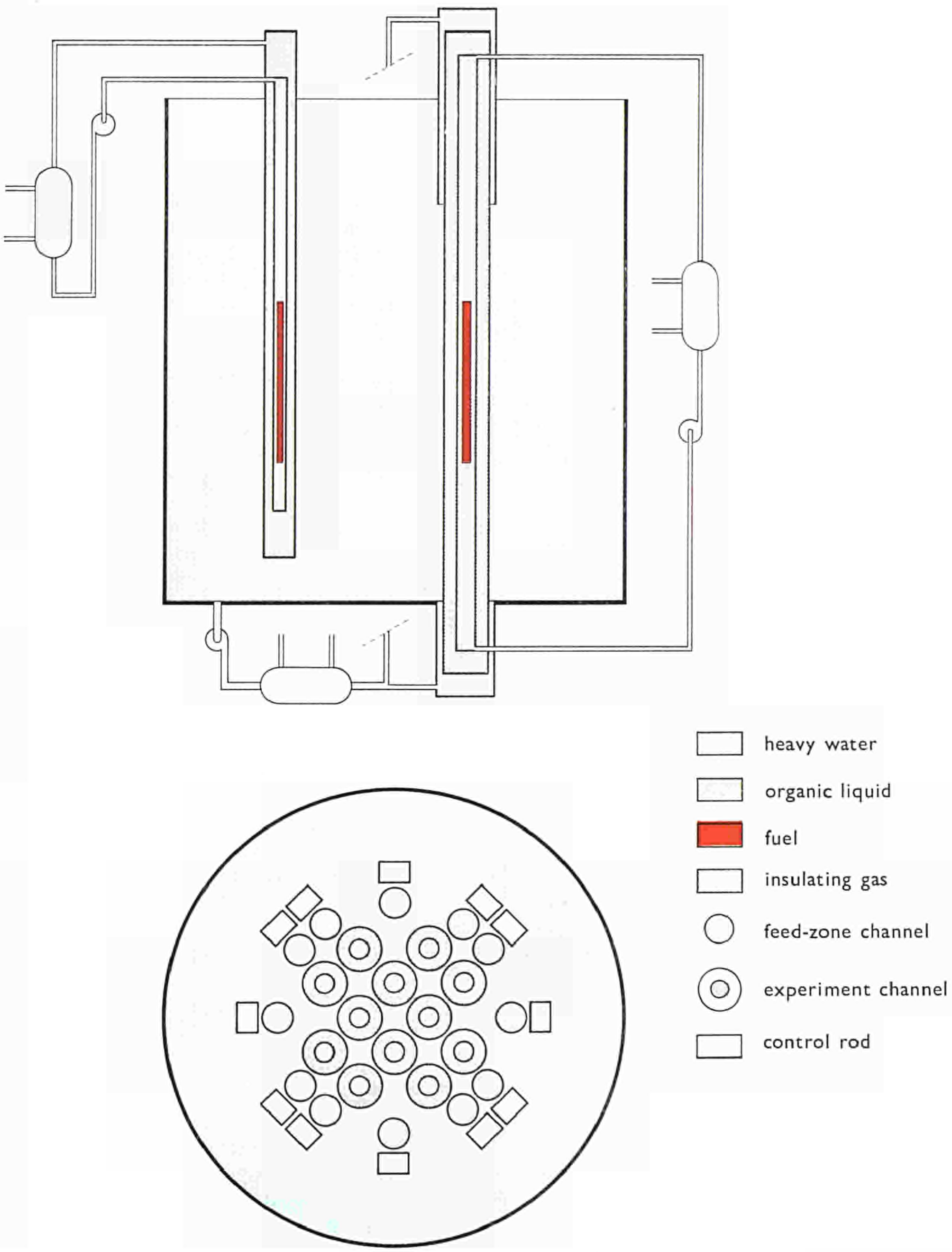
Among others of this family, mention may be made of the EOCR, HWCTR and PEGASE reactors. Of the first two, both of which were built in the United States [1], EOCR (Experimental Organic Cooled Reactor), belongs to the string of reactors which are moderated and cooled by an organic liquid, whereas HWCTR (Heavy Water Components Test Reactor) forms part of the reactor string in which heavy water is used as the moderator and coolant. Finally, the PEGASE reactor (Pile d'Essai Gaz) [2] is intended primarily for the development of graphite- or heavy-water-moderated carbon dioxide-cooled reactors.

Apart from differences in design, the basic idea behind each of these reactors is to create around one or more sub-assemblies–which might, for example, be called core components–the ambient conditions that would prevail in a power reactor, and then to study the behaviour of the sub-assembly with a view to further development. By sub-assembly is meant the basic unit which, when reproduced in a sufficient

1 HWCTR reached criticality in March 1962 at the Savannah River Centre; EOCR is at present nearing completion at the Nuclear Reactor Testing Station in Idaho.
2. The PEGASE reactor went critical this year at the Cadarache Centre in France.

number, will make up the power reactor; in the case of heterogeneous reactors it consists of a fuel element and its immediate environment, which, of course, will depend on the type of reactor concerned.
In a power reactor this sub-assembly is subjected to certain operating conditions depending on the other sub-assemblies which surround it and in conjunction with which it constitutes the nuclear reactor. It is this environment which determines the neutron flux, the temperature effects arising from the cooling and moderating media, and all the interactions of neutronic, mechanical or thermal origin, etc.
Indeed, the solution that suggests itself at first sight is to reproduce these environmental conditions by building a prototype reactor, that is to say a power reactor of minimum size; however, this is only possible in certain fields in which the ground has been largely cleared and the sub-assembly is already developed to a sufficiently advanced degree to enable its manufacture in large numbers to be undertaken with confidence. But in most cases, where various possibilities still remain to be put to the test before the safest and most economical solution can be worked out, it is useful to have a device available whereby the operating conditions can be reproduced without at the same time unduly enlarging the test reactor, which has to be of small dimensions.
It is for this reason that in the ESSOR reactor the neutron flux is set up in a zone in which the fuel consists of highly enriched uranium. This part of the reactor, appropriately termed the "feeding zone", consequently feeds the experimental positions used to accommodate sub-assemblies the behaviour of which is to be studied (see Fig. 1).
The basic unit of the core in a reactor moderated by cold heavy water is the channel. In order to retain the advantages conferred by a low pressure in the pressure vessel containing the moderator, it is necessary to keep the latter at a low temperature (40-60°C) and therefore to insulate it mechanically and thermally from the cooling liquid, for which, on the other hand, high temperatures (400°C and over) are aimed at. It is consequently necessary to insert the fuel element in a tube in which the cooling liquid will circulate and to provide this tube with a double jacket which will act as thermal insulation. If it is borne in mind that all these structures are intro-

Figure 1. Diagram of the ESSOR reactor (vertical and horizontal sections)



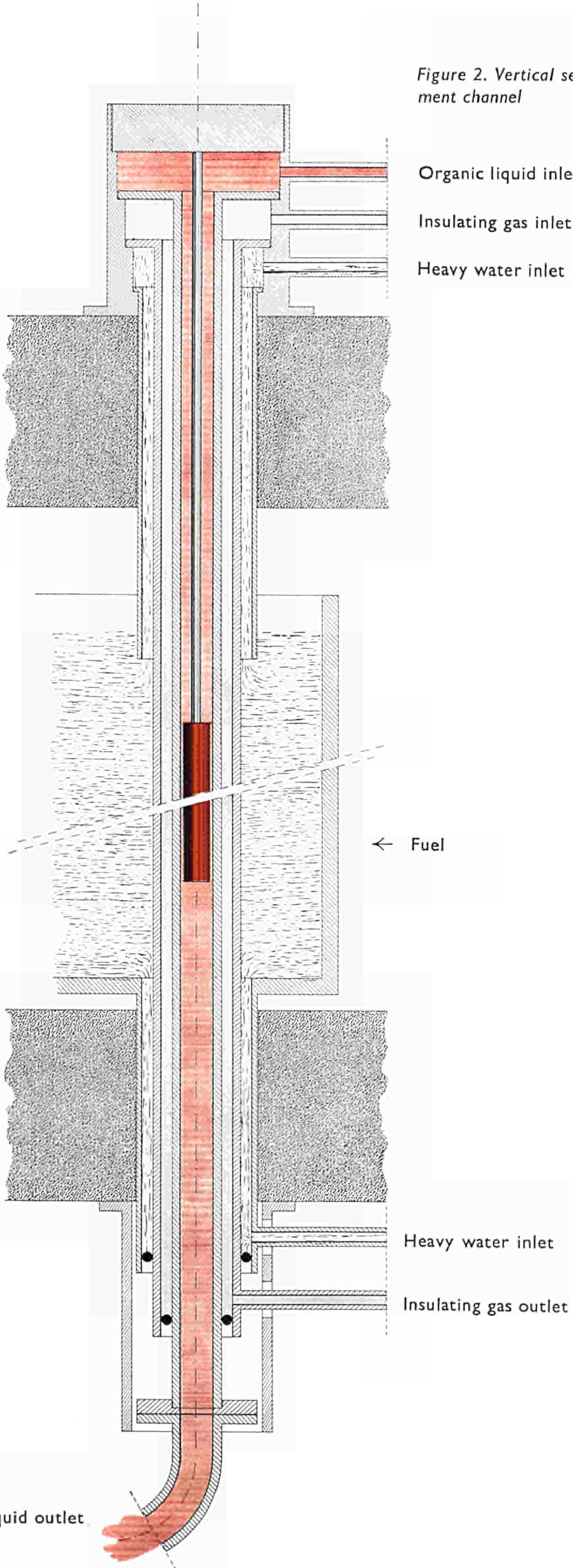


Figure 2. Vertical section of an ESSOR experiment channel

duced into the reactor core, where they absorb neutrons, it will be realized that in order to obtain a favourable neutron balance–which is particularly important when, for instance, the use of natural uranium is envisaged–it is imperative that great care be devoted to their design and construction. The complete channel (see Fig. 2) will thus be composed of the fuel element and its support, the various tubes or tubular members and the devices connecting them with the pressure vessel containing the moderator. The latter devices, which ensure mechanical and thermal insulation between the two liquids, allow the coolant to circulate round the fuel element so as to evacuate the heat generated in it; they must also be provided with leak-tight connections for each of the liquids to the pressure vessel or to the piping, whilst at the same time allowing sufficient play for the expansion differentials due to temperature surges.

In the ESSOR reactor, 12 of these channels can be installed in the central experimental zone (see Fig. 1) or arranged within the lattice pitch (approx. 25 cm square); they constitute a small section of the core. The feeding zone forms around the central zone a crown of 16 elements using fuel which is highly enriched with fissile uranium (U^{235}). The second crown, surrounding the feeding zone, is composed of absorbing rods which ensure the regulation, control and safety of the reactor.

This entire structure is immersed in the heavy water, which is itself contained in a stainless-steel vessel about 2.5 m in diameter.

Design of the reactor

The overall reactor design is based on the fundamental principles summarized above and in each of the sections that we shall now briefly consider we shall find that the recurrent concern is to produce a piece of equipment which is in every respect suitable from the standpoint of the tests scheduled. The main part of the reactor is the core, that is to say the fuel, the moderator, the coolant and the structural materials which confine each of these components to its allotted space. The term "reactor block" is used to designate this assembly together with its various thermal or biological shielding barriers and its radiation-shielded approaches such as upper and lower chambers and access corridors.

After passing through the reactor core, the cooling and moderating liquids evacuate the heat generated into heat-exchangers via primary circuits. By virtue of the fact that only these circuits are exposed to contamination, they are located with the reactor block inside a containment shell. The secondary circuits, on the other hand, never carry irradiated fluid and may accordingly be located on the outside.

Another important operational section is made up of the loading and discharging system, which, since it is used for extracting fuel, or an entire channel, from the reactor block, must permit a detailed examination of these components and facilitate a complete analysis of the results of the experiment. From this point of view, the reactor no longer consists solely of a core and its heat transfer circuits, but becomes in fact a complex flanked by "hot" workshops for the examination of the irradiated material extracted from the core and "cold" workshops for the preparation of the new material for insertion.

Finally, in order to meet the wide range of requirements stemming from the variety of experiments carried out, this complex must have a "nervous system" which itself can be readily adapted to the purposes of the various tests. The regulation and control device employed, after pooling all information, then processes it and works out the necessary adjustments in a digital computer serving as the "brain". Besides permitting rapid action to be taken appropriate to the needs of each particular situation, this makes it possible to adapt the operating procedure to the features of the individual experiment.

Description of the reactor

Fig. 3 gives an idea of the outside appearance of the ESSOR reactor .

The most important structure is the cylindrical containment shell surmounted by the dome which has become a distinctive feature of many nuclear installations. This shell, which is 45 m in diameter and rises to a height of 33 m above ground level, contains the reactor block, the cooling circuits and the handling gear.

The casks for the handling of radioactive materials travel across the operations floor on a track built along one of its diameters. Beneath this floor the reactor and the primary circuits are arranged in a systematic manner in shielded rooms. The reactor itself, located at the centre, occupies a cylindrical space of only about 3 m in diameter, of which only the outline and the heads of the plugs corresponding to the various reactor channels project into the operations floor. It is through these apertures that the radioactive materials are passed from the reactor into the handling casks, which, together with their contents, can be moved along the track to a number of special points located between the rails. The irradiated material can be examined at these points and subjected to various operations: washing, reshuffling, temporary storage and packing in containers. Removal from the containment shell takes place at both ends of the track. By means of a hydraulic lock the fuel elements can be deposited in the "cooling" pond; another lock enables the channels or components other than the fuel to be transported to a suitable workshop after removal from the reactor. Inside the containment shell, therefore, the handling equipment occupies a parallelepipedal space some 6 m wide and 43 m long beneath the operations floor. The cooling circuits will consequently be arranged on both sides of this space; on one side there will be the heavy-water circuit and its auxiliaries, and on the other casemates containing the cooling circuits for the experimental zone. There may be up to five of these latter circuits (four, feeding one channel each, for isolated experiments and the fifth feeding the other eight channels for general experiments).

The outside buildings form a kind of horseshoe around the containment shell, with which they communicate via the two abovementioned extraction locks. In one arm of the horseshoe is a chain of "hot" cells for the examination and dismantling of the fuel element after its removal from the deactivation pool, as well as a "cold" workshop in which the new elements are prepared and conditioned before insertion in the reactor. The other side of the horseshoe houses the workshop for the irradiated pressure tubes and all the rooms for the regulation and control of the reactor.

Finally, part of the main building contains a number of workshops, stores and ancillary rooms the purpose of which is to render the ESSOR complex capable of meeting the specific requirements of the ORGEL string.

The entire design of the ESSOR reactor, as briefly described in the foregoing, testifies to the efforts which have been made to create a practical device which is adapted to the problems to which solutions have to be found.

Since the project was launched, Euratom has called upon industries throughout the Community for their co-operation, thus giving rise to far-reaching competition in a wide variety of fields. This policy, although to some extent acting as a brake on the procedures necessary for the implementation of the project, is now reaping its reward, as exemplified by the fact that several companies in different countries have decided to pool their recources and work as a team—a worth-while development in the context of the new Europe.

ESSOR

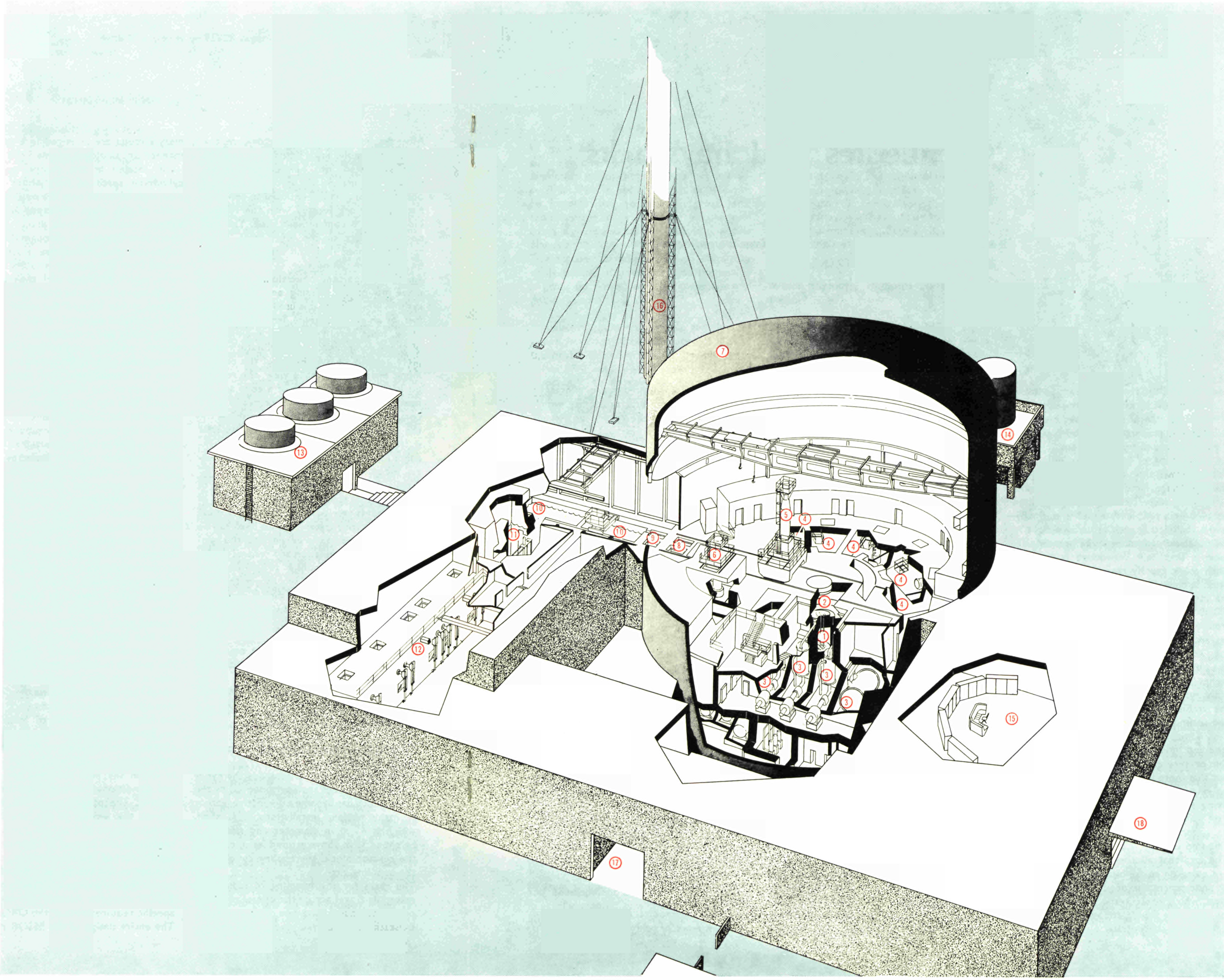


Fig. 3

1. *Reactor core*
2. *Upper chamber*
3. *Heavy water circuits and auxiliaries*
4. *Chambers for organic liquid circuits*
5. *Fuel handling cask (Orgel zone)*
6. *Fuel handling cask (feeding zone)*
7. *Metal leak-tight containment*
8. *Washing station and packaging point*
9. *Fuel element locks*
10. *Cooling pond*
11. *Access lock to hot cells*
12. *Workshop for dismantling of Orgel fuel elements*
13. *Cooling towers*
14. *Air cooler*
15. *Control room*
16. *Stack*
17. *Materials' entrance*
18. *Personnel entrance*

Of needles and haystacks

RUDOLF BREE *Director of the Centre for Information and Documentation, Euratom*

A few decades ago it was very rare to speak of scientific or technical information as a problem. Its rate of growth was manageable, and the processing methods involved were no different from those employed in any other field of learning, including the arts. Since then this situation has undergone a radical change. How to master the mounting flood of technical-scientific information has become a problem in itself and, finally, even a technical branch in its own right.

The outstanding feature of the present situation is that new knowledge is acquired much more rapidly than it can be assimilated. In medicine and biology, for example, the rate of growth is in each case about 400,000 articles or reports per year, while around 30,000 new reports concerned with research into space travel are expected in the course of 1963. Other disciplines, like physics, chemistry, aviation and nuclear technology are progressing ever more rapidly, not only in the countries which were the traditional centres of natural science and technology, but also in Russia, the Far East, Latin America, Australia, New Zealand and India. For a graphic illustration of the present situation it suffices to point out that more than 90% of all the scientists on record since the beginning of time are living and working among us to-day. The first fruits of their activities are memoranda, reports, articles; in other words, scientific information.

The fact that all these scientific activities are going on at the same time automatically underscores the need for *rapid* information, which enables the research worker, on the one hand, to avoid unnecessary effort and concentrate on new developments and, on the other, to take advantage for the purposes of his own studies of all the available discoveries which are of direct concern to him.

Progress to-day is not so much a matter of making great leaps forward in the solving of central problems, as of devising improved combinations of innumerable individual facts and of stimulating development by bringing together the findings of disciplines and techniques which are not strictly speaking very closely allied.

It is increasingly rare to meet the great scientific innovator, exemplified in Newton, Planck and other eminent figures; it is the scientific "worker" in his white overall, investigating, in ever greater detail and under specific conditions, the behaviour and properties of the various forms of matter, for example, who is more and more the rule to-day.

In order to gain a more thorough insight into the subjects studied, more and more scientists must be employed; they, in their turn, require more complicated and costly apparatus. As a result, the initiative in promoting, planning and financing certain main fields of technical and scientific research has progressively shifted from the sphere of what may still be considered individual and private institutes or industries to State authorities: the expenditures and the risks involved in such fields are usually far beyond the means of private individuals or concerns.

All this must be kept in mind if we wish to grasp the importance of technical-scientific information, which constitutes the clearing-house for this constant influx of knowledge–of both the positive and negative results of these really gigantic efforts. It thus represents the first possibility which we have of judging the return on expenditure which, year in year out, can only be expressed in billions. It thus adds up to quite invaluable treasures, which are, moreover, kept lying in the open market-place, available to each and everyman. True, information of considerable general importance is mixed pell-mell with a great deal of dross. The systematic collection and critical processing of these treasures is, however, extremely difficult, not only because of their volume, but also because of the varieties of language and divergences of terminology. But the greatest drawback is the disproportion between the mass of information and the individual's capacity to make use of it, while the exploitation of this store-house of information is even further complicated by the rules of political life, and of the economic activities so closely linked with it.

With so much purposeful technical-scientific activity going on simultaneously it is, of course, highly probable that the solution sought for a problem has already been if not fully at least partially worked out, or that, on closer view, another more promising answer can be substituted for the one supposed to exist or sought in a given direction. But where is it? Faced with this enormous mass of individual items of information, we recall to mind the famous simile of the needle in the haystack–but the particularly galling thing is that the needle must not only be found, it must be found *quickly*.

For if a bibliographical or information study lasts five years, or perhaps only five months–

or even as little as five weeks–this may suffice to discourage any attempt to use information which in fact exists but is inaccessible. People either cannot or will not be kept waiting so long. In great joint achievements of a technical nature one thing is geared to another and delay in one place can seriously hold up all other work. The outcome of such a state of affairs may easily be that all attempt to find the needle is given up when there is no certainty of finding it *soon*.

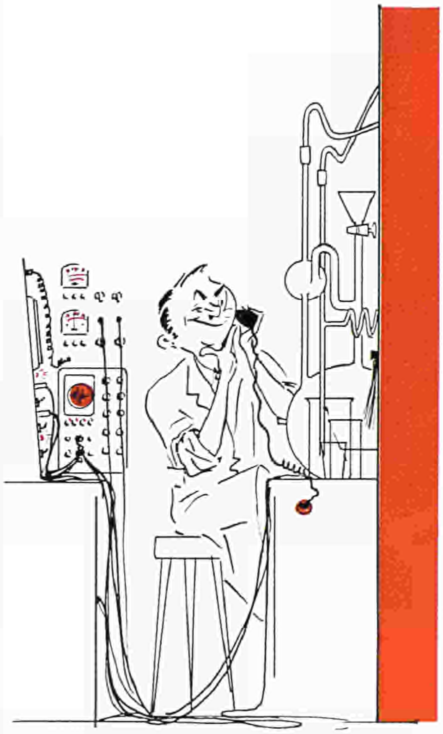
The above argument has been greatly simplified in order to convey a rough idea of the problems and orders of magnitude involved. But despite all the aids which make it possible to narrow down the search, very serious problems arise when it is a question of tracking down information necessary for projects calling for knowledge from several branches of science. Nuclear techniques and their applications involve a particularly wide range of problems of this kind.

Types of information

Information becomes available in certain forms, most of which are derived from old traditions, often no longer suited to present needs.
First there is that age-old, hallowed symbol of assembled knowledge, the *book*. A hundred years ago it was most probably the most important medium of information. To-day statistics have shown that, according to subject, it is three to ten years behind the latest state of knowledge, for long periods of critical work are necessary before it can be put together.
Then there is the *periodical*, which also has an already long tradition behind it. Although naturally much more up to date, its reporting often lags two to four years behind the events or discoveries described.
The *individual report* is usually less out of date. Its "literary" pretensions are more modest and it is a record of results which concentrates on the facts. This vehicle of information has expanded rapidly since the twenties owing to the more generous appropriations of public funds for research and development purposes. Public money is usually granted only if the knowledge it helps to produce is made available either to a restricted circle or to the public at large. On the average, the findings reported by this form of technical information, which is especially vital in nucleonics, ae nor more than one or two years old.
It is at scientific conferences that the results reported are the most up to date. The material presented is often available in the form of "conference papers" or "preprints".

What normally happens to this material?

Obviously it is collected in libraries, where in earlier times it was traditionally the book which played the leading role. Still to-day libraries are the depositories and guardians *par excellence* of all printed matter, and the scientific and technically minded countries vie with each other in the size and completeness of their collections. But the larger and more comprehensive these become, the more difficult it is to prevent them from turning into first-class "family mausoleums" of information.
The critical study of a book is a long business; even to digest a scientific report takes time. But in practically every instance it is not *one* but *many* reports that have to be examined in order to obtain the desired knowledge and insight, and they are sought out by reading the signals which indicate their contents. These are the traditional bibliographical data: author, title (very often unreliable and misleading), year and place of publication, publisher. All this, however, is not sufficient to give a research worker who is not completely at home in a special field an adequate idea of what the work may be expected to contain.
To help out, summaries, reviews and extracts are resorted to–the so-called "abstracts" of 100 to 200 words, condensed versions which are designed to help the investigator feel his way more rapidly to the information sought.
The regular collection of such abstracts or reviews in special periodicals provides an essential tool for mastering technical-scientific information. Important examples are: "Chemisches Zentralblatt", "Chemical Abstracts", "Biological Abstracts", "Excerpta Medica" and others in the same line. Unfortunately, many of them are now finding it hard to keep pace with the flood of new information and are already trailing one or two years behind the publication of the articles or reports they summarize. They have thus lost half their original *raison d'être*. Nevertheless they are still valuable, since, thanks to their condensed form, they can render essential and lasting help in the quest for information.
Their original purpose is now fulfilled by periodicals which are nothing more than well-chosen collections of titles, such as "Chemical Titles", "Biological Titles", "Index Medicus", etc. But even these can hardly keep abreast of the mass of new publications.
As the old library methods became too ponderous, new techniques had to be developed. Librarians specialized in particular fields to help users find "their" literature quickly. They reflected on how they could do their work more expeditiously and effectively by constant improvement in the use of classification media and codifying systems. Independently of the libraries, the



. . . more complicated and costly apparatus . . .

Ispra computer centre: Operation at the control pannel. In the background: removing a magnetic tape.

users of the information themselves tackled this problem, and in the modern world of division of labour a new kind of animal developed whose business was "documentation". He called himself a "documentalist" or "information officer" and, in his turn, systematically set about designing fairly elaborate tools to serve his purposes. In doing so he became increasingly familiar with the problems and pitfalls of his calling, and gradually a whole group of specialists was built up with an ever clearer awareness of the economic and scientific importance of the proper uses of information.

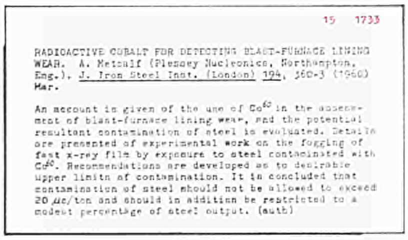
Just as the lover's overriding concern is with the object of his affections, while he never vouchsafes a thought to mother-in-law, registry office, children, or material considerations, so the information officer, in blissful ignorance, too, of all the legal and economic impedimenta which are the cement of our modern society, in the first flush of his idealism naturally thought only of the information to be conveyed to the client and did his job without thinking of the wider implications. And, of course, it was no time at all before the whole tribe were about his ears: copyright, editors, embargoes on information, patent law, official secrets acts, trade secrets, etc. He saw himself hemmed in by all these, and there was nothing for it but to arrive at a *modus vivendi* with them if he was to have any chance of pursuing what he felt to be his vocation.

From the cost angle he had reason in any case to be continually concerned for his position.

The problem which is everywhere so vital met him at every step: to be of use information had to be *pertinent* and available as *rapidly* and in the *fullest form* possible. To find *pertinent* information *clear-sighted* preparation was required. This called for time and experience, both of which cost money. If the information officer wished to give a comprehensive answer, the material on the basis of which he worked had to be comprehensive, i.e. quite full and constantly supplemented and processed. This again takes time and costs still more money. If he wanted to be quick, he needed either unlimited personnel–a numerically strong team–or suitable mechanical or other aids, which could perhaps help, assuming they existed at all. Thus the money question yet again raised its ugly head in more acute form.

Only when a perfect system was brought into being for the collection and keeping up to date of the costly material was it

Information storage

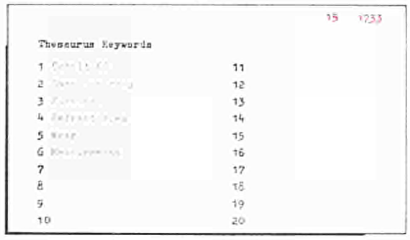


15 1733

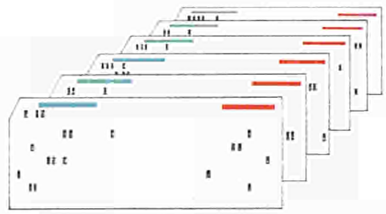
RADIOACTIVE COBALT FOR DETECTING BLAST-FURNACE LINING WEAR. A. Metcalf (Plessey Nucleonics, Northampton, Eng.). J. Iron Steel Inst. (London) 194, 360-3 (1960) Mar.

An account is given of the use of Co^{60} in the assessment of blast-furnace lining wear, and the potential resultant contamination of steel is evaluated. Details are presented of experimental work on the fogging of fast x-ray film by exposure to steel contaminated with Co^{60}. Recommendations are developed as to desirable upper limits of contamination. It is concluded that contamination of steel should not be allowed to exceed 20 μc/ton and should in addition be restricted to a modest percentage of steel output. (auth)

Abstract of the document (report, article, etc.) to be stored



The abstract is analyzed. Its contents are expressed in the form of several keywords.



A card is punched for each keyword. Thus each card contains the information that a certain keyword appears on the analysis-sheet of a certain document.

possible to pay attention to the very expensive and time-consuming processing operations, the forming of a team capable of working together intelligently and the procurement of suitable aids.
Unless all these requisites were fulfilled there was no hope of being able to perform services of real value to the clients.
The further point must be made that we live in a world which uses economic competition as one of its regulators. This, too, makes for difficulties in implementing the well-meaning intentions of the dispenser of technical-scientific information. According to the rules of the game, processed, i.e. exploitable, information counts as an asset to the individual, the enterprise, or even the whole national economy. As a lead in information is an advantage only if the information is withheld from competitors, documentation was developed, particularly in the economic field, as a means of furthering individual interests.

Any major changes in this situation could only be brought about when it was realized that individual interests were better served if they were subordinated to the common good in order to achieve an all round improvement in performance. This meant that those responsible for public affairs encouraged private enterprise to obey this principle. Now they could support establishments to exploit the precious knowledge which, although everywhere accessible, had been so long ignored.

Special features of technical and scientific information in the field of nuclear energy

Nucleonics, even in its widest sense, is a relatively recent field of scientific activity. In fact it has only really existed as an independent field with extensive publishing activities since the United States Atomic Energy Act made it incumbent on the Adminis-

Storage by transfer of the information contained in the punched cards to the magnetic tape.

tration to make public all knowledge of this branch of technology which could serve peaceful ends. This happened barely fifteen years ago, a very brief span compared with the age of such venerable sciences as physics and chemistry. In other words, all activity in nuclear science is young and has not yet set in a rigid mould. This is also true of the organizations providing information; they are still relatively adaptable. A second important point here is that within the Western world the United States Atomic Energy Commission (USAEC) was initially so predominant in knowledge, resources and organization that the other authorities in the West engaged on the same activities modelled themselves on it more or less automatically.

A third noteworthy fact is that the possibilities afforded by the less peaceful application of atomic processes led all States to exercise control over all scientific activity in this field, which means that the allocation of work and the follow-up of results are much more strictly centralized than in most other fields of scientific and technical activity, except space travel and defence.

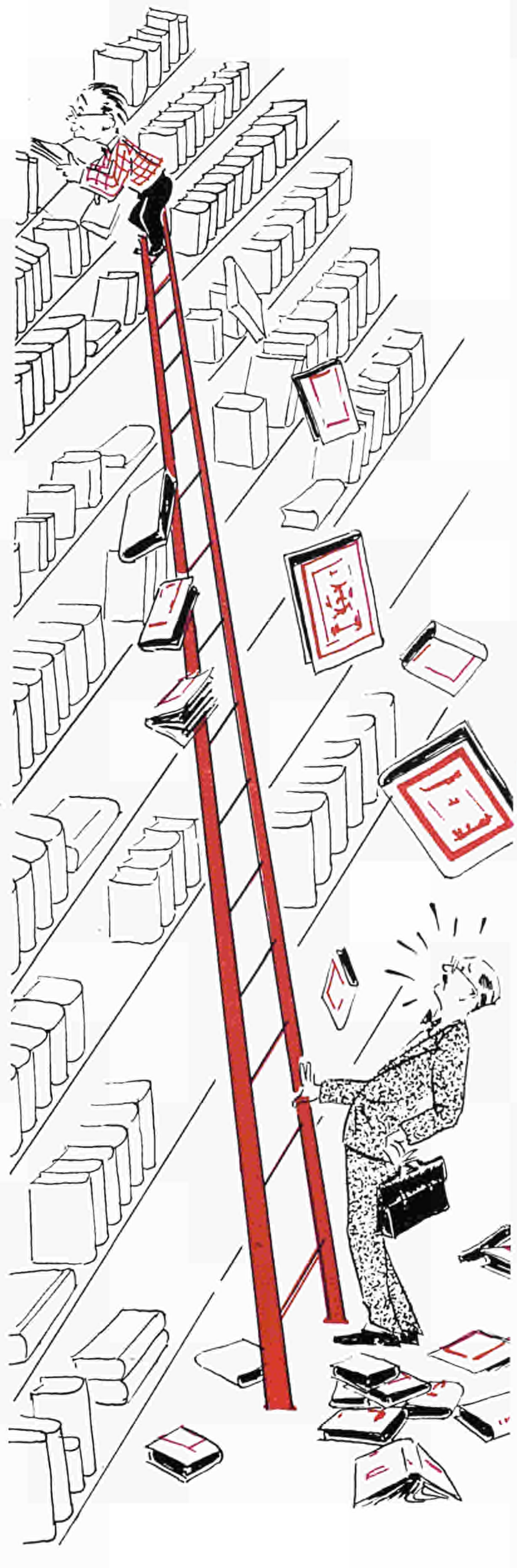
The USAEC also created a reference organ of its own, "Nuclear Science Abstracts" for the indexing of technical and scientific literature in this field. It developed this to such a high level and reliability that, apart from a similar but much more guarded Soviet publication, absolutely nothing comparable has emerged.

One last feature of exceptional importance is that, as a result of the historical development of this relatively callow branch of science, the English language by far predominates. This simplifies things fundamentally compared with many other fields of knowledge.

All the special characteristics listed here make it easier to deal with information relating to modern technology. We have been spared the usual dispersion over an enormous range of competing publications, while, with the proportion of public investments so high, there is a strong emphasis on the publication of development and research results in series of reports. More than two-thirds of the available information in the atomic field is contained in series of this kind.

Technical and scientific information in Euratom

Euratom originated at a time when the struggles for the recognition of the value of information described at the beginning of this article were already a thing of the past and when, not least because of the USAEC's example, its importance had long been acknowledged. This had a felicitous influence on the text of the Euratom Treaty, which lays down a series of rules dealing explicitly with the Commission's duty to disseminate information.
The major advantage of this state of affairs is that information and documentation became legitimate branches of activity which could be provided for efficiently by appropriations under the Euratom budget. This is still far from being the case to-day with many other institutions, where information must take refuge in the budgets of libraries or other departments and often lives a completely wall-flower existence.
This, as it were, privileged position naturally imposes weighty obligations upon those who are to use the information on behalf of the European Atomic Energy Community. Euratom attempts to take account of this obligation in its "Dissemination of Information" directorate, which co-ordinates all efforts in the information field, irrespective of whether it is a question of disseminating knowledge gained as a result of work carried out in Euratom's own research establishments or under contract by research institutes and industrial enterprises, or else stemming from Euratom participation in contracts of association.
Of course, the knowledge which is already available must also be disseminated, that knowledge which provides a better and firmer foothold for every step in the progress of research workers who would otherwise have to start from scratch. As has already been pointed out, this existing knowledge conceals treasures worth billions. It is estimated that, at the present time, half a million individual items of important nuclear information exist and that the number is swelling by between forty and fifty thousand annually.
The knowledge gained by work in the Euratom research establishments or under research agreements is made public in scientific reports and reviews which come out at regular intervals.
There is nothing extraordinary about this,



. . . as the old library methods became too ponderous . . .

. . . the need to find quite specific stalks . . .

but what is being done to exploit the great volume of information already available on nuclear technology?

At the beginning of its activities the Euratom Commission set up a research group on machine or automatic documentation. This was the CETIS Group ("Centre européen de traitement de l'information scientifique) which works in Ispra. Among other things it is to study in a systematic fashion the possibilities which electronic computers afford for the handling of non-numerical problems, including those bound up with automatic translation. It is clear that all the activities of the Euratom Commission are further complicated by language problems and that there is much to be gained by finding out whether time-consuming human translation cannot one day be–if not replaced–at least speeded up by means of fairly accurate rough drafts.

The decision to set up this research group is clear evidence that the Euratom Commission was alive to the importance of the information problem, and therefore felt itself responsible for providing facilities designed to meet the information needs of the research centres and nuclear industries to be built up in the Community countries.

It is now possible, as has already been made clear, to construe documentation as the blanket concept for the collection, sifting and examination of available information and for the tracking down of answers to specific questions.

On this point of tracing information, let us revert to the haystack methaphor. First of all the haystack must be built.

All items of information are in fact just hay until they are specifically needed. It is the need to find quite specific stalks of hay which causes all the difficulties. They are naturally well hidden and difficult to isolate. We must therefore endeavour to devise a suitable process so that, when a particular question is put, the stalks in question stand out quite automatically from the other stalks in the haystack, let us say that they light up when the question is uttered. It then perhaps ceases to be so difficult to distinguish the fifty or so little stalks sought from the 500 000 which we don't happen to require at the time. This is precisely the job of the Euratom Documentation Centre. Such a centre had indeed to be established to serve both the requirements of the Euratom research centre itself and those of all other interested parties in the member countries.

From what has already been said it should be clear that this cannot be brought about overnight: this centre is therefore still in the process of being built up and, in this respect, its situation is no different from that of a nuclear power plant under construction. To begin with it consumes a great deal of money and a long time must elapse before it goes "critical" and reaches the production stage, an exact parallel of the power plant.

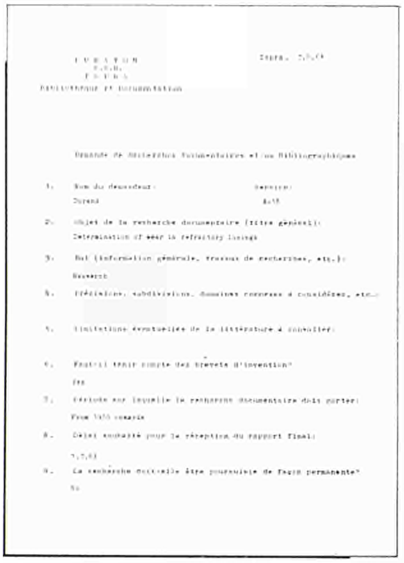
In collaboration with the CETIS research group, the documentation centre has worked out a plan enabling it to perform the precise operation that we attempted to illustrate with the haystack metaphor.

Fortunately, other organizations had already built the haystack, for instance, the USAEC, whose "Nuclear Science Abstracts" contains the lion's share of the information dealing with atomic processes of concern to Euratom.

A system had first to be devised by which the stalks could be so prepared as to light up when given questions were put.

Furthermore, a process was developed by which the glowing hay stalk could be rapidly picked out of the heap and subjected to close scrutiny. The whole adds up to, if not the biggest, at least one of the biggest European projects for electronic information storage with fast automatic selection. In more technical terms this means the utilization of an IBM 1401 magnetic tape storage unit of the kind common in electronic computers. It is adapted in a specific way

Information retrieval

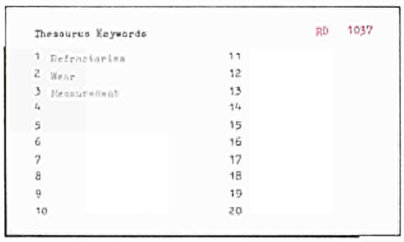


EURATOM
C.C.R.
ISPRA
Bibliothèque et Documentation

Demande de recherches documentaires et/ou bibliographiques

1. Nom du demandeur: Service:
2. Objet de la recherche documentaire (titre général):
Determination of wear in refractory linings
3. But (information générale, travaux de recherches, etc.):
Research
4. Précisions, subdivisions, domaines connexes à considérer, etc.:
5. Limitations éventuelles de la littérature à consulter:
6. Faut-il tenir compte des brevets d'invention?
Yes
7. Période sur laquelle la recherche documentaire doit porter:
From 1950 onwards
8. Délai souhaité pour la réception du rapport final:
9. La recherche doit-elle être poursuivie de façon permanente?
No

Request for information



Thesaurus Keywords — RD 1037

1 Refractories	11
2 Wear	12
3 Measurement	13
4	14
5	15
6	16
7	17
8	18
9	19
10	20

The request is analyzed and expressed in the form of keywords.

to store up hundreds of thousands of items of information and, when particular questions are put, to single out and to disgorge those items bearing on the question.

The subterfuge which makes this possible is no stage conjurer's feat: the essential points in each individual unit of information are inscribed in a suitable code on the recording tape and with it the unit's "house number", which is no more than a serial number.

It is obvious that the encoding is a very responsible task, for only if the content of the information is correctly encoded can the information be retrieved. The work must therefore be done by specialists–chemists, physicists, engineers, biologists–expert in the field covered by the information. But in order to encode an item of information you must first have a code containing all the necessary concepts. It would be outside the scope of this article to describe the genesis of such a code, which has already been tentatively outlined in Euratom Bulletin No. 3/1962.

It is sufficient to note that such a code has already been created for Euratom's nuclear information and that work is now going on to encode the new material coming in and to reduce the considerable backlog.

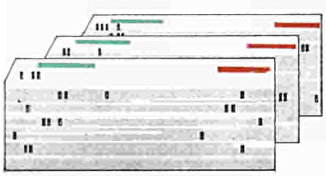
It emerges from the statistical experience acquired to date that an average of about eight or nine key-words are allotted to each research report. These words represent the content of the information with sufficient accuracy.

We therefore write down the serial number, the author and all key-words, i.e. our code, and then a few other points. These are inscribed on punched cards and from them transferred automatically to the magnetic tape.

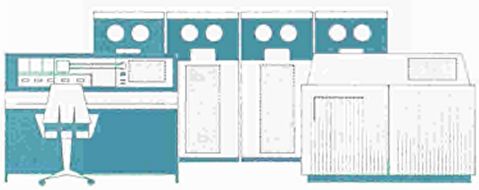
How do we retrieve the information from the tape?

Thus, by means of the programming operation, the small stalks–figuratively speaking–are so prepared as to become recognizable when the proper question is put. To revert to our metaphor, they light up.

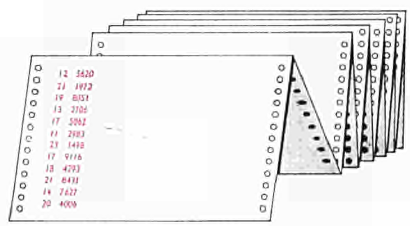
When we have a question, we write this, too, on the recording tape in the terms of our code and feed it into the machine, where all the tapes with the stored information are then compared with it at great speed. Each time the relevant combination of key-words is met on the swiftly unwinding tape, the machine notes the serial number of the item in question. The complete bibliographical data belonging to each item of information are registered on another recording tape, and given the corresponding



A card is punched for each keyword of the request.



The machine retrieves the documents which contain the request's keywords on their analysis-sheet.



The reference numbers of retrieved documents are printed automatically.

serial numbers. The numbers selected are now in their turn put back into the machine, which can then automatically print all relevant bibliographical data one after another on a fast tabulator.

This combination is the answer to the question put. With it the questioner can now obtain all the available information.

Since the electronic machines work very rapidly and have a high storage capacity, i.e. since they can, so to speak, digest very large stacks of hay very rapidly, we hope that they will make it so easy for us to find information that it will be possible to provide the answers to the questions put in days instead of weeks.

In this whole process nothing is demanded of the machine which it cannot with certainty perform. First, it speeds up the search. To look up a register in card index form with 500.000 units of information would take time. And a card index with eight or nine entries for every item of information would need about 4.5 million cards; manual search would be practically out of the question.

But the machine has one further paramount advantage: in posing the question it is possible to form any positive and negative logical sums desired, for instance, to ask for all information about welding, steel and pressure vessels, but, for example, exclusively those dealing with acetylene gas welding and then only information of more recent vintage than 1960. By hand this could be done only by extremely laborious and lengthy search, comparison and discarding, while the machine is in a position to master it all in one run.

In addition, the machine can copy down the data required with extraordinary speed and completely automatically. This alone would require an enormous staff if done by hand and would take an extremely long time.

No comparable information storage unit is being prepared at the present time in either the United States or the United Kingdom. It requires a considerable investment and a great deal of brainwork for codifying the material. Machine operating costs are also high and a team of specialists must be constantly in attendance to analyze the questions put, prepare them for storage, make a critical assessment of the answers obtained, and be able generally to extract optimum information from the magnetic memory.

Euratom is in a position to undertake such a task because the expenditure is shared by six countries and the advantages can also directly benefit the many persons interested in those countries. The results are infinitely more favourable than could be obtained by establishing such a system in a single country.

The extensive encoding work required takes years and the memory cannot be used to full capacity before it is completed. Meanwhile, we must live on credit. Here the comparison used above with the building of a nuclear power plant is thoroughly apt. It is common knowledge that investment credits are needed for the power plant, but it is unexpected to learn that the same problem arises in building an information storage system.

The parallel lies not only in the period of time for which credits must be requested, but in the equivalent uncertainty as to whether the performance hoped for will in fact be achieved. Half a million individual items of information have to be encoded; it goes without saying that this raises a multitude of problems.

As to the dimensions of the storage units which will be needed for the next ten years, it will probably be possible to make do with the present system, which offers the advantage that it asks no more from the machine than it can perform without considerable extra preparatory work. For all the steps requiring associational ability and decisions on combinations, the help of the human brain, which is superior in this respect, will continue to be required, while the machine's incomparable memory and its unsurpassed ability to make comparisons at speed will be exploited, as well as its capability of copying with scarcely credible rapidity the information sought.

Until such time as the memory can be put into operation, work must be carried out manually. At present this means that a small group of information officers must wade through registers and card indexes to answer the questions asked. Output is, however, so small that for the time being this work can only be done for the staff of the Atomic Energy Community and not for interested circles in the Six. And everyone is waiting, full of impatience and anxiety, for the time when the electronic memory will make it possible to provide this service more rapidly, in an improved form and for the benefit of the Community as a whole.

We quite realize that what we are doing is not very spectacular. We are conscious of performing an auxiliary service whose importance has not yet become perfectly clear even to all potential beneficiaries.

This service must naturally be provided within the framework delimited by the Euratom Treaty. This, however, is a legal construction which is only at the outset of its testing time.

Thus we have to find, as we go along, constructive compromise solutions and answers enabling the knowledge acquired or to be disseminated to be exploited as a whole, striking a reasonable balance between private and State interests and the claims of the Community.

The task is a fascinating, if an elaborately complicated one, and we are aware that the privileged position in which we have been placed by circumstances represents first and foremost a duty–the duty to derive the utmost advantage from it.

The rôle of the chemist in nuclear energy

M. ZIFFERERO

Professor of radiochemistry at the Universitv of Rome and Head of the Italian nuclear fuel reprocessing programme

Although the phenomenon involved in the production of nuclear energy, the splitting of the atom, is of a physical nature, as are the laws which govern it and permit it to be put to practical use, it is chemistry and chemical engineering which played the major part in the early development of nuclear energy right from the outset at the time of the Manhattan Project, when one of the fundamental problems was concerned with enriching uranium in the isotope 235 and separating the plutonium produced in the Hanford reactors. We have come a long way, since those early days, and to-day it can be said that the ability of nuclear power to compete with energy obtained from conventional sources is largely dependent on the contribution made by chemistry and chemical engineering.

In order to appreciate this it is sufficient to look at the nuclear fuel cycle and the considerable savings which can be effected by improvements in the fissile material production processes, in fuel fabrication methods as well as in post-irradiation processing techniques and the treatment and disposal of waste. In the case of special materials such as those used as fuel cladding, moderators and coolants, substantial savings may be brought about by attempts to devise cheaper production methods or by the use of new materials possessing better characteristics.

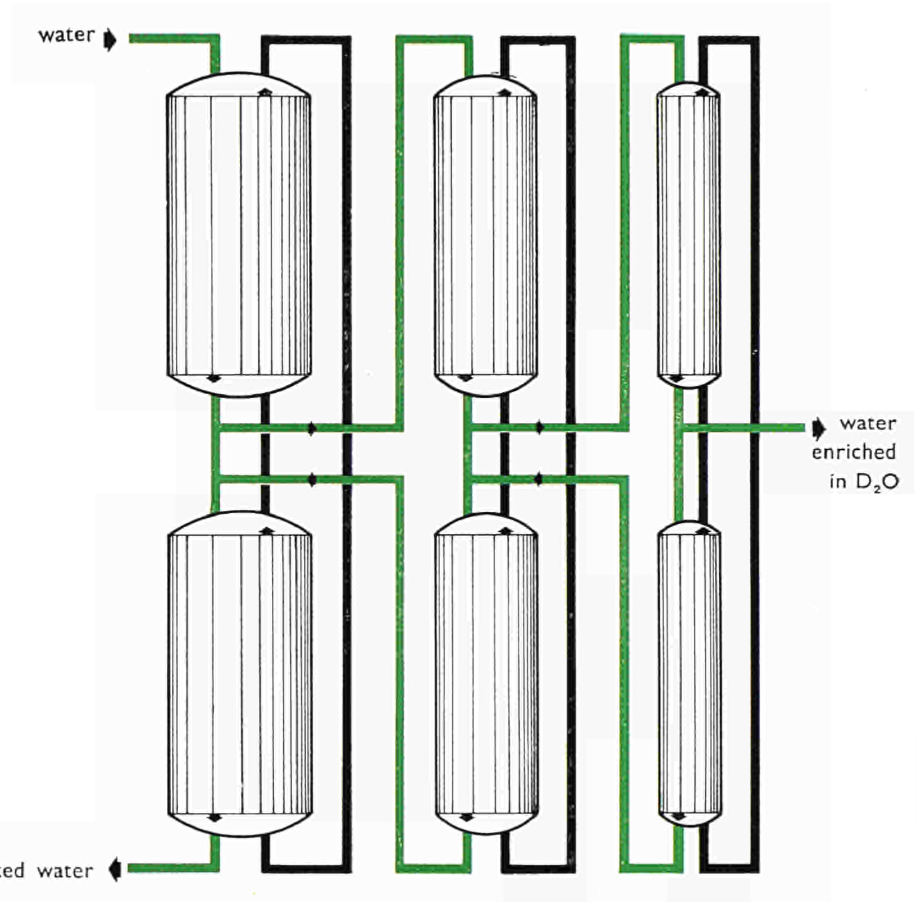
These distinctly technological tasks are accompanied by large-scale projects connected with pure and applied chemical research, which are the inevitable concomitants of any new technical advance. For the chemist, this involves studies on the properties of a large number of little-known or even completely unknown elements, the development of appropriate methods of analysis, the mapping-out of vast new fields of research such as radiochemistry, the study of radiation effects, high-temperature chemistry, the chemistry of melted salts and, finally, the elaboration of new techniques such as activation analysis, the use of isotopes as tracers and the extraction of metallic ions in organic solvents.

Very few elements escape the attention of the chemist engaged on nuclear research, from the light elements (H, Be, B, C, F and Al), some of which are of paramount importance for the moderation and control of chain reactions, to the elements in the centre of the periodic system, all of which are represented among the fission products, and the heavy elements, or actinides, whose peculiar properties have paved the way for this new form of energy.

The fact that so much interest, from such novel standpoints, is focussed on elements which as little as twenty years ago made up little more than just a small section of the periodic system, has imparted a tremendous impetus to inorganic chemistry–a discipline which, after an access of feverish activity in the second half of the last century, fell into a decline at the beginning of the twentieth century due partly to the rapid pace of developments in physical and organic chemistry. This development emerges clearly if we glance at Chemical Abstracts, which reviews specialized chemical publications from all over the world, and if we observe the way in which journals devoted to research on inorganic chemistry have sprung up or been revived at various times.

Starting Materials

From the mining of the uranium-bearing ore right up to the nuclear-pure uranium metal ingot or the uranium hexafluoride sent for isotope enrichment in diffusion plants, the chemist and chemical engineer play their part in the nuclear energy process. The Western world's annual output of U_3O_8 is around 30,000 tons, but the fact that the ore does not on the average contain more than 1% of U_3O_8 means that about three million tons of ore are processed annually. In the US alone 9,000 people are employed in this, the first stage in the production of nuclear fuel. Taken as a



whole, therefore, the industry engaged on the extraction and refinement of uranium is on roughly the same scale as some of the major chemical industries, which is not surprising when it is realized that the finished product has to be of a very high grade of purity, comparable at least to that of pharmaceutical products. The production of U^{235} by the enrichment process involving the gaseous diffusion of natural uranium hexafluoride can also be regarded as part of the source material production process. The development of these techniques has necessitated intensive research activities into the properties of fluorinated compounds and fluorine-resistant materials. This has led to new, unexpected applications, such as, for instance, polytetrafluoroethylene and polyfluorotrichloroethylene, which the plastics industry has by now placed in the forefront of materials resistant to chemical attack. Isotope separation, or the concentration of isotopes which are present only in small proportions in the natural element, is a process required in many fields of nuclear technology, from the production of fissile materials to the manufacture of neutron moderators, shielding and neutron absorbers.

A good example of the important part played by the chemist in solving the problems bound up with isotope separation is provided by heavy water production.

It is common knowledge that deuterium oxide, more generally known as heavy water, possesses exceptional properties as a neutron moderator. The separation process is a somewhat laborious one, as it is present in ordinary water only in the proportion of 150 ppm.

The methods originally used for heavy water production consisted in progressive enrichment by distillation with a separation factor of 1.05[1] and enrichment by electrolysis with a separation factor of 7. The energy consumption gives rise in both cases to high production costs.

The method most widely used at the present moment is that based on isotopic exchange at two different temperatures– a method, therefore, which is basically chemical.

The reaction

$$H_2O + HDS \rightleftharpoons HDO + H_2S$$

Fig. 1

Heavy water production by means of H_2S-H_2O isotope exchange–a typical flow diagram. In the top columns water is enriched in deuterium by stripping hydrogen sulphide (H_2S); in the bottom columns the reverse phenomenon occurs, enabling the hydrogen sulphide to be regenerated. Since the isotope exchange process differs with varying temperature, the flow can be so arranged as to produce an excess of enriched water, e.g. the top columns can operate as cold columns and the bottom ones as hot columns. The deuterium content of the water can be progressively stepped up by connecting several columns in series.

1 The separation factor α of an isotope enrichment process is expressed by the relation

$$\alpha = \frac{y\,(1-y)}{x\,(1-x)}$$

where y is the atomic fraction of the light isotope in the depleted effluent, and
x is the atomic fraction of the light isotope in the enriched effluent.

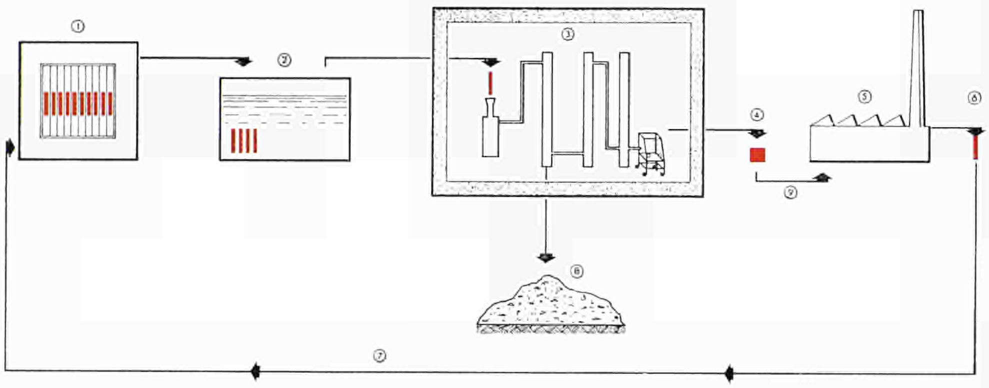


Fig. 2: Fuel cycle in a research reactor
1. Nuclear reactor
2. Cooling pond
3. Reprocessing plant
4. Uranium billet
5. Fuel manufacturing plant
6. Fuel element
7. Recycle
8. Waste storage
9. U^{235} make up

has an equilibrium constant of 1.92 at 100°C and 2.35 at 25°C. It is thus possible to obtain enrichment with a theoretical factor of 1.22. When hydrogen sulphide is bubbled through water at 25°C, some of the deuterium passes from the hydrogen sulphide into the water. Part of the water thus enriched, e.g. 20%, is set aside, while the H_2S, depleted in deuterium, is bubbled through the remainder at 100° C, the water yielding up some of its deuterium to the H_2S. Due to the increased temperature, the hydrogen sulphide regains its initial deuterium content while the water, the deuterium content of which has been depleted, is discarded.
The enriched part of the water is now recycled in exactly the same way, at a low temperature at first, to enrich it in deuterium, and then at a high temperature, to permit the hydrogen sulphide to regain its original deuterium content from the water enriched in the preceding colder stage (see Fig. 1).

A process of this type, repeated for a very large number of stages, enables us to obtain, in a comparatively simple and economical way, a deuterium enrichment of the order of several per cent. Subsequent enrichment up to 99.6-99.8% is arrived at by means of distillation or electrolysis. This method, originally evolved in Great Britain, is now widely used in the US and France.

Other isotopes are of particular importance in connection with reactor technology and it is on these that chemists and engineers engaged on research into economical means of production are focussing their attention. Natural lithium, for instance, is a mixture of Li^6 (7%) and Li^7 (93%). The first isotope has a neutron capture cross-section of 930 barn[2], while that of the latter is only 0.033 barn. The capture cross-section of sodium is 0.50 barn. If Li^7 could be isolated cheaply, it would constitute an excellent reactor coolant. Such a process would likewise afford the advantage of making available material enriched in Li^6, which is utilized in the production of tritium, for example.
The separation of B^{10} (capture cross-section = 3990 barn), which is present in natural boron in the proportion of 18.8%, would likewise open up interesting possibilities by yielding improved materials for the control of chain reactions and the construction of neutron-counting devices. An immediate effect would consist in the reduction in the size of neutron shielding. Numerous methods of separation are now being examined, one of the most promising being the distillation of the complex dimethyl ether borotrifluoride.

In addition to the problems bound up with isotope separation, other difficulties connected with the separation of starting materials have engaged the attention of chemists; for example, the obstacles encountered in hafnium-zirconium separation and in the separation and production of rare earths have sparked off a whole series of studies into these elements, about which virtually nothing was known prior to 1945.

Fuel and Reactor Technology

The nuclear fuel cycle is an inexhaustible source of problems for the chemist (see Fig. 2). The difficulties connected with the recovery of unused fissile material or material produced by breeding reactions vary considerably depending on the fuel and reactor type involved.
Techniques for the recovery of uranium, plutonium and thorium and the elimination of fission products constitute one aspect of nuclear technology which comes under the heading of "recovery processing" or "reprocessing." In this field, which belongs essentially to chemistry, numerous processes have been developed based on extraction techniques involving the use of organic solvents, and major production plants have been set up in all the countries in which nuclear technology has reached an advanced stage.
Plutonium is produced by all reactors running on natural or slightly enriched uranium (i.e., reactors used for the production of energy). On average the burn-up of one kilogram of uranium-235 indirectly produces 500 grams of plutonium. One megawatt-year corresponds roughly to the fission of one kilogram of uranium-235. On the basis of these figures and assuming an expansion in nuclear energy production, it is not hard to see that huge amounts of plutonium will be available in the not-so-distant future.

2 Unit expressing the probability of a particular nuclear process, in this caase the probability of neutron capture.

At the moment, the main use to which plutonium is put is the production of nuclear weapons. It is safe to predict, however, that, as the number of reactors in countries which have no military programmes increases, a use will have to be found for the growing quantities of plutonium on hand. The most obvious way of absorbing these expanding supplies of plutonium is to re-use it as fuel in reactors. A vast programme with this aim in view has been launched by Euratom and is to be carried through in the course of its second five-year programme. The part played by the chemist in this field, too, is a vital one, for plutonium is an extremely toxic material and exceptional precautions must be taken in the handling and conversion of this element, its compounds and materials in which it is present.

The fuel cycle based on the conversion of thorium into uranium-233, which is a fissile element, likewise offers excellent possibilities, but this is another instance in which the chemical problems of separation, in this case the separation of uranium from thorium and from the fission products, can have a considerable effect on the apparently self-evident economic advantages afforded by reactors which convert non-fissile into fissile material.

The US and Italy, two countries in which the Th-U cycle is being put to practical use, have realized the need to give priority to the construction of special chemical processing plants for these extremely problematic fuels.

In addition to fuel cycling, other major problems within the ambit of chemistry and chemical engineering have yet to be solved in the field of reactor technology. Nuclear power reactors must operate at the maximum possible temperatures if they are to reach an adequate standard of thermodynamic efficiency; this means that the materials used in the construction of the reactor are called upon to withstand considerable stresses and may be subjected to chemical reactions which would not take place at lower temperatures.

Dozens of laboratories and hundreds of technicians are now engaged on a vast research programme in the field of chemistry and high-temperature chemical technology (above 500°C). While small areas of this field of investigation have already been explored as a result of the development of the internal combustion engine and then the jet engine, the stimulus which the expansion of nuclear technology has given to high-temperature chemistry is without precedent.

So little work has been carried out on the behaviour of salts and molten metals and their mutual solubility, the solubility of gases in metals and salts, the kinetics of high-temperature reactions, lattice structure and relative densities, vapour pressure, the thermodynamic values and the actual formulae of the various compounds, that chemists and metallurgists are now beginning to investigate them for purposes of nuclear technology.

The need for operating power reactors at high temperatures raises new chemical problems relating to the fuel cycle. On the one hand, it is the task of metallurgy to produce fuel elements which do not corrode at high temperatures, while on the other the chemist has to dissolve these non-corroding elements after irradiation in order to recover the fissile material by the simplest and most economical means possible. From these contradictory requirements emerges the need to make an entirely new departure in processing techniques, e.g., high-temperature reprocessing by pyrometallurgical methods or the use of fluorine and its derivatives to convert all the fuel into fluorides, from which the fissile elements can then be isolated by means of distillation.

In order to eliminate as soon as possible the conflict which exists between these requirements, it is essential, in addition to the necessary chemical and metallurgical research, that chemists, metallurgists, engineers and physicists work together right from the start on the designing of new types of fuel elements in which greater attention is paid to fabrication and reprocessing costs.

Radiation and Radioisotope Chemistry

The interactions which occur between radiations and matter have been a subject of research for the chemist since the turn of the century, when the first studies were made into the radiolysis of water induced by α-rays, but it is only due to the rapid emergence of nuclear energy that these studies, which started out as simple scientific curiosities cultivated in one or two specialized laboratories, now form part of the activities of all research centres and, suitably organized, have paved the way for new industrial applications and uses.

The effects which radiations have on matter are numerous, depending in the first place on the type and energy of the radiation involved and in the second place on the physical state and composition of the substance irradiated. Since, depending on these factors, the effects can be extremely dissimilar (from polymerization to fragmentation of molecules, from reduction to oxidation), it is obvious that, if used correctly, the radiations lend themselves to practical uses which could, in the not-too-distant future, supersede present production methods. As an instance of this we can point to the use already being made of radiations on a commercial scale to sterilize the nylon thread used for surgical sutures; the British Navy is experimenting with foodstuffs conserved by irradiation treatment; the impregnation of wood with monomers followed by radiation-induced polymerization is being studied in the USSR with an eye to possible industrial applications.

The interaction of radiations and matter give rise to a wide range of chemical problems to which satisfactory solutions have yet to be devised, with regard to the nuclear fuel cycle. Due to the intense radiation field set up inside a reactor, all the materials used in its construction undergo processes of modification to varying extents. Graphite, for instance, which is exposed to neutron bombardment, accumulates substantial quantities of energy in the course of time, and certain routine operations must be carried out (the so-called Wigner energy release), if serious mishaps, such as the one which occurred recently in Britain, are to be avoided.

In the radiolysis of water, which is used as a moderator and coolant in a large number of reactors, the water is split up into hydrogen and oxygen, which, in view of the explosion hazard, are separated or recombined by means of suitable catalysts. This phenomenon is of special significance in the case of homogeneous reactors, while it is particularly vital in reactors using heavy water in view of the high cost of the material.

The development of reactors which use new varieties of coolants or moderators, e.g., organic substances of the polyphenyl type (see Fig. 3), necessitates exhaustive experiments to determine the irradiation resistance of the molecules of these materials and the effects which they are liable to sustain under irradiation. These effects can, in fact, bring about the deterioration or polymerization of the material, changing its viscosity and boiling point and thus causing pressure and pressure drop fluctuations as well as variations in the heat transfer coefficients in reactor circuits.

The effect of radiations on solutions is especially important with regard to the methods normally used for the processing of irradiated fuels. On coming into contact with the high activities of fission products, the organic solvents used for liquid-liquid extraction undergo a series of deterioration processes causing serious prejudice in the long term to the efficiency of the process and the various separations, so that serious attempts must be made to devise systems with better irradiation-resistance properties and to find means of restoring the quality of the damaged solvent. All these problems, again, will have to be solved by the chemist.

The irradiated fuel reprocessing techniques themselves result in the production of vast quantities of fission products, of the order of hundreds of millions of curies per year. These highly radioactive waste products constitute at the moment one of the most pressing problems yet to be overcome in the field of nuclear energy. These extremely dangerous substances have to be kept under strict control to prevent them from becoming dispersed in any way and entering living organisms via the atmosphere or the food chain. The method used today consists in storing these wastes in suitable containers in which they can safely be kept for a period of not less than ten years. This is only a temporary solution, of course, since the potential hazard of these wastes remains virtually unchanged for many decades and in some cases for several centuries.

A wide variety of proposals have been advanced concerning the final settlement of the waste problem, the majority being based on the conversion of the solutions into insoluble or difficultly soluble solids in which the fission products could be retained for a very long time and would thus not present any appreciable contamination hazard to the environment. Other suggestions entail the separation from the radioactive wastes of those components which might constitute major biological hazards, in order to reduce in bulk the substances to be processed and to enable the greater part of the solution thus purified to be released under control. For these problems, too, a comprehensive and painstaking programme of chemical research is necessary. But whatever the difficulties, it is absolutely vital that they be overcome.

Finally, the preparation and use of radioisotopes make up a vast field of interest to the chemist. The uses to which radioisotopes can be put to help solve problems relating to chemical, physical and biological research are countless and constitute now what is one of the most thoroughly explored fields of science. At this juncture, it is possibly advisable to stress the growing importance of the use of radioactive tracers in industry. In the US, the annual savings due to the use of radioisotope techniques for monitoring and regulation purposes in industrial processes are estimated roughly at around 200 million dollars. It is imperative that these methods find their way to Europe, too, for in addition to the substantial savings and industrial rationalization which would result, they would also give rise to greater confidence in the by-products of nuclear energy, a force which manifested itself to man for the first time in 1945 in so dreadful and unforgettable a form.

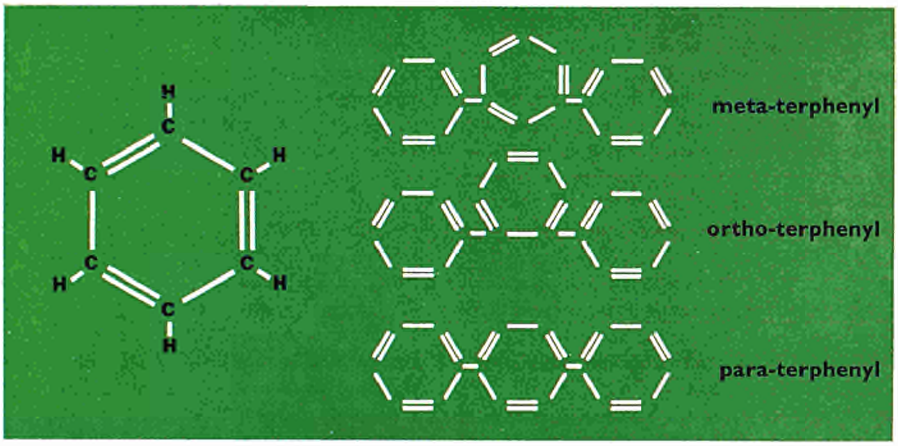
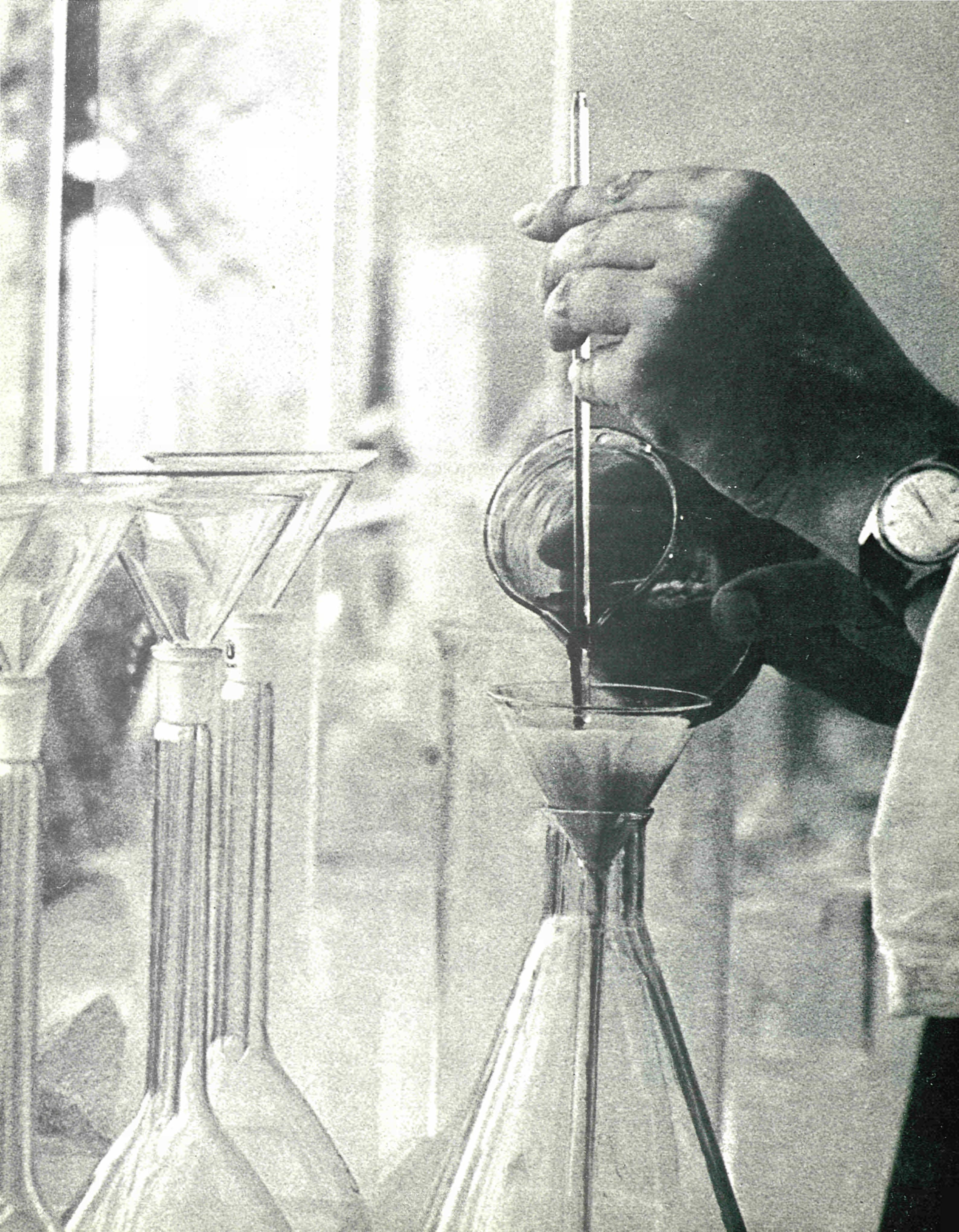


Fig. 3 The terphenyls
The molecule consists of three benzene rings. When the position of the outer rings is changed with respect to the central ring, isomers (ortho-, meta and para-terphenyls) are obtained. This is the mixture chiefly used as moderator or coolant in certain types of reactor (e.g. OMR, ORGEL)



EURATOM NEWS

Euratom Participation in SEP Reactor Project

The Euratom Commission is to contribute up to $ 5 million to the construction and operation costs of the 50 MWe Boiling Water reactor to be built by the N.V. Samenwerkende Electriciteits Produktiebedrijven (SEP) of Arnhem, Holland. The total cost of the plant is put at some $ 25 million. In return for this aid, SEP will make available to Euratom information and experience obtained during the preparatory work, construction and operation of the plant and Euratom may second its own engineers or personnel from Community enterprises to the project.
This co-operation between Euratom and SEP is based on the belief that nuclear energy will play an increasingly important rôle in the Community (and thus in the Netherlands), if only because it is developing into a source of low-cost power and helping to ensure regular supply of energy. It is therefore necessary that industry, i.e. both Community construction and electricity enterprises, should acquire immediate experience in the design, construction and operation of nuclear power plants.

The plant envisaged by SEP—although uneconomic on account of its relatively low power—offers the twofold advantage that it will be constructed entirely by Community industries and that it offers the opportunity for gaining experience in electricity production. In its construction, the benefit will be available of US know-how.

The reactor will in addition be equipped with extensive in-core instrumentation, the aim being to obtain more detailed information on the fission process in a power reactor.
The contract between Euratom and SEP, which has been given the go-ahead by the various Dutch electricity enterprises involved, is likely to be signed in the near future.

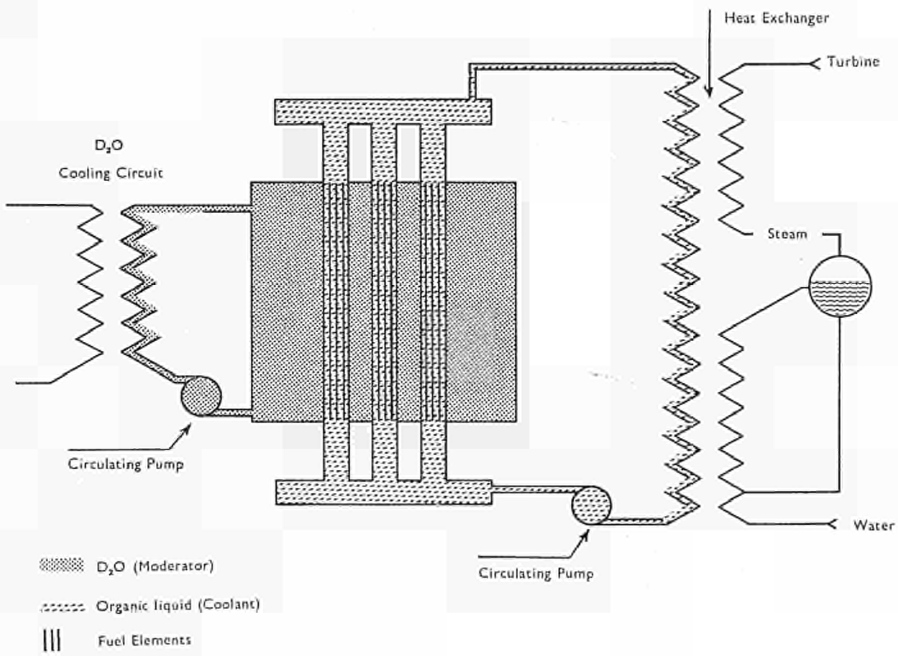
Study Bears out Advantage of ORGEL

In January 1962, the Euratom Commission entered into a contract with the Belgo-Nucléaire-Indatom-Siemens industrial design group for the drawing up of a reference design for a 250 MWe power plant of the ORGEL (natural-uranium-fuelled, heavy-water-moderated, organic-cooled) type.

The aim of this project was not only to highlight the technical problems involved in the construction of an ORGEL reactor, but also to provide a detailed estimate of its cost. The following overall design was selected by the study directors, who consider it as "definitely feasible":

Nuclear Part

A prestressed concrete shell houses the reactor block, which has a vertical axis and consists of a stainless steel cylindrical vessel 6 metres in diameter penetrated by about 400 channels. The function of the vessel is to contain the heavy water; that of each of the various channels is to form both a mechanical and a thermal barrier between the hot organic liquid, which is pressurized, and the cold heavy water, which is at atmospheric pressure. From the outside to the inside, the channels consist of a zirconium tube, a layer of gas, which acts



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as an insulator, and a sintered aluminium powder (SAP) tube.
The fuel element, which is immersed in the organic liquid, is made up of a cluster of 7 rodlets, 25 mm in diameter, in SAP-clad natural uranium carbide.
The organic-liquid cooling circuit is composed of 6 separate carbon-steel loops, each of which comprises a 1200 HP pump and a heat-exchanger.
A 40 MW cooling circuit serves to evacuate into the river the heat transmitted to the moderator.
Among the important auxiliaries are the circuit for purifying the organic liquid and the loading/unloading machine, which is designed to handle the fuel elements while the reactor is in operation.

Conventional Part

An outbuilding contains the conventional part of the plant, which takes the form of a single 250 MWe turbo-alternator. During expansion, the steam is returned into the main exchangers, where it is re-superheated.
The plant's principal characteristics are:

Thermal power	759 MW (th)
Net electric power	235 MWe
Net efficiency	0.32
Organic liquid inlet temperature	250° C
Organic liquid outlet temperature	400° C
Organic liquid pressure	15 atm.
Moderator temperature	70° C
Steam inlet temperature	385° C
Steam pressure	55 atm.
Expected burn-up	8,000 MWd/t
Heavy water	200 tons
UC	70 tons

The direct investments (including contingencies and heavy water) have been calculated by the study directors for this version alone on the basis of the prices ruling in 1962. From the results obtained, it is possible to set the net kWe price for an optimized power plant in the region of $ 170. It may therefore be concluded that the good prospects of the heavy-water/organic string, which have already been indicated by various studies now in progress in the United States and Canada, are now confirmed.

Euratom/Karlsruhe Association Contract for Fast Breeder Reactor Research signed

The Kernreaktor Bau- und Betriebsgesellschaft mbH (KBB), Karlsruhe and Euratom have signed a five-year association contract for joint research on fast breeder reactors. The contract covers an expenditure of $ 46 million, 40% of which is to be contributed by Euratom, who will also contribute scientists and technicians to the project. The direction of the research will be the responsibility of a steering committee, to which each of the contracting parties will appoint four members.
At Karlsruhe, plutonium reactors with three different cooling systems (helium, dry steam and sodium) will be tested, the aim being to prepare a thoroughly developed and tested power reactor prototype plan.
The following construction projects will be carried out at Karlsruhe under the contract:
1) the Karlsruhe fast zero-power plant (SNEAK)—a plutonium fuelled critical assembly,
2) a fast/thermal Argonaut reactor (STARK), to be built by converting the existing Karlsruhe Argonaut reactor,
3) the Karlsruhe fast sub-critical assembly (SUAK).
In July 1962, a similar association contract for the development of fast breeder reactors at the Cadarache centre was concluded with the French Atomic Energy Commission (CEA). A large part of the plutonium required for the Cadarache and Karlsruhe projects is being made available to Euratom by the United States. Negociations for the supply of this material are now under way between the US and Euratom.
A further fast-breeder association contract is to be concluded with the Italian Nuclear Energy Commission (CNEN). Thus Euratom is participating in all fast reactor projects in the Community.

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