euro spectra

SCIENTIFIC
AND
TECHNICAL REVIEW
OF THE
EUROPEAN
COMMUNITIES

JUNE 1969
VOL. VIII
NO. 2

A mass of molten metal suspended in a vacuum (see page 46).

CONTENTS

spectra

Scientific and Technical Review of the European Communities (ex-Euratom Review)

1969-2

Quarterly publication

Five editions:

English, German, French, Italian and Dutch

Published and edited by:

Commission of the European Communities,
Directorate-General Dissemination of Information,
51-53 rue Belliard, Brussels 4.
Telephone: 13 40 90

Subscriptions:

For details on how to subscribe please see order form facing last page.

Picture credits: pages 34, 35, 36, 39, 40, 41, 42, 46 (top) 50, 51, 55 and 60: Gaston Bogaert, Brussels; page 64: KLM Aerocarto n.v., Prinses Beatrixlaan 7, The Hague; page 64a: Luftbild G. Büse/AEG Telefunken; page 63: Siemens Aktiengesellschaft, Technischer Pressedienst, Munich 1, Oskar-von-Miller-Ring 18.

Sales office:

Agence et Messageries de la Presse (AMP)
1, rue de la Petite Ile
Brussels 1
Belgium

Yearly subscription rates:

United Kingdom 21/-; United States $ 3.50

Basic rate:

Europe: 125 Belgian Francs

Other countries: 175 Belgian Francs

Single copies:

United Kingdom 7/-; United States $ 1.-

Printed in the Netherlands
by A. W. Sijthoff, Leiden

Scientific and Technical Review of the European Communities (ex-Euratom-Review)

1969-2

A first step towards the realisation of a European scientific and technical research policy was taken a few weeks ago, when the Aigrain Group submitted to the Medium-Term Economic Policy Committee the report which the Council of Ministers of the Six had called for in its Resolutions of 31 October 1967 and 10 December 1968.

In this report the Group proposes a series of cooperative projects, 47 in all, which could conceivably be carried out on a European scale in the seven fields chosen by the Council. At the same time it puts forward certain ideas on the "horizontal" problems involved in technological cooperation, such as the collation of national research programmes and budgets, scientific information and the training of research scientists.

This, we repeat, is only a first step. The report has to be discussed by the competent authorities. Moreover, the Group still has to look more closely into some of the questions it has raised. And then, when the proposals have received the final touches, they will have to be communicated to non-member countries that have expressed a wish to take part in a cooperative technological programme. We shall thus be able to publish the details in a coming issue.

The Aigrain Group has carried out its first task remarkably quickly. Let us hope that its example will be widely copied, particularly when it comes to transforming the proposed technological cooperation into action.

Towards a symbiosis of oil, coal and the atom

Cheap energy can not only contribute to the stability of the Community's energy economy but also reduce the cost of certain oil and coal derivatives.

MANFRED SIEBKER and HENRI MARTIN

IT IS generally recognised that nuclear energy is in direct and non-stop competition with the traditional energy sources such as coal or oil. As we shall see, however, recent studies have shown that this situation could be altered substantially.

The importance of the energy sector to an industrial economy in our time is self-evident. As this rule holds good for the Community too, a consistent Community policy is essential[1], not only to break down trade barriers but also, and particularly, to guard against the hazards that may result from the Community's over-dependence on imports. Even now, the Community imports more than half its primary energy; in 1967, this accounted for about 5,500 million u.a., or about 18% of the total value of imports.

MANFRED SIEBKER and HENRI MARTIN are on the staff of the Directorate-General for Research and Technology at the Commission of the European Communities.

It is therefore essential that the Community secure a reliable source of reasonably cheap supplies.

This is one of the main objectives that could be achieved by greater diversification of the primary energy sources and their better exploitation, e.g. as raw materials for derived products rather than as mere fuel. Every day sees a bigger demand for such products in the giant organic-chemicals industry. Naturally, due weight must be given to the economic aspect of this objective; but some people might well feel that dependability of supply outweighs economic considerations in certain cases.

Be that as it may, the solution we shall try to analyse here provides, insofar as it offers a new outlet for coal, an answer to the social questions raised by the reorganisation of the coal industry.

Let us first see how this dependence on imports grew up and whither it is tending.

Frailty of an oil-based Community economy

Recent years have brought rapid changes in the structure of the Community's energy sector—a severe slump in coal, the spectacular rise of oil and gas, the launching of nuclear energy. The figures speak for themselves (see Figure 1). In 1958, coal covered 65% of the Community's total energy consumption, while oil only accounted for 15%. In 1967, the proportions were 35 and 50% respectively.

At present roughly one-third of the coal is used to generate electricity, one-third to manufacture coke for the steel industry, and one-third for chemicals and household use.

The likelihood is that in the future coal will be used less and less to generate electricity. Similarly, in the steel industry, coke requirements are expected to shrink as the hydrogen method of reducing ores spreads. This trend might even be accelerated if hydrogen were produced more cheaply by means of nuclear heat (see *Euratom Bulletin*, Vol. VI (1967), No. 4, pp. 115-120 and *Euratom Review*, Vol. VII (1968), No. 4, pp. 124-125).

At the same time, households and the chemicals sector are turning increasingly to oil and natural gas.

Thus oil is tending to step into a monopoly position, so that the Community, with little oil of its own, will find itself more and more dependent on imports, which are closely tied to political contingencies that make the instability of both price and supply.

1. See "First Guidelines for a Community Energy Policy", a communication from the Commission of the European Communities to the Council of Ministers, published in the supplement to the *Bulletin of the European Communities*, No. 12/1968.

. . . a better exploitation of the primary energy sources, e.g. as raw materials for derived products . . .

The Community should lose no time in seeing how far other energy sources could be used instead of oil. How can this be done?

Use nuclear power to process fossil fuels . . .

The growing use of nuclear energy to generate electricity is certainly one step in this substitution process, but there are other fields where it could be used under certain conditions. In particular, the production of some basic materials could be made profitable by the combined use of two primary energy sources, for instance by using a cheap heat source, such as nuclear energy, with a hydrocarbon source like coal which, unless subsidised, is no longer competitive in Europe today as a heat source.

There can, of course, be no question of restoring King Coal to his empire over all the sectors where coal is still used. However, one sector deserves particular attention, and that is coal chemistry.

The organic-chemicals industry, which is at present based mainly on petrochemicals, has achieved spectacular growth over the last fifteen years, principally because it offered a means of overcoming the scarcity of natural animal, vegetable or mineral substances by providing either cheaper and better quality substitutes or completely new products. By 1985 the plastics turnover is expected to equal that of steel and aluminium.

Generally speaking, however, coal chemistry has not shown the same drive as petroleum chemistry and has continued to centre around the now declining production of gas and metallurgical coke.

And yet it is coal chemistry that could put Community coal in a stronger position with respect to the other primary energy sources. To do this, it would have to be regarded as an end in itself and not, as has so often been the case hitherto, as a bondservant of the steel industry. Then we could advance beyond the mere burning of coal and build profit-earning plants that would only produce certain raw materials needed in the chemicals industry, notably hydrogen and synthesis gas ($H_2 + CO$).

Research on fossil fuel processing along these lines has been carried out by Professors Schulten and Wenzel of the *Technische Hochschule Aachen*[2], more especially on the integral gasification of coal using nuclear energy as heat source (Figures 2 and 3). The chemical reactions that govern these processes are endothermic and require temperatures in the 900-1,150°C range, depending on the process.

Two methods deserve consideration. In one (Figure 2) the coal is converted into methane by hydrogenation under pressure and the methane is then reformed.

For reasons which are in fact connected with the 900°C temperature needed and which are set out further on, this process offers good medium-term prospects. The other process (Figure 3), however, though simpler in concept, requires a temperature of 1,150°C.

The gases thus produced in the gasification ovens are a mixture in variable proportions of CO, H_2 and CH_4, and of CO_2, H_2S, COS, with a tar content. A series of entirely traditional purifying operations are then carried out, yielding such end-products as hydrogen or synthesis gas and methane.

The preliminary studies showed that this process could considerably lower the cost of the basic materials produced. There can be no doubt that, for economic reasons, only low-grade coal and brown coal would be involved in such processes. In this connection, new coal-winning

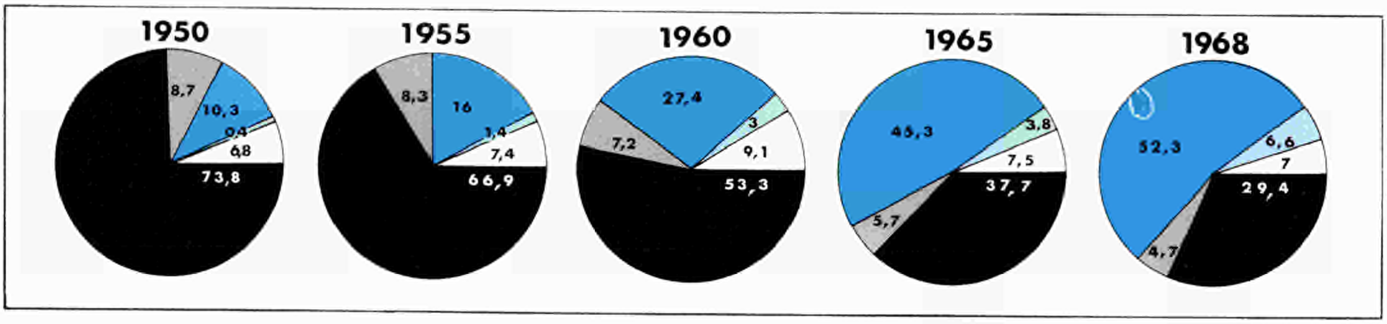


Figure 1: *Breakdown, by energy source, of primary energy consumption in the Community (in %).*
in black: *hard coal;* in grey: *brown coal;* in full colour: *oil refinery products;* in light colour: *natural gas;* in white: *energy of hydroelectric, geothermal and nuclear origin. The comparison between 1960 and 1968 is particularly striking: within a space of eight years the roles of coal and oil have to all intents and purposes been reversed.*

2. A report on the economic and technological aspects of fossil fuel processing methods using nuclear energy, which was prepared by Professors Schulten and Wenzel at the request of the Commission of the European Communities, will be published shortly. The report is based on work carried out at the *Kernforschungsanlage Jülich* and the *Technische Hochschule Aachen*.

methods, e.g. hydromechanical methods, which are still being tested but hold out good economic prospects, would be perfectly suitable for these processes, for which the requisite water should already be present in the crude extraction product.

This research on the processing of fossil fuels with nuclear heat is not, however, confined to coal but deals likewise with the reforming of natural gas (Figure 4) and hydrocracking of heavy fuel-oil (Figure 5).

In the latter process, nuclear energy can replace a substantial proportion of the oil used purely for heating purposes in the traditional cracking techniques.

We have seen that the temperatures required in these various processes are in the 900-1,150°C range. At the moment, the nuclear reactors capable of meeting these requirements are the helium-cooled high-temperature reactors. The outlet temperatures of the primary-circuit helium must, of course, be higher—between 950 and 1,200°C. Table I summarises the incidence of the various foregoing processes on the oil-consuming sectors.

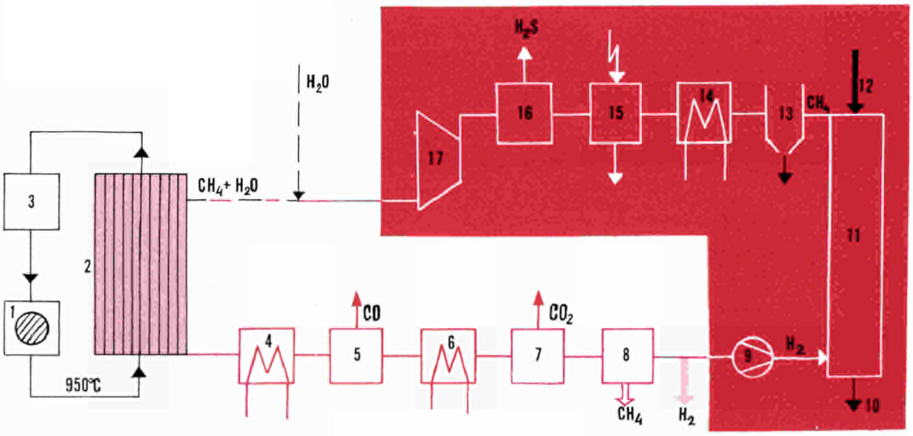
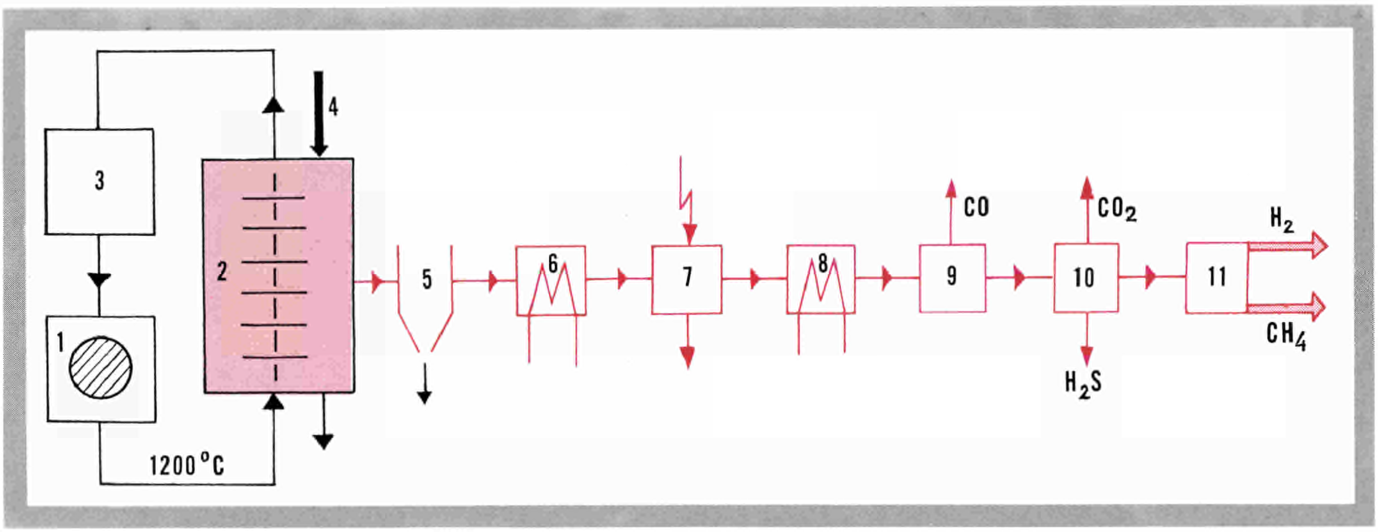


Figure 2: *Hydrogenation of coal.*
1. Nuclear reactor; 2. reforming furnace; 3. gas turbine; 4. and 6. condensers; 5. converter; 7. CO_2 scrubber; 8. low-temperature separator; 9. compressor; 10. ash; 11. hydrogenating furnace; 12. coal; 13. cyclone for separating ash; 14. condenser; 15. electrostatic tar remover; 16. H_2S scrubber; 17. decompressor.
The coal (12) is converted into methane by hydrogenation under pressure in the furnace (11) by the process described at figure 4. Part of the hydrogen obtained is subsequently used for the coal hydrogenation process. The energy balance of the process is as follows:
1 kg C + 7.24 nuclear Mcal → 0.81 m³ CH_4 + 0.86 m³ H_2 + 5.05 recoverable Mcal.

. . . but not before the eighties

In all these processes, it is the nuclear reactor and the heat-exchange equipment linking the nuclear and the chemical parts that really raise the largest number of technological problems, because of the temperatures required. At present, the

Figure 3: *Complete gasification of coal.*
1. Nuclear reactor; 2. gasifying furnace; 3. gas turbine; 4. coal and steam; 5. cyclone for separating ash; 6. and 8. condensers; 7. electrostatic tar remover; 9. converter; 10. CO_2 and H_2S scrubber; 11. low-temperature separator.
In this process, the coal mixed with steam (4) is completely gasified in the furnace (2). The helium in the reactor primary circuit is at a temperature of 1,200°C. The gas produced is a mixture in variable proportions of H_2, CH_4 and also H_2S, CO, CO_2. The energy balance is as follows:
1 kg C + 6.3 nuclear Mcal → 3.6 m³ (H_2 + CO) + 2.8 recoverable Mcal.



maximum helium outlet temperature that is technologically achievable is 850°C. This means that a certain amount of development work has still to be done, more especially on the rate of fission product release from the coated particles, the behaviour of the core internals, graphite corrosion, and insulation of the concrete pressure vessel, as well as the problem of the vessel penetrations.

Of the two temperature levels required for these processes, it appears that the 950°C level can be attained in a few years' time. In the first place, it is only a slight extrapolation from the performances already attained, and secondly, it has attracted the interest of those in the electricity generating industry who are considering coupling a gas turbine to a nuclear reactor (see *Euratom Review*, Vol. VII (1968), No. 2, pp. 52-58).

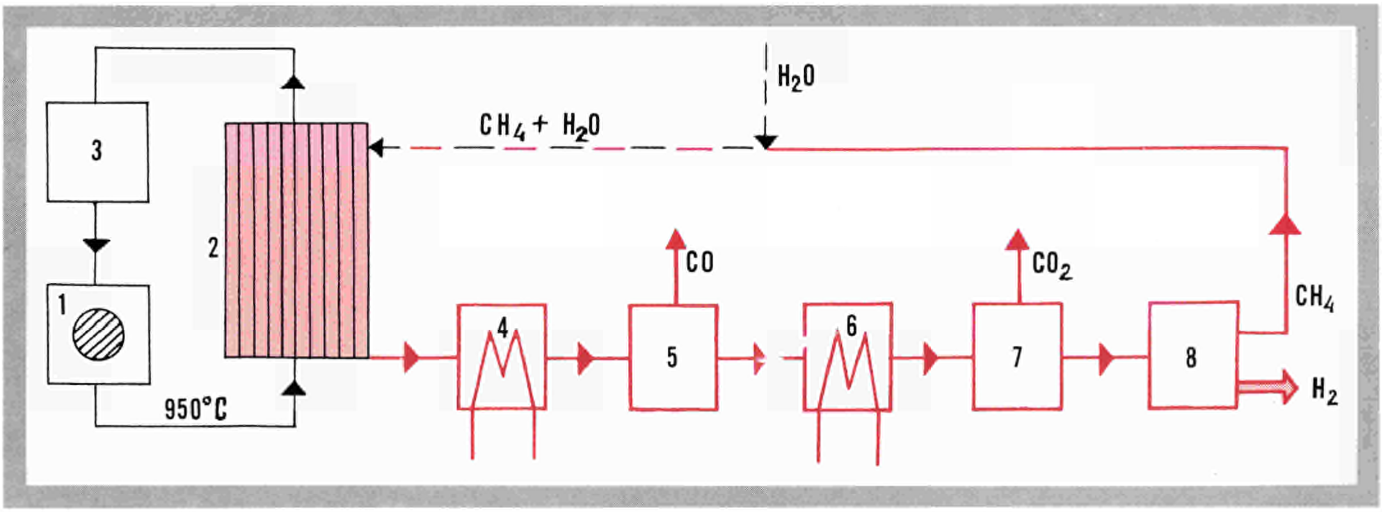


Figure 4: *Reforming of methane.*
1. Nuclear reactor; 2. reforming furnace; 3. gas turbine; 4. and 6. condensers; 5. converter; 7. CO_2 scrubber; 8. low- temperature separator.
The methane/steam mixture is reformed in a furnace (2) with Ni-Cr steel pressure tubes in which the 950°C helium of the nuclear reactor's (1) primary loop circulates. The reforming action is:
$CH_4 + H_2O \rightarrow CO + 3H_2$ — 49 Kcal/mol.
After passing through the reforming furnace the helium, now at 750°C, flows into a gas turbine (3) and is then recycled into the reactor at a temperature of 400°C. The final product, which may be hydrogen or synthesis gas, is reached by separating the CO_2 (7) and the unreformed CH_4 (8). The energy balance, assuming that all the methane is reformed, is as follows:
1 m^3 CH_4 + 6.8 nuclear Mcal → 4.0 m^3 H_2 + 4.8 recoverable Mcal.

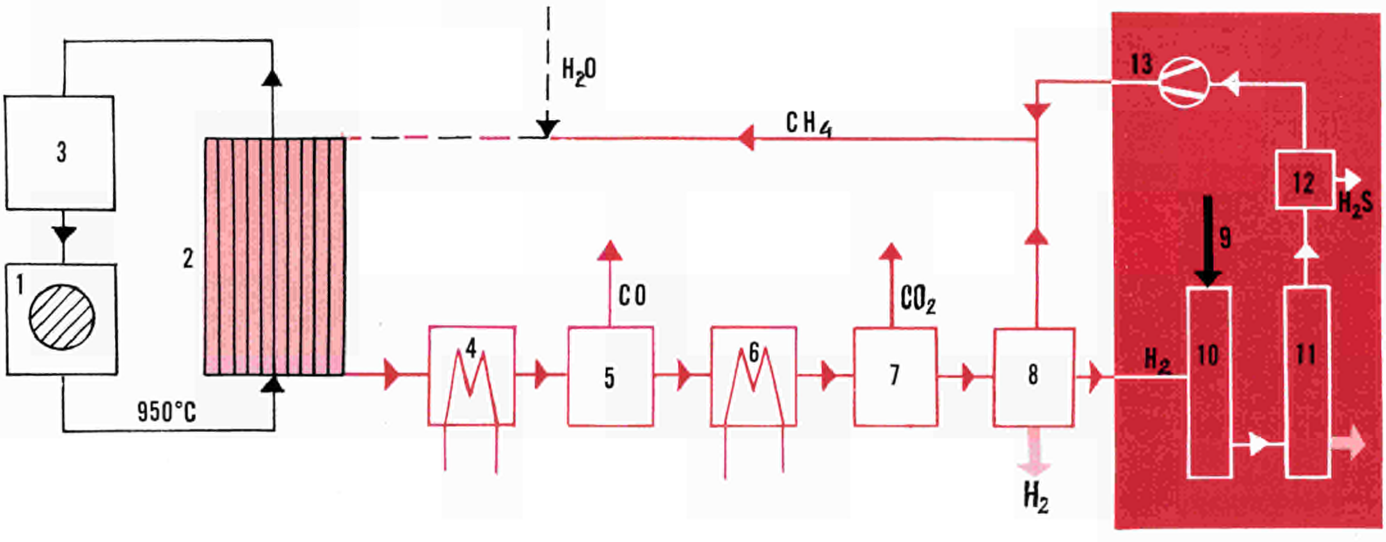


Figure 5: *Hydrocracking of heavy fuel-oil.*
1.-8. see figure 2; 9. heavy fuel-oil; 10. hydrocracking column; 11. distillation column, with extraction of liquid hydrocarbons; 12. H_2S scrubber; 13. compressor.
In this process, the heavy fuel-oil (9) is converted by hydrocracking (10) into liquid and gaseous hydrocarbons which are separated in the distillation column (11). The H_2S is separated (12) from the rest of the gas. This gas mixed with steam is then reformed by the process described in Figure 4 to yield hydrogen as the end-product. The energy balance of the process is as follows:
1 kg heavy fuel-oil + 2.04 nuclear Mcal → 0.54 m^3 H_2 + 604 g gasoline + 1.44 recoverable Mcal.

Table I: *Breakdown of substitute processes by oil consumption sector.*

Oil consumption sector	Substitute processes		
	I combined nuclear/ hydrocarbon energy	II combined nuclear/ coal energy	III nuclear energy
Transport	–hydrocracking –new hydrocarbon fuels	gasification and Bergius or Fischer-Tropsch processes	
Households	gas production		
Steel industry	direct reduction of ores		
Chemical and other industries	synthesis of NH_3, C_2H_2 . . . etc. from processes generating H_2 or (H_2 + CO)		
Electricity production			nuclear power plants

The 1,200°C level, on the other hand, is specific to the applications mentioned and in addition constitutes a really sharp rise in temperature, which suggests that a much longer time will be needed to develop the technology. It is worth noting, however, that various steelmaking operations such as the agglomeration of iron ores or preheating of the air in blast furnaces also call for temperatures of this order and might therefore offer further potential applications.

In any case, even for the 950°C level, the end of the seventies appears to be the earliest date at which any large-scale industrial application can reasonably be expected.

In view of the interdependence of various sectors in this particular case, such as the steel, coal and nuclear sectors, and the similarity of many of the development problems to be solved for each application, it would be a pity if such work were undertaken in a piecemeal fashion. A skeleton development programme should be envisaged. In view of the experience it acquired in these sectors from implementation of the Euratom and *ECSC* Treaties, the Commission of the European Communities would be in a good position to offer its assistance in preparing and carrying out such a programme.

Conclusion

Thus, under the cross-fire of various factors—the competition between primary energy sources to be the first to achieve profitability, and certain political demands, a new road is opening up for the Community along which these energy sources will enter a kind of symbiosis. The use of nuclear energy to process certain fossil fuels should therefore provide the Community with the means of attaining one of the objectives of its energy policy. Through diversification and more radical rationalisation of the energy sources, it would eventually tend to cut down the disquietingly powerful position that oil is acquiring on the European energy market. We have just described the potential opportunities. They are full of promise. The time has come to set out on this new road to strengthen the future of Europe's energy supply.
EREA-A 8-5

Chemonuclear reactors

In the preceding article, nuclear energy was looked upon as a source of heat, which could take the place of others, particularly in the chemical industry, in fairly near future. However, over the longer term, it is worth considering reactors in which nuclear fission would lead directly to chemical reactions.

GOTTFRIED JUPPE

The tremendous economic potential of a chemonuclear reactor, i.e. a reactor which would produce chemicals instead of energy, was first discussed about 12 years ago by the American scientists P. Harteck and S. Dondes. The idea was that it might be cheaper to produce certain highly important chemicals by such a process than by conventional means, because of its essential directness and simplicity.

After the initial great enthusiasm, which was apparently shared by Russian and Japanese workers and to a lesser degree by Europeans, interest in chemonuclear reactor research has waned considerably, especially in the past three years and even in the USA. However, there still seems to exist a definite interest in a reactor type which produces chemicals and not, at least not only, heat and electricity as conventional power reactors do.

In a highly industrialised country the annual production of chemicals represents a ten times higher value than the annual production of electricity. And the demand for cheap energy for the production of chemicals is steadily rising. In 1967 the chemical industry in West Germany used 34,000 million kilowatt-hours of electricity directly or indirectly for the production of chemicals and over four million tons of coal units for producing process steam. The production of some important basic chemicals, like fertilisers, is at the moment growing at a rate of over 20% a year, whereas the average annual increase of new fossil fuel resources is less than 10%. But even if at present coal and other fossil fuels are abundantly available—in some countries like Germany and Belgium coal mines have to be closed—this situation might look very different in a few decades.

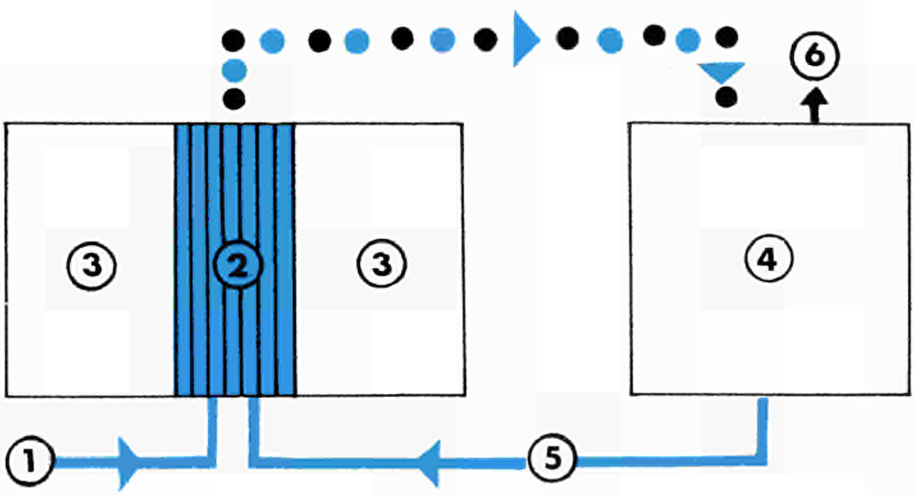
There still remains the fact that it is unreasonable to burn gas, coal or oil to valueless carbon dioxide instead of preserving this raw material for future generations, for which it will be an irreplaceable basis for the production of chemicals.

What is a chemonuclear reactor?

The ideal chemonuclear reactor would use all the energy liberated by the decay of U^{235}, Pu^{239} or U^{233} atoms to excite or ionise the molecules of appropriate starting materials, and in doing so lead to the breaking of bonds which eventually results in the formation of some desired end product.

The energy liberated during the fission of the above-mentioned fuels consists of neutrons, gamma rays, electron radiation, neutrinos and the kinetic energy of the fission fragments. Of the total energy released, only about 7.5% is delayed energy, that is energy which can be employed for radiation chemistry some time after the occurrence of fission, outside the reactor in an irradiation plant. These are the decay gammas, decay betas and the gammas and secondary electrons from capture radiation. Eight percent of the total fission energy is promptly released in the form of neutrons and gamma rays. Only this part is penetrating

Figure 1: *Diagram of a chemonuclear reactor. 1. Starting material; 2. core; 3. moderator; 4. decontamination and purification; 5. unreacted starting material; 6. end product.*



GOTTFRIED JUPPE is head of the Radiation Chemistry Group at the Ispra Establishment of the European Communities' *Joint Research Centre*.

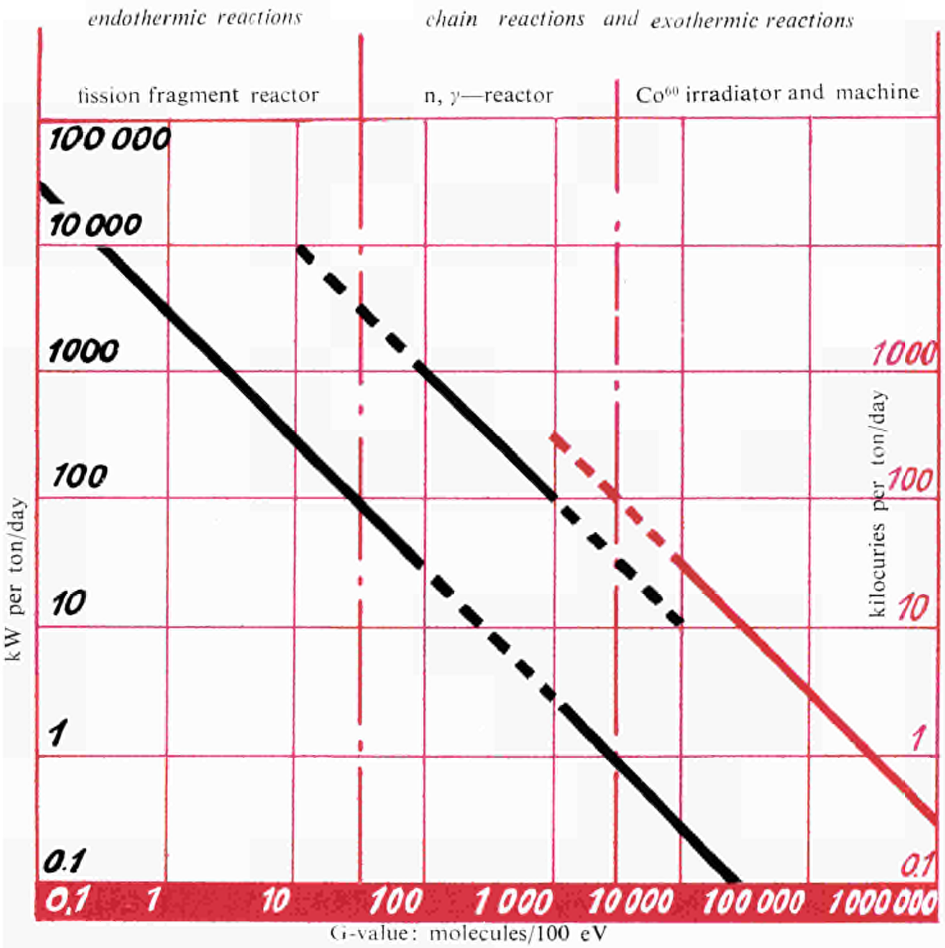


Figure 2: *Power requirements of radiation sources v. G-value (for average product molecular weight = 50).*
Left-hand scale: *reactor power, in kW, required for production at the rate of one ton per day.*
Right-hand scale: *activity required of a cobalt 60 source, in kilocuries, for production at the rate of one ton per day.*

radiation, which could be used for radiation chemistry purposes in a reactor with a conventional fuel design. A reactor utilising this 8% of the total energy for chemical synthesis would be a "neutron-gamma" chemical reactor, being only slightly different in its concept from an ordinary power reactor. The coolant is then simply replaced by a chemical reaction system.

Most of the available energy of the fission process (84%) is promptly released in the form of the kinetic energy of the fission fragments. In a conventional power reactor or in a gamma neutron reactor the interaction of the highly energetic fission fragments with the material of the reactor results in a degradation to thermal energy which in a power reactor is then converted to electricity. In a chemonuclear reactor this transformation of the kinetic energy of the fission fragments into heat must be avoided, as the kinetic energy should at least partly be utilised to excite and ionise chemical molecules and to break chemical bonds. It must be borne in mind that the average range of fission fragments in gases is only 2 to 2.5 cm. The fission track length in condensed systems is even shorter, being only 5 to 25 microns and the width of the fission track is only 100 to 300 Å. From this it follows that a very close contact between a large surface uranium or plutonium fuel and the chemical molecules has to be achieved. This leads to the serious consequence that a high contamination of the reaction product is to be expected.

The temperature in the fission track is about 1,000°C in gaseous systems and 1,200 to 3,200°C in condensed systems. The surrounding chemical molecules within the track are very rapidly heated to these high temperatures, the time required for this process being less than 10^{-8} seconds. During the following tenth of a second the "hot" chemical molecules or their fragments are again quenched to the surrounding temperature of the unaffected neighbour molecules. These reaction conditions are somewhat unique if compared with classical chemical synthesis. They resemble in some way the Birkeland-Eyde flaming arc process for the synthesis of nitrogen oxide from molecular nitrogen and oxygen. At 2,500 to 3,000°C, 5 to 10% nitric oxide is present at thermal equilibrium with nitrogen and oxygen. The hot reaction mixture has to be chilled immediately after product formation or the nitric oxide will again decompose into the starting components. In the track of the fission fragments both steps, fast heating and fast quenching, are combined, a condition ideal for promoting endothermic chemical reactions where the subsequent thermal decomposition of the reaction product has to be hindered or at least minimised by an immediate cooling process.

As illustrated in Figure 1, a complete chemonuclear reactor should consist of a pile where the highly dispersed fuel is in intimate contact with a gaseous or liquid chemical reaction system. The latter would act as a coolant. For neutron economy reasons a moderator is also needed. But in addition to the reactor itself we also have to supply a decontamination plant serving both for the removal of the highly radioactive impurities and for the separation of the unreacted starting material from the reaction product. The unreacted starting material is then fed back to the reactor.

There are three problem areas involved in the design of such a reactor, namely the development of a new type of fuel, the decontamination of the chemical product for highly radioactive impurities, and the proper choice of a chemical system in which radiation leads to the desired end products.

Technical problem No. 1: the fuel

The fuel problem is perhaps on the way to being solved. A research group in the United States was successful in constructing extremely thin foils consisting of an alloy of 20% U^{235} and 80% palladium and having a thickness of less than 2.5 microns. The energy deposition efficiency of these foils, that is the fraction of fission fragment energy available (but not necessarily used) for chemical reactions, is 38%. It seems possible to achieve an efficiency of 50% by further decreasing the foil thickness. Static tests have shown that the foil can undergo a burn-up of 25% of the fissile atoms and still maintain its integrity.

How could these extremely thin foils be arranged in a reactor so that severe flow conditions will not cause any mechanical damage to them? It turns out that a honeycomb structure has the highest mechanical strength. Each cell should have a diameter between one and five millimetres. The honeycomb elements have been built and tested. They have been exposed to air flows of ten metres per second at 600°C and this for 1,000 hours. No mechanical damage was noted afterwards.

The fuel foils have to be coated with an additional layer of one to two microns of platinum. This layer protects the fuel from the corrosive action of chemicals. It is also intended to reduce the spallation effect.

What is the spallation effect? A fission fragment passing through the fuel has the capacity to eject surrounding matrix atoms from the fuel. These virgin, unfissioned uranium atoms would be carried away by our chemical reactants, thus reducing the overall efficiency of the uranium fuel and adding a further radioactive impurity to the chemical reaction product. This effect would be especially

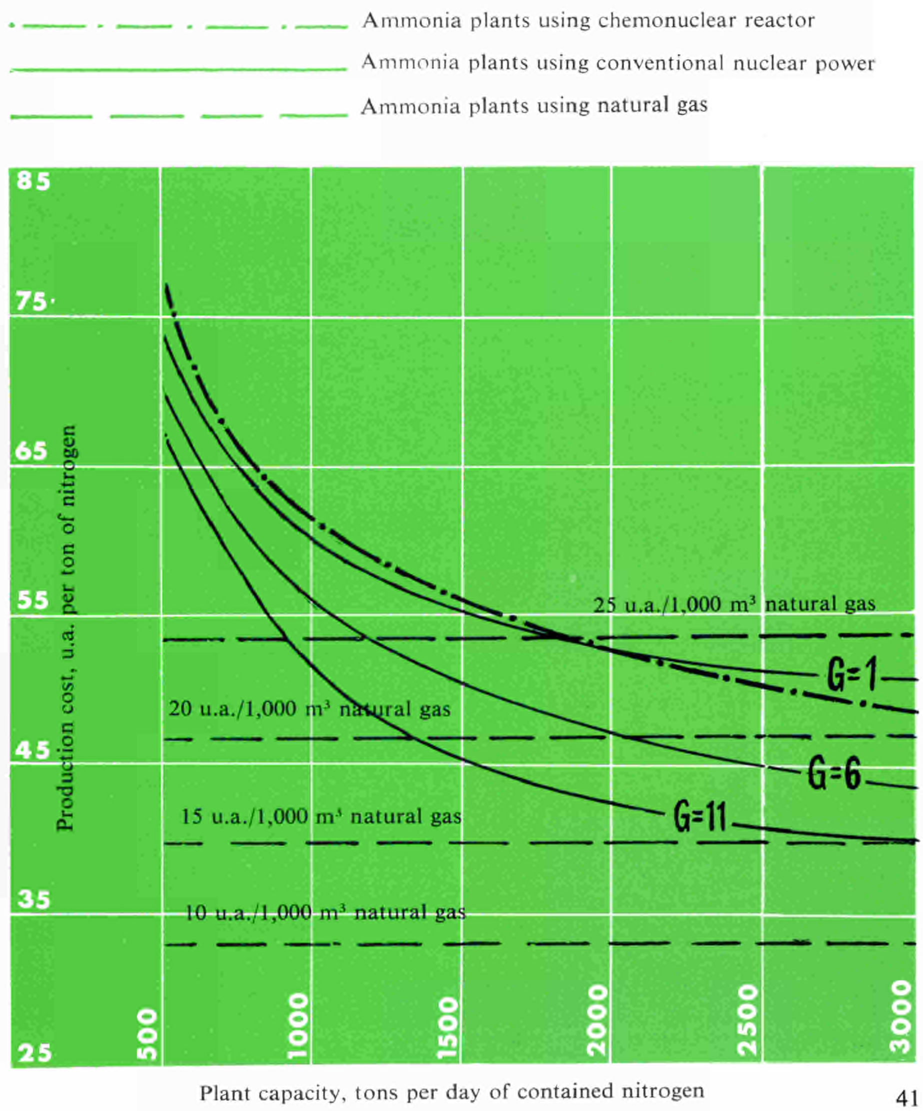
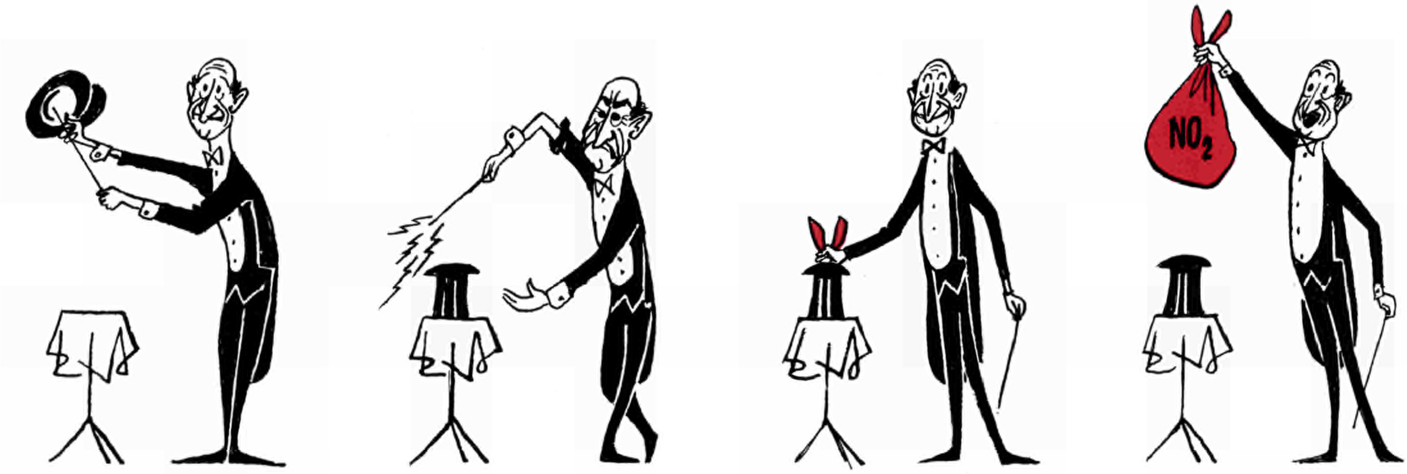


Figure 3: *Nitrogen production costs. (Present cost of natural gas to large industrial consumers in the Community is in the range 20-25 u.a./1,000 m³).*



severe for a thin foil fuel becoming mechanically disintegrated by the loss of matrix atoms. Earlier work has indicated that the number of escaping uranium atoms ejected per escaping fission fragment could amount to 1,000-3,000. This would create a rather hopeless situation for a chemonuclear reactor fuelled with thin foils. The fuel would be consumed at a 1,000 to 3,000 times higher rate than necessary. More recent fundamental research has shown, however, that there will only be approximately six uranium atoms lost per fission event and that this number might even be smaller, approaching two, when coated uranium metal alloys are used instead of uranium with its usual thin oxidised layer.

The honeycombs manufactured from thin foils appear to be the most advanced fuel type. Other research groups are still

Table I: *Annual market for various chemical products and their maximum and experimental G-values.*

Start	Product	Application	u.a./kg	USA market (10^6 kg/year)	EEC market (10^6 kg/year)	Maximum G-value	Highest experimental G-value obtained
CH_3OH (methanol)	$(CH_2OH)_2$ (glycol)	antifreeze	0.13	600		640	3
H_2O (water)	H_2O_2 (hydrogen peroxide)	oxidant	0.50	55			3.1
NH_3 (ammonia)	NH_2NH_2 (hydrazine)	rocket fuel, fuel for fuel cells	1.20	7		48.1	1.9
CO (carbon monoxide)	C_3O_2 (carbon suboxide)	organic acids	0.18	550			2.5
O_2 (oxygen)	O_3 (ozone)	oxidant	0.15	300		68.1	15
N_2+O_2 (air)	NO_2 (nitrogen dioxide)	fertiliser	0.03	10,000	5,000	284	1.2

considering glass fibres containing up to 27% of U^{235} as alternative fuel. It certainly would have the advantage of a higher corrosion stability. Glass fibres, nevertheless, tend to be brittle and to powder on flexing owing to their low bending strength. This could lead to severe nuclear hazards. These disadvantages of glass fibres, however, are not to be expected when fibres of zirconium dioxide or uranium dioxide or nickel uranium fibres are used. In these cases, nevertheless, corrosion problems might again arise.

A third alternative, a reactor core in which a dust or slurry of uranium oxide circulates, contains some serious handicaps. Difficult problems involving the separation of unburnt fuel from the chemical starting and end products will arise, and hot spots in the reactor due to agglomeration and caking of the fuel would most certainly lead to serious nuclear hazards.

Technical problem No. 2: decontamination

How serious are the problems connected with the contamination of chemical reactants due to radioactive fission products, uranium from the spallation effect, and to radioactivity produced by neutron activation?

If atmospheric gases are processed in a chemonuclear reactor, such as for the production of nitrogen oxides from air, Ar^{41} from neutron activation of Ar^{40} has to be expected. Experience with gas-cooled reactors and gaseous waste from nuclear fuel reprocessing plants indicate that this gaseous activity can effectively be controlled both by storage and controlled release to the atmosphere.

Volatile fission product activity is to be expected from radioactive iodine, bromine, xenon and krypton isotopes. The halogens could be removed by silver in a mesh form or in silver nitrate coated packings. The more prominent radioisotopes contributing to the longer-lived non-volatile fission product activity will be Pm^{147}, Sr^{90}, Cs^{137}, Ba^{140}, Zr^{95} and Ce^{144}. The worst offenders from the health standard point of view will be Sr^{90}, Zr^{95}, Nb^{95}, Ba^{140} and Ce^{144}. Storage of the reaction product, whether volatile or non-volatile, over a certain period will usually allow decay of most of the shorter-lived activity. Removal of the largest part of the longer-lived activity could be effected at higher temperatures and pressures by glass fibre asbestos filters.

Modern technology offers effective methods for *final* decontamination, owing to the advanced state of the art of fuel reprocessing. Centrifugal gas separators, high velocity cyclones, electrostatic precipitators, packed beds, liquid scrubbers, ultracentrifuges and absolute filters could be applied for achieving extremely high decontamination factors for the last traces of contamination from fission products, uranium or activated corrosion and erosion products from reactor material.

For the nitrogen fixation process neutron activation of nitrogen according to the N^{14} (n, p) C^{14}-reaction has to be expected. Preliminary calculations show, nevertheless, that the contamination due to C^{14} will not be significant. Only about 1 kilogramme of C^{14} as carbon dioxide will be formed per 100,000 tons of nitrogen dioxide product. This contributes little to the total activity and can either be removed as a carbonate or distilled with volatile fission products for release to the atmosphere.

The major problem: economics

Neither the fuel nor the contamination problems of a chemonuclear reactor seem to involve inherent technological barriers. Where are the real trouble spots? A fissiochemical process can only compete with a conventional process if the costs are lower or at least comparable. And this seems not to be the case, at least not at this moment. Not only is the decontamination of the chemical product obtained certain to become quite elaborate, and therefore expensive, but the radiation chemical yields observed up to now for fissiochemical syntheses are not yet sufficient to make these processes competitive with conventional processes. This is even the case for a dual purpose reactor, which produces both a chemical product and heat for the production of electricity.

For radiation processes it is important to know the amount of chemical conversion for a given dose of radiation, i.e. the radiation chemical yield. Accurate yield values for a given reaction can only be determined experimentally. The radiation chemist expresses the yield in terms of the G-value, that is the number of molecules formed per 100 eV of radiation energy absorbed in the system. If the product formation has a high G-value little radiation energy is necessary to form many molecules and vice versa. For endothermic reactions there exists a theoretical maximum G-value which can be calculated and which can never be exceeded. For all radiation reactions, the experimentally observed G-values differ from the theoretical values, and in many cases are considerably lower.

Design studies have shown that for low G-value endothermic reactions the radiation energy must come from a chemonuclear reactor, while other sources of radiation, such as radioactive isotope sources or machine irradiation, can be more economical for high G-value exothermic or chain reactions (see figure 2). For the production of one ton per day of a product with a molecular weight of 50, a 70 kilocurie Co^{60} or Cs^{137} source is sufficient if the product formation has a G-value of 10,000. For reactions having a G-value of 100, a source of more than 10,000 kilocurie would be required. For these cases it would be more economical to employ a neutron-gamma reactor. The energy deposition efficiency of this reactor type is rather low, as only 2.5% of the available neutron and gamma energy can be used for radiation chemical synthesis. To produce one ton per day of a product whose formation reaction has a G-value of 100, a 1 MW neutron-gamma reactor would be needed.

The really interesting products for industrial large scale productions are, nevertheless, formed in *endo*thermic reactions. The hitherto achieved G-values are rather low, normally between 50 and less than 1. These are experimentally observed G-values differing in most cases considerably from the calculated maximum G-values. If for a certain product a G-value of only 1 is required and if a 50% energy deposition efficiency could be achieved for the fissiochemical synthesis with honeycomb fuel elements, a 2 MW chemonuclear reactor would be necessary to produce 1 ton of a product per day having a molecular weight of 50. But with the same reactor 10 tons of product could be made if the G-value could be raised from 1 to 10.

Table II: *G-values and thermal efficiencies for possible chemonuclear processes.*

Reaction	Heat of reaction	G_{max}	G_{exp}	Thermal efficiency (%)	Radiation
$2CH_4 = C_2H_4 + 2H_2$	48.3 kcal	47.3	3	6.3	β
$2CH_4 = C_2H_2 + 3H_2$	90.0	25.6	0.5	2.0	β
$1/3C_6H_6 = C_2H_2$	49.0	47.0	0.42	0.9	β
$CO_2 + H_2O = CH_2O + O_2$	134.7	19.2	0.85	4.4	γ
$H_2O = H_2 + 1/2O_2$	68.3	338.8	1.75	0.5	fission fragment kinetic energy
$H_2O = H_2 + 1/2O_2$	57.9	39.9	6.0	15.0	α
$N_2 + 1/2O_2 = N_2O$	19.6	118	3.0	2.5	n, γ
$CO_2 = CO + 1/2O_2$	48.0	48.1	0.13	0.3	γ
			1.9	4.0	fission fragment kinetic energy

The thermal efficiencies (based on the ratio between the calculated G-value for an endothermic reaction and the hitherto experimental G-value) are in some cases only available for α, β or γ radiation. In view of linear energy effects, it is likely that the values for fission fragment irradiation will be somewhat different.

A chemonuclear reactor appears to be the only economical radiation source that can induce low G-value endothermic reactions. But it is also apparent that the experimental G-values hitherto achieved are too low for chemonuclear technology to compete economically with conventional processes.

Table I lists some systems which have attracted the greatest interest for fissiochemical synthesis. For the choice of these systems two points have been considered: the present annual production rate, i.e. an indication of the importance of the end product, and the cost of the present conventional production. The higher the cost the higher also would be the probability for a breakthrough in fissiochemical synthesis, the economics of which are fairly standard for the different reaction systems (see figure 3).

For all these reactions there is a large discrepancy between the highest experimental G-values hitherto obtained and the maximum G-values calculated from thermochemical data.

They all have a certain economic potential. It can be expected that the market for all these compounds would increase considerably once a cheaper method of production were found.

Undoubtedly, the greatest challenge is the fissiochemical synthesis of nitrogen dioxide from nitrogen and oxygen (i.e. air), a reaction which could form a basis for the production of fertilisers. In the United States alone 10 million tons of fertilisers are at present being produced annually and the production is growing at a rate of over 10% a year. Furthermore, a strongly increased production of cheap fertilisers along with seawater desalination could contribute to eliminating starvation in developing countries.

Several research groups in the United States have been working extensively on the fissiochemistry of fixing nitrogen to oxygen. Some of the experimental results are quite encouraging; in capsule experiments over 90% of the oxygen could be converted to oxides of nitrogen. These experiments, however, yielded G-values of only one percent of the maximum. Experiments are still in progress at the *Brookhaven National Laboratory*, and in the near future will be extended to include in-pile loop studies. Still more information is needed about parameters of the reaction influencing the radiation yields. Pressure, temperature, gas composition, dose rate, total dose, gas velocity, rare gas sensitation and catalytic effects have to be known in more detail. The loop will also be applied to the development of new fuel elements; honeycomb type fuels composed of uranium, aluminium or other less expensive metals will be studied; the efficiency of neutron, gamma and fission fragment energy deposition will for each case be determined; and the radiational, mechanical, chemical and thermal stabilities of these elements under reactor conditions will be tested. Also the decontamination efficiency of various activity removing devices will be determined; the loop itself contains a silver reactor, for the removal of halogens, and ceramic asbestos filters. It can also be used for studying gas phase reactions other than that between nitrogen and oxygen.

Other reactions of high industrial potential which are attractive for fissiochemical synthesis are listed in Table II.

There is a large amount of natural gas available, consisting mostly of methane, which is presently being wasted to a large extent for energy production. More valuable ethylene or acetylene could be produced from methane. From virtually worthless carbon dioxide valuable formaldehyd could be synthesised. This fissiochemical process would be identical to the assimilation of carbon dioxide by plants. Hydrogen is a most important raw material for the chemical industry. Nitrogen suboxide represents another basis for the production of fertilisers.

Carbon monoxide from carbon dioxide could be a starting component of a broad spectrum of organic syntheses. It could be converted into formaldehyd, formic acid, carbonyl compounds, methanol, acrolein, acrylic acid and other chemicals of great industrial potential.

Future outlook

From conceptual design studies and preliminary cost estimates it is apparent that the time is not yet ripe for considering any direct action aimed at the development and construction of a fissiochemical reactor. There certainly does not seem to be any inherent technological barriers involved prohibiting a chemonuclear reactor. But the decontamination problems encountered with fissiochemical syntheses leave many questions about practicability open. The radiation chemical yields obtained up to now are not at all satisfactory when the fissiochemical process is compared with chemical production by conventional methods.

This situation might however change drastically if it becomes possible to raise the experimental G-values of some reactions of large industrial potential by a significant factor. The nitrogen fixation process might be reconsidered if a radiation induced process yields a G-value ten times higher than hitherto observed. What is needed is a better understanding of the mechanism and much more knowledge about fission fragment induced radiation chemistry before the concept of a chemonuclear reactor can be dismissed as impractical. EREA-A 8-6

Bibliography: (1) P. HARTECK and S. DONDES: *Nucleonics* 14 (1956), 32; (2) P. HARTECK and S. DONDES: *Nucleonics* 15 (1957), 94; (3) P. HARTECK: *Zeitschrift für Elektrochemie* 64 (1960), 983; (4) H. KRAUCH, W. BAUR, K. JECHT and W. KUNZ: *Kerntechnik* 3 (1961), 522; (5) M. STEINBERG: *Electrochemical Technology* 3 (1965), 283; (6) M. STEINBERG: *Brookhaven National Laboratory Report* 100 (1966), 20; (7) M. BELLER, L. G. EPEL and M. STEINBERG: *Chemical Engineering Progress Symposium Series* 71 (1967), 31.

Levitation melting

A preparation technique for reference samples

A technique for the levitation and heating of materials, initially developed for the production of standards, promises to find applications in industry.

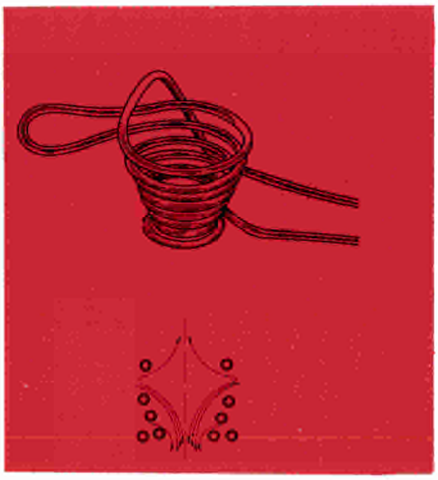
JAN VAN AUDENHOVE

EVER SINCE ITS foundation in 1960 the *Central Bureau for Nuclear Measurements (CBNM)* has had to prepare samples in order to be able to perform its primary task, namely the production of standards and the carrying out of nuclear measurements.

At first, the *CBNM* had only to meet its own requirements so far as samples were concerned, but the number of requests from research workers throughout the Community soon became such that in 1960 it was decided to set up within the *CBNM* a specialised laboratory for the sole purpose of preparing, defining and distributing samples for nuclear measurements.

JAN VAN AUDENHOVE is on the staff of the *Central Bureau for Nuclear Measurements*, Geel, Belgium.

Figure 1: *Principle of high-frequency levitation.*



Besides the preparation and definition of samples by known methods it was often necessary to improve existing techniques and even to develop new ones, some of which seem likely to find—notably in industry—considerably wider fields of application than those for which they were originally designed.

A striking example of this is the evaporation technique described below, which was developed in order to obtain extremely pure coatings of uranium, thorium and aluminium. Mention may also be made of the methods employed for the manufacture of alloys with the high precision that is indispensable in the nuclear field when these alloys are required to serve as reference samples.

Evaporation of metals and semiconductors by induction heating under ultra-high vacuum

Resistance heating and electron-beam heating are the techniques generally employed for the evaporation of metals and the production of super-pure coatings by vacuum deposition. These methods, however, have certain drawbacks if the metal to be evaporated has a high melting point or if it is very reactive at the evaporation temperature.

In the case of resistance heating, a reaction between the molten pool and the filament will result in the presence of impurities in the deposited coating.

If evaporation is effected by electron bombardment there is a danger that the deposited coating will become contaminated owing to overheating of the electron-gun components, interaction between the melt and its substrate or evaporation of certain portions of the vacuum vessel under the action of non-focused electrons.

Induction heating, on the other hand, enables these risks to be eliminated; the magnetic field that is set up can be used to obtain the levitation of the material to be evaporated, and hence it is possible to melt the metal without any physical contact.

Levitation

The principle of levitation can be summarised as follows: the eddy currents produced in a piece of metal placed in an induction coil set up a magnetic field. As a result of the interaction between this field and the high-frequency field of the induction coil, the metal begins to "float".

If the top turn of the induction coil is wound in the opposite direction to the rest, there is set up inside this coil a magnetic field with a zone of lesser intensity at its centre; it is in this portion of the internal space that the piece of metal tends to become centred.

Figure 1 illustrates the principle of this high-frequency levitation process, while figure 5 shows a drop of molten metal in an induction coil.

Evaporation

The evaporation experiments were carried out in an ultra-high vacuum ves-

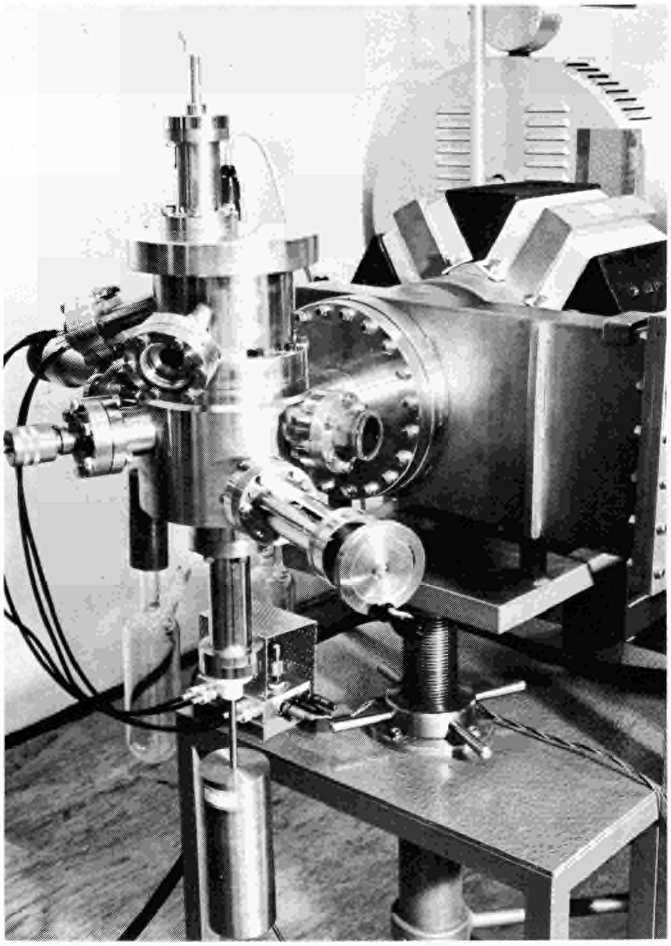


Figure 2: *Photograph of the ultra-high vacuum levitation evaporator constructed by the* CBNM.

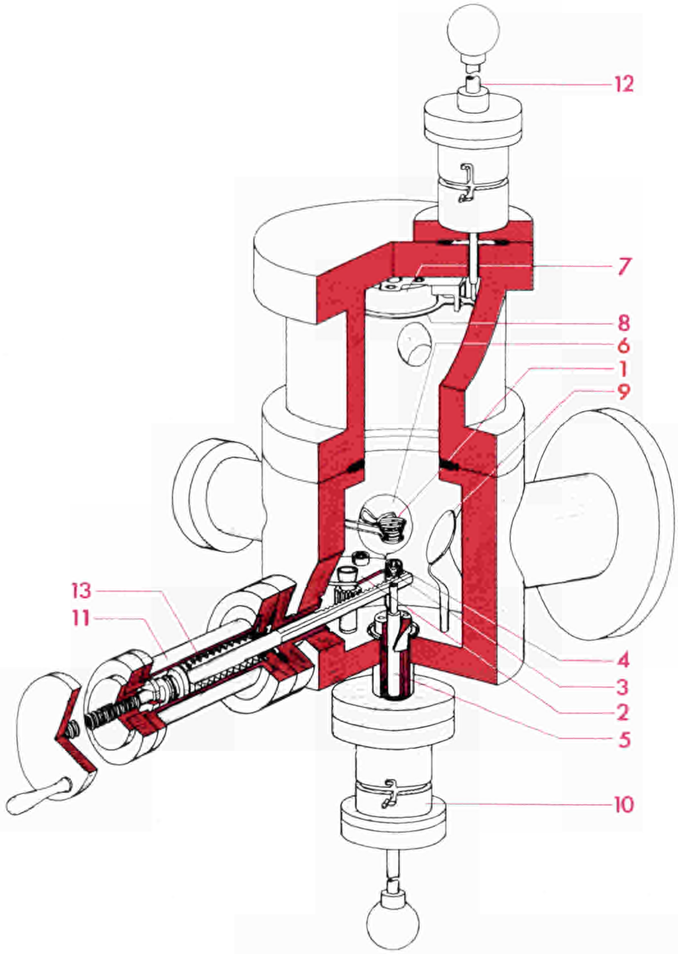


Figure 3: *Exploded view of the ultra-high vacuum levitation evaporator, showing the following components: the water-cooled induction coil (1); the externally actuated turntable (2), which enables various pieces of metal or various crucibles to be inserted along the axis of the coil; the quartz supports (3), with their charge of metal to be evaporated (4) and the manipulating rod (5) for introducing the piece of metal to be evaporated into the coil. When the evaporation is stopped, a refractory crucible is inserted under the top turn of the coil by means of the turntable to catch the molten drop that remains. At the same time the manipulating rod (5) rotates the visors which normally protect the sight-holes (6), so that the latter are uncovered and the operator can observe the inside of the vessel when the metal is introduced. Also shown in the figure are the bakeable substrate mounting (7) and its cover (8).*
The vacuum chamber is of stainless steel and all the removable flanges are rendered leaktight by copper seals. The mechanisms (10), (11), (12) of the manipulating rod, turntable and substrate cover are rendered leaktight by stainless-steel bellows (13). After degassing for five hours at 200°C, a final pressure of less than 3 . 10^{-9} torr is obtained.

sel. Owing to the ultra-high vacuum there is a minimum amount of contamination by the residual gas, so that very pure coatings can be obtained. Figures 2 and 3 show the equipment used at the *CBNM* for the preparation of samples.

With this apparatus quantities of between 100 mg and 2 g of aluminium, silver, titanium, copper, cobalt, germanium, uranium or thorium can be levitated in the solid state and then melted to form a stable liquid drop during evaporation.

The purest metals commercially available were used as the evaporating sources. Coatings were produced under a vacuum of 10^{-8}-10^{-9} torr without any detectable sputtering—a phenomenon which is difficult to avoid when other methods, such as electron bombardment, are employed.

During evaporation a considerable quantity of metal condenses on the induction coil, and this metal can give rise to short-circuits between the turns when it becomes detached from them locally. Nevertheless, with a coil as illustrated here and with a distance of 10 cm between the substrate and the source, coatings of, for example, uranium with a thickness of more than 550 $\mu g/cm^2$ were prepared in a single operation without any danger of short-circuiting.

Table I gives the results of levitation evaporations carried out with several metals; experiments with other metals are in hand. For example, the levitation evaporation of 100 mg—1.5 g quantities of germanium preheated to 700°C was successfully carried out at the request of a vacuum equipment manufacturer who was subsequently granted a licence on the process by the Commission.

The evaporation rate is not constant, since the volume of the source decreases progressively as it evaporates. The experiments performed, however, revealed that by maintaining the same conditions

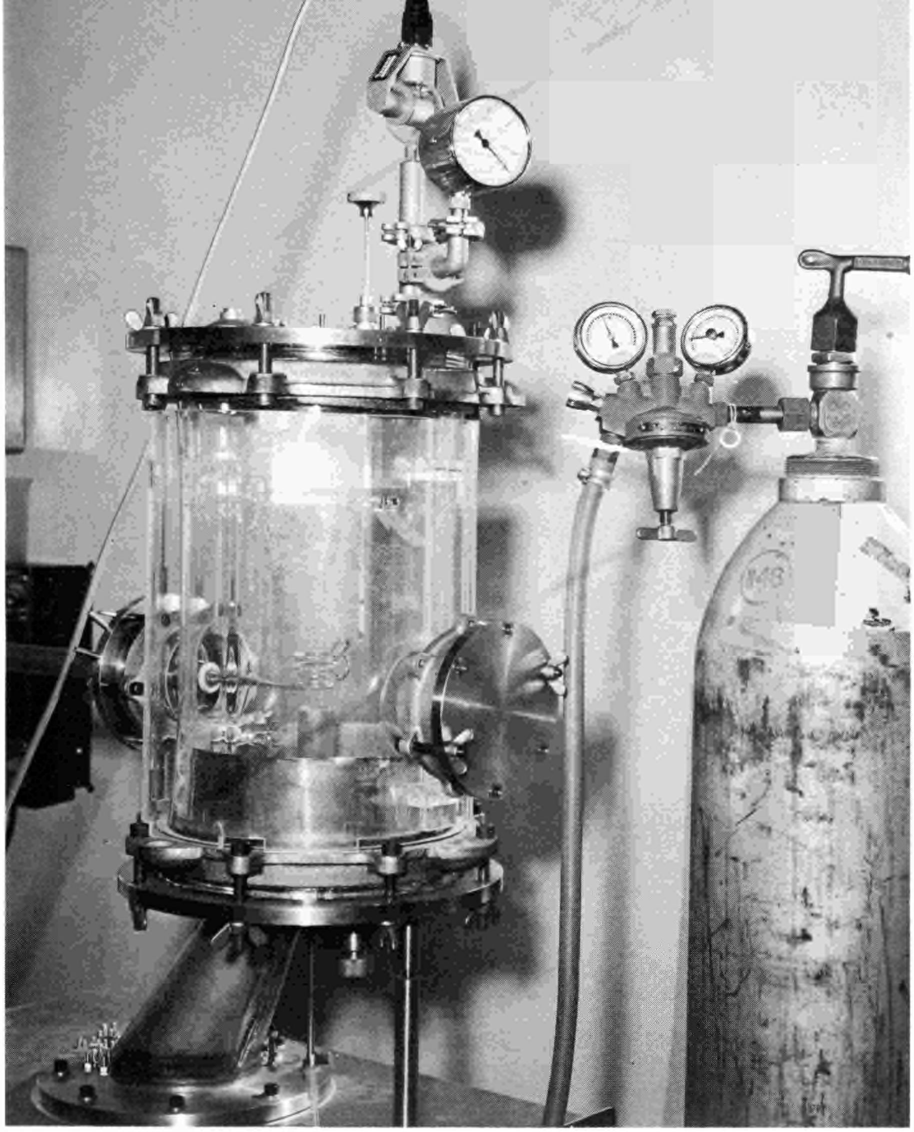
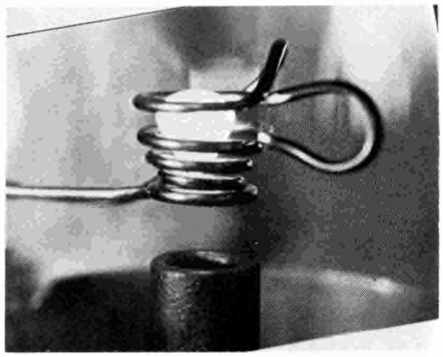


Figure 4: *Levitation-melting apparatus for the production of alloys.*

Figure 5: *Levitation of a drop of molten metal.*



(pressure, initial mass of source, evaporation time, HF power input) it is possible to obtain coatings of identical thickness.

In the course of a series of experiments aimed at producing coatings in the 15-30 $\mu g/cm^2$ range, it was possible, for example, to achieve the same thicknesses with a reproducibility of $\pm$ 1% merely by varying the evaporation time, the other factors being maintained constant.

It can therefore be seen that this type of evaporation device, in which induction heating is used, offers attractive prospects in all sectors where purity and reproducibility are of paramount importance, such as the semiconductor industry.

Quantitative alloying

The same principle of melting by levitation can form the basis for an entirely different application, namely the preparation of small quantities of alloys having a well-defined composition as well as high purity and very good homogeneity. This application was developed by the *CBNM*, in response to numerous requests from inside and outside the Community, in order to be able to supply aluminium alloys of very specific composition for use in reactors, e.g. for accurate neutron-flux measurements. These "activation detectors" take the form of small discs or rods weighing 20 mg or sometimes even less.

In most cases the user wants to know, to within 1-0.3% (relative), the quantity of addition element present in the detector or reference alloy.

Conventional methods for the preparation of alloys, such as melting by induction heating in a refractory crucible, arc melting or electron-beam melting, frequently suffer from disadvantages, e.g. contamination by the crucible material, difficulty of casting small quantities, poor homogeneity, etc. These drawbacks can, however, be avoided by employing the technique of induction heating and levitation in an inert-gas atmosphere.

The purest metals commercially available are taken in quantities of 10-25 g and melted together in an apparatus similar to that described above, the inert gas being maintained at a pressure of between 0.5 and 1 atmosphere, depending on the vapour pressure of the metals being melted (Figure 4).

A special feature of the levitation process is the intensive puddling to which the drop of molten metal is subjected, mainly under the action of the magnetic field. On completion of the operation the molten metal is poured into a cold mould so as to ensure rapid solidification. The vigorous puddling and quick solidification guarantee good homogeneity of the alloy.

About 30 aluminium-base alloys have already been made to order at the *CBNM* and are regularly available. Thanks to the assistance of the Bureau's department of chemistry and metrology and various other institutes, it was possible to show that the losses that occur during the preparation of these alloys are so small and the homogeneity such that the composition of 20 mg quantities of alloy does not differ by more than 0.3-1% (relative) from that which can be calculated by simply weighing the components before alloying them. Metallographs of the alloys Al-24%U, Al-10%Th and Al-1%B, showing the homogeneity and fineness of structure, are reproduced in figures 6, 7 and 8.

Between 1963 and 1968 the *CBNM* supplied more than 10,000 samples of certificated alloys produced by levitation. Over 200 requests from eight countries were complied with in this way.

Levitation melting can also be used for the quantitative preparation and liquid-phase formulation of high-purity intermetallic compounds. It has been possible, for example, to make such compounds as $AuAl_2$, $TiAl_3$, $ZrAl_3$ and UAl_2 in rod form, a geometry which is particularly suitable for determining the physical constants of intermetallic compounds.

One of the studies currently in progress consists in the preparation of alloys with a very low content of one or more elements. By means of isotopic dilution analyses carried out by our mass spectrometry and chemistry departments, it has already been demonstrated that the preparation of Al-20 ppm Eu and Al-2 ppm Eu by dilution of Al-1% Eu (likewise obtained by levitation) gives results with an accuracy within 2% in respect of both quantitativity and reproducibility.

The reason why the *CBNM* has so far concentrated on the preparation of aluminium alloys is merely that the requirements stated by its clients have centred predominantly on this metal. More highly-diversified working methods are, however, in the course of development, and all the indications are that the quantitative alloying of practically all metals and semiconductors is possible by means of the levitation process.

Obviously, therefore, there is a prospect of wide-scale application of the process in non-nuclear sectors, e.g. in the preparation of the reference standards required in analytical chemistry or mass spectrometry. EREA-A 8-7

Bibliography: (1) J. VAN AUDENHOVE: Vacuum evaporation of metals by high frequency levitation heating. *Rev. Scient. Instr.* Vol. 36 (1965), n° 3, pp. 383-385. (2) J. VAN AUDENHOVE, J. JOYEUX, M. PARENGH: Evaporation des métaux et des semi-conducteurs par chauffage inductif sous ultra-vide. *International Colloquium on the applications of vacuum science and techniques to coatings and surface finishes* (October 1968). (3) J. VAN AUDENHOVE, J. JOYEUX: The preparation by levitation melting in argon of homogeneous aluminium alloys for neutron measurements. *Journal of Nuclear Materials* 19 (1966) pp. 97-102.

Table I: *Some typical results of levitation evaporation.*

Metal	Initial mass of source (mg)	Average evaporation rate (mg/sec)	Evaporation time (sec)	Mass per cm² at a distance of 10 cm (μg/cm²)
Al	370	0.31	1,080	266
Ag	681	6.35	103	520
Co	361	3.14	35	12
Cu	828	3	240	573
Th	680	0.065	1,800	93
U	881	4.12	133	436

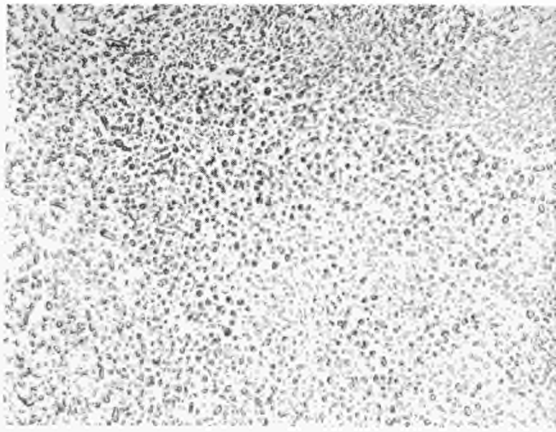


Figure 6: *Al-24%U alloy heat-treated at 600°C for 14 hours, showing globulised UAl_4 crystals in an α-Al matrix (electropolished; × 500).*

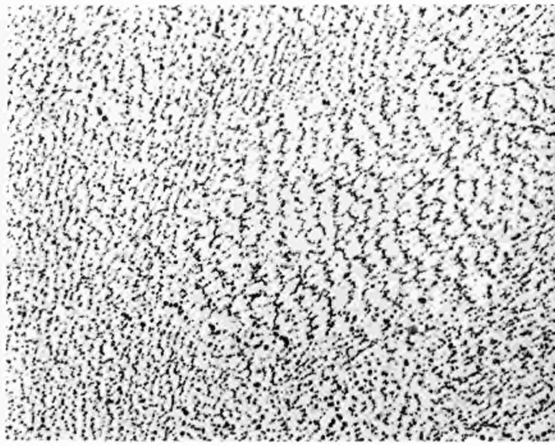


Figure 7: *Al-10%Th alloy heat-treated at 600°C for 14 hours, showing globulised $ThAl_3$ crystals in an α-Al matrix (electropolished; × 240).*

Figure 8: *Structure of a cast Al-1%B alloy, showing aluminium-boride needles in an α-Al matrix (electropolished; × 200).*

Heat transfer in tightly-packed fuel rod bundles with liquid metal cooling

A case is made out for solving this heat transfer problem through a basic approach.

REINIER NIJSING and WALTER EIFLER

The design of nuclear power systems for space and of pulsed neutron sources has recently stimulated interest in tightly-packed fuel rod elements cooled by liquid metal. Examples are the *SNAP* space power programmes in the United States and the *SORA* pulsed neutron reactor proposed by Euratom. Nuclear and thermal factors also favour close rod spacing in the blanket regions of fast breeder power reactors.

REINIER NIJSING and WALTER EIFLER are members of the Heat Exchange Section of the Ispra Establishment of the European Communities' *Joint Research Centre.*

A particular problem to be solved when designing these compact fuel rod assemblies stems from the variations in temperature within both cladding and fuel of each individual rod; clearly, cooling will be less efficient in the region where a rod is in contact or in near-contact with another. In view of the thermal stresses involved, it may therefore be necessary to limit the fuel element power. This problem becomes acute as the pitch to diameter ratio (the ratio of rod centre distance to rod diameter) of the assembly decreases to values near unity (i.e. the limiting case of rod contact).

One approach to the problem is to carry out experiments on an electrically heated tube bundle simulating the fuel element. An alternative method consists in providing a theoretical analysis of the heat transfer situation. In view of the interactions that occur between conduction in the rod materials (fuel, cladding and bond) and heat transport in the coolant, this is by no means a simple way of tackling the problem, but without a theoretical interpretation and a mathematical formulation of these phenomena it is impossible to give accurate predictions of the temperature distribution within the rod bundle under different conditions. The advantage of this basic approach, which was adopted in Ispra, is that it provides a deeper understanding of the phenomena; the knowledge acquired can thus be applied subsequently to a wide variety of individual cases.

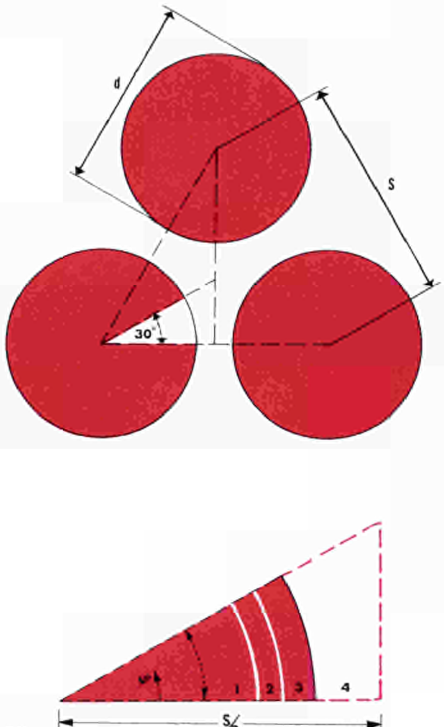


Figure 1: *Cross-section of part of a typical tightly-packed fuel rod bundle. In analysing the heat transfer situation account has to be taken of symmetry factors. It is clear that it is sufficient to consider the area shown in colour, which is situated within an angular interval of 30°. As is shown in the enlargement of this area, consideration is given to a fuel (1), bond (2), cladding (3) and coolant region (4).*

Liquid metal cooled fuel elements generally contain a relatively large number of smooth rods positioned in a triangular array. A characteristic part of the cross-section of such a fuel element is shown for illustration in Figure 1. At sufficiently large axial distances downstream from the fuel element inlet or from grids supporting the fuel rods, coolant velocity profiles and rod bundle temperature profiles are fully developed. Such conditions are considered here. Since liquid metals are characterised by a very high thermal conductivity, heat transport in the coolant through turbulence will, in most cases of practical interest, be of negligible importance in comparison with heat conduction. This fact considerably simplifies the mathematical analysis. To calculate the detailed temperature distribution in a rod bundle section one therefore need specify, apart from rod bundle dimensions and thermal conductivity values, only an analytical expression for the distribution of the axial coolant velocity. On the latter much information has been acquired through theoretical work and experimental studies.

For illustration numerical results are presented in Figures 2 and 3. In Figure 2 the difference between outer cladding temperature and bulk average coolant temperature is given as a function of angular position φ for the case of an uranium carbide fuel rod clad in stainless steel and cooled by sodium. As is to be expected, cladding temperatures assume maximum values at $\varphi = 0$, corresponding to the position of closest rod distance.

After irradiation radial cracks may arise in the carbide fuel, which reduce the ability to conduct heat circumferentially in the extreme case to zero. Fuel swelling may further lead to disappearance of the bond, whose contribution to peripheral heat conduction is thus eliminated. The curves of Figure 2 show that these effects do significantly increase the circumferential cladding temperature variation. It is shown that the thermal conductivity of the bond and cladding materials may have a significant effect on the amplitude of these variations. Similar results are shown in Figure 3 for the *SNAP 8* fuel rod assembly. It appears that the amplitude of the circumferential cladding temperature variation decreases by a factor of almost 2 when the rod spacing is increased only from $\frac{s}{d} = 1$ to $\frac{s}{d} = 1.025$.

It was mentioned earlier that an alternative method would consist in attempting to simulate the thermal characteristics of a fuel rod bundle in an out-of-pile liquid metal heat transfer experimental rig; however, it is practically impossible to achieve complete simulation by this means. Furthermore this method is expensive and requires a very specific know-how in test section technology and heat transfer instrumentation.

The basic approach adopted in Ispra does not suffer from these drawbacks. It involves a programme of simple hydrodynamic experiments with water under ambient conditions, aimed at determining the coolant velocity distribution. This information, together with data on the measured thermal conductivity of the rod materials, is used as input information for the heat transfer analysis.

EREA 8-8

Figure 2: *Circumferential variation of the outer cladding temperature for carbide fuel and a pitch to diameter ratio (see figure 1)* $\frac{s}{d} = 1.05$.

The difference (Δt) *between the outer cladding temperature and bulk average coolant temperature is given as a function of angular position* φ *(see figure 1). The results pertain to a linear fuel rod power of 400 W/cm. The cladding is stainless steel, outer diameter 12.8 mm, thickness 0.4 mm. The bond is sodium, thickness 0.2 mm. Thermal conductivities in W/m °C are, for the fuel 22, for the bond 60, for the cladding 23 and for the coolant 67.*

The full white line *represents the normal case, the* black line *the case where the ability of the fuel to conduct heat circumferentially is nil and the* black dotted line *the case where, in addition, the bond has disappeared.*

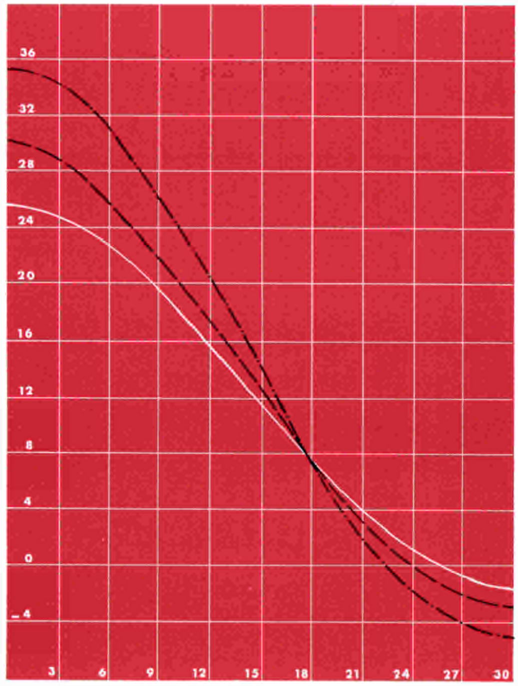
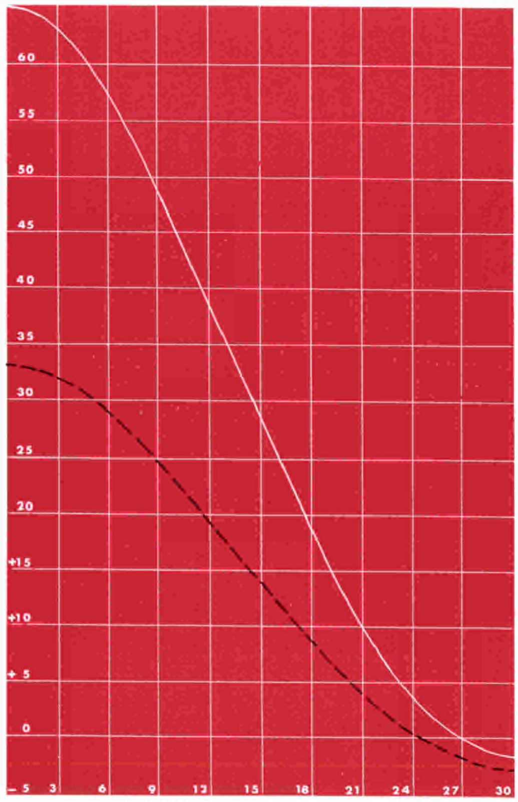


Figure 3: *Circumferential variation of the outer cladding temperature for the* SNAP 8 *fuel rod array. The results pertain to a linear fuel rod power of 120 W/cm. The difference* (Δt) *between outer cladding temperature and bulk average coolant temperature is given as a function of angular position* φ.

White line: *pitch to diameter ratio* $\frac{s}{d} = 1$.

Black line: *pitch to diameter ratio* $\frac{s}{d} = 1.025$.



Bibliography: (1) R. NIJSING and W. EIFLER: Analysis of liquid metal heat transfer in assemblies of closely spaced rods (a theoretical evaluation of two-dimensional temperature and heat flux distribution for conditions of turbulent axial flow at relatively low Peclet numbers). *Nucl. Eng. & Design* (in press). (2) W. EIFLER and R. NIJSING: Experimental investigation of velocity distribution and flow resistance in a triangular array of rods. *Nucl. Eng. & Design* 5 (1967), 22.

Are there national research habits?

According to a recent sociological investigation carried out at the Ispra Research Establishment, the answer is both yes and no.

MICHEL GIBB

THE IDEAS which people have about national characteristics are often amazingly clear-cut. It is, however, probably true to say that, in this as in other matters, the degree of certainty is inversely proportional to actual experience.

By dint of meeting modest Frenchmen, cool-headed Italians, generous Scotsmen and Dutchmen, one's set ideas take a serious knock on the head and there is no alternative but to adopt a more rigorous approach.

This is no doubt what makes the popularity of the numerous comparative surveys which are conducted today on anything from national eating habits, drinking habits and driving habits to national attitudes on politics and religion. If these surveys contribute to a better understanding of one's fellow-citizens of the world, and there is every reason to believe that they do, their proliferation must be welcomed.

An investigation which partly comes under this category was carried out recently by Mr. Michael Useem, of the Department for Social Relations, Harvard University; his aim was, broadly speaking, to explore possible national variations in the approach of scientists and engineers to their job. For this purpose he spent two months at the *European Communities' Ispra Research Establishment* in Italy, which is convenient inasmuch as it employs engineers and scientists from the six Common Market countries.

Michel Gibb is Editor of *euro-spectra*.

Mr. Useem first established contact through informal chats. This helped him to focus his subsequent more formal investigation on features of particular interest, for instance those likely to exhibit the largest national variation. Here are some examples of the kind of comment which was picked up at that stage:

"The Italians are not so interested in publishing because of the nature of their thesis. On the other hand, there is a heavy emphasis on publishing in Germany and Belgium" (Belgium respondent).

"The Germans are very good experimentalists, but they are focused in their interests. They will not go over to something intrinsically more interesting as it crops up. They want to solve narrow problems, which is very good for fundamental research, but not for the research here, where we are looking for applications" (Italian respondent).

"The training of the French is directed toward industrial application, owing to the character of the country" (German respondent).

Some of the observations collected in the course of these preliminary discussions found support in the later formal interviews and questionnaire data, though others were not corroborated. Occasionally observations gathered in one discussion would even be in direct opposition to information obtained in another, and these contradictions reinforced the decision to collect the primary data through systematic questionnaire techniques.

A problem plaguing studies of this nature is, of course, whether the individuals participating in the research are truly representative. The problem was made even more acute in this particular case in view of the relatively small number of questionnaires which were returned (73 in fact) and of the need for splitting up the

Table I: *Sense of educational preparation for the first post-degree research position, on three aspects of training, for three national groups*[1].

Question 1: "Do you feel that your education as a whole was an adequate preparation for the research aspects of your first research position after completion of your education?"
Question 2: "Do you feel that your training in mathematics and theory was adequate?"
Question 3: "Do you feel that your training in methods and techniques was adequate?"

Aspects of training	National average		
	D	F	I
General education	1.5	2.2	2.1
Preparation in maths. and theory	2.3	2.1	2.1
Preparation in research methods and techniques	1.7	2.3	2.9

1. A five point scale ranging from "very adequate" (scored as 1) to "passable" (= 3) to "very inadequate" (= 5) is associated with each question.

replies even further according to nationality. For this reason the interpretation of the results was restricted to the three major national groups (German, French and Italian).

The individual's background

Part of the questionnaire items had to do with what one might call the respondents' background. They were asked, for instance, whether they felt the teaching they had received, in mathematics and theory, as well as in research procedures and techniques, had adequately prepared them for their profession. An analysis of the replies (see Table I) shows that the Germans have a somewhat greater confidence in their general education. It would be worth going more deeply into this, but it appears that the relative quality of professional education in Italy, France and Germany is a problem which has hitherto received little systematic study.

There is an interesting discrepancy between the national assessments of the preparation in mathematics and theory versus the training in research methods and techniques. All three groups profess that their foundation in theory is fairly solid, but the Germans seem especially confident in their methodological preparation, whereas the Italians are comparatively weaker, with the French holding an intermediate position. The explanation is again elusive, although the interviews did provide a few insights concerning the German-Italian divergence.

The normal Italian terminal degree is obtained on completion of about five to seven years of academic work, the last half-year being normally reserved for work on a thesis. The time devoted to the thesis is therefore fairly short, and is often spent mainly on a review of the literature and not on an exercise in active scientific research.

In Germany, on the other hand, a "Diplom-Ingenieur" degree, for instance, requires approximately five years for completion, the final year of which is spent compiling a research thesis; moreover, this may have followed some practical experience in an industrial laboratory as part of the programme. If one stays on to obtain a doctorate, several more years may be spent on performing an experiment or carrying out theoretical calculations.

It is easier to bring out the contrast between the Italians and the Germans than to document the reasons for the middle position of the French.

The French system has been described in a recent *OECD* report as having a dual structure: potential scientists and engineers may progress through either a university or an engineering school, a "Grande Ecole".

At the "Grandes Ecoles", in the words of the report, "a very theoretically-oriented curriculum, few full-time research professors, and inadequate research equipment have contributed, over a long period, to the fact that a relatively small place is accorded to research in the education . . . It is only in the past few years that research has come to be considered as an attractive career for the graduate of a "Grande Ecole".

Conversely, the French university system introduced in 1954 a doctorate which has become the "principal means of training for fundamental research".

The French respondents in Mr. Useem's study derive from both engineering schools and universities and this may explain why the overall group sense of adequacy of research preparation is intermediate between that of the Germans and the Italians.

One of the questions, still under the heading of general background, which

Table II: *The nature of research (applied v. basic) actually being done, and preferred, for the aggregate and three national groups*[2].

"A research topic may vary from highly applied (technological applications) to very basic (advance of the field of knowledge)."

Question 1: "What is the nature of most of the work you do?"
Question 2: "If you were free to choose your research topics, what type of work would you prefer?"

	Aggregate	National average		
		D	F	I
Actual research	2.7	3.1	1.8	2.8
Preferred research	3.2	3.6	3.0	2.9

2. A five point scale ranging from "completely applied" (scored as 1) to "both basic and applied" (= 3) to "completely basic" (= 5) is associated with each question.

was put to the Ispra scientists and engineers concerned the extent to which the research on which they were actually engaged was applied or basic. They were at the same time asked what their personal preferences were in this respect (see Table II).

From the replies it is clear that the Italians and Germans are significantly less involved in applied research than the French. However, whereas the Italian are relatively satisfied with their current work, both the Germans and the French hanker for more fundamental research.

These results, especially those obtained from the French respondents, are puzzling at first, but an attempt can be made to explain them.

For example, according to an *OECD* report on the organisation of scientific research in Germany, "about two-thirds of all research in the Federal Republic is done in university institutes, and these are above all concerned with fundamental research. In the field of science and technology, however, members of university staffs are often urged to undertake research by outside sponsors, especially in industry".

The situation is somewhat different in France. The "Grandes Ecoles" have traditionally had a higher scientific and academic status than the universities; at the same time they and other engineering schools are the standard avenue to industrial research, whereas the universities are the channel to teaching and fundamental research. The interaction of these two factors has resulted in the net flow of potential scientists with interests in fundamental research into the higher status engineering career with its emphasis on applied investigations.

An important part of Mr. Useem's investigation dealt with some of the major norms which control the conduct of scientific enquiry. He picked out two for special study, "organised scepticism", i.e. the obligation to evaluate critically the work of one's professional colleagues and to make this criticism known publicly, and "communality", i.e. the requirement that new information and knowledge be entered into the scientific public domain.

"Organised scepticism"

Before he can conform to the general norm termed "organised scepticism", the individual scientist must be well aware of the latest major developments in his special field. It was found that, compared with the French and the Italians, the Germans profess to devote more time to reading and to critical evaluation of the literature in their field. Besides, the criteria which they claim to use for this purpose are slightly more scientific in the strictest sense.

On the other hand the French, Italian

and German researchers use the various channels for incoming information (professional journals, colleagues, professional meetings, visitors, reports) with comparable frequency, and all three groups seem equally committed to ensuring that their scientific work is screened before it is published. Similarly, most of the engineers and scientists of all three nationalities display little inhibition in expressing their critical opinions concerning the work of other members of their scientific community.

Thus, the main finding under this heading of "organised scepticism" is that the Germans tend to be more information-conscious. This does not, of course, come as a great surprise, in view of the traditional German interest in documentation. It is however worth suggesting that there may be a link between a scientist's attitudes to information and the type of research (applied or basic) on which he is engaged or on which he would prefer to be engaged. It can be argued that basic research involves a more widespread scientific community and requires a more intense knowledge of the published literature than applied research. If this is true, the Germans' greater information-consciousness tallies with and may be partially explained by their greater inclination toward basic research.

"Communality"

Organised scepticism is a responsibility imposed upon all members of a scientific community to review constantly the product of the other members of that community. The complementary requirement is self-evident: the researcher must make his findings public, thus enabling other scientists and engineers to scrutinise the new knowledge and even to fashion their own research around it. This second normative requirement is sometimes termed "communality".

The member of the scientific community is, of course, faced with many alternatives in the process of disseminating the results of his work. What particular channel should be used for communicating them: the specialised journal, the professional meeting, informal discussions, etc? If he chooses to publish them in a journal, what are the criteria which he applies in its selection: is it the readership of the journal which counts, its reputation, etc. . .? It was therefore worth investigating whether national patterns of behaviour could be recognised.

In truth this part of Mr. Useem's study has not produced many clear-cut conclusions. Although certain national patterns did emerge, the diversity of orientations within a national group frequently overshadowed any meaning which might be attached to variations between the groups. Of course this in itself constitutes a finding which is not devoid of importance, for it implies that in many cases the individual's personality and research career are stronger factors than his national background.

However, the national divergences of some significance which could be detected are several. For instance, the major national variation in the importance, for the advancement of his special field, granted by the individual researcher to the different channels is to be found in attitudes to professional meetings; the Italians and Germans regard the presentation of a paper at a conference as more influential than do the French. On the other hand, publication in a journal is regarded equally highly by all groups for the advance of the field.

When it comes to regarding the different communication channels as more or less suitable for the progress of one's career, the Germans find both journals and meetings more useful than do either the French or Italians. The position of the Germans in this respect is partly explained by the fact that they orient more than do the other two groups to the wider scientific community.

Finally, all three groups are equally inclined to publish negative results and are equally eager to converse and compare notes within the organisation, but outside the organisational boundary, the French are noticeably more reserved than either the Italians or Germans. Here again, it is tempting to ascribe these variations simply to the fact that the French are those who are most involved in applied research.

Methodology and motivation of research

The final topics explored as part of Mr. Useem's study are the methodology and motivation of research. A few examples will be given of the results obtained under this general heading.

One of the questions put to the Ispra scientists and engineers concerned the importance of a number of criteria in the selection of a research topic. Table III presents an analysis of the replies, for each national group. It can be seen that the Germans and the French ascribe equivalent weight to the role of their personal predilections in selecting topics

Table III: *The importance of several criteria in the selection of a research topic, for the three national groups*[3].

Criterion	National average		
	D	F	I
Personal interest and ideas	1.9	2.0	2.4
Significance of the goal or topic to the advance of a scientific or technical field	1.7	1.9	2.0
The feasibility of topic or goal	2.5	1.6	2.4
Availability of apparatus and equipment	2.3	2.0	2.3
The significance of the goal or topic for the organisation	2.4	2.0	2.7

3. A five point scale ranging from "very important" (scored as 1) to "moderately important" (= 3) to "not important" (= 5) is associated with each criterion.

for investigation, which contrasts with the somewhat lesser importance the Italian researchers attribute to this factor. On the other hand, the feasibility of the topic is of prime importance for the French and in fact it is the most important among the criteria which influence their choice. The German and Italian groups assign considerably less strength to this factor. In other respects the three groups demonstrate little significant national variation.

In the course of early informal discussions it was pointed out occasionally that upon the selection of a research project one of the national groups tended to make fairly extensive preparations before starting, in contrast to a second national group which preferred to solve procedural problems as they came up in the course of the actual investigation. Consequently a question was developed to probe for the existence of a systematic national variation in this dimension. When it came to analysing the replies, however, it turned out that there was none.

Similarly, the following question was asked: "In the course of carrying out a project new ideas for investigation may appear. Generally, do you prefer to complete the original topic before exploring these new ideas, or do you prefer to take time out from the original project to explore these new ideas?" This question was suggested by several people's comments in the course of informal discussions; it was claimed, for instance, that the Italian researcher tends to pick up interesting tangential ideas, to take a "zig-zag" route toward the solution of a problem, in contrast to the German researcher, who deviates little from the original topic.

When the results were analysed, however, no evidence was found of any significant national variation. Thus yet another hypothesis—it is tempting to say prejudice—was blown.

Mr. Useem's purpose was to examine whether the cumulative effects of national scientific structures are manifest in the self-assessed orientations and activities of the researcher. Although no consistent national variations were observed, the few instances in which differences were shown up do imply that some of the facets of an engineer or a scientist's personality are shaped by his national background.

Thus the major finding of this study, that there are some systematic national variations, which is positive, is also in a sense negative, as the differences are so small. Although diversity in a society is in many respects the key to its success, it is perhaps reassuring to find that, when he applies his wits to research, an activity which requires imagination but also discipline, the European has a fairly standard behaviour.

EREA-A 8-9

NEWS FROM THE EUROPEAN COMMUNITIES

The Commission of the European Communities defines "Euratom's future activities"

The programme of Euratom's future activities, which the Commission of the European Communities has forwarded to the Council of Ministers, after consulting interested circles in the Community, is in line with the findings of the White Paper issued by the Commission toward the end of 1968 (and published as a special issue of *Euratom Review* under the title "Survey of the nuclear policy of the European Community"). It sums up a situation that has gone downhill through the scattering of the member countries' efforts, which have been marked by a fundamentally national orientation. *For lack of a clearly stated political determination* to take the imperative corrective measures, the creation of a genuine common market will be irremediably jeopardised and the present walling-off of each country's market will become yet more pronounced, thus helping non-Community techniques to consolidate a supremacy that will soon be impregnable. While the funds which the Commission is asking for in order to carry out its programme then seem to be comparatively small, representing as they do only some 8.5% of the total sum spent on nuclear research by the Member States, it is the political commitment for which the Commission is appealing that is the decisive factor in the success of the proposed programme, since the aim is to bring about:

1. *An improvement in the structures of the nuclear industries*, by encouraging transnational groupings of firms with a view to setting up a small number of competitive consortia capable of obtaining a large volume of business.

As is also the case with most advanced-technology industries, the nuclear industry has so far reaped scarcely any benefit from the Common Market: the abolition of customs duties has not done away with the compartmentation of the market because the development of advanced industries depends much more on the actions of the public authorities than on the normal working of the laws of supply and demand. Even today it is still an easier matter for a European constructor to sell a nuclear power plant to a non-member country than to another Community country. The *reorganisation of the industry on a multinational basis* is therefore an essential condition both for the actual creation of the Common Market and for the development of healthy competition. In order to achieve this the Commission proposes, in particular:

— that guarantees be given against the exceptional uncertainties inherent even now in the use of nuclear power, provided that calls for bids are open and that suppliers have grouped themselves into multinational consortia;

— that Community or national aid be granted for the development of advanced designs, with a view to helping one or more multinational groupings, depending on the sector;

— that assistance at Community or national level be coordinated in order to promote also the reorganisation of the reactor component industry on a Community basis;

— that an attempt be made to unify technical and safety standards, in order to prevent new obstacles from hampering the creation of a wide market and the reorganisation of industry.

2. *Rapid definition of a joint policy as regards the choice of reactor types* on which the Community must concentrate its efforts.

By granting certain reactor families selective aids ("joint enterprise" status, partial guarantee against certain risks inherent in plant start-up, financial aid for head-of-line advanced power reactors, participation in research and development, etc.), the Community must promote the concentration of resources on a common concept in respect of fast breeders, high-temperature reactors and heavy-water reactors (in the last-mentioned field the Commission proposes that the development of the *ORGEL* family be abandoned).

3. *Adoption of a joint policy on fissile materials* and especially on *enriched uranium*.

In order to assure reactor constructors in the Community of a continuous supply of nuclear fuels on satisfactory terms, the Community must encourage exploration for resources both at home and abroad, systematically diversify its external sources of supply and review the provisions governing the operation of its *Supply Agency*. With regard to the construction of a uranium enrichment facility in the Community, the Commission will shortly submit to the Council of Ministers a number of proposals for action, which will amount to the pursuance of the activities already undertaken on this subject.

4. *More effective coordination of the nuclear research programmes* carried out in the Community.

In order to avoid duplication of effort, which is still all too frequent, the Commission proposes that the activities of national and Community laboratories engaged on research projects which come within the same field should be closely coordinated by appropriate committees at whose meetings the programmes would be discussed.

The *Euratom research programme* proper (see table) will concentrate on the following matters:

— support for *reactor development work*, which will absorb about one-third of the total proposed manpower and funds, in activities orientated in accordance with precise objectives chosen on the basis of long-term industrial considerations;

— the general problems of the *fuel cycle*, which on account of their wide range are particularly suitable for activity at Community level;

— intensification of *public service* activities in the nuclear field; in addition to Euratom's traditional activities in this field (*Central Bureau for Nuclear Measurements*, highflux irradiations, the *Scientific Data Processing Centre (CETIS)*, development of methods for the control of fissile materials, nuclear plant safety, biology, health and safety, industrial applications of radiations, dissemination of information, training and instruction) *work will henceforward be carried out in the establishments of the Joint Research Centre on request and for payment*, on behalf of third parties, public authorities or industrial undertakings;

— the pursuit of basic research in the fields of *thermonuclear fusion* and plasma physics, and in that of *condensed state physics* (the Commission proposes here the construction of a pulsed reactor, *SORA*, wich would give Community researchers a modern instrument for the study of matter in the condensed state).

Lastly, the Commission proposes the *gradual reorientation of the research potential of the Joint Centre towards non-nuclear fields.*

The attainment of industrial maturity by some nuclear research projects will free some of this potential. A slight cutback in staff thus becomes possible, and some employees can therefore be transferred to Community industries. Above all, however, the Commission proposes that non-nuclear activities should be carried out by the *Joint Research Centre*, in accordance with the wishes of the Council of Ministers. These projects, which are indisputably the province of the Community, and for which the *Joint Research Centre* possesses the necessary technical skills, are for the time being confined to:

— *information science* (with the development of software and certain hardware components) and *abatement of nuisances* (aimed at greater protection of man and his environment), two of the seven fields adopted by the Council of Ministers as priority areas for the development of broader-based scientific cooperation;

Proposed Euratom research programme
(Proposed appropriations for a five-year period)

Activities	Personnel	Appropriations (in millions of u.a.)
I. *Contribution to reactor development*		
● Fast reactors	175	29
● High-temperature reactors	185	45.2
● Heavy-water reactors	490	55.9
II. *General fuel-cycle problems*	220	25.3
III. *Public service activities*		
● Central Bureau for Nuclear Measurements	180	24.9
● CETIS	177	16.3
● Control of fissile materials	40	3.2
● Nuclear plant safety	47	3.8
● Biology and health physics	112	38
● Training and instruction	9	7
● High flux irradiation	90	20.9
IV. *Basic research*		
● Thermonuclear fusion	94	45
● Condensed-state physics	180	29.7
V. *Non-nuclear field*		
● Abatement of nuisances	103	8.2
● Information science	105	11
● Community Bureau of Standards	189	15.3
Total amount to be charged to research budget	2.336	378.7
III bis. *Public-service activities to be charged to Operating Budget*		
● Uses of radiations	9	0.9
● Dissemination of information	119	12
Grand total	2.464	391.6

— the settıng-up of a *Community Bureau of Standards*, which would provide the Community with the technical instrument it requires for harmonsing the various countries' technical standards, which still hamper intra-Community exchanges in too many cases.

It is a fact that ten years after the creation of the European Atomic Energy Community the target is still far from being achieved, i.e. the development of a powerful nuclear industry within the Community.

The causes of this situation are not to be sought in a lack of funds, nor in any inadequacy on the part of European scientists and technicians, but mainly in the fragmentation of the activities being pursued in the six Community countries.

The programme of action which the Commission has just submitted to the Council of Ministers would make it possible to remedy the situation if each of the six Community countries were to back it up with a political will which it is in the interest of all concerned to focus on the joint objectives specified by the Commission.

"Aigrain" report forwarded to Council

At its meeting on 31 March and 1 April 1969 the Community's Medium-Term Economic Policy Committee discussed and approved the report of the "Working Group on scientific and technical research policy" (known also as the "Aigrain Group" — see *euro-spectra* Vol. VIII (1969) No. 1, p. 28) and decided to forward it to the Council of Ministers.

It will be recalled that on 10 December 1968 the Council of Ministers decided to put proposals for cooperation to interested non-member countries.

The Working Group has since continued its work, in particular in order to ensure that by July it can submit to the Council practical ways of implementing the joint projects decided upon.

Report on enriched uranium

During a session of the European Parliament in March Mr. Wilhelm Haferkamp, member of the Commission of the European Communities responsible for energy, presented the report entitled "First Guidelines for a Community Energy Policy."

Mr. Haferkamp mentioned on the same occasion that representatives of the Commission and of Member States had recently completed a report on the question of supplies of enriched uranium to the Community over the longer term. According to Mr. Haferkamp, the cooperation between two Member States and the United Kingdom in the field of isotope separation in no way lessened the need for the Community to undertake studies with a view to setting up its own plant for the production of enriched uranium (see *Euratom Review*, Vol. VII (1968) No. 1, pp. 24-29). Such a study might show that it is in the Community's interest to employ the two techniques—gaseous diffusion and ultracentrifugation—simultaneously.

The ESSOR reactor is presented to industry

On 6 March 1969 the Ispra Establishment welcomed representatives of the Community's nuclear industry to introduce them to the *ESSOR* reactor and its auxiliary equipment. This reactor, which is mainly designed for the irradiation of fuel elements and channels for the heavy water family under power reactor conditions as regards neutron spectrum, cooling and geometry (see *Euratom Bulletin* Vol. II (1963) No. 2, pp. 12-17), is now available to the Community.

For the irradiation of cells (i.e. assemblies consisting of the fuel element and the channel), *ESSOR* is fitted with 12 experimental positions and five independent chambers to hold the cooling circuits. The diagram shows the case where three experimental cells are connected to the same cooling circuit, the assembly forming an independent loop. Parallel tests can therefore be carried out, not only on different cells of the same reactor type in a single loop, but also on cells of different types in up to five separate cooling circuits, owing to the presence of the five chambers.

The feed zone of the core is now being tested and has undergone an endurance test at 12 MW (half rated power). A loop which is cooled by light water (*CART* circuit of *CIRENE* programme) and uses one position and one chamber is now in operation. A second loop (*MK*-5), which has an organic coolant, can be connected to several positions (four for example) and is housed in one chamber, has been tested out of pile. A third loop (*EK*-2) is nearing completion. It also has an organic liquid as its working fluid, occupies one chamber and can be connected to one position.

Six of the twelve experimental positions and two of the five chambers are therefore now available and could be used for new irradiation programmes.

On the other hand, if the *MK-5* is regarded as a multi-purpose cooling circuit, the channels which will soon be ready for installation in the core could be employed for preliminary irradiations for various future programmes. In this context it must be remembered that, with the organic coolant, operating temperatures of well above 300°C are possible, and there is no corrosion problem with regard to steel, aluminium or zirconium alloys over a wide range of temperatures. In addition, the organic coolant does not react with metallic or ceramic fuels nor with alkaline metals.

The use of *MK-5* for the development of water-cooled reactors would, moreover, be in line with present Canadian activities, whereby fuel elements of the heavy water/heavy water and heavy water/light water reactor types are being irradiated in the organic-cooled *WR-1* reactor.

As well as the irradiation devices, *ESSOR* has a stripping shop and facilities for examining irradiated fuel elements. It is also provided with a workshop for irradiated channels, which in view of the dimensions of the channels it can handle (up to 10 m long), is a completely original piece of equipment.

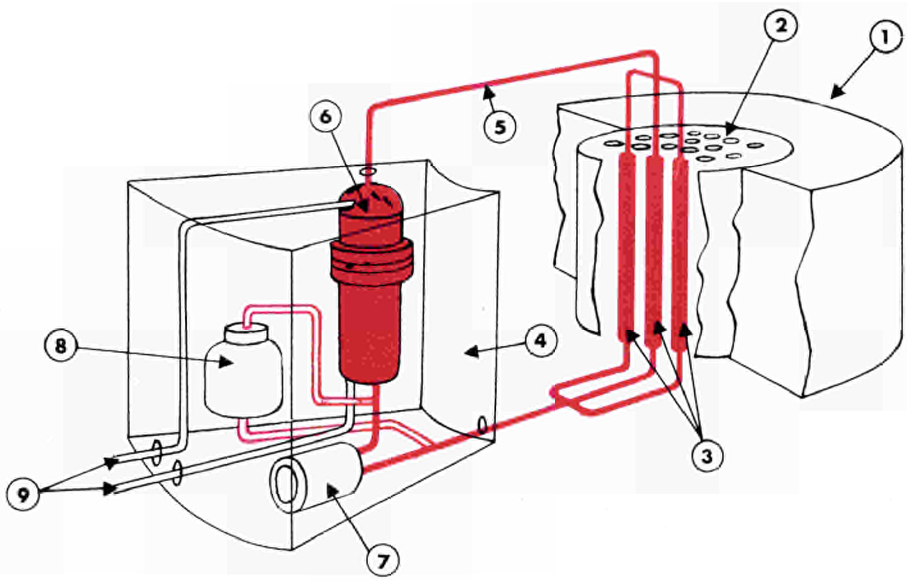


Diagram of ESSOR *reactor core and an experimental loop.*
1) reactor core (effective height = 150 cm)
2) experimental zone of core
3) experimental cells connected to the same cooling circuit
4) chamber
5) primary cooling circuit
6) heat exchanger
7) circulating pump
8) primary coolant purification circuit
9) secondary cooling circuit.

New move towards European patent

Following a decision taken by the Council of Ministers in March, the Six have invited seven other European States—Austria, Denmark, Ireland, Norway, Great Britain, Sweden and Switzerland—to participate in negotiations with the object of signing a convention on the granting of a European patent. This step marks the resumption of the work undertaken by the Six on the Commission's initiative; as early as 1962 they had succeeded in preparing a preliminary draft, but in 1965 the work had to be suspended owing to certain differences of opinion on the expediency of broadening the Community's boundaries in this particular field of industrial property.

At the same time the Council decided that a second convention should be prepared, to be signed by the six member countries only; this will go further than the other one in that it will lay down uniform legal regulations applicable to patents on the territory of the Six, thus taking due account of the existence of the Common Market.

The first convention will mainly establish the rules of law and procedure regarding the *granting* of a patent by an international body to be set up, the European Patent Office. Once granted, the European patent would comprise two distinct elements—a set of national patents for the non-member states, and a single patent for the six member states.

As now envisaged, this first convention offers patent seekers two major advantages.

In the first place, when they wish to protect their invention in a number of countries, they will no longer need to recommence the same tedious and expensive proceeding in each and every one of them. A single application submitted to the European Office will suffice.

Secondly, since the convention provides for a severe investigation procedure to verify the novelty of the invention, the applicant who obtains a patent will possess a reliable assurance of the legal safety of his invention in a vast territory; in other words, the risk that his patent will be challenged, and consequently invalidated, will be extremely small. This will be especially attractive to applicants for patents in countries that have no national examining office—and that means the majority of countries.

There is, however, provision for deferring the examination for a period not exceeding seven years, which is advantageous to both the applicant and the European Office. For if the applicant is not confident from the outset as to his invention's good commercial prospects, he can, by waiving the examination, save himself the attendant expenses. At the same time this will lighten the Office's task and obviate the unnecessary overloading that has long afflicted most of the national offices that examine inventions, by reason of the applications for patents that are not exploited afterwards. This system of deferred examination, which was already featured in the 1962 preliminary draft, has in fact since been adopted by certain countries.

It is also proposed that the European Office shall call upon the *International Patent Institute* (The Hague), for the purpose of drawing up documentary reports on each application. The role of the Hague Institute, which has years of experience in this field, will be to assemble, for each case, all possible relevant documents, which the Office will use as its basis when it proceeds to an examination. In any case the convention requires that the Institute's report be published, at the same time as the application, at the end of an eighteen-month period. As from the date of such publication, the applicant would enjoy a certain degree of protection which would enable him to exploit his invention.

As can be seen, the first convention relates only to the *grant* of the patent, and does not deal with the aspects concerning the lifetime of the patent once it is granted. It is precisely these aspects which form the subject-matter of the convention to be signed by the Six. Since the convention's aim is to establish a single patent, it is obvious that the lifetime, for instance, will be uniform, instead of varying from one Community country to another as it does today. Similarly, a uniform basis will be laid down for infringement proceedings, the criteria for assessing the nullity or otherwise of a patent, etc.

It is to be hoped that the two proposed conventions can be signed and ratified quickly. They will help, in the field of patent rights, to strengthen international cooperation and also the bonds uniting the member States of the European Community.

The fight against the Colorado beetle

In the biology department of the Ispra Establishment of the *Joint Research Centre*, studies are being carried out into the possibilities offered by radiosterilisation of the males in the battle against noxious insects such as *Dacus oleae* (olive fly) and *Chrysomela decemlineata* (Colorado beetle).

In the case of the Colorado beetle, research has revealed means of cutting out the winter diapause, which until now has hampered the continuous breeding of this insect. It was found that it will remain fully active when subjected to a temperature of 29°C during the day and 18°C during the night, with the length of daytime artificially fixed at 16 hours and the light intensity at 4,000 lux. This has greatly facilitated studies on the radio-entomology of the Colorado beetle.

At the same time the studies showed the feasibility of continuous breeding of the *Perillus bioculatus*, a parasite of the Colorado beetle, which could be used by biologists in their fight against this pest.

Creating higher-yield varieties of millet

For four years Senegalese and French research scientists are going to work together to develop new varieties of millet with higher yields than the traditional kinds.

Consequent upon a favourable opinion expressed by the *European Development Fund (FED)* Committee, the Commission of the European Communities has approved a project on the *FED* non-repayable aid budget, aimed at improving millet varieties in Senegal and amounting to CFA Fr. 277,500,000, i.e. about 1,124,000 u.a.

Classical methods will not be the only ones employed to achieve this aim. The researchers will use ionising radiations, on the genetics side, to produce mutations, and radioactive tracers such as carbon-14 for detailed plant physiology studies.

The greater part of the programme will be carried out in the *Centre national de recherches agronomiques (CNRA)* at Bambey, Senegal, and the part concerned with radiogenetics in the laboratories of the *Office de la recherche sientifique et technique d'outre-mer (ORSTOM)* at Bondy, France.

Millet is, together with sorghum, the plant most widely cultivated in Senegal. Production, however, is still quite inadequate to meet the needs of the population. Every year, therefore, a higher tonnage of cereals has to be imported, causing a heavy outflow of capital.

The Senegalese government, aware of the menace in this prospect of a growing food shortage, took action some years ago along a number of lines such as the distribution of selected seed and the introduction of more suitable farming methods. It was very soon apparent, however, that these measures would not suffice to raise production beyond a relatively low level.

The fact is that the plants grown at present are far more like a grass than a cereal. Consequently, the main obstacle to any substantial increase in yield lies in the fact that these varieties use up too much of the soil's goodness—which is limited in any case—in building stem and leaves at the expense of the reproductive organs and especially of the seed. Whereas more highly developed cereals such as wheat produce two tons of straw to a ton of grain, the ratio rises to six or even 10 in the case of the millets grown today.

It is this crucial yield-limiting factor that is to be tackled under the research project. The essential aim is to produce new varieties of millet with a satisfactory, i.e. about two to one, ratio of straw to grain. At the same time, the basic requirements of the new varieties obtained will be defined so that appropriate farming methods can be worked out.

Calculations have shown that the economic effects to be expected from this scheme amply warrant the financial effort it entails. The efficiency factor of the project (initial investment/net additional yield in normal-running year attributable to execution of project) is estimated at 0.8, whereas projects with factors of 4 or more are often accepted in farming, and in the developing countries.

Nuclear hazards and the public

The Commission of the European Communities recently asked the Brussels University *Institute of Sociology* to carry out a study aimed at shedding a better light on the public attitude in Belgium and Luxembourg to nuclear hazards. The study will be based essentially on the results of a survey to be conducted among people who are representative of various occupations, regions, etc. It will constitute a useful supplement to similar studies relating to Germany and Italy which are now nearing completion, and will enable the Commission to assemble all the relevant data for a consolidated report towards the end of the year.

These activities are to some extent the counterpart of the research on the *psychological attitudes of nuclear workers* to radioactivity hazards, an investigation which had previously been assigned to the *Psychopathological Research Centre* in Paris headed by Prof. Sivadon (see *Euratom Bulletin*, Vol. VI 1967 No. 1, pp. 6-9). This research, the results of which were recently published under report No. EUR-4198 f, has provided a valuable contribution to the knowledge of the various psychological aspects of accident prevention among nuclear workers. On the practical level, moreover, it should prove beneficial as regards personnel information and training and, above all, in securing the active participation of the workers in radiological protection.

Conference on the Dodewaard, Lingen and Obrigheim nuclear power plants

As one of the series of conferences on Community nuclear power plants held over the past few years, the Commission of the European Communities organised a meeting in Arnhem on 27-29 November which was devoted to the nuclear plants at Dodewaard *(GKN)*, in Holland, and Lingen *(KWL)* and Obrigheim *(KWO)* in Germany. All three plants were only completed and commissioned in 1968, so that it was to be expected that technical details and experience acquired during the important start-up phase would be disclosed at the Conference. There was an attendance of about 250, and they were not disappointed in this respect. With remarkable frankness, representatives of the power plant operating companies and constructors devoted a total of 26 papers and subsequent discussions to reports on numerous and varied technical points, problems and difficulties encountered during construction and start-up of the plants.

Preparations for criticality: insertion of the fuel elements in the pressurised water reactor of Obrigheim 300 MWe nuclear power plant.

Unlike those discussed at the earlier conferences, these three plants are almost entirely European: the Lingen and Obrigheim plants were built by German firms on a turnkey basis, while the Dodewaard plant was built mainly by the Dutch industry, with the client *GKN* placing individual orders and using *General Electric* drawings, specifications and technical knowhow for the construction of the reactor. The pre-operational tests and start-up of all three plants were completed without major difficulties and in a remarkably short time.

The 54 MWe boiling water reactor plant at Dodewaard was built in only three and a half years, despite considerable delays in the delivery of the pressure vessel and the containment. By the use of modern methods of planning and careful dovetailing of the work by *GKN*, the reactor first went critical only six months after delivery of the pressure vessel and the full rated turbine power was reached only five months after that.

In order to amass as much experience as possible, *GKN* performed some of the quality control checks, acceptance tests and start-up themselves.

In addition, their own core calculations and reactor physics measurements provided the necessary basis for an in-house and independent fuel-cycle calculation.

The Dodewaard nuclear power plant seen from the air.
Owing to the use of a pressure-suppression containment, the installation has a fairly conventional appearance, which sets it apart from most other water reactor plants.

A new feature for European reactors is the use at Dodewaard of a pressure-suppression system as the containment. The hydrocyclones for the clean-up of the water system are also new and the results obtained with them so far are satisfactory.

Interest was also aroused by the reports on a number of difficulties and malfunctions during start-up. These included leaks at the pressure vessel penetrations for the nuclear instrumentation, the reactor water clean-up system pumps, the turbine drainage system, hunting in the turbine governor and minor leaks in the safety valves.

There were 10 papers on the Lingen plant, which has a net electric rating of 240 MWe (70% nuclear); after Dresden-1 and *KRB*, it is the largest boiling water reactor plant now in operation and is also, as was shown by a highly informative comparison, the most modern of its kind. It took four years to build, including four weeks' trial operation. The full thermal rating was achieved and according to present measurements the reactor still has a power reserve of about 10%.

A detailed report was given of start-up and of the defects that came to light in the process, above all the difficulties with the control rod drives, which had been specially developed for the *KWL* reactor and were of a new type. Uneven thermal expansion at temperatures above 200°C had caused jamming of the long piston rods. The cause of the malfunction was pinpointed in a test programme and, following modification of the drives, functioning is now normal.

A description, with the help of examples, of initial experience with the circulation regulating system for reactor power control, also newly developed, was of particular interest. The inlet subcooling of the reactor water is varied here by regulating the speed of the forced-circulation pumps by frequency control. This permits rapid power variations—up to 1%/sec over a wide range. Present experience shows that circulation control can be used without risk even in large plants. Special emphasis was laid on the very close agreement between the behaviour of the various regulating systems as calculated in comprehensive analogue computer studies and in actual operation.

After lengthy development work the downflow cyclones for steam/water separation now being used for the first time have also proved satisfactory. They are installed in the pressure vessel above the downcomer and thus do not interfere with refuelling.

The oil-fired superheater also ran satisfactorily during the period of trial operation and it runs in perfect harmony with the reactor and turbine.

The neutron-sensitive temperature probes used to determine the core power distribution—also new—yielded satisfactory results. However, 10 out of the 60 used in the core failed during the trials. The remaining nuclear instrumentation, including the mobile chamber system, worked faultlessly.

The last nine papers at the conference related to the Obrigheim pressurised-water plant. Construction began in March 1965, and it was connected up to the grid for the first time in October 1968, supplying 45 MWe. The plant's power can be expected to be raised shortly from the contractual rating of 283 to 300 MWe.

The most important result of the first hot tests was the appearance of excessive thermal shield vibration. After lengthy model tests and measurements in operating conditions (never carried out before on the internals of a pressurised water reactor), a satisfactory means of attaching the thermal shield was found.

The high pressure pumps in the two primary circuits of the *KWO* reactor have hydrodynamic shaft seals of a new type which have already functioned reliably in operating conditions. On the other hand, difficulties have been encountered with the valves and gears of the charging pumps.

Cluster rods of a new type are used for neutron flux and thus temperature regulation. These rods require no followers, leading to a considerable reduction in the installed height of the core support structure and pressure vessel.

The remarks about the volume regulating system and the reactor power control system, designed for variable-load operation, also interested the audience. For power control, short-term coolant temperature control (with the control rods) and long-term rod reactivity control (using boric acid) are employed in conjunction.

The transistorised control, interlock and regulating systems performed well in service. They are built up from easily replaceable printed circuits which make it easy to build up even complicated control sequences into automated modules.

Trouble was experienced when the aeroball system for measuring the core power distribution was taken into service, primarily on account of mechanical defects. The system will not be reliable until various modifications have been carried out.

An important addition to the construction contract was the process computer, which was not originally planned but which proved, as a multi-purpose computer system, to be of great value for monitoring tests and logging data during start-up. The wide range of requirements

SHOULD YOU WISH TO RECEIVE *euro-spectra* REGULARLY, PLEASE SEND YOUR ORDER FORM TO:

Agence et Messageries de la Presse
1, rue de la petite île
Brussels 1, Belgium
(Postal account C.C.P. 416.69)

or:

H.M. Stationery Office
P.O. Box 569
London S.E. 1, Great Britain

or:

European Communities Information Service
Suite 808
Farragut Building
Washington, D.C. 20006
U.S.A.

please see overleaf

SHOULD YOU WISH TO RECEIVE *euro-spectra* REGULARLY, PLEASE SEND YOUR ORDER FORM TO:

Agence et Messageries de la Presse
1, rue de la petite île
Brussels 1, Belgium
(Postal account C.C.P. 416.69)

or:

H.M. Stationery Office
P.O. Box 569
London S.E. 1, Great Britain

or:

European Communities Information Service
Suite 808
Farragut Building
Washington, D.C. 20006
U.S.A.

ORDER FORM

I wish to subscribe to the **English/**................ edition* of **euro-spectra** for one year at the price of 21/-; US $ 3.50

as from..

Name ....

Full address..

....

....

....
(Signature)

☐ Please invoice me.

☐ I am sending my remittance forthwith by money order/transfer/cheque (enclosed)/ ....

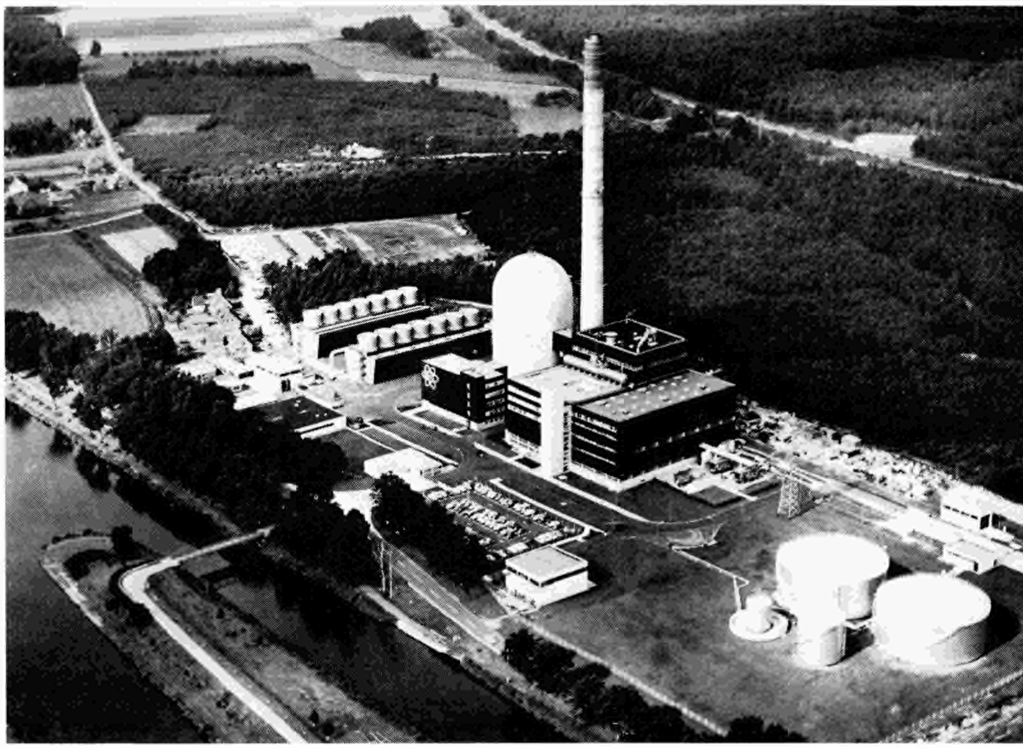
* Besides the English edition, **euro-spectra** is published in German, French, Italian and Dutch.

laid down in this case makes the use of a process computer of this kind an economic proposition.

In the case of the *KWO* reactor, too, a programme of reactor physics measurements was carried out in order to check the theoretically calculated reactor data. The reactimeter, which is really a small on-line analogue computer, was very useful for the measurements.

Although start-up has proceeded satisfactorily so far, it was pointed out that it had been complicated by the use of new types of components whose behaviour was still little known. It was therefore suggested that newly developed equipment be introduced only gradually in order to avoid trouble.

To sum up, two points can be said to emerge clearly from the large number of papers. Firstly, the conference showed an impressive picture of the European nuclear industry, which, in building these three plants, has to some extent covered new ground and added a number of novel and original solutions to light water reactor engineering. Secondly, it has again been shown that development in this field is nonetheless not yet concluded and a number of technical tasks still await a satisfactory solution. It was therefore appropriate to point out the usefulness and also the necessity of an intensive exchange of experience, in order to profit better from the store of experience built up in the Community and thus to help to avoid as far as possible any mistakes and delays with the Phase 2 nuclear power stations now in the planning stage. The large attendance at the conference and the animated discussions showed that there is a genuine interest in such an exchange of experience.



Aerial photograph of Lingen 250 MWe nuclear power plant.

Axel FRAUDE

Forthcoming conferences

The Commission of the European Communities announces the following conferences:

- *Second symposium on MICRODOSIMETRY*, to be held on 20-24 October 1969 in Ispra. For further information write to: Dr. H. G. Ebert, 51-53 rue Belliard, Brussels 4, Belgium.
- *Second conference on PRESTRESSED CONCRETE REACTOR VESSELS AND THEIR THERMAL INSULATION*, to be held in Brussels on 18-20 November 1969. For further information write to: Mr. H. Benzler, 51-53 rue Belliard, Brussels 4, Belgium.

topi radioisotopen s
hip propulsion schiffs
antrieb propulsion na
vale propulsione nava
le scheepsvoortstuwi
ng biology biologie
biologie biologia bio
logie medicine medi
zin médecine medicin
a geneeskunde healt
h protection gesundh
eitsschutz protection
sanitaire protezione s
anitaria bescherming
van de gezondheid
automatic data proces
sing automatische inf
ormation information
automatique informa
zione automatica auto
matische verwerking
van gegevens insura
nce versicherungswes
en assurances assicura
zione verzekeringen
economics wirtschaft
économie economia e
conomie education
and training ausbildu
ng enseignement inse
gnamento onderwijs
en opleiding power
reactors leistungsreak
toren réacteurs de pu
issance reattori di po
tenza energie reactor
en nuclear fusion ke
rnverschmelzung fusi
on nucléaire fusione
nucleare kernversmel
ting radioisotopes r
adioisotope radioisot
opes radioisotopi ra
dioisotopen ship pr
opulsion schiffsantrie
b propulsion navale
propulsione navale
scheepsvoortstuwing
biology biologie biolo
gie biologia biologie
medicine medizin mé
decine medicina gene
eskunde health pro
tection gesundheitssc
hutz protection sanit
aire protezione sanita
ria bescherming van
de gezondheid auto
matic data processing
automatische informa
tion information auto
matique informazione
automatica automatis
che verwerking van g
egevens insurance v
ersicherungswesen as
surances assicurazioni
verzekeringen econ
omics wirtschaft éco
nomie economia eco
nomie education and
training ausbildung
enseignement insegn
amento onderwijs en
opleiding power reac
tors leistungsreakto
ren réacteurs de pu
issance reattori di po
tenza energie reactor
en nuclear fusion ke
rnverschmelzung fusi
on nucléaire fusione
nucleare kernversmel
ting radioisotopes r
adioisotope radioisot
opes radioisotopi ra
dioisotopen ship pr
opulsion schiffsantrie
b propulsion navale