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Euratom Research Establishment Ispra: medium-activity laboratory. Technicians, wearing special clothing for protection against contamination, enter a hot cell to carry out repairs to a handling device.

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

1967 - 1

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).

According to P. Caprioglio and M. De Bacci, who have contributed an article in this issue, power reactors of the "thermal" type, in particular the so-called "advanced converters", have a long future before them. They disagree firmly with the generally held opinion that these machines are condemned to be in due course completely squeezed out of the nuclear power market by fast neutron reactors.

They have stated the arguments brought forward in support of this thesis in a condensed form and although they have thereby made it easier for the reader to catch a bird's eye view of the whole problem, they have at the same time left themselves more open to attack.

Our object in publishing this article is, however, to stimulate controversy—not to avoid it. As the issues at stake are important, it appears to us unwise not to give them every chance of being thrashed out.

Long life for

PIETRO CAPRIOGLIO, *Director of the Petten Establis*

MARIO DE BACCI, *Directorate-General for Research*

THE INSERTION of nuclear power plants into a national grid presents many problems. Two of them will be considered here, namely:

— What is the impact of capital investment in a nuclear plant on the cost of the electricity it produces?

— Given the necessity of building up a nuclear capacity of given size, how can fissile material requirements be kept at a minimum?

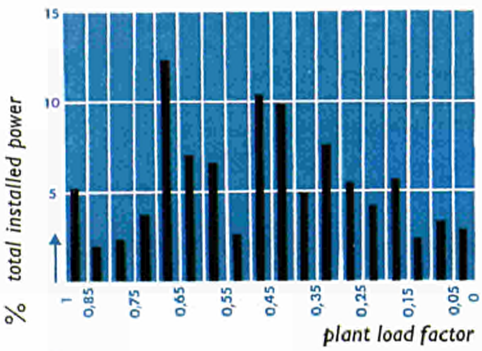
How many hours per year?

The planning of nuclear power generation in a given country entails taking into account the characteristics of the existing network of conventional stations and making intelligent assumptions regarding the gradual integration of nuclear power plants.

An important factor in this connection is the annual utilisation of existing plants, which can be anything from a few hours to the theoretical maximum of 8,760 hours (i.e. a load-factor of 1). As an example, figure 1 shows what the situation was in the United Kingdom in the year 1963-64. One particularly striking fact is that the fraction of the total generating capacity which worked at a load factor of 0.8 or above was less than 10% and that about 50% of the total capacity worked at a load factor between zero and 0.4.

For each country a diagram like the one shown in figure 1 can be drawn. The way of life of the country will have a direct influence on the shape of this diagram, as well as the structure of the national economy; for instance, the presence of electrochemical industries tends to increase the base load, while the contrary applies in the case of seasonal industries.

Figure 1: Output capacity of stations analysed according to plant load factor (United Kingdom 1963/64—data extracted from the Ministry of Power Statistical Digest 1964).



A number of purely technical factors have an equally important influence, such as the degree of interconnection which has been achieved in the national grid and the extent to which repairs and maintenance necessitate shut-downs. It may be said in passing that these technical factors are liable to vast improvements. In fact it is worth speculating whether, for certain countries, the task of modernising the grid is not much more urgent and rewarding than the task of developing nuclear power.

Furthermore, quite a number of new applications of electricity as well as a more subtle tariff policy can improve the situation. It is therefore not easy to make accurate assumptions as to how the shape of annual utilisation diagrams will change during, say, the next 30 years, but one can suggest that, unless we are going to revolutionise our way of life, the fraction of total generating capacity which will work less than 5,000 hours per year will still be substantial, say of the order of 50%. How does nuclear power fit into this picture?

Two different assumptions can be made:

a. Because of their high capital costs and low fuel costs, operation of reactors will be restricted to the base load, in which case very precise limits will be imposed on the expansion of nuclear power. With this assumption, much of the emphasis today placed on the problem of cheap uranium ore supply would be unjustified, in spite of the fact that a relatively large fraction of the total electricity production comes from the base load stations.

b. Nuclear power will expand very quickly, in which case nuclear plants will soon have to perform non-base duties, and it can be expected that annual utilisations as low as 4,000 hours will have to be achieved before the amortisation period of the station has expired. This situation has evident economic consequences, stemming from the reduction in the total number of kilowatt-hours produced by the stations during their lifetime, but, as we shall see, it has an influence which is not so immediately apparent on the fissile material requirements of the whole system.

It will be taken for granted that the second assumption is correct, namely that a very rapid expansion of nuclear power plant capacity will take place and that reactors will therefore have to perform non-base-load duties. Of course reactors, as conceived today, are not particularly suited for non-base load duties and therefore one of the first problems to be tackled is how to develop them so that they can play this role. It might well be that the problem is without economic solution. If this were the case, nuclear power would have to be relegated to the base load for as long as fossil fuel would be available. However, it is likely that solutions will be found in due course.

The effect of lower annual utilisation

Figure 2 shows in graphical form the effect reductions in annual utilisation have on the cost of the kilowatt-hours produced by several different types of thermal electricity generating stations, conventional as well as nuclear. In order to draw the curves, account was taken of their annual fixed charges (interest, amortisation of capital invested in the station, interest on capital invested in the fuel charge, insurance and maintenance) and of their "proportional" costs (fuel consumption, reprocessing, re-fabrication where applicable, etc.). The interest plus amortisation rate has been taken as 10%, assuming an amortisation period of 20 years. As for capital costs, first charge costs and proportional fuel costs, they have been taken from well-known reference designs or tenders.

It is clear that as annual utilisation de-

creases, the fixed annual charges, as opposed to the proportional costs, do not change and therefore have to be spread out over a smaller number of kilowatt-hours. Consequently, if two different types of plant are considered, the cost of the kilowatt-hours produced by the plant with the higher fixed charges will rise more steeply as annual utilisation decreases. The respective shapes of the *AGR* reactor and advanced steam boiler curves in figure 2 illustrate this point. Although an *AGR* is considerably cheaper than a steam boiler on fuel costs, it is more expensive to instal. The turbo-jet curve, as expected, is the flattest of all at high utilisations: turbo-jet plants have extravagant fuel requirements, which makes their operation uneconomical at higher annual utilisations, but their extremely low investment costs eventually permit them to beat all other types of plant for peak-load duties.
It will also be clear from figure 2 that the curves drawn for the different types of nuclear plants all have approximately the type of reactor is considered, are almost negligible in relation to fixed costs. Fixed costs therefore become decisive.
The conclusion to be drawn is that reactors capable of working at a low annual utilisation have to be cheap on capital without any particular necessity for fuel cycle costs which are lower than those achievable today. *This means relatively low conversion factors and high uranium ore costs will not upset the basic economic advantage of a low investment cost.* One could say that any reactor type showing a total investment cost of less than $ 130/kWe installed will be competitive for low annual utilisation, almost no matter what its fuel cycle may be.
It could be objected that this conclusion makes light of the threat of a possible shortage of cheap fissile materials and, by putting fast reactors on an equal footing with other types of reactor, ignores the promise they show of being able to lift this threat thanks to breeding. that this expansion will correspond to a doubling of capacity every 6 years over a period of 50 years, starting from a reference value of 1,000 MWe installed and ending with a total capacity of 314,000 MWe. It is also assumed that the stations of the future will be equipped with fast reactors, so good at converting fertile into fissile material that they can be termed "breeders", and "advanced" thermal reactors (sometimes, but if what follows is true, wrongly called "intermediate" reactors), which have a good fuel utilisation also, but cannot, except in extreme cases, attain breeding.

High temperature gas-cooled thorium converters (of the *Dragon* or *THTR* pebble-bed type) are here taken to be representative of the latter "advanced" class of thermal reactors, although most of the arguments put forward apply to all good thermal converters, such as those which use heavy-water moderation (*Orgel*, *EL 4*, *CIRENE*, *SGHWR* etc.).

converters

ment of Euratom's Joint Research Centre

nd Training, Euratom

It is often assumed that the present generation of "proven" reactors will be succeeded by a generation of so-called "intermediate" reactors, which will act as a stop-gap before fast breeder reactors conquer the nuclear power production market. The argument that the intermediate reactors risk being "squeezed" between the ever improving proven reactors and the inevitable fast reactors is also heard quite often. It is here suggested that this simplified view could be incorrect.

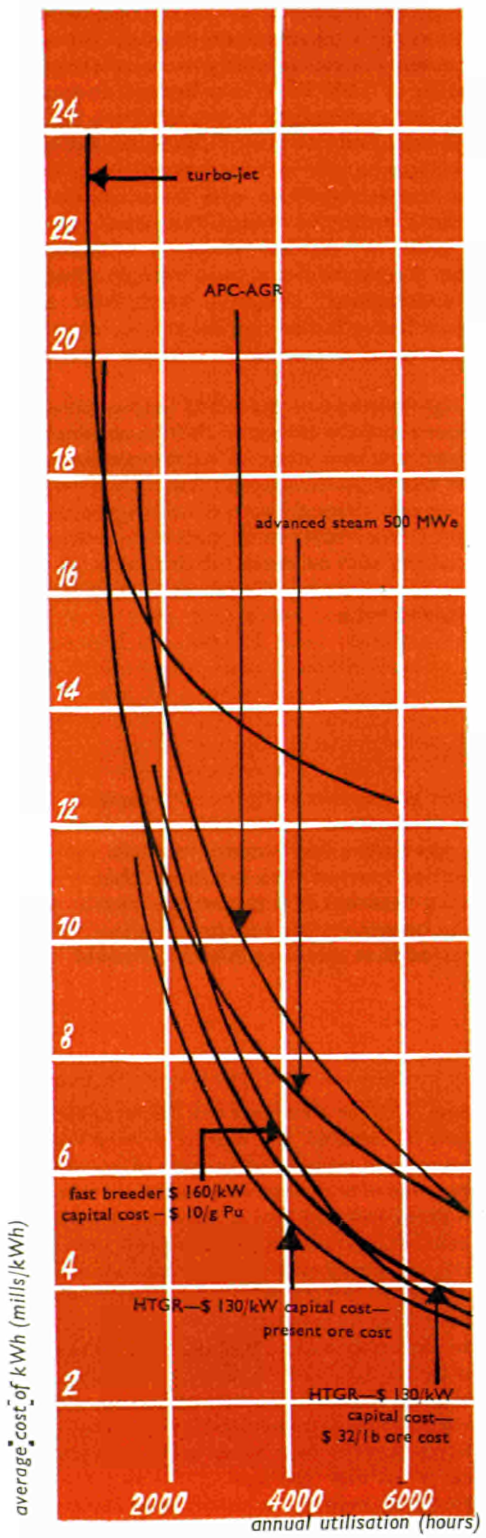
same shape. This is because *all* nuclear plants have relatively low fuel costs. Moreover, even if uranium ore becomes dearer, some types of reactor will be little affected in this respect (in order to show this, two curves have been drawn for the advanced thorium converter, one of which assumes a *fourfold* increase in the price of uranium ore). Some, and this should prove true of fast breeders in particular, admittedly may achieve a cheaper fuel cycle than others, but the margin of advantage which this gives them over their rivals becomes tenuous when cost comparisons have to be made on the basis of low annual utilisations. In this region of the graph, fuel costs, whatever

Although this objection is virtually answered by what has just been said, it is worthy of closer examination. The conclusions which can be reached are quite paradoxical.

Reducing fissile material requirements

Indeed another important aspect of the problem of non-base load operation of nuclear plants concerns the amount of fissile material required to expand nuclear generating capacity at a given (and quick) rate.
It is assumed here for the sake of argument

Supposing for a moment that fast breeders only be installed, and bearing in mind the assumption made about the rate of growth required of nuclear power, we can see that, if these reactors can be made to have a doubling time of 6 years, their fissile material requirements from outside sources will be nil. This is in fact only possible if two conditions are fulfilled: first, they must have an extremely high conversion ratio, of the order of 1.5; second, they must not be allowed to stay idle, since a breeder obviously stops breeding when it stays idle—let us say that their *annual utilisation must not be less than 7,000 hours.*
However, even if it turns out to be techni-



cally possible, without increasing capital costs unduly, to design fast reactors with such extremely good breeding capabilities, it follows from what was said earlier, about the annual utilisation problem, that it is impossible to keep earmarking these reactors indefinitely for base-load duties. At some stage, their annual utilisation would inevitably start falling short of 7,000 hours. It would therefore be necessary (still keeping to the assumption that only fast breeders are installed) to fuel some of the reactors, as and when they were commissioned, with fissile material from "outside" sources. But it so happens that, for a given power output, fast reactors need a fissile material inventory about three times as big as that of a thorium converter, which means that each extra megawatt of fast reactor power installed under these conditions would immobilise roughly three times as much fissile material as a megawatt of thorium converter power.

Figure 2: Average cost of a kWh as a function of annual utilisation, for different types of power plant.

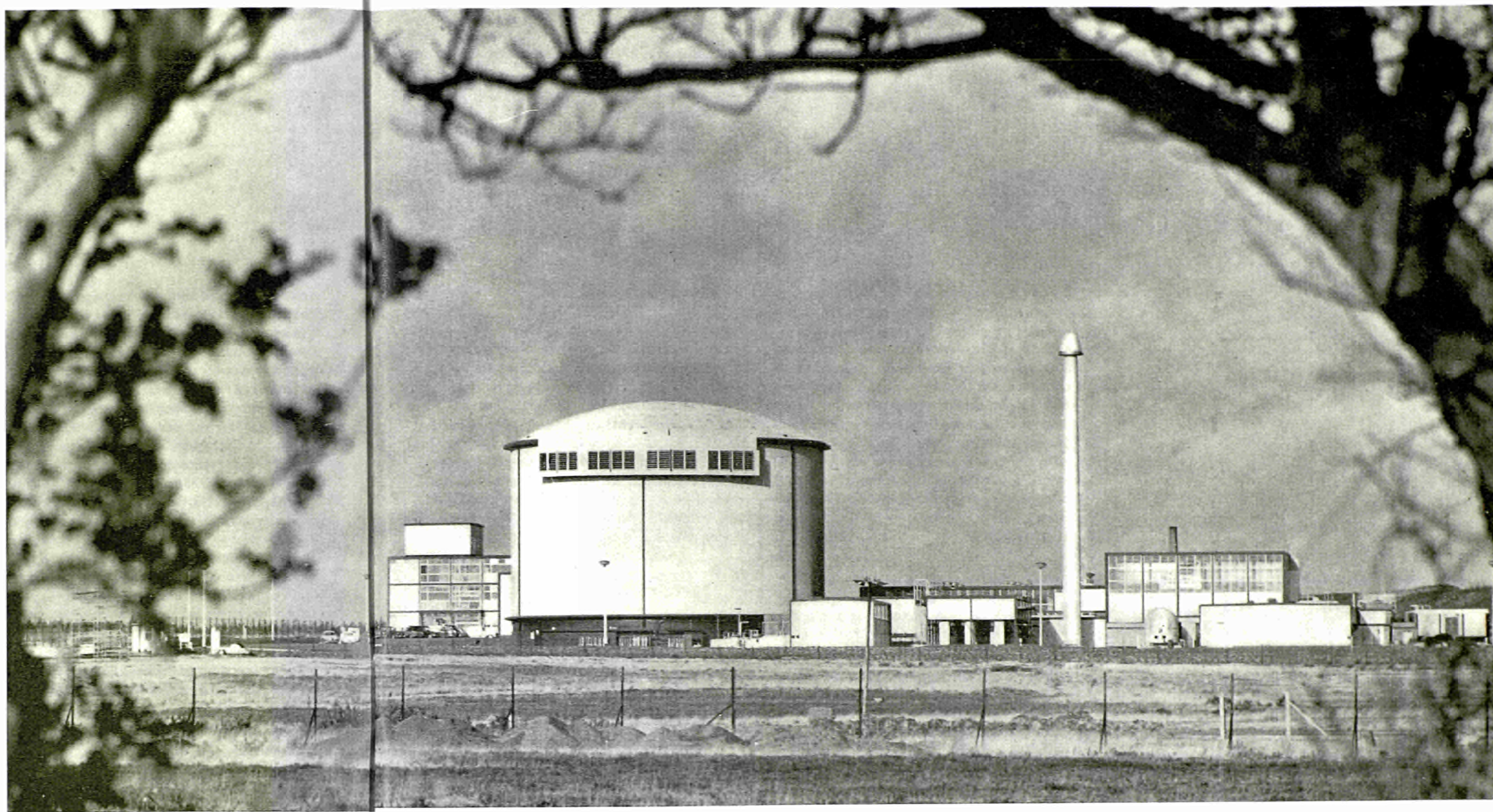
Figure 3 sums up the consequences of this situation; it shows in graphical form how total fissile requirements for fast breeder and thorium converters vary with annual utilisation. It can be seen that fissile material requirements for breeders *increase* with decreasing annual utilisations and fissile material requirements for converters *decrease* with decreasing annual utilisations. This is simply because breeders stop breeding and converters stop consuming fissile material if they are kept idle.

However, it is evident from figure 3 that, according to the conversion factors which will in practice be attainable in future for both fast breeders and thorium converters, there will be a range of annual utilisation where breeders will minimise fissile material requirements and another range where converters will do so.

This fact leads to a conception whereby fast breeders should cover base-load duties, thus taking best advantage of their good conversion factors, and thorium converters should carry non-base loads, thus taking the best advantage of the fact that they immobilise relatively small amounts of fuel. Thus not only would fissile material requirements be minimised during the period of rapid expansion, but, on the long term, when the rate of growth would slacken, self-sufficiency could be achieved; breeders could supply enough fissile material to keep the converters going and thus make them independent of external fissile material sources.

It must of course be stressed that this kind of thinking will only be valid *if it indeed turns out to be essential to minimise fissile material requirements.* If, on the contrary, this condition is not considered essential, the arguments which have been developed in the second part of this article become irrelevant. We are then obliged to face the first conclusion, namely that, on the long term, the most economic reactors will be, quite simply, those which are cheapest to instal. Will these be fast breeders or thermal converters? No one knows yet for sure.

We have pointed out some important implications of the fact that nuclear power stations cannot continue to assume base-load duties indefinitely. The main implication seems to be that it is wrong to classify the reactors of the future into two distinct castes, in such a way that fast reactors are, by a kind of birthright, assured of supremacy. (EUBU 6-1)



The Dragon high-temperature gas-cooled experimental reactor.

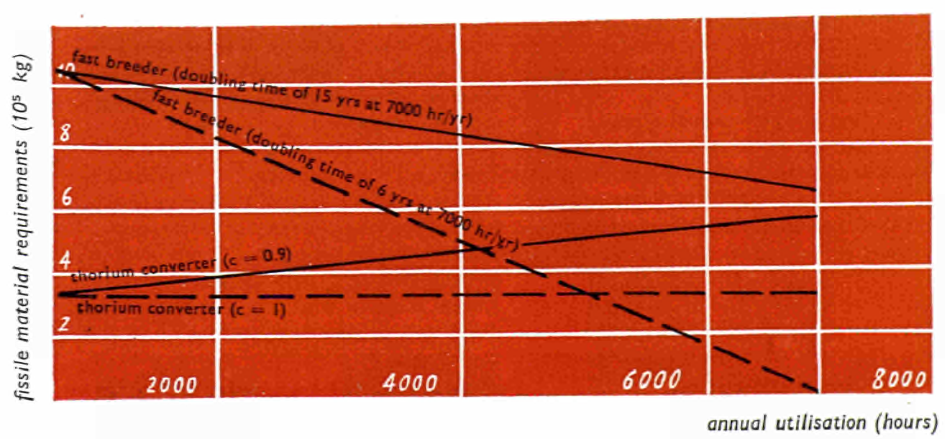


Figure 3: Total amount of fissile material required in the next 50 years to ensure the steady growth of nuclear power, according to the type of reactor installed. It is assumed that this growth corresponds to a doubling of nuclear capacity every six years (P_0 = 1,000 MWe; P_{50} = 314,000 MWe).

Psychological aspects of the prevention of accidental irradiations

PROFESSOR PAUL SIVADON, *Professor of Psychiatry, Brussels*

A FEW years ago, the World Health Organisation adopted as the theme of its annual campaign the formula "an accident is never accidental". It is true that very often, when an analysis of the causes of an accident is carried out after the event, astonishment and indignation are expressed that a particular measure has not been taken, or that a particular instruction has not been complied with. And the safety measures are reinforced and increased to such an extent that today it may be said that, if all the instructions were observed, accidents would become impossible. As it is, accidents persist and are very rightly attributed to a mysterious "human factor".

While industrial psychopathology as a discipline is as yet in its infancy, its contributions to the world of science are by no means negligible. From a study which we have been conducting for three years together with Dr. Fernandez[1] under Euratom contract, several points have emerged which I propose to outline in this article.

Psychological factors hinge mainly on:

1. the personality of the subject;
2. the conditions in which he received his training and information;
3. his relations with the work group.

This does not embrace the entire range of psychological factors nor, *a fortiori*, all the human factors involved. The latter include in particular physiological and pathological aspects which do not come within the compass of our survey. Fatigue itself, a factor which is important enough to have been adopted as the central theme at the last Congress on Psychosomatic Medicine, will not be considered here.

Personality of the worker

The earliest investigations into psychosomatic medicine undertaken by Flanders Dunbar revealed that casualties are by no means casual in the selection of their victims. Out of a vast army of workers, 20% sustain 80% of the accidents. If the case-history of sufferers from fractures in a surgical ward is studied and compared with the case-history of the patients in the neighbouring medical ward, it will be found that the "surgicals" have previously averaged twice as many accidents as the "medicals". And those who have the dubious honour of heading the list of accidents are not always the stupidest or the most clumsy. By way of example, it is the 18-25 age-group, whose reflexes are never thelessthe quickest, which causes the largest proportion of road accidents.

Among the personality factors most frequently at work is an *inability to picture the danger* when it is not immediately apparent. This incapacity derives from a general conceptual difficulty which is particularly characteristic of certain young people but also of some older people who have suffered in their childhood from bad affective conditions and who have not acquired the capacity to take in pictures of what is not perceptible at the time. This difficulty, one suspects, is particularly serious when the hazard by its very nature is unapparent, as in the case of radioactivity.

Another personality factor is *the need to flirt with danger*, a characteristic of anxiety-ridden subjects who are preoccupied by death and unconsciously seek to exorcise the danger by constantly toying with it. These are timorous persons with a despe-

1. Work carried out by the *Centre de recherches psychopathologiques*, 11 rue Tronchet, Paris—Euratom contract No 002/62/10 PSTF.

rado streak in them, who gamble with their fate as well as with that of others by indulging in brinkmanship in order to reassure themselves as to both their capacities and their inherent good luck. Wearing devotional charms or mascots, they evoke admiration for their scorn of danger—until the day when luck deserts them. To them an accident is a more or less unconscious form of suicide.

Then there is *opposition to parental discipline*. This marks another type of refractory individual. Here it is not a case of being unable to comprehend the purport of the order but simply of being infuriated by anything which smacks of an order. Convergent studies have shown that such people are anticonformists who have suffered in their childhood from poor affective relations with their father or a paternal type.

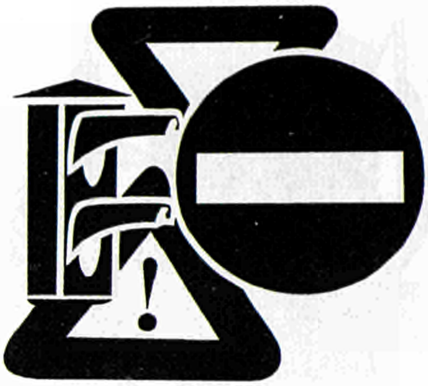
Certain subjects are afflicted with *mental rigidity*; that is, they are incapable of seeing other people's points of view and cling to their own, which, when the situation changes, leads them into errors of judgement which may find expression in erroneous convictions and dangerous behaviour. These are what the psychiatrists call "paranoiacs".

Others, called "obsessionals", are rigid in their conformism. By contrast with the rebels against parental authority, they are unable to deviate from the principles and habits which they acquired in their childhood. And when these principles clash with the exigency of the moment, the latter is liable to be relegated to the background.

Training and information

Accident is in a great many cases due to inadequacy, i.e., inability to cope with a situation. This inadequacy may stem from the fact that an unexpected situation has not elicited a response appropriate to its novelty or that a routine situation has not engendered the automatised pattern of behaviour towards such a situation.

The first hypothesis represents a loss of the warning function. With everything always happening in the same way, the subject ultimately forgets that unforeseen events may occur and his attention becomes lulled. In the face of unforeseen danger, either our vigilance is sharpened and our behaviour instantly adapts itself to the originality of the situation, or else our attention is dulled and our reflexes are those which have been developed to meet previous situations of the same kind. If the divergence between the prevailing situation and the experiences registered is not too pronounced, our automatic reflexes may suffice to trigger off satisfactory behaviour. Otherwise, the inordinate difference between the event and the prefabricated behavioural patterns at the subject's disposal will either inhibit



any response or else disorganise his behaviour. And intelligent professional men will be shown up as completely stupid or incoherent.

The second hypothesis is consistent with an obliteration of previously acquired behavioural patterns. These patterns are in point of fact reflexes corresponding to a series of interrelated acts capable of being performed with the perfection of a frequently rehearsed musical scale or acrobatic stunt. Just as artists, musicians or acrobats have to train unremittingly to keep up to scratch, so do the simplest occupational reflexes have to be strengthened, or otherwise they become extinct.

We are familiar with these conditioned reflexes, which have been so thoroughly investigated since Pavlov's time and one type of which approximates to what is required of the worker: this is the so-called "operative" reflex. A rat soon learns that it has to press a lever to avoid receiving an electric shock. It makes a gesture in order to obtain a result. This result is negative. Consequently, after a certain time, the rat omits to press the lever and the electric shock reminds it of its forgetfulness. If fulfilment of a safety instruction finds expression in no other form than the absence of an accident, it is to be feared that in the long run the automatised behaviour will atrophy. To be sure, a man is not a rat, but the acquisition and strengthening of reflexes do have certain points of resemblance in the two species.

Just as a radioactive hazard, which is naturally not perceptible by our senses, has to be made apparent through the medium of visual or acoustic signals, so would it be necessary for the proper execution of

safety instructions to be confirmed by some kind of pleasant response, a substitute for the rat's electric shock signalling on the other hand faulty behaviour before it became irremediable. Like the devices themselves, safety movements must be maintained in a perfect state of readiness.

Of particular importance among the efficient educational and informational factors are the first few moments of training upon starting work, the attitude to the job—and above all the anxiety which it causes—and the influence of inaccurate information, such as that spread around by the general public.

Important influence of first impressions

Under the designation of *imprint*, specialists in animal behaviour (Lorenz, Tinbergen) have described a highly interesting biological phenomenon. When an animal has just come into the world, the first moving

object the size and shape of which approximate to those of the adults of its species is regarded by the newborn animal as being the image of this species. If a large tortoise is placed before a newborn gosling, the latter will, when it becomes adult, behave towards tortoises as if they were congeneric. The first impression, therefore, retains an exceptional value, and it would appear that nothing can ever obliterate it. Migratory animals return to their birthplace after covering thousands of miles. From time immemorial, throughout the world, creation, hatching, the laying of foundation stones and inauguration ceremonies have been invested with a certain veneration and accompanied by special rituals.

Time does not flow by at an even pace. Like a tickertape crammed with information, it has dense zones, prolific moments followed by long blank stretches after which it rolls up, evoking at each turn the memory of the primordial event. These are the first encounters—that of the suckling with its mother's face, that of the infant with its own image, that of the young man with his first love, of the first embrace, of entry into a new environment.

Each of these events, and as a general rule each of those which compel us to reorganise the structure of our personality, is accompanied by a return to childhood, a regression to a more primitive functional mode which facilitates the adaptation process. The personality can only be fashioned to accommodate new standards by capturing the plasticity of the earliest moments. But the imprint thus acquired persists indefinitely; each time it is a case of rebirth.

We know how important the initial reception is, whether in a new family, in a hospital or in a business firm. What we possibly do not realise sufficiently is the importance of the very first moments. Entering a factory which is known to contain dangers of a somewhat mysterious character inevitably involves a mobilisation of the emotions which is a stimulus to the imprint. During the initial conversations, the first few days, certain attitudes and certain gestures will stamp themselves on the mind of the new arrival. There are habits which are acquired in the course of time, but there are also forms of behaviour which are adopted right at the outset and which are more persistent than habits. This serves to illustrate the capital importance of offering the newcomer, in the very first days of his starting on the job, behavioural models in the form of examples. Thereafter, he will bear perennial traces of the types of behaviour which he witnessed at this period, the most pregnant of all, when he makes his initial contacts.

Must he, then, from this time onwards be crammed with information, laden with documents and made to undergo a "crash" apprenticeship? Certainly not. The infantile regression which accompanies this pregnant moment renders the subject impervious to any written or even spoken message of the least complexity. Like the child, the newcomer learns by imitation, his capacity for integrating time and space being limited. He must immediately be shown the most essential and the simplest behavioural models. It is no doubt advisable to provide him with documents in order to sustain his attention and help his memory. These

documents will have the gratifying value of a present to the extent that they are pleasing to the eye.

The screen of fear

Our organism is so constructed that it has a tendency to select from the environment, for absorption and assimilation, the factors which are favourable to it and to reject those which appear to it to be dangerous. Instinctively, it gives preference to situations which it experiences in an atmosphere of safety, while shunning those which cause it distress.

Hence the advisability of teaching the newcomer the safety movements not by conjuring up pictures of disaster but by highlighting the safety factors. Once confidence has been established, it will be desirable to portray in evocative or in narrative form, or even by means of an analogical model, the dangers which are liable to arise. The crux of the matter is the security/insecurity ratio. A mere recital of terrifying situations in an atmosphere of

insecurity may be enough to induce rejection or aggression reactions to any sort of adaptation. On the other hand, if portrayed or simulated in an atmosphere of security, the same situations will have a high adaptational and educative value.
Thus, terrifying stories of the big bad wolf or of children put in the salting-tube evoke a rapturous emotion while the listener is sitting on Grandma's knee by the fireside. They may cause the most acute distress when related to children without any loved one present.
Distress sets up a screen which prevents ordeals already undergone from being mentally absorbed and which sometimes even masks them to the point of rendering them imperceptible. Frequently, too, the screen is sufficiently transparent to reveal the situation but opaque to its significance for the subject, in whom it arouses no emotion, as if it did not concern him. This phenomenon, known by the name of emotional isolation, may induce an illusion; the subject has seen the situation but he has not experienced it; it has been kept at a distance and will never have any educative value.

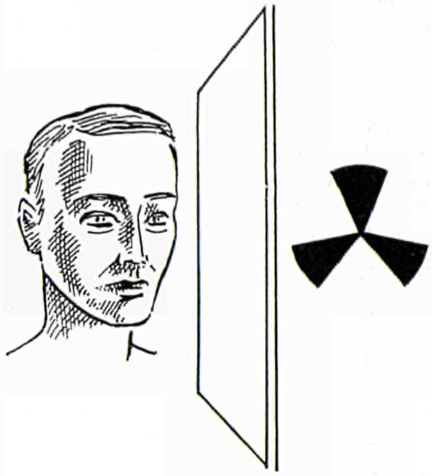
The poisonous rumour

The newcomer readily identifies himself, like the gosling to which reference was made a few moments ago, with the first representative of his species that he meets. The gestures which the latter performs, the words which he pronounces, the rumours which he recounts, the things that go on behind the scenes which he reveals, the intrigues which he denounces, the dangers which he foreshadows are to the new employee assurances which have a far greater effect than information given by some faceless person in the management during a lecture.

Thus in all groupings there are those who take an unrepentant delight in seizing upon the easy prey which these "new boys" constitute. "Old sweats", soured to a greater or lesser extent by seldom finding receptive audiences, they experience a malicious joy in printing in the virgin wax what they know to be the indelible stamp of their personal rancours and disillusionments. Embittered, they maintain that the safety measures are bunkum, that everything the staff is told is just so much talk and they leave their victim perplexed, if he is not paralysed with fear.
If over-intensive information is illusive, lack of information leaves a void which is soon filled by poisonous rumour. It is accordingly necessary to see that the new employee obtains a reassuring first impression and is given concrete and simple information. It is also as well to be careful about his first contacts, in view of the fact that they will condition the imprint which will persist throughout his working life.
Experience shows that meetings in small groups comprising several persons of executive rank and several older staff members of a status similar to that of the new arrivals are by far the most efficacious.

The value of small groups

The work of Kurt Lewin and his school, and a great many studies and findings since, has shown the importance of the group in adaptation to work and in accident prevention.
Quickness on the uptake, output and safety, and at the same time, the workers' well-being, are best catered for in small groups. This is the name given to gatherings consisting of about seven individuals. A good meal, said Brillat-Savarin, is one at which there are more than three and less than nine people. Or as the Ancients put it, more than the Parcae and less than the Muses.
In a homogeneous, well-knit group, with well-balanced relationships on the personal level, everyone feels secure and the automatic reflexes are created and function smoothly.
By contrast, accidents are found to occur more frequently when for some reason or other the group is disorganised (holiday periods, tension within the group).



Conclusions

The psychological factors enumerated above deserve to be singled out mainly because of the practical consequences which they may involve.
Personality tests may be used during recruitment selection procedures in order to winkle out the inflexible subjects and keep them out of jobs which may in certain circumstances require rapid adaptation. In this way it is also possible to eliminate the most accident-prone subjects. Just as important, in my view, is the problem of building up and maintaining safety behaviours. They must be learned early, benefiting from the productive period in the first few days, eliminating insecurity factors and unofficial information. Provision must be made for their reinforcement by a feed-back system which provides a perceptible response to the prescribed routine movements.
Finally, particular merit attaches to small groups, on account of their reassuring quality, their value as regards initial learning and adaptation to new situations.
The nuclear industry is no doubt one of the most sophisticated forms of our present-day technical civilisation. Its greatest psychological problem is to eliminate human anxiety as much as possible among its workers.
If, as Ferrero says, civilisation is "a struggle against fear" it must adjust its structures in such a way that fear can never find its way into them again. (EUBU 6-2)

JEAN LECLERCQ and MICHEL VAN MEERBEECK,

Directorate-General for Industry and Economy, Euratom

Nuclear energy, a factor making for greater de

ENERGY PROBLEMS loom large in modern life. An essential factor in the economic growth of a country or community, energy has also become a yardstick for the prosperity of the individual. It took Suez to bring home to the nations of the world, accustomed as they were to think in terms of abundance, the vulnerability of their energy supply and the incalculable damage which would result from a protracted breakdown in the flow of deliveries.

Growing demand

The speedy growth of energy demand traces its origin back to the industrial revolution—a phenomenon characterising countries—one should say regions—which possess a fuel with which they have been lavishly endowed by an accident of nature, namely coal. The world rapidly becomes divided into industrialised and non-industrialised regions.

The problems at the outset are mainly technical—the gradual mechanisation of all sectors of activity which lend themselves to it, and the reduction of specific consumption. Energy exchanges are on a modest scale. Industries spring up where the coal is mined, the coal itself is cheap and plentiful and surpluses are marketed without difficulty.

Thus between 1860 and 1900, world output of solid fuels soared from 139 million to 721 million tce[1], accounting for 100% and 96% respectively of all commercial energy production.

Since the beginning of this century, and particularly in the last few years, the situation has been transformed.

The advent of petroleum and its derivatives and of natural gas gives a fresh impetus to energy demand. Their specific qualities breed new applications; in the case of oil products, for instance, the internal combustion engine opens up a market with a truly remarkable future. Natural gas and oil encroach upon sectors which have hitherto been the special preserve of coal, notably the chemical industry and power plants.

Thus between 1937 and 1963, world primary energy needs swelled from 1,977 to 4,849 million tce (see Fig. 1).

Structural change in demand

This quantitative trend has been paralleled by qualitative changes in the choice made between the various forms of energy which have come on the market. The consumer is increasingly showing a clear-cut preference for converted energies, which are richer, better-yielding, easily transportable, etc. As long as these secondary energies consisted mainly in electricity and manufactured gases, coal, which is the principal source, remained unaffected. But oil-refining is making available to the user an extremely wide range of products, each of which meets very specific requirements—as fuel, or raw material. This is causing a gradual shift in demand, at periods which differ according to the country concerned, from coal to oil. In some countries, natural gas is enjoying the same success, ousting coal for numerous applications.

This diversification has been observed in all industrialised countries (see Fig. 2). Here, however, we shall concern ourselves more particularly with the consequences experienced in the European Community.

Competition from imported energies

One of the most striking aspects of this trend in Europe is that it has been accompanied by recourse on an ever-growing scale to external sources of supply. It is obviously because their prices are far more advantageous than those of European coal that imported energies—coal and oil—have been able to gain such a firm foothold in Europe. American coking coal, for instance, is cheaper than Community coal throughout the Common Market, while in all the member countries the delivered price, including taxes, of heavy oils is lower, in terms of tce, than the list price ex-mine for Community coal.

Covering the Community's energy requirements

Fig. 3a shows how, during the past fifteen years, the various forms of primary energy have shared in covering demand in the Community. In Fig. 3b, we see the respective proportions accounted for by internal production and imports over the same period.

These figures afford a clear illustration of the tendencies analysed above, to wit:

— rapid growth of overall energy consumption;

— steep rise in oil consumption (10% in 1950, 48% in 1966);

— increasing recourse to imports, which jumped from 11% in 1950 to 27% in 1960 and 48% in 1966;

— decline in the use of coal, whose share of the market has been shrinking and which in 1966 represented no more than 32% of

Fig. 1: Development of world primary-energy requirements (boxed in) between 1937 and 1963 (in millions of tce).

1. tce = tonnes of coal equivalent

the total energy demand, as compared with 53% in 1960 and 74% in 1950; in absolute figures, coal is flattening out at a level of 225 million tonnes and is not benefiting at all from the marked expansion in overall energy demand. Within the Community, indigenous coal consumption, although still preponderant, is nevertheless very much on the downgrade.

Dependability

The volume of imports entails a degree of dependence which involves various dangers. These may take the concrete form of an actual breakdown of supplies, notably as a result of conflicts or political disorders affecting the exporting countries, or in concerted pressure exerted by the suppliers with the aim of forcing up prices.
The position is obviously made all the more precarious since supplies largely come from non-Community countries and are insufficiently diversified as regards type and origin.

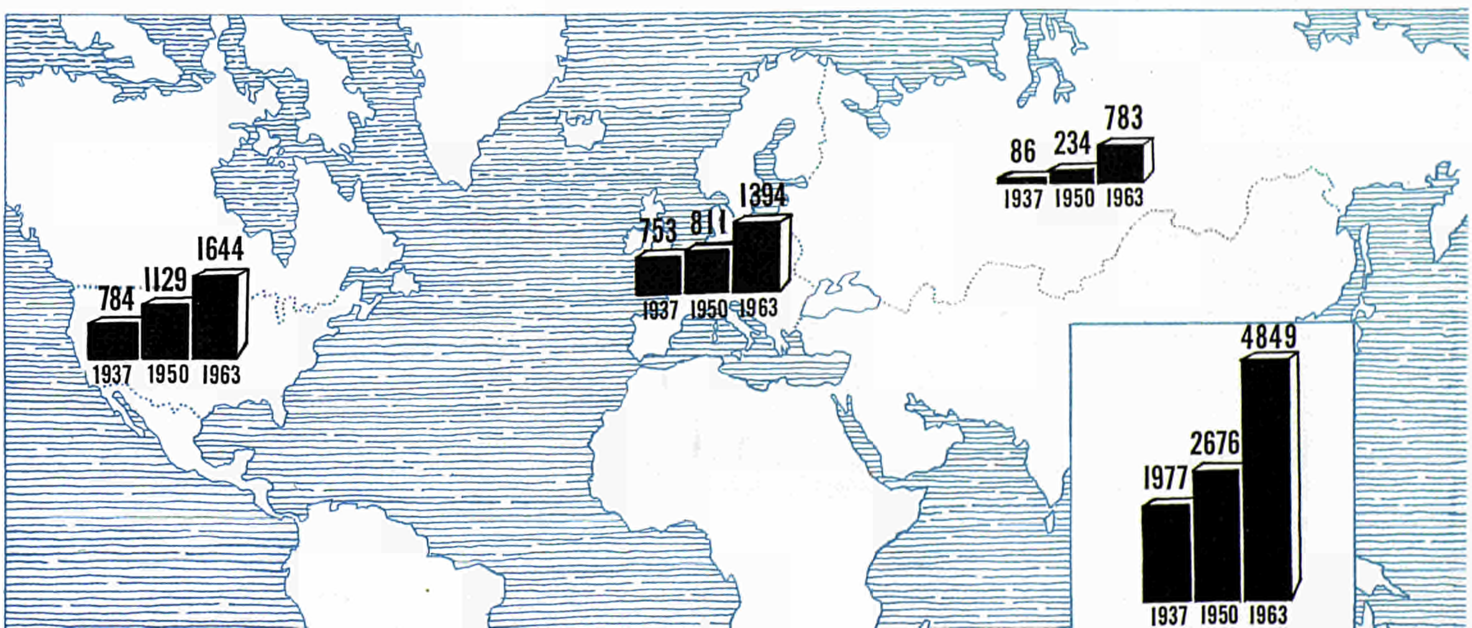
Remedies

Various measures can be visualised for mitigating these risks. The most effective course would undoubtedly be to reduce imports by boosting domestic output.
However, despite the fact that the Community already relies on other countries for nearly half its energy supplies, the probability is that the upward tendency of imports will persist. Requirements of petroleum products, for example, are bound to increase with the development of industrial uses and the expansion of transport networks. Furthermore, the price ratios between indigenous sources and supplies from outside the Community will continue to favour the latter.
In the years ahead, the Community will be unable to maintain its high-cost coal production at the present level, even by resorting to protectionist measures. The known reserves are of poor quality and their exploitation would not warrant the necessary investment.
The substantial quantities of natural gas so far discovered in the Netherlands ought partly to offset the declining coal output, but it is to be feared that the emergence of this highly competitive new form of energy will merely depress the coal market even faster, leading to the closure of further mines.
As to crude oil, it must be borne in mind that in 1965 the Community's production amounted to no more than 15.5 million tonnes, with a level of internal demand standing at 244 million tonnes.
It would therefore appear that, failing very substantial finds either of oil or of natural gas in the near future, only nuclear energy can provide the Community with a new and virtually unlimited source of abundant, cheap power to supplement indigenous energy sources which are either too expensive, such as coal, or insufficient in quantity, such as petroleum.

Future demand

On the world level, while a growth in

pendability of energy supplies



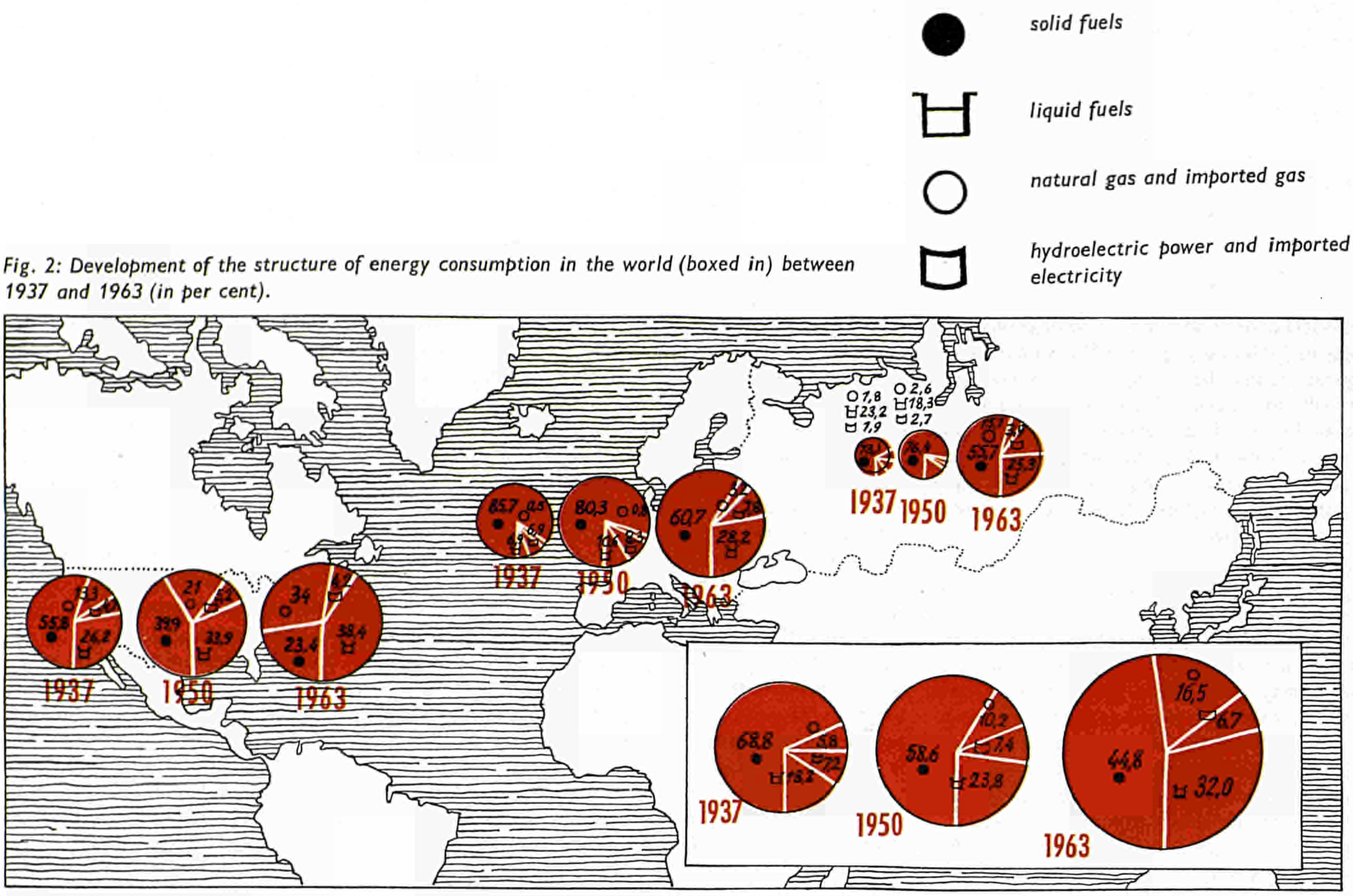


Fig. 2: Development of the structure of energy consumption in the world (boxed in) between 1937 and 1963 (in per cent).

energy consumption similar to that in the Community is anticipated in the industrialised countries, demand will certainly increase much faster still in countries which are on the verge of an industrial expansion or at least of an initial upsurge of consumption.

From Fig. 4, which depicts the pattern of total energy requirements in the non-Communist world for the period 1960-1980, it is seen that a very sizeable part of the increase in energy demand is accounted for by liquid fuels. Japan, where oil consumption shows a growth factor of 10 over 20 years, is a noteworthy case in point.

The full significance of the figures in this forecast is also brought out by an examination of the energy deficits (consumption less production) expected in the highly industrialised areas by 1980.

These deficits are assessed (in million tce) at:

— Western Europe:	975 to 1230
— (European Community):	(590 to 750)
— North America:	25 to 330
— Japan:	440 to 460
Total:	1440 to 2020

The gap is filled for the most part by oil imports from the Middle East.

These figures are clear evidence of the dependence of one part of the world on another, and the significance of this is brought out to the full by the scale of the quantities involved. During the coming years, considerable reserves will have to be located and developed.

It is difficult to predict the pattern which will be followed by exploration costs compared with the trend to date. But it is not impossible that average production costs will tend upwards on account of the need to make greater use of secondary recovery techniques.

Furthermore, the huge volume of demand may also bring about a change in market conditions and give a boost to oil prices.

Nuclear energy, a dependable and cheap source

Euratom's "first target programme" defines the role likely to be played by nuclear energy in meeting the Community's electricity requirements. The studies carried out envisage a maximum contribution for each of the primary-energy sources capable of being used for electricity production, including hydropower and geothermal energy, and the conclusion is reached that it will be necessary to employ nuclear energy to generate an increasing proportion of the electricity required, namely:

5% in 1970 (i.e. 28 $\times$ 10^9 kWh),
28% in 1980 (i.e. 280 $\times$ 10^9 kWh),
48% in 1990 (i.e. 920 $\times$ 10^9 kWh),
70% in 2000 (i.e. 2,400 $\times$ 10^9 kWh).

Used on this scale, nuclear energy will oust considerable quantities of conventional fuels. But for this source, in fact, it would be necessary—even assuming maximum conceivable domestic supplies—to import an additional 10, 90 and 672 million tce in 1970, 1980 and 2000 respectively. The cut in imports resulting from the anticipated output of nuclear energy will amount to 1%, 9% and 28% respectively of the total energy consumption.

Reasoning along these lines implies that nuclear energy may be classed as a domestic source.

This idea is readily admissible, even though much of the fissile material has to be imported. Actually the quantities of nuclear fuels to be imported are relatively small, their cost being appreciably lower than that of the equivalent quantities of fossil fuels, and they can be stored more easily and cheaply.

There are also technical arguments to

warrant the inclusion of nuclear energy among the "indigenous" sources, notably the ability of nuclear power plants to run for long periods without refuelling and the possibilities offered by the recycling of the new fissile materials produced during reactor operation; we know that reactors of the "breeder" type can even generate from fertile material more fissile material than they consume.
Before examining the various characteristics of nuclear energy in detail, it must be stressed that recent developments augur a more important role for this form of energy than that assigned to it in the target programme. As from 1980, therefore, it will very probably play an even more significant part in meeting the Community's energy requirements than had hitherto been expected.

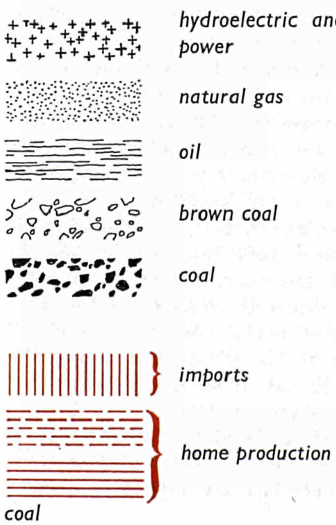
Dependability of supply

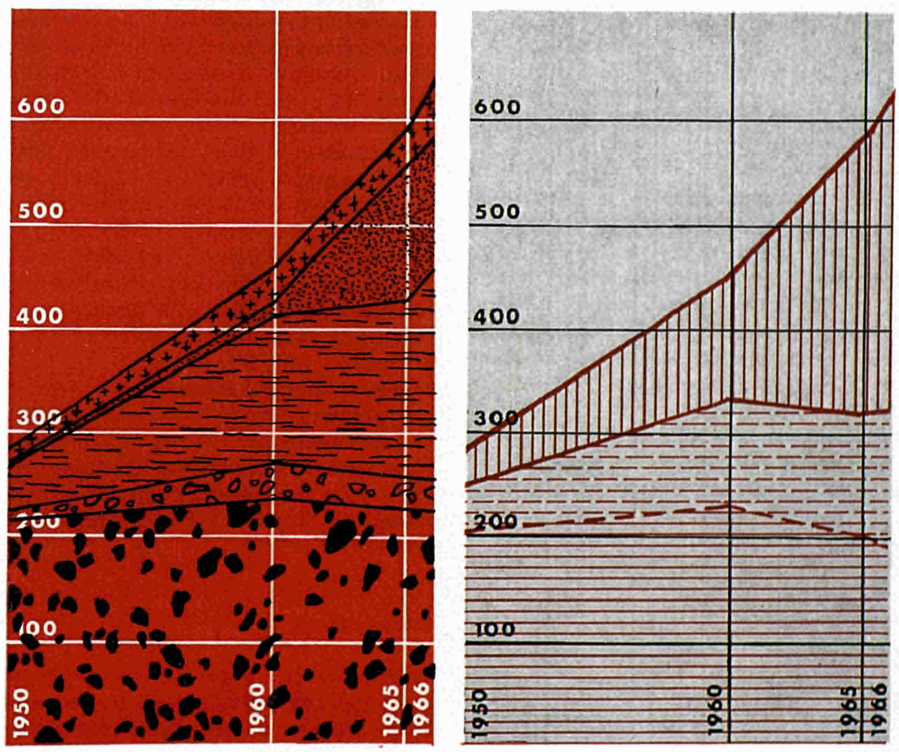
The Community's annual production of uranium concentrate—which amounts to some 1,100 tonnes of natural-uranium metal—is low in relation to the fuel quantities required for the electricity output envisaged in the target programme. On the assumption that this production level is maintained, which presupposes the discovery and exploitation of new deposits in the Community, annual imports of natural-uranium metal will be approximately:
1,200 tonnes in 1970 (replacing 10,000,000 tce of fossil fuels), 7,000 tonnes in 1980 (replacing 90,000,000 tce of fossil fuels), 12,000 tonnes in 1990 (replacing 276,000,000 tce of fossil fuels) and 14,000 tonnes in 2000 (replacing 672,000,000 tce of fossil fuels).
It will be observed that these estimates allow for the gradual introduction of advanced and fast reactors, as a result of which the energy potential of uranium will be more efficiently exploited than today.
These tonnages, which are very low in comparison with the quantities of fossil fuels that would yield an equivalent energy content, cannot give rise to any supply problems. Uranium deposits are widely distributed throughout the world, and the principal supplying countries (United States, Canada, South Africa) offer satisfactory guarantees.
Finally, again because of the small volume of the freights involved—which can, if necessary, be carried by air—nuclear fuel supply is less dependent on the regularity and continuity of sea transport than is the case with conventional fuels.

Lower import costs

To illustrate the advantages afforded by nuclear energy as regards supply costs, it can be shown, succinctly but irrefutably, that this form of power will substantially alleviate the burden of Community energy imports.
According to the forecasts in Euratom's first target programme, the Community will have to import, in order to cover its electricity requirements:
— in 1980: 637 million tce of fossil fuel and 7,000 tonnes of nuclear fuel;

Figs. 3a and 3b: Satisfaction of the European Community's energy requirements in 1950, 1960, 1965 and (estimated) 1966 (in millions of tce). Fig. 3a—Shares of various forms of primary energy; Fig. 3b—Breakdown between indigenous production and imports.





— in 2000: 1,365 million tce of fossil fuel and 14,000 tonnes of nuclear fuel.

Without nuclear energy, the volume of conventional-fuel imports would be at least:

- 680 million tce in 1980,
- 1,965 million tce in 2000.

These figures take account of the fact that the absence of nuclear energy would have prompted the Community countries to intensify fossil-fuel production and exploration.

In the range of prices that can reasonably be expected to prevail, we shall, for the sake of simplification, assume 12 dollars/tce for fossil fuels and 10 and 15 dollars/lb of U_3O_8 for natural uranium in the years 1980 and 2000 respectively. The total cost of *external* supplies would then be:

- 7,826 million dollars with nuclear energy, as against 8,160 million dollars without nuclear energy in 1980;
- 16,926 million dollars with nuclear energy, as against 23,580 million dollars without nuclear energy, in 2000.

Lower production cost

A different approach to the same problem leads to identical conclusions.

The cost of the conventional fuel needed to produce one kWh is of the order of *3.6 mills*, assuming a heat input of 2,100 kcal/kWh (300 gr coal equivalent at 7,000 kcal) and an average fuel price of 12 dollars/tce.

In proven-type nuclear reactors, the fuel cycle cost varies from 1.5 to 2.5 mills, of which the actual fuel accounts for *0.75 to 1.25 mills*. In the light of current progress, the fuel cost in the case of reactors of the advanced-converter type is likely to be between *0.35* and *0.45 mill/kWh* (the overall fuel-cylce cost being estimated at 0.7 to 0.9 mill).

Consequently, the cost of the fuel necessary to generate one kWh in a proven-type nuclear power plant would be 3 to 5 times lower than in a conventional power station, while the more advanced reactors hold out prospects of improving on this with a cost 8 to 10 times lower.

Easily stored

In view of their high energy content for a small volume, nuclear fuels are obviously much cheaper to store than conventional fuels. Warehousing involves no danger, nor does it call for either large land areas, costly handling equipment (as is the case with coal), bulky tanks or expensive pumping stations (as do liquid or gaseous fuels).

From the standpoint of supply dependability, this advantage is of paramount importance, affording as it does the opportunity of guarding against a possible shortage with less outlay. In the view of some experts, the storage cost for a reserve supply in the form of uranium concentrate would be only 10% to 20% of that for an equivalent stock of coal.

Operational self-sufficiency of nuclear reactors

It is undoubtedly the specific characteristics of the nuclear fuel itself that make the biggest contribution towards increasing the dependability of supply.

Unlike conventional generating stations, which require a non-stop fuel supply and run down immediately that supply fails, nuclear power plants can continue to operate for a certain period without refuelling.

Furthermore, this asset is reinforced by the availability on site of reserve fuel elements, as well as by various other factors which stem from the actual structure of the nuclear fuel cycle.

However, the situation differs appreciably according to whether the reactors under consideration are refuelled periodically (e.g. enriched-uranium light-water reactors) or refuelled continuously (e.g. natural-uranium gas-graphite reactors).

As regards the former, it may be assumed — to take a greatly simplified view of things— that about one-third of the core is unloaded every year and replaced by new fuel elements, the elements in the remaining two-thirds being merely reshuffled.

If we assume a sufficiently large number of reactors with refuelling evenly spaced throughout the year, we arrive at the conclusion that with suitable management of the fuel elements it would be possible to operate all the plants at nearly peak power for at least three months after the scheduled refuelling date.

With regard to on-load refuelling, the situation is rather different, since the reactors concerned are always in steady

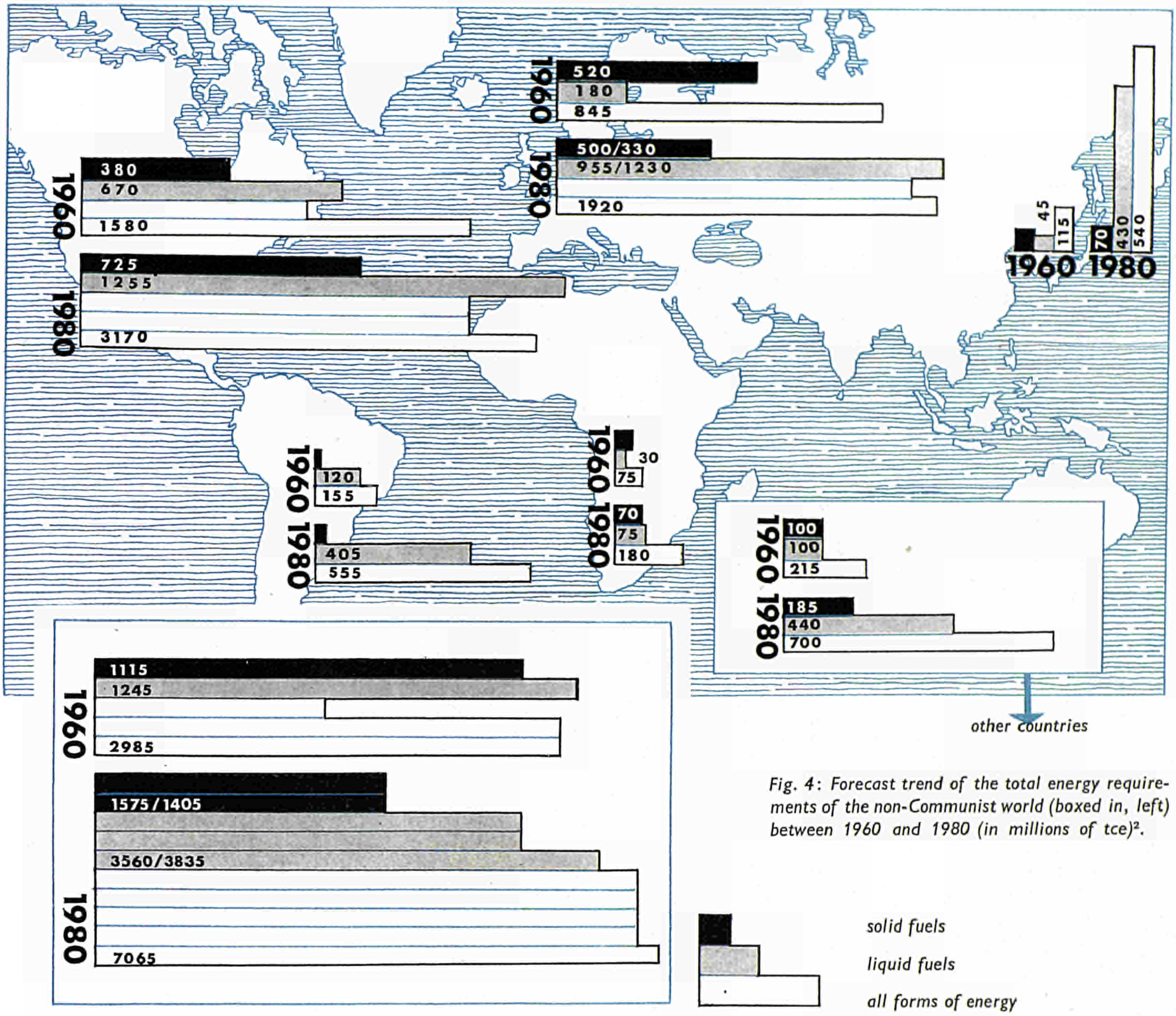


Fig. 4: Forecast trend of the total energy requirements of the non-Communist world (boxed in, left) between 1960 and 1980 (in millions of tce)[2].

state, with only a slight over-reactivity. Consequently, a breakdown in the supply of fresh fuel elements would cause shutdown after a fairly short period, probably of not more than a week. All the same, by rearranging the elements in the core it might still be possible to extend this period without having to insert any new elements.

There are, however, other factors, which, although they do not entirely offset the handicap of continuously refuelled reactors from the standpoint of dependability, do offer some possibility of keeping them in operation for a much longer period.

All reactor types, in fact, normally have a stock of fuel elements intended for the replacement of defective ones. It is true that, since defects are occurring far more seldom than had been expected, the tendency at present is to cut down drastically the size of this reserve. Nevertheless, as the average life of a fuel element and a core is three to five years, even a reserve of 2% or 3% of the core would enable the operation of a reactor to be prolonged by one to two months. On-load refuelled reactors have a larger standby than the other types, since in addition to the technical safety reserve there is a sort of "working capital". In the case of such reactors, a normal reserve of, say, 5% would enable operation to be carried on for about three months after supplies, if obtained from abroad, came to a halt.

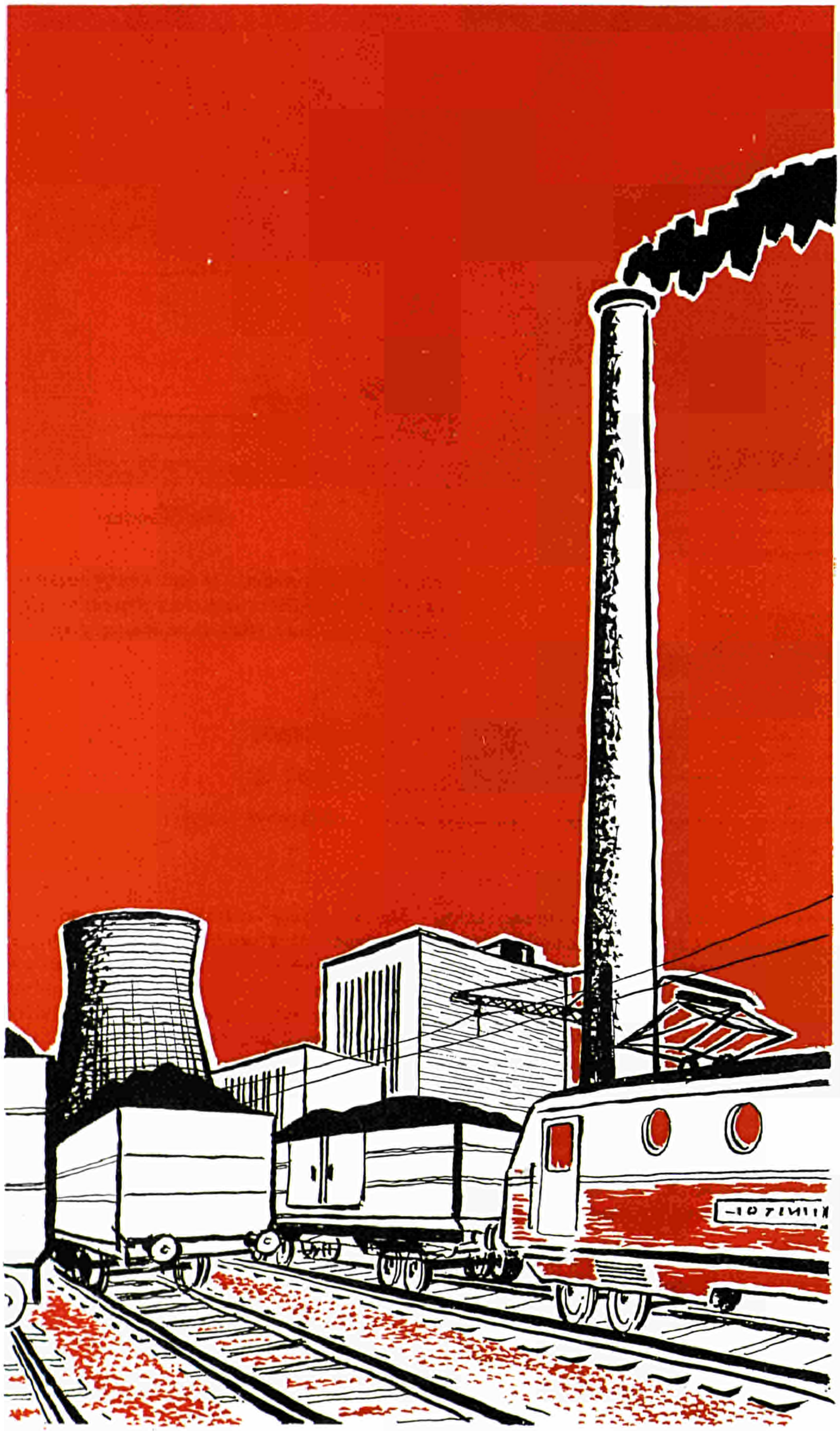
It should be stressed that these reserves in no way constitute a stockpile; they are absolutely essential whatever supply policy may be pursued.

Since it is already certain that a considerable proportion of the fuel elements will be fabricated in the Community, it is desirable for reasons of industrial policy—and thus irrespective of any considerations on the score of dependability of supply—that the domestic production should meet the entire demand. In that case, owing to the fairly long fabrication times, the stock in hand could certainly cover the reactors' normal supplies for more than six months. Consequently, the impact of an interruption in nuclear fuel deliveries during this time would fall primarily on the fuel-element fabrication industry, which would therefore work as a kind of shock absorber.

In view of the fact that certain reactors burn uranium at a degree of enrichment similar

2. "Nouvelles réflexions sur les perspectives énergetiques à long terme de la Communauté européenne" (Luxembourg—April 1966).

Ten 1,500-ton trainloads of coal are needed each day to fuel a 1,000 megawatt conventional electricity-generating station.



to that of the uranium recovered from the elements unloaded from other reactor types, whether proven or advanced, it is possible to conceive of a joint system of management under which the nuclear fuels would be kept within the Community by being passed successively from one reactor type to the next in descending order of enrichment, finally coming down to natural uranium. Here again, irrespective of any question of stockpiling, the Community would thereby enjoy a very substantial safety margin, since in a well-balanced system it would be several years before the repercussions of any supply difficulties were transmitted from one stage to the next.
Finally, all reactor types in service produce plutonium, which, being itself a fissile material, is recovered by chemical processing of the irradiated fuel elements. The recycling of such plutonium in thermal reactors and its subsequent use in fast reactors would substantially buttress the operational dependability of nuclear power plants, but the greatest advantages from these techniques would be felt particularly in the event of a protracted crisis.

In this brief study, we have endeavoured to outline the decisive role played by nuclear energy, which is both a condition and an instrument of economic and social expansion in the Member States.
It is unfortunate that the urgent need to provide a sufficiently dependable supply to meet the growing energy needs of the Community coincides with the irreversible decline of coal, on which the industrial power of Western Europe, and of the Community countries in particular, was founded. Over the last few decades, these countries have ceased to be self-sufficient in the energy sector and have become increasingly dependent on overseas sources. Tolerable as it has been hitherto, this dependence cannot become accentuated without entailing appreciable risks as regards vulnerability of supplies.
Nuclear energy figures prominently among the new sources likely to help solve the problems posed by the Community's dependence on external suppliers.
The atom, which can be classed as an indigenous source of energy, along with coal and natural gas, will enable us to keep our imports within acceptable limits and thereby increase an independence with regard to supplies. (EUBU 6-3)

What is being done about scientific information?

ANDRÉ MAUPERON, *Directorate-General for Dissemination of Information, Euratom*

BEFORE THE Second World War, scientific and technical libraries were relatively easy to run; in those days, the fullest and most durable knowledge was stored in books, whilst the scientific magazines published, with reasonable promptness, information which was often fragmentary and ephemeral. Librarians, therefore, concerned themselves mainly with books, and, with regard to magazines, did little more than dispatch the sets for binding.

It was only towards 1940 that reports, which hitherto had not generally been used except in certain large organisations, began to make their appearance in the scientific world. This created certain problems for specialists; what attitude, indeed, were they to adopt towards these hybrid documents which, unlike books and periodicals, are practically never subjected to critical review before publication and rarely to commentary afterwards, whose matter is generally more enduring than that of magazine articles, and whose shape, size and limpness prevent them from being classed as books?

Furthermore, there was no established procedure for distributing them (whereas one can take out subscriptions to magazines).

From this new factor, the report, stemmed the psychosis of the scientific literature explosion, aggravated more recently by the spate of new scientific journals attributable chiefly to the inevitable overlapping of many disciplines.

Now that we can look back a little, we see today that the apparently exponential growth of such literature may well turn out to have an asymptotic trend. There are several reasons for this. Certain matters of topical interest are, at the outset of their vogue and for several months or years afterwards, the subject of intensive research and numerous publications, and then sink into virtual oblivion. Between 1950 and 1958 there appeared hundreds of publications dealing with research on controlled thermonuclear fusion; after the second Geneva conference, Dr. Teller having uttered a public warning against intemperate enthusiasm in this field, such publications vanished almost entirely. It is, indeed, a commonplace that when an industrialist trumpets abroad research performed in his laboratories on subjects which in some cases are highly controversial, it is nearly always because he knows that, commercially speaking, the research in question has no hope of success. Be that as it may, it is certain that, apart from these anomalies, the problem is a sizeable one.

An enquiry, unfortunately rather dated, which was carried out by the *National Science Foundation* in 1961, revealed that, in the particular case of American industry, a hundred researchers publish an average of 41-42 scientific and technical documents a year (i.e., roughly one report per 2.4 researchers). It is estimated that there are 1,000,000 research scientists and engineers in the Community; a simple rule of three shows that, bearing in mind that Europeans publish far less material than Americans, the annual output of scientific and technical publications in the Community must be in the region of 300,000. For the world as a whole, the figure of 3,000,000 documents a year has been advanced, and this is probably not far out. As regards nuclear energy in particular, there are some 500,000 publications in existence today, with at least a hundred thousand more coming along every year.

What is the information worth?

Obviously the value of such information depends first and foremost on its intrinsic quality. Having regard to the fact that, as we learn from the *National Science Foundation's* aforementioned enquiry, one of the main reasons that impel nine out of ten American firms to go into print is prestige, we may well fear that the quality of those publications will not be impeccable. These statistics, however, apply only to a part of the world-wide body of published information, since they do not include, for instance, publications issued by public bodies, who are not as a rule swayed by commercial motives.

Another all too frequently neglected aspect of scientific literature is its *validity*; this is essentially liable to change and responsible research has shown that the useful lifetime of scientific publications is nowadays very short. In the field of physics, most works published twenty years ago are out of date and some of them contain information which, in the light of recent discoveries, proves to be misleading or completely erroneous; in short, the first year of the average book on physics constitutes practically 20% of its useful life.

Exploiting information

Long ago Aesop told us the tongue is the best and the worst of things. The same may be said of information—it all depends on how you use it. This is illustrated by the following tale, which is all the better for being true. In order to assess the practical and economic feasibility of using underground nuclear explosions for non-military purposes (cutting canals, creating underground reservoirs, etc.), the Americans spent 45 million dollars on their "*Plowshare*" project up to 1 July 1964; and it so happened that the results of their experiments provided material enough for 45 official reports. We may thus conclude that each report involved an average expenditure of one million dollars, apart from printing costs, and everything points to the belief that before carrying out these experiments the Americans calculated that the knowledge to be gained from them would be worth at least 45 million dollars. When it is

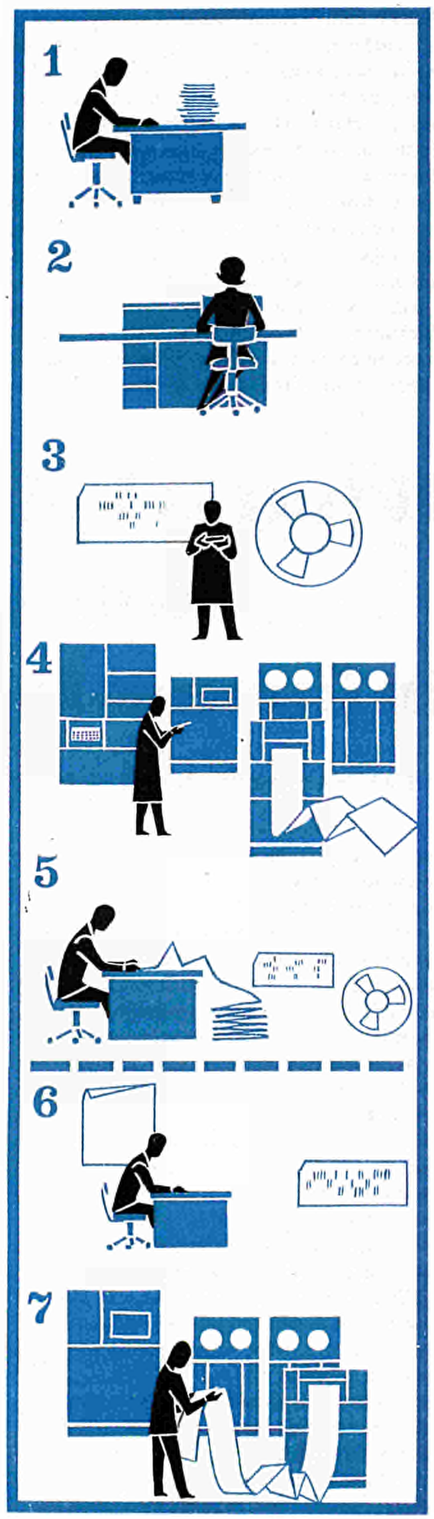


Figure 1a—Today: semi-automatic documentation
Although computers are now being used increasingly in documentation, human agency is still required at several stages. Here, for instance, is the way operations proceed at the Euratom Information and Documentation Centre: -
Information storage—*An expert analyses the documents and indexes them with key-words (1). The data emerging from this analysis are converted into punched cards (2), and then transferred on to magnetic tapes (3). Errors recorded on the tapes are spotted automatically (4) and then put right by an expert (5).*
Information retrieval—*The query is translated into key-words by an expert (6). Retrieval, which is an automatic process, yields a list of references to documents which constitute the reply to the query.*

considered that the 45 reports are sold by the *Federal Clearing-House for Scientific and Technical Information* for something less than 45 dollars, this may be thought to be a ridiculously low price; and so it is, if the information it buys is both usable and used. If, on the other hand, it collects dust on the ibrary shelves although there may be or, worse still, are potential users to whom it is inaccessible or comes too late, then it is a waste even of 45 dollars.

Exploiting information means seeing that it is put to intelligent use, i.e., supplying it to research workers and scientists who need it when they need it. This cosy, one might almost say platitudinous, form of words nevertheless implies a great deal of work; it means close, rapid and easy contact between the supplier of information—the librarian or documentalist—and his client; it means knowing the client's needs (which may not necessarily be the same as his requests); and lastly, it means providing relevant and sufficient information quickly.

While admitting that we are still far from this goal, let us see what the position is today.

The contacts system may work wonderfully well if one is willing to pay for the luxury (?) of having qualified scientists, who are likewise competent in information matters, to act as go-betweens for the researchers and the reference-room or library. This method gives very good results, notably in the United Kingdom, and usually provides an answer to the eternal problem of interpreting, and often divining, the researchers' wants. When a researcher needs information, other than data or constants, he very seldom knows exactly what he is looking for. How could he? What he seeks is knowledge, suggestions, analogies, or simply inspiration.

The user's requirements

Is prompt, full and relevant information being supplied today; in short, are the researchers getting what they need? The answer is "No", and this is why:—

One of the main reasons is that documentalists do not know their clients well enough. Numerous surveys have been carried out on various lines, but the results on the whole have been very disappointing, doubtless because the problem contains so many variables, and also because the techniques employed were not really founded on genuine scientific principles. Whereas the Gallup type of general and market surveys are based on selective sampling and can yield extrapolable information, most of the surveys on researchers' needs seem to have had a fine disregard of statistics; methods have been chosen mainly with an eye to their price, so that researchers have been flooded with questionnaires, the cheap substitute for a proper survey. Apart from the fact that a considerable degree of competence and psychology is needed to draw up the questionnaire, the "binary" questions (requiring the answer "Yes" or "No") make for lengthy question-lists covering ten pages and more, and it is a well-known fact that researchers' readiness to read and reply to such screeds is in inverse proportion to their length. To this must be added the difficulty of assessing the comments that accompany the answers.

A better method, of course, would be to put questions to and, preferably, discuss them with researchers in person. This, however, would only work if questioner and questioned both spoke the same language; indeed, they would almost need to have had the same training.

Turning for a moment from this Utopian

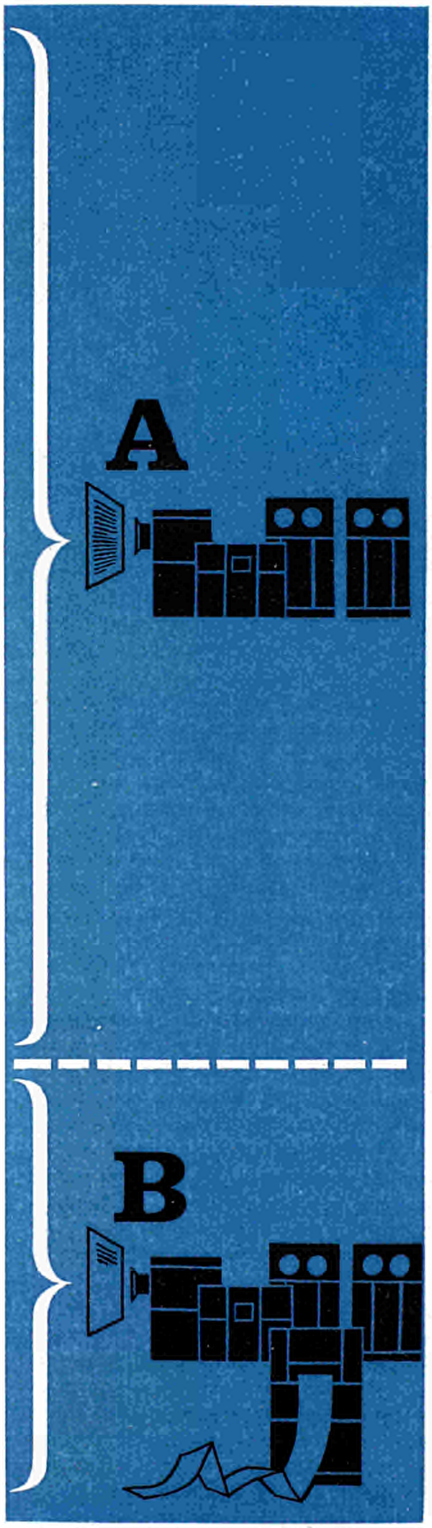


Figure 1b—Tomorrow: automatic documentation
Information storage (A)—*The documents (or abstracts thereof) will be read by a reading machine and automatically analysed; the analysis results will be recorded straight on to magnetic tape. This A set of operations is wholly automatic and will replace operations 1-5 which are necessary today.*
Information retrieval (B)—*The query will be read by the reading machine and automatically analysed; the computer will then provide the answer unaided.*

dream, let us try to draw some conclusions, however fragmentary, from these enquiries.

a. A researcher's useful reading amounts to some 5,000 pages a year.

b. For his information requirements he tends to follow a methodical and even hierarchic system. He accumulates as many books, reports, index-cards, etc., as possible, keeping them within arm's reach in his office or laboratory. He first of all gets what he can from this store of knowledge, then he sees what he can get from his immediate neighbours; next, he tries his department's library and finally he will approach the central library. This library, because it is the last resort, will be called upon to deal with far harder requests than the others.

c. He generally prefers, according to Hanson, to receive very short lists of documents (say half a dozen) in reply to his enquiries, and sets far more store by quality than by quantity; many other equally dependable authors, however, believe that researchers like to receive the fullest possible reference lists on the subject in which they are interested. The truth probably lies somewhere between these two extremes.

How best to satisfy requirements?

Lack of knowledge of the researcher's habits and requirements is by no means the only obstacle in the way of an efficient information service; even if the documentalist knew exactly what was wanted, is there any assurance that he could find it?

The documentalist's task is to select and then acquire the largest possible number of documents—the starting material from which the information will subsequently be extracted. There are two courses he can follow: either he can stack the documents as they arrive in a large empty room, or he can carefully catalogue the contents and then store them methodically.

The first method involves little or no work at the incoming stage, but it costs an enormous amount to locate a document containing a specific item of information. If the second method is used, the proportion of work to expenditure is reversed. Financially speaking, the two methods may be about even; nevertheless the second is distinctly preferable because it is quicker, particularly now that, thanks to recent technical advances, the speed and efficiency of document-retrieval can be vastly increased by the use of high-powered computers. In that case, of course, it is necessary to record the contents of the documents, e.g. on magnetic carriers, in the language best suited for man-computer communication.

We are obliged to J. C. R. Licklider for the following little calculation: our entire knowledge can be described in 10 billion (10^{12}) words, or, assuming that 100 bits (binary digits) are needed to represent one word, the whole could be stored in 10^{15} binary cells; science and technology account for 10% of our total knowledge, i.e. 10^{14} bits; of this only 10%, i.e. 10^{13} bits, is useful information worth recording; if science and technology can be subdivided into about 1,000 main heads, it will take 10^{10} binary cells to record one head. The capacity of the large computers' primary memories is shortly going to rise from 10^6 to 10^8 bits, while that of the secondary memories, on discs and microfilm, is increasing from 10^8 to 10^{12} bits.

There are other factors involved which should be allowed for in any exacting investigation; yet as they stand, the foregoing figures are enough to give a rough

Figure 2—Reading Machine. Though still in the laboratory stage, a reading machine has been built which, like television, "reads" texts by sweeping over each letter (1). The reflected light is of very low intensity when the spotlight passes over black, and this intensity variation is expressed by signals containing dips of varying length(2). Appropriate electronic circuits are used to obtain squared signals (3). The memory then records the letter in binary form (4) and will recognise it each time it appears in a text.

idea, and there seems to be no reason why it should not soon be possible to record 10% of the whole of science and technology with the aid of a single computer. Using an average-quality programme, the computer can carry out a search at the rate of 10,000 words a second and run through a major scientific head in a little under three hours; a man reads 100 words a minute and therefore it would take him ten years to read through the same head.

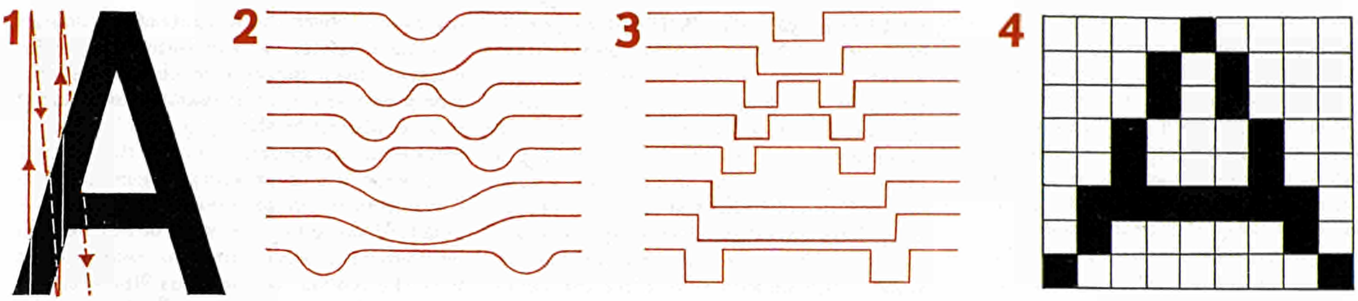
Key-words

Nobody today seriously contemplates the storing of full-length texts, for the cost and length of such work would be prohibitive, in view of the limitations of the storage technique at the present time. A large number of institutions and universities which have set up major documentation services simply record key-words, which are meant to represent more or less successfully the substance of the documents to which they refer; some prefer restricted vocabularies with a great many arbitrary rules, others use more extensive vocabularies allied with fairly sophisticated structures (e.g. Euratom's Information and Documentation Centre).

The choosing of the degree of sophistication with which a document is to be processed before the data representing it are introduced into a machine system is probably the most crucial decision of all. This is because the degree of sophistication largely determines not only the efficiency, but also the cost, of the system. The optimisation that should be effected to balance these two factors as nearly as possible cannot yet, unfortunately, be calculated by theory but must be based on large-scale experiments.

Is all this really satisfactory? First of all, let us try to follow the information through its successive breakdown stages. We start with the experimental results developed by the researcher, usually in the form of graphs or tables; tradition demands that these results be put into written form, with comments, when they can be published as a conference paper, a review article, or a report. Thus a kind of editorial superstructure is built around purely technical data; we have the introduction, then the statement with the author's personal interpretation, perhaps a short polemical section, a summary and a list of references; such is the make-up of the usual scientific publication. The publication is then interpreted by somebody who, it is to be hoped, possesses the necessary qualifications in the branch of science concerned. This person produces an analytical summary, or abstract, even if the author has already provided a summary. The abstract must mention one or two methodological aspects and the conclusions, but does not usually contain data. At a later stage the abstract —but very seldom the original publication—is analysed by experts, who condense the substance into a dozen keywords; it is these key-words that will subsequently be used to retrieve the document.

It should be noted that the results of applied research are far easier to process that are those of fundamental research, since applied research covers a narrower field, uses more clear-cut processes, and is simpler to describe; whereas there are times in fundamental research when the reasoning processes are too difficult for even the authors themselves to describe.



The road to future solutions

Advocates of automation have, of course, long hoped to see texts analysed directly by machine. A good many theoretical studies are in progress but are proving very tricky. Some people maintain that the most frequent significant words should be "starred"; we may note in passing that there is far more trouble over synonyms or near-synonyms in French than in English, the English having no qualms about using the same word several times over. Other experts claim that the frequency criterion is meaningless and that the semantic value of the words is all that counts. One thing that does seem to be settled, however, is that the suppression of syntax does not give rise to any really paralysing ambiguities.

At present there are several document-retrieval systems which operate satisfactorily, permitting high-speed bibliographical searches of good quality in all respects but one: with one or two exceptions, the references they provide are relatively old, owing mainly to the time inevitably lost in preparing and publishing the abstract journals used by documentalists. On an average, the references received by researchers are from 10 to 12 months old. This time-lag is not a serious drawback where a researcher wants to read up a fairly broad subject with which he is perhaps unfamiliar, but it is inadmissible if he wants day-to-day information on the latest advances in his own particular line of science or technology. Automation could be the answer here, with a machine reading and recording the essentials of every interesting publication as it leaves the press i.e. bibliographical data, summary, and perhaps the characteristic key-words.

In the present state of automation, this means that such features would have to be printed in a standard form, suitable for reading by a computer. But the most widely-read scientific periodicals currently use 93 different types, in 70 different sizes; thus the 36,000 publishers of these journals would have to be persuaded (and this is being done) of the advantages that standardisation would bring to the scientific world. Other important points also need standardising; why do the abstracts in *Nuclear Science Abstracts*, *Physics Abstracts*, *Chemical Abstracts* and *Excerpta Medica* begin with the title, followed by the authors' names and the article sources, whereas the *Bulletin signalétique du CNRS* and *Biological Abstracts* prefer to give the authors first, the titles next and the sources last, and *STAR* (American journal of space-technology abstracts) starts with the names of the firms or laboratories to which the authors belong? Is it really so hard to achieve that unity which looks —to the outsider at all events—so easy and so profitable?

A shorter-term aim now being pursued is that, in the field of nuclear energy at least, each Western country should assume responsibility, from the documentation standpoint, for the information published on its territory. This means that in each country one body would note nuclear publications as they came out, summarise them if the authors had not already done so, and translate the summaries into a vehicular language, which for reasons of convenience might well be English; these abstracts would be forwarded to an international centre to be analysed, and the analysis results, in key-word form, would be stored in a computer memory.

The countries concerned would, of course, be able to obtain recent and, let us hope, pertinent references, theoretically in a very short time, from the international centre. The organisation of such a network would doubtless call for considerable effort, both political and material.

This somewhat gloomy picture need not drive us into defeatism; though there is still much to do, a great deal has already been accomplished. Technological progress, by reducing the cost, has brought the computer within reach of numerous bodies. Other improvements now enable it to be used simultaneously from several consoles; the memories are more capacious, sorting more rapid. As to method, various ideas are being tried, various systems studied in the light of large-scale experiments, and some day this stammering infancy will be finally superseded by a new, mature generation.

All that remains is to convince documentalists that documentation is not an end in itself, scientists that they must regard documentalists as fully qualified scientists capable of understanding and solving problems, and executives that it is to their advantage to use men to think and let computers take over the card-indexing. This entails a considerable effort but it is the only way to secure a dynamic information system.

Then, perhaps, we shall witness a curtailment or even the elimination of the present-day waste of money and men occupied, through lack of information, in doing over again what has been done already.

(EUBU 6-4)

Radioactive waste

GASTON GRISON, *Directorate-General for Research and Training, Euratom*

NUCLEAR INSTALLATIONS, like any ordinary industrial plant, produce solid waste, liquid effluents and contaminated gases. But over and above the problems caused by the presence of noxious elements, detergents and various solvents, these residues contain radioactive elements whose residual specific activities at the disposal stage have to satisfy extremely stringent standards. Thus, as regards industrial waste waters, the disposal levels set for toxic substances are a few parts per million, whereas the maximum concentrations permitted in radioactive effluents are frequently several thousand times lower.

There are three classes of radioactive waste: *gaseous effluents*, produced by reactors, irradiated-fuel reprocessing plants and laboratories; *liquid effluents*, produced by all nuclear installations in highly varying concentrations, with specific activities ranging from only a few picocuries (millionths of a millionth of a curie) per millilitre up to several curies per millilitre in the case of fission-product solutions; *solid wastes*, which are also produced by all nuclear installations and can be subdivided into combustible and non-combustible waste.

Waste processing

Radioactive waste must first be processed, which means concentrating as much of the radioactivity as possible into the smallest possible bulk and, subject to the local, national and international regulations, discharging the resultant purified liquids and gases to the environment. In certain cases only, where the waste is of low bulk, low radioactivity or contains short-lived nuclides, they can simply be diluted or stored to allow the radioactivity to decay to a permissible level.

For certain categories of waste there is a very wide choice of processing methods. For instance, most gaseous waste and liquids of low radioactivity can be dealt with by physical processes (cyclone separation, pulverisation washing, various filters, electrostatic precipitation) or normal chemical processes such as co-precipitation, or physico-chemical techniques (adsorption on natural-mineral or synthetic-resin ion exchangers), all of which methods have given satisfactory results.

But as the radioactivity level rises, the number of industrial methods available to processing stations shrinks very quickly. For medium-activity liquid effluents, only the evaporation process has reached an advanced stage of industrialisation without, however, providing an answer to certain specific problems. As to the other methods under study, such as electrodialysis or flotation, they have not generally got beyond the laboratory stage. The situation as regards high-activity effluents is even more serious, for at present there is no reliable process for dealing efficiently and quickly with this type of waste.

Packaging waste

The second step in the handling of waste is the packaging of the residues. This consists in binding the semi-solid concentrations obtained by processing and the ashed

residue of combustible waste with solid materials such as concrete or asphalt. The non-combustible solid waste is compacted in steel casks which may be provided with concrete shielding against radiation.
These processes, too, are only suitable for comparatively low-activity waste; but they are adequate for the present, because there is still only a very small output of high-activity waste in the Community and the problem is therefore not immediate.

Future waste output in the Community

But this situation cannot go on indefinitely. In the years ahead nuclear energy will be of ever-increasing importance to the modern economy, and as more and more power reactors come into operation, their fuel-elements will produce ever greater quantities of fission products.
With several types of reactor, e.g. the water reactors, this gradual poisoning makes it necessary to extract the fuel-elements and have them reprocessed so as to recover the uranium and isolate the fission products. Assuming that the reprocessing of one ton of uranium produces approximately 7 cubic metres of liquid effluent, containing about 600,000 curies of fission products, we arrive at the following estimate: in 1980, about 35,000 cubic metres of fission products will be produced in the Community, containing some 10,000 million curies of fission products.
It must be emphasised, however, that these figures are purely a rough guide. They depend on numerous factors—the type of reactor, the quality of the fuel, the burn-up, the reprocessing methods used, etc. The fact remains, though, that these estimates show that the European Community will be faced fairly shortly with the problem of disposing of large quantities of highly radioactive waste.
With such a prospect it is essential to ask a certain number of questions, the chief of which may be expressed thus:
Should these liquid wastes be kept in their original state or is it better to process them?
If processing is advisable, how far should they be concentrated? How should the concentrate be packaged to limit the release of radio-elements into the environment?
How can the products obtained be stored with optimum safety?

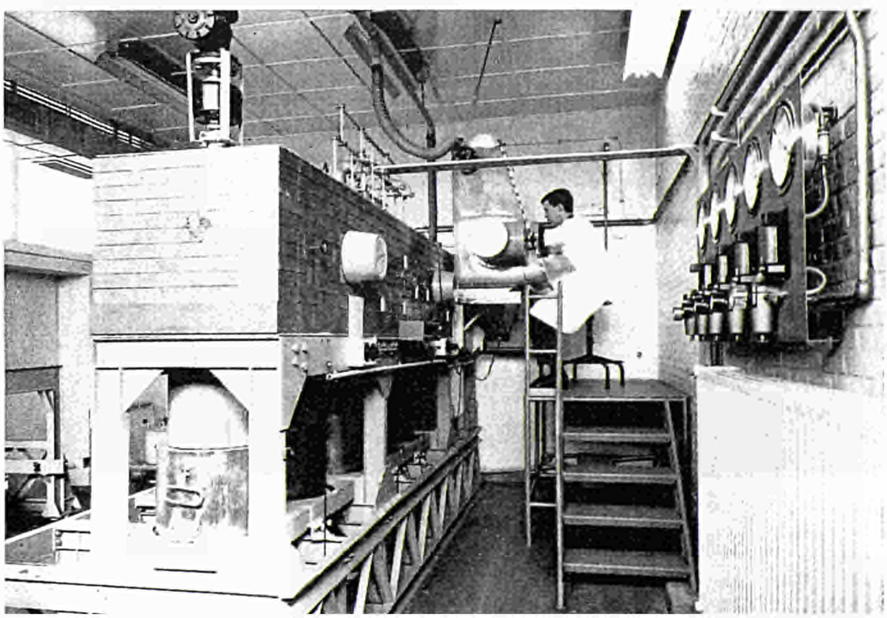
Solutions planned and the Euratom Programme

The problem is complicated because it depends on economic, psychological, political and technical factors. It forms the subject of numerous studies and experiments now going on in all major nuclear centres throughout the world. Euratom likewise contributes in the various fields concerned with the cycles that radioisotopes may go through between the time of their production and their possible incorporation in the human organism. In particular, it is co-operating through the Euratom "Radioactive Waste Processing and Storage Programme". Comparatively modest during the first Five-Year Plan, the appropriation for this work came to the sum of 3 million dollars for the second plan (1 January 1963 to 31 December 1967).

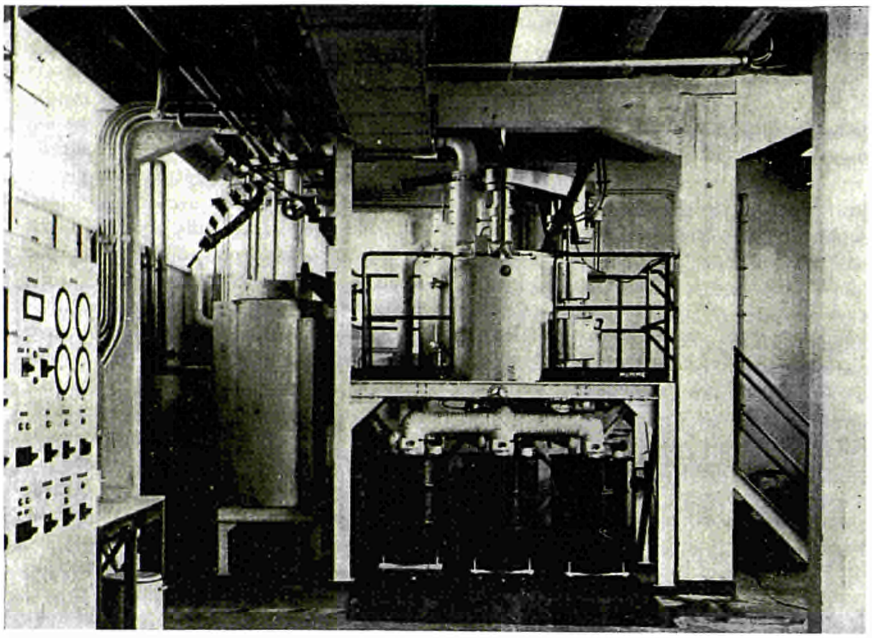
New processing and packaging techniques

As we have seen, the range of processing and packaging methods for low-activity effluents can be regarded as satisfactory, but with higher specific activities the difficulties increase proportionately. Some help in this respect has already emerged from researches carried out by the Nuclear Studies Centre at Mol under Euratom contract, whereby an industrial process has been developed which consists basically in insolubilising the co-precipitation sludge and burnt ashes in bitumen. This process, which has been adopted by other Community nuclear installations and has engaged the attention of certain American centres, is suitable for medium-activity waste.
One of the main purposes of the Euratom Programme, however, has been to promote research on new methods and techniques for packaging high-activity products so as to obtain a dry concentrate suitable for transport and storage. Such processes are needed to replace the present methods, which, consisting merely in storing the liquid solutions as they are, must be regarded as temporary expedients because of the high investment, maintenance and surveillance costs they entail.
This part of the programme, pursued in agreement with the various national authorities, was implemented by the award of a number of research contracts, in particular to the *Etablissements Kuhlmann*, the *Comitato Nazionale per l'Energia Nucleare*, the firm *Leybold* and the Belgian *Centre d'étude de l'énergie nucléaire*. The contracts relate to the fixing of highly radioactive products on natural or artificial silicates,

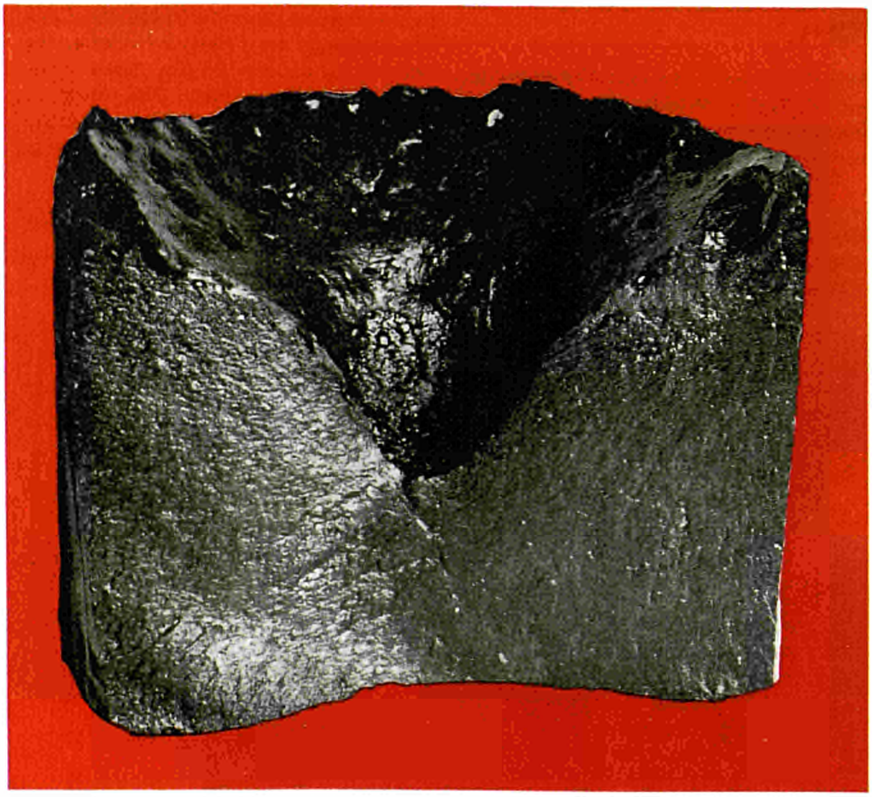
Belgian Nuclear Studies Centre (CEN): *Shielded installation for separating caesium 137 and strontium 90 from highly active fission products (using method developed by L. H. Baetslé and D. Huys).*



General view of the plant for insolubilising radioactive sludge in bitumen, operated by Belgo-Nucléaire *on behalf of the* CEN *at Mol.*



Cross-section of a sample obtained in the insolubilisation plant, Mol, after mixing 50% bitumen and 50% tricalcium phosphate.



the development of a new concentration method based on freeze-drying, and the elaboration of techniques by which such products can be converted into useful radiation sources.

New storage methods

Numerous solutions for the final storage of radioactive waste have been proposed or conceived; but for this ultimate stage of waste disposal, the potential danger represented by high-activity substances leaves us with only a few methods that offer reasonable security, allowing for the special situation of the West-European countries.

In choosing a suitable site, a great many factors have to be taken into account. For that reason Euratom invited the French firm *Cotrel* to carry out a general survey, covering the whole territory of the Community, with a view to locating areas in which storage of a particular type might be contemplated. This task is being performed in close collaboration with certain national bodies.

The various types of final storage contemplated by the Community are:

Storage in salt formations

Salt layers offer a very promising site by reason of the intrinsic properties of the material and the geological nature of the formations enclosing it;

— salt is impermeable;

— a salt layer always lies between two impermeable geological formations;

— salt is abundant and widely distributed;

— the excavation of cavities in salt is very cheap;

— seismic activity is slight in salt regions;

— the compression strength of salt is similar to that of concrete;

— salt is a good heat conductor (an important factor where highly active wastes are to be stored, for they release a considerable heat).

Salt deposits can be used for storing liquids in pools and also for packaged solids. Both these types of storage can be employed either in bored cavities, where the substances are buried for good, or in abandoned workings from which the stored substances

can be removed later for the recovery of certain radioelements.
In view of the results already achieved in the United States, where laboratory and pilot-scale studies have been conducted, Euratom decided to develop a prototype salt-layer storage facility. This work was entrusted to the *Gesellschaft für Strahlenforschung* (see *Euratom Bulletin* No. 3, September 1965, pp. 87-90).

Ground-level storage

Storage on the ground or at shallow depth is only possible where certain conditions are fulfilled. The geology and hydrogeology of the area chosen must be studied, for the discovery of any factor favouring the infiltration of water, such as the presence of limestone formations, would tend to disqualify the site. For the same reasons, a thorough knowledge is needed of the physical and chemical characteristics of the soil and the sub-soil, which determine the retention or migration of the radioelements in the event of their leaking or being washed away. Generally speaking, the best regions will be those with light precipitation, a low-density hydrographical network, a deep-lying water table, scant vegetation and sparsely populated.
Thus climate is a dominant factor in assessing a site, and arid regions are obviously far more satisfactory than damp areas. On the strength of these considerations, Euratom invited the *Comitato Nazionale per l'Energia Nucleare* to study the feasibility of this storage method in Italy.

Disposal at sea

Disposal at sea presents certain peculiar features. Since it entails a certain amount of handling, very careful packaging is necessary; furthermore, there can be no question of recovery and, lastly, surveillance is very difficult.
As with all other storage solutions put forward, there have been many objections to disposal at sea, particularly where the nearest coast is frequented by tourists. It seems, however, that a well-considered plan may finally allay the various fears that have been expressed, particularly as regards the disposal of low-activity waste.
Budget restrictions prevented Euratom from launching a scheme covering this method, under its second Five-Year Plan, which would have made it possible in a few years' time to draw up a comparison of the three most practicable possibilities for final disposal.

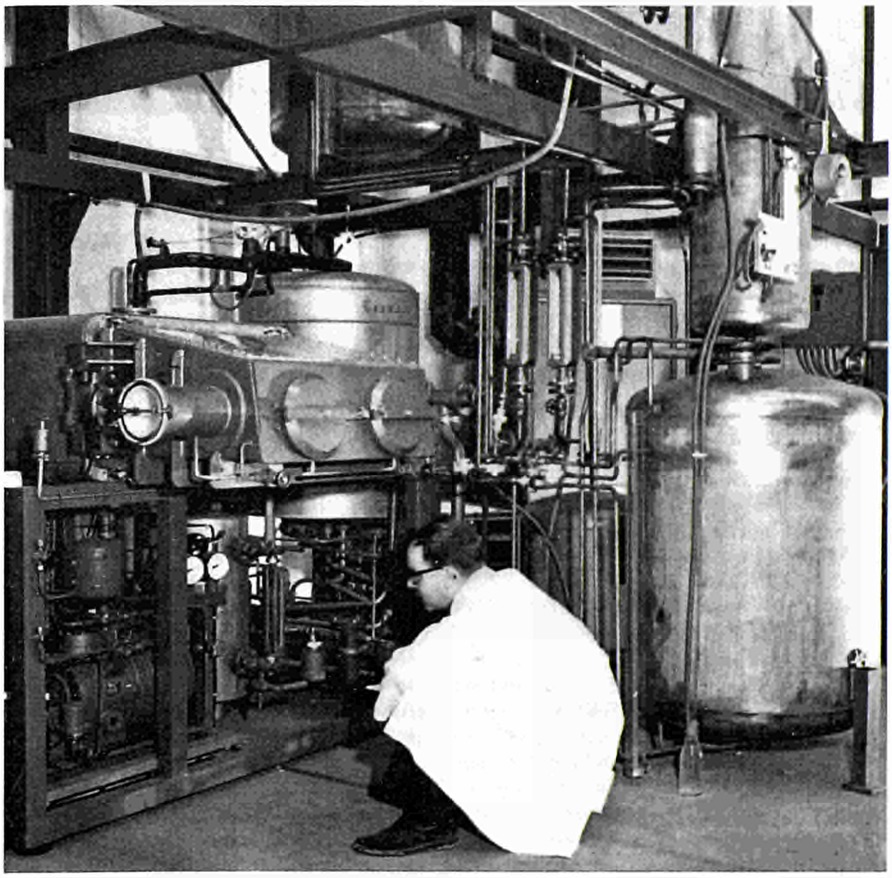
Disposal by injection

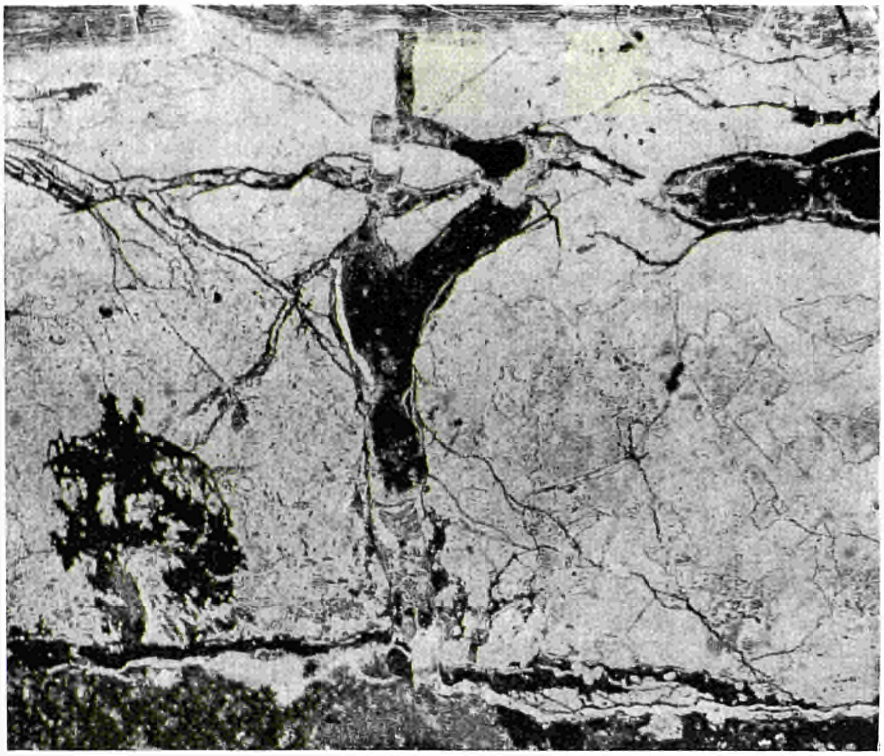
This review of disposal methods would not be complete without mention of this fourth process, which is the injection, under pressure, of a paste into hard rock layers containing natural fractures, such as limestone and sandstone, or easily cracked artificially, such as schists. The paste, which then sets hard, is composed of radioactive liquids or slurry mixed with cement and, where necessary, with fixing agents. Adapted from a technique widely used in civil engineering, this method would only be applied in very special cases where all the necessary geological conditions obtained locally and the distance over which the non-solid radioactive material had to be transported was very short.
Owing to the existence of higher-priority projects and the local nature of the process, Euratom has deferred action in this field to a later date.

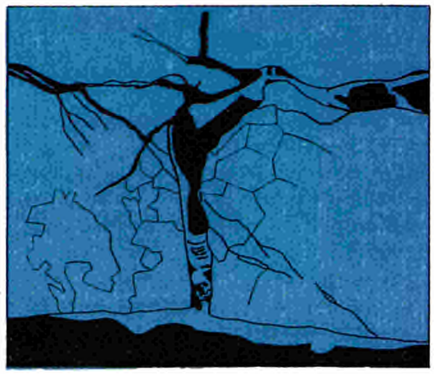
An important factor — water

Water, an excellent vehicle for radioelements, is an overruling factor in the

Installation for research on active effluent processing by the freeze-drying method (comprising the three following stages—partial evaporation, pre-freezing and the actual freeze-drying)— (Leybold Hochvakuum-Anlagen GmbH, *Köln-Bayental*).







A promising method of disposing of radioactive waste is by injecting it under pressure, in the form of a hardening paste, into natural cracks in hard rock layers.
The photograph shows the course of cement grout in a granite fissure (documents taken from a study by Madame Capitant, of the Bureau de recherches géologiques et minières, *Paris).*

choice of a disposal site. Hence the necessity, already referred to, of obtaining a thorough knowledge of the hydrogeology of any district considered, so as to avoid contamination of the ground water and also to provide for surveillance facilities and, in case of accident, anti-contamination devices.

Radioelements themselves, employed as tracers, can facilitate hydrogeological surveys, which is why Euratom, several years ago, asked the Belgian *Centre d'étude de l'énergie nucléaire* to develop certain radioactive tracer methods. Following up its policy in this field, Euratom subsequently signed a contract with the French *Bureau de recherches géologiques et minières*, for research into the conditions governing the use of certain anionic and cationic radioactive tracers, depending on the physical and chemical nature of the medium through which they pass. In addition, the Belgian *Centre d'étude de l'énergie nucléaire* was asked to carry out new research on the feasibility of putting "chemical barriers" into the ground with a view to preventing the spread of any high artificial contamination.
It is worth mentioning that as well as producing results that will be widely useful during the examination of short-listed sites for radioactive waste disposal, these researches will help to bring new scientific tools to everyone who has to study the movements of water in the natural world.

Conclusion

The funds for the two main heads of Euratom's second Five-Year Plan—processing and disposal—are apportioned in the ratio of roughly one to two. The preponderant concern with questions of disposal is warranted by the fact that, unlike the processing and packaging problems, they are ineluctable. Whatever form the radioactive waste may take, its producers must be provided, at the right moment, with adequate methods of disposal.

For all that, the processing and packaging of waste are still essential stages, whose object is to improve the intrinsic qualities of the substances disposed of and especially to keep the risk of any water contamination within tight limits.

But are nuclear hazards a greater threat than the hazards which result from the pollution caused by certain so-called "conventional" industries? The first generation of reactors has grown up without any outstanding accident occurring. Research installations have been operating for years without harmful consequences. These results have only been achieved by an attitude of purposeful caution, every new siting being thoroughly considered before any construction is started. The effects of the plant on the workers, the public and the surroundings are carefully studied, as regards both normal and accident conditions. This compulsory examination has led nuclear energy along lines of such safety as no other branch of industrial activity has yet attained. (EUBU 6-5)

Installation of a loop in the BR-2 reactor for the study of in-pile graphite corrosion

A new loop is currently being mounted in the BR-2 materials testing reactor at Mol (Belgium). Developed for Euratom by *Deutsche Babcock und Wilcox*, it will provide fresh data on a well-known phenomenon, detrimental to the smooth operation of graphite-gas reactors, of graphite oxidation during irradiation in CO_2.

While non-irradiated CO_2 is virtually inert to graphite below 625°C, graphite is oxidised by this gas during irradiation even at temperatures below 600°C. However, the oxidation rate can be appreciably reduced by admixing carbon monoxide or hydrogenated substances such as methane or water vapour with the CO_2.

With the new loop it will now be possible to study the exact effect of these additions on the in-pile corrosion of graphite in the extreme pressure and radiation conditions which obtain in graphite-CO_2 reactors of recent design.
The study programme, to be performed by *Deutsche Babcock und Wilcox*, will also include the testing of various types of graphite supplied by a number of European manufacturers, so that on its completion it will be possible to select the most suitable graphite for this reactor type.

Irradiation experiments at Dounreay for Community fast reactor programme

On 10 November 1966 the Euratom Commission signed a contract with the *United Kingdom Atomic Energy Authority* covering irradiation experiments to be carried out for the Community in the Dounreay fast reactor (*DFR*). Under the terms of the contract fuels and materials, from the fast reactor development programme being undertaken by Euratom and her partners, may be irradiated in both core and blanket positions of the *DFR* for varying periods between January 1967 and July 1968. The work is aimed principally at developing fast reactor fuel capable of reaching high burn-up of fissile material, for which the *DFR* is a particularly suitable irradiation facility. The *UKAEA* has also undertaken to carry out pre- and post-irradiation examinations of irradiated specimens.

The cost of the irradiation programme will be up to a maximum of $ 2.155 million.

How far are nuclear plants let down by their conventional components?

Experience in building and working nuclear power plants has shown that late deliveries and outages are often not due to trouble with the reactor itself but with other plant components.
This problem was the subject of a symposium held by Euratom in Amsterdam on 17/18 November 1966 and attended by representatives of 19 electricity generating undertakings from the European Community. The participants were in particular able to learn the results of enquiries carried out by six working groups created by Euratom early in 1966 with the specific aim of pooling and analysing the experience acquired hitherto and deriving lessons for the future. The six working groups had dealt respectively with reactor containment, heat exchangers, pumps and valves, ga circulators, ventilation and off-gas systems, and steam turbines.
In view of the interest raised by the results obtained, it was proposed at the symposium to extend such enquiries to other components; further working groups are therefore to be created, to cover reactor pressure vessels, instrumentation and control, water treatment systems, burst fuel element detection systems, corrosion and mass transport by working media and coolants, and fuel handling.

EURATOM NEWS

Information meeting on European light water reactors

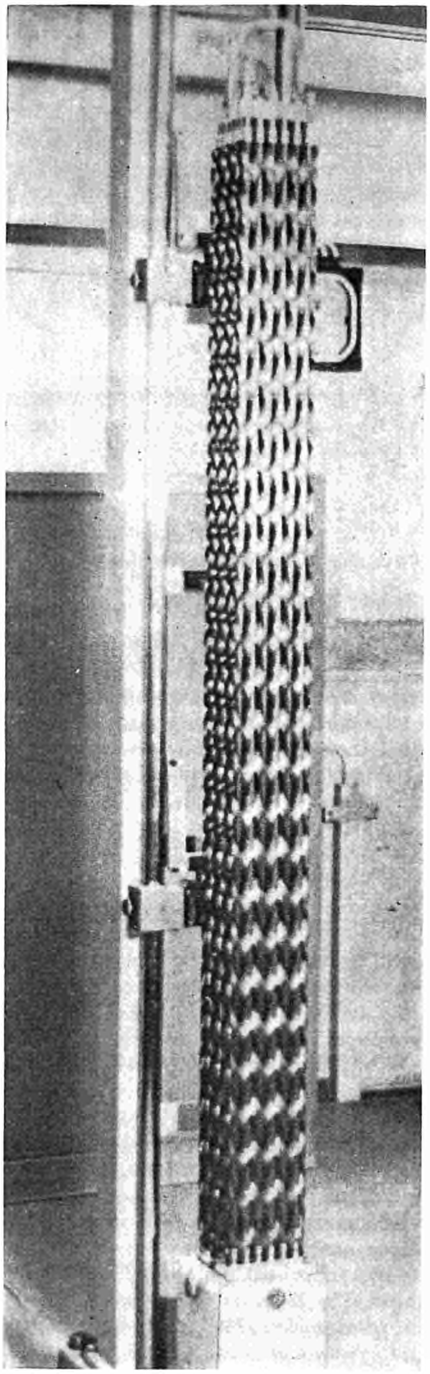
On 23 and 24 November 1966 the Euratom Commission held an information meeting on the development of light water reactors in the Community. This meeting was one of a series of colloquia and seminars organised by Euratom on various aspects of this area of research in the last few years.

The objective of the meeting was to survey the progress made in the Community in developing European variants of boiling and pressurised light water reactors. The results of the work presented at the meeting concerned both work under the Community research programme and that undertaken by public or private authorities in the member countries.

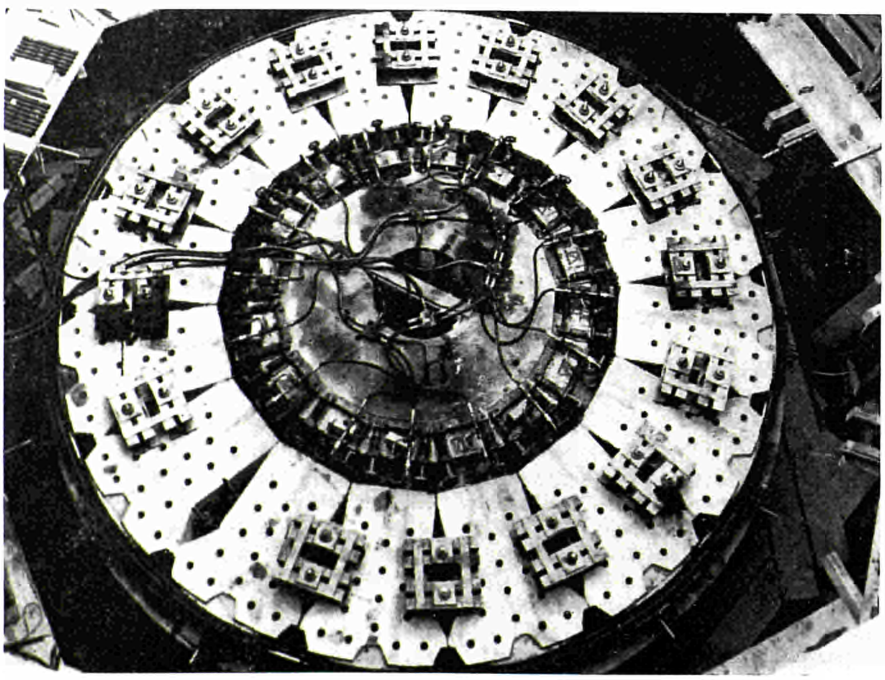
It will be recalled that, alongside its work on advanced converter and fast breeder reactors, Euratom has been carrying out an important research and development programme on proven-type reactors, both gas-graphite and light water. Most of the work in the latter sector has been undertaken within the scope of the Euratom-US Joint Research and Development Programme. To-date some 144 contracts, to a total value of about $ 56 million have been signed with concerns in the Community and the USA. Including the work performed outside the scope of the Joint Programme, Euratom will have roughly allocated $ 36 million to light water reactor research and development in the Community during the period 1959-1966. This work has so far given rise to the publication of 1,650 research reports and the issue of 21 patents.

The most recent developments in light

Twisted tape fuel bundle for irradiation in the Kahl reactor during assembly in the A.E.G. laboratory at Grosswelzheim.



On-site pre-stressing of a layer of concrete blocks. Siemens has developed a concrete pressure vessel design based on the use of prefabricated concrete blocks.



water reactor systems now under way in the Community were presented. They were illustrated by a detailed description of the *AEG* boiling water reactor using internal axial mechanical pumps which substitute for the low efficiency jet-pumps and eliminate completely the recirculation loops. The pumps were described in detail by the manufacturing company *KSB*.

The *Twisted Tape Boiling Water Reactor (TTBWR)* project was also presented publicly for the first time. The *TTBWR* is the result of a research programme carried out jointly by the French *SNECMA* and German *AEG* firms and is the development of the *Vortex* fuel assembly system conceived by the former. This work has been supported by Euratom since 1960. The *Vortex* geometry allows burn-out heat fluxes twice as high as in the fuel assemblies presently used in *BWRs* to be obtained. It confirms that very high power densities (up to 100 kW/l) could be obtained in boiling water reactors.

Three papers dealt also with the development of the prestressed concrete pressure vessel technology to both pressurised and boiling water reactors.

Siemens presented a very original concept based on the on-site assembling of pre-stressed concrete blocs. The possibility of an easy removal of the top head pre-stressed concrete blocs allowing complete access to the reactor core and internals is one of the most noteworthy characteristics of the *Siemens* project. Latest results of the testing programme on an already built model were given.

A pre-stressed concrete pressure vessel boiling water reactor project was also described. This work was carried out jointly by the French firm *SEEE* and the American *General Electric Co.* within the framework of Euratom-United States Joint Programme contracts.

Among other highlights of this meeting arousing great interest were a discussion of the research and development programmes carried out by *ENEL* on its two light water power stations. The work on the Garigliano boiling water reactor involved an integrated effort of *ENEL* and *General Electric Co.* carried out under the terms of the US-Euratom Agreement for Co-operation. It has shown, inter alia, that even with an average void fraction as high as 48%, a boiling water reactor system remains perfectly stable. On the other hand, the research and development programme on the *E. FERMI* pressurised water reactor carried out under a Euratom-*ENEL* contract was also presented and the results of the first tests were discussed.

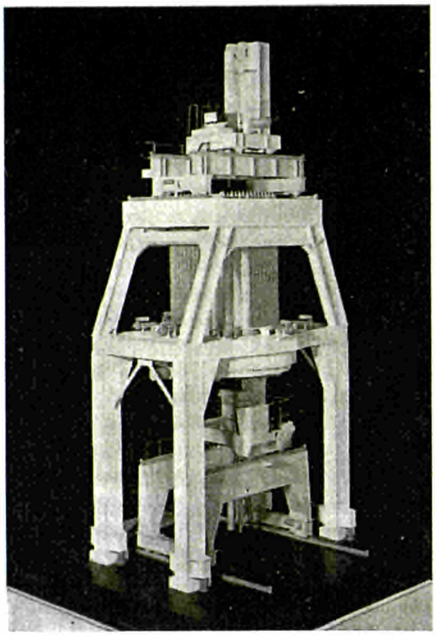
Finally, the *CEN/BelgoNucléaire Association* presented the status of its development work on plutonium fuel fabrication technology and on UO_2-PuO_2 light water lattices typical of *PWRs*, while a Community participant in the US-Euratom Joint Programme contract allocated to *Westinghouse* described the most important results in the latter company's work on plutonium recycling in the *Saxton* reactor. At the present time, more than six hundred rods made of UO_2-PuO_2 pellets or vibrated powder have reached an average burn-up of over 7,000 MWd/t.

The proceedings of this information meeting will be published shortly.

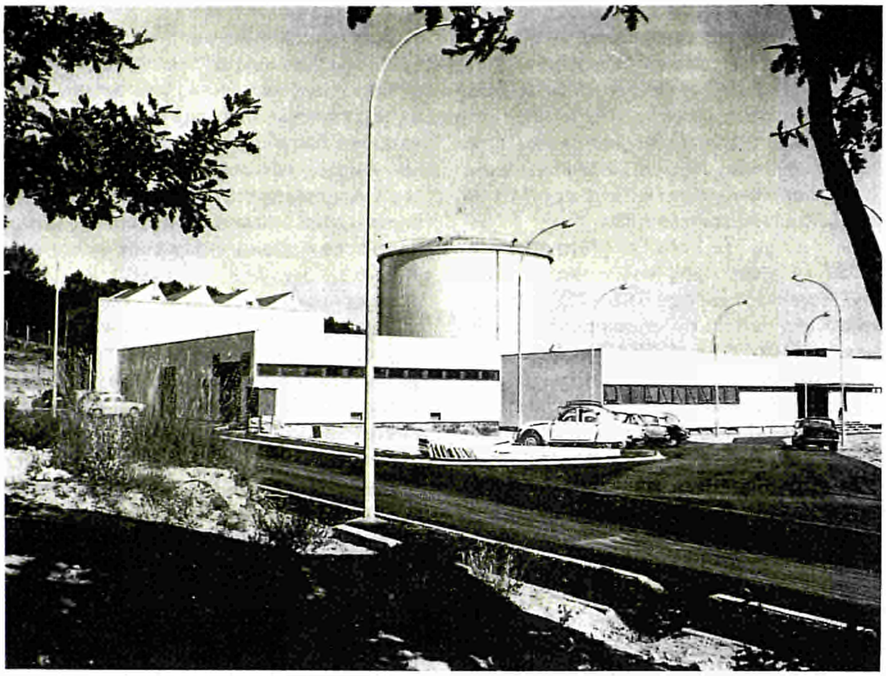
MASURCA and SNEAK go critical

During the night of 14-15 December 1966, an important milestone was reached in the fast-breeder reactor development programme that Euratom is carrying out in association with five of its member states. Two fast-neutron critical assemblies, *MASURCA (MAquette SURrégénératrice CAdarache)* and *SNEAK (Schnelle Null-Energie Anordnung Karlsruhe)*, went critical for the first time. *MASURCA* and *SNEAK* are to be used for simulating the nuclear characteristics of large-scale fast-breeder reactors; their volume is sufficient for neutron studies of power reactors of 1,000 MWe and over, which it is hoped to bring into commercial opera-

Institute for Applied Reactor Physics and Fast Zero-Energy Facility Karlsruhe (SNEAK).



Model of SNEAK *test rig with support, reactor and lower and upper loading machine.*



MASURCA (MA*quette* SUR*régénératrice* CA*darache*).

tion towards 1980. These critical assemblies were both designed to use plutonium, the preferential fuel for fast reactors. *MASURCA* was built under the terms of an association between Euratom and the French *Commissariat à l'Energie Atomique*, and *SNEAK* under a similar arrangement between Euratom and the *Gesellschaft für Kernforschung*.

Fast reactors occupy a predominant position in Euratom's and the member states' programmes, as indeed they do throughout the world, more especially in the United Kingdom, the United States and the USSR; their importance is justified by the singularly promising economic prospects for this type of reactor, which produces more fissionable material than it consumes.

The experimental plants installed in the Community for fast-reactor research also include *STARK*, a fast-thermal coupled critical assembly at Karlsruhe (see *Euratom Bulletin* 1966, no. 4, pp. 118-124), *HARMONIE*, a source reactor at Cadarache (see *Euratom Bulletin* 1965, no. 4, pp. 127-128), *SUAK*, a pulsed subcritical assembly at Karlsruhe—all in use since over a year ago—and the *RAPSODIE* 20 MW (th) sodium-cooled experimental reactor at Cadarache, which is due to go critical in the next few months.

The fissionable materials that *SNEAK* and *MASURCA* will be using in the next two years (about 1,500 kg uranium-235 and 400 kg plutonium) are supplied by the *USAEC* through the Community's Supply Agency under the fast-reactor exchange agreement between Euratom and the *USAEC*. *MASURCA*'s plutonium fuel-elements were fabricated by the European Transuranium Institute, a Euratom Joint Research Centre establishment, and *SNEAK*'s by the German firm *ALKEM*.

The *MASURCA* project involved the participation of a very wide range of firms within the Community. *SNEAK* was built mainly by German industry. Each of the installations, with ancillaries, cost about 6 million dollars to construct.

Enriched uranium: the Community's future supply prospects

"It is becoming steadily clearer that a very large proportion of the uranium to be used in power reactors will be in the form of *enriched uranium*", declared Dr. Michaelis, head of the Euratom Directorate for Economy, in a recent statement. "Until it is superseded by plutonium, enriched uranium will be the chief fuel. As regards supplies, we must bear in mind that, in the Western world, the *USAEC* in fact holds a monopoly of uranium enrichment.

From the standpoint of quantity, in the first place, there is no more need to fear supply difficulties with enriched than with natural uranium. According to often-repeated official statements, the *USAEC*'s capacity should be enough to meet Western requirements until quite late in the seventies. Nevertheless, the recent boosting of requirement estimates has already raised the question of setting up new enrichment plants, which could usefully come into operation during the next ten years. The *USAEC* says it is willing to increase its capacity in step with demand. Seeing how important enriched uranium is going to be as an energy source it would, however, be advisable to consider, on this side of the Atlantic, whether there is not a substantial possibility of setting up plant to enrich uranium by isotope separation. The Euratom Commission is giving its active attention to this problem, being well aware that such a scheme would have a welcome effect not only on supplies but also in a number of industrial sectors.

The consumer countries and the principal producer country are broadly agreed on the essentials governing enriched uranium supplies. It is generally recognised that a fair, regular supply system entails, first, non-discrimination among users, especially between nationals of the producer country and those of the importing countries, and, secondly, the opportunity to arrange long-term supply contracts. This is not the place to discuss the question of how far these requirements are met by the policies pursued by the producer countries and particularly the *USAEC*. Lastly, it is very important for the user countries to be able to have market-bought uranium enriched on a toll basis. This limits dependence on the sole producer to the field of services only and contributes towards the establishing of an open, competitive uranium market, by ensuring that the *USAEC* is not the predominant buyer in the natural uranium market."

Water treatment: removal of radioactive ruthenium

A contract relating to health and safety was concluded on 20 December 1966 between Euratom and the *Etablissements Kuhlmann* (France). The subject of the contract is research on and development of a method for removing radioactive ruthenium isotopes from water likely to be used by human beings either directly, for alimentary purposes, or indirectly, e.g. for agricultural purposes.

Radioactive isotopes of ruthenium are present in large quantities in the liquid wastes discharged from nuclear installations, owing to the difficulties of removal by the usual purifying methods. The chief source of such difficulties is the lack of knowledge concerning the physico-chemical behaviour of this element, which has as many as eight valency states and forms a great many more or less stable complexes.

The scheduled research will therefore be aimed first of all at characterising the various physico-chemical states of radioactive ruthenium. The results will then be used to discover effective and economically sound methods of decontaminating water for human consumption without impairing its properties.

Dust analysis by radiometry

The *VEREWA* company, Mülheim/Ruhr (Germany), has been commissioned by Euratom to develop an instrument for analysing the dust content in gases, particularly in smoke flues.

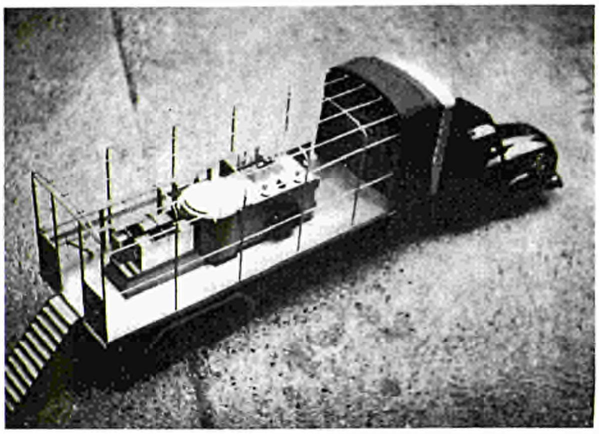
The growing air pollution in large industrial and residential areas is causing both the authorities and the public considerable disquiet. The first step towards forestalling the dangers that may threaten public health is to monitor such pollution continuously and to keep the emission of industrial dusts below the limits tolerable to man.

This, however, can only be done with proper measuring instruments. The pro-

cesses and devices produced so far are either not sufficiently precise or too complicated to manage, so that they are not suitable for permanent monitoring systems.
The work programme provides for the development of an appliance for analysing dust contents of industrial origin by radiometrical methods. Radioactive sources can be employed to determine the quantity of dust continuously (at roughly 10 minute intervals), and to analyse a number of chemical components present. By thus monitoring the substances discharged into the atmosphere, the instrument will be capable of regulating the combustion processes.

Measurement of oxygen content of steels by activation analysis

The oxygen content of steels can be measured on an industrial scale by means of activation analysis. This emerges from a study which the *Aciéries Réunies de Burbach-Eich-Dudelange (ARBED)* in Luxembourg have carried out on behalf of Euratom.
With nitrogen and hydrogen, activation analysis does not produce the same results. Further details are contained in Report EUR-3161. The first part contains a bibliographical survey and the second the test data, while in the third the tests are discussed and the conclusions to be drawn from the study enumerated.



Model of the mobile pilot irradiator IRMA

IRMA to tour Europe

In 1967 the Eurisotop Bureau is to organise a Community scheme to promote the industrial use of irradiation techniques.
Under this scheme, "*IRMA*", a mobile pilot irradiator equipped with a caesium 137 source and with a power of 175,000 curies will be made available to industrial firms, research centres and interested organisations in the member states for carrying out irradiation tests and demonstrations.

Meeting on food preservation by irradiation

The Eurisotop Bureau held a working meeting in Brussels on 23 and 24 February 1967 on the use of irradiation techniques to preserve foodstuffs, a subject which is attracting ever greater interest in the food industry.
As the United States, Canada and the USSR have already authorised the consumption of various irradiated foodstuffs, it is likely that the Community countries will soon follow suit.
These irradiation processes can be employed for several different purposes, e.g.:
—to prevent sprouting (potatoes, onions, garlic, etc.);
—disinfestation (cereals, produce of animal origin);
—pasteurisation (fish, meat, fruit, etc.);
—sterilisation (bacon, ham, etc.).
The objects of the working meeting were to give the Community enterprises and organisations concerned information on current research programmes, and to discuss the technical and economic prospects, the measures to be recommended and the steps to be taken to introduce the use of irradiation methods in the food industry.

Labelled molecules and cancer research

At the second international conference on methods of preparing and storing labelled compounds, held at Brussels on 28 November-3 December 1966 (see *Euratom Bulletin* 1966 No. 4, p. 128a) Professor Lettré, head of the Cancer Experimental Research Institute at Heidelberg, was asked to illustrate the potential uses of labelled compounds by describing certain results obtained at his institute.
Among these results there are some which

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may have a useful future in the field of cancer therapy. For instance, in the course of his own work Professor Lettré discovered certain substances which, in cell culture, destroy cancerous cells while leaving the normal cells unharmed. The only way to reveal the mechanism of this process was by labelling these substances. It was found that their molecules attach themselves to the surface of both normal and malignant cells; but whereas the normal cells possess an enzyme which breaks down the molecules and thus prevents them from acting, the malignant cells lack this enzyme and so cannot destroy them. The molecules affect the permeability of the cell membrane towards nutritive substances, and the cancerous cells die for lack of the necessary growth material. This characteristic modification was demonstrated in particular on the histones —the cell nucleus proteins —through the use of labelled molecules. It must be understood that these are only laboratory results obtained with cultured cells and that prolonged research with animals will be needed before the principle can be applied therapeutically.

Professor Lettré also spoke of the autoradiography method, which uses the radiation emitted by the labelled molecules to make them directly visible. There has been considerable progress in the interpreting of autoradiographs; a method has been developed to improve the findings obtainable by optical and, more especially, electronic microscopy.

Forthcoming conferences:

May 8-10, 1967
Evian-les-Bains
(France)

Sponsored by Euratom:
Conference on the "Applications of radiometric methods and the elimination of static electricity in the textile industry".

May 11-12, 1967
Evian-les-Bains
(France)

Sponsored by the *Association Technique pour l'Energie Nucléaire (ATEN)* and Euratom:
Information meeting on "The application of radioisotopes and nuclear radiations in the paper, plastics, rubber and photographic industries".

July 3-5, 1967
Baden-Baden
(Germany)

Sponsored by Euratom:
Conference on the "Applications of radiochemical methods and of irradiation techniques in the textile industry".

For further information about these three conferences, write to Euratom, Bureau Eurisotop, 51-53, rue Belliard, Brussels 4, Belgium.

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