ATOM

Number 139 / **May 1968**

MONTHLY INFORMATION BULLETIN OF
THE UNITED KINGDOM ATOMIC ENERGY AUTHORITY

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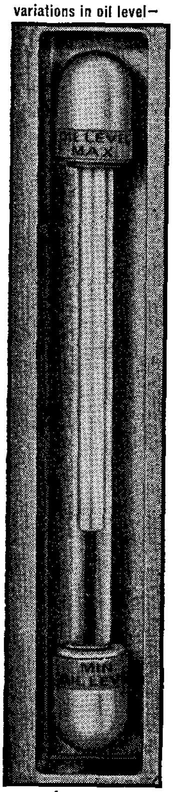

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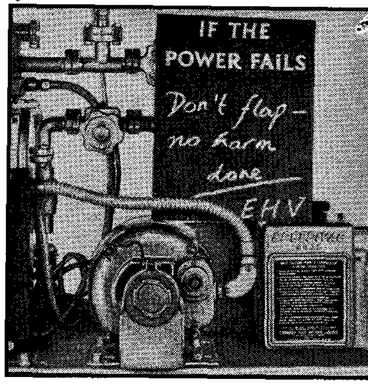

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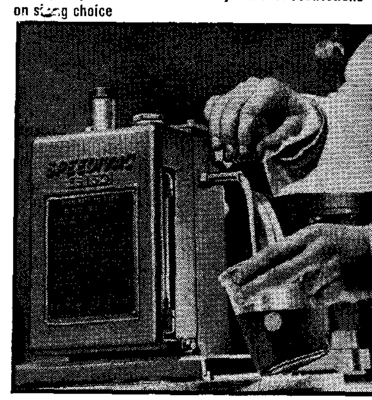

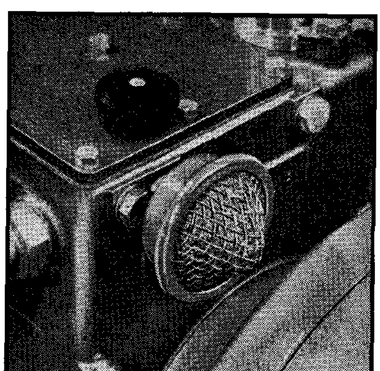

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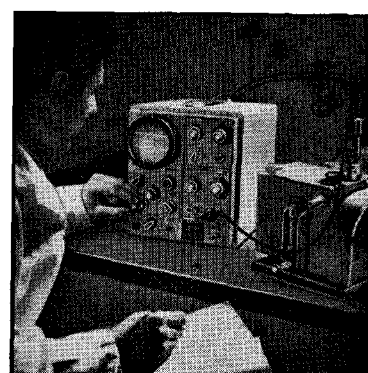

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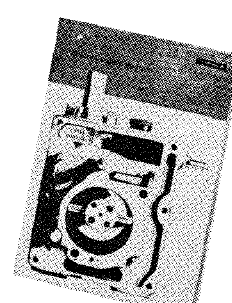

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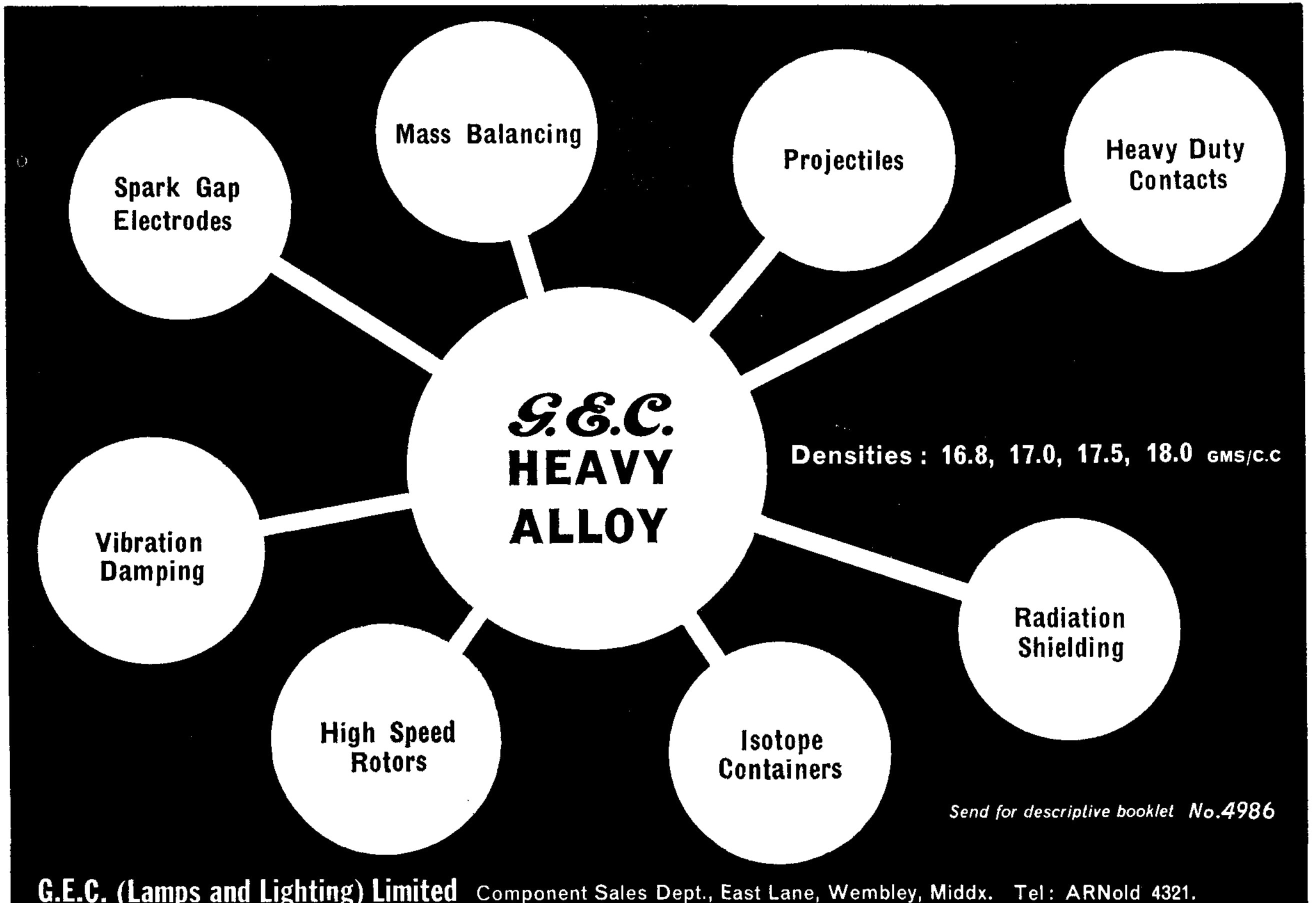
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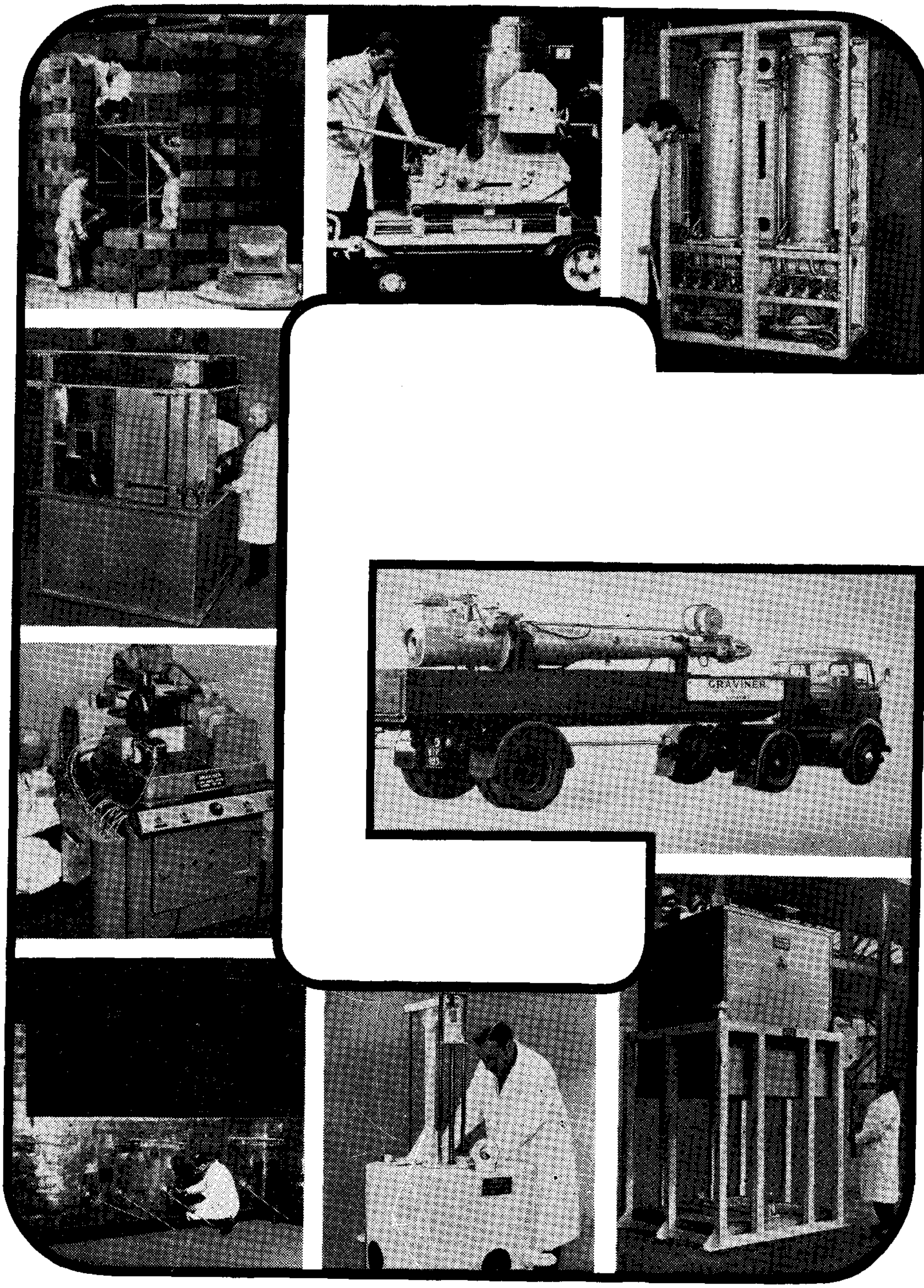
GRAVINER

ATOM

MONTHLY INFORMATION BULLETIN
OF THE UNITED KINGDOM
ATOMIC ENERGY AUTHORITY

NUMBER 139

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Contents

ATOM
monthly bulletin of the U.K.A.E.A. is distributed to the staff of the Authority, to similar organisations overseas, to industrial firms concerned with the exploitation of nuclear energy, to the Press and to others to whom a record of information of the work of the Authority may be useful.

Enquiries concerning the contents and circulation of the bulletin should be addressed to

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U.K.A.E.A. PRESS RELEASES

Reactor systems study for Norway

An agreement has recently been signed between the Institutt for Atomenergi of Norway (IFA) and the United Kingdom Atomic Energy Authority (U.K.A.E.A.) to co-operate in the study of power reactor systems for construction in Norway in furtherance of the agreement made in 1957 between the two countries covering the promotion and development of peaceful uses of atomic energy.

The IFA as part of its activities has a programme for power reactor assessment and is collaborating with the Norwegian Water Resources and Electricity Board (NVE) and Norsk Hydro-Elektrisk Kvaelstofaktieselskab (Norsk Hydro) in a joint study of atomic power plants in the 500 Megawatt (electrical) range including the assessment of alternative reactor types.

During 1967 various discussions were held between the British Nuclear Export Executive (BNX) and the IFA and other organisations in Norway with interests in the atomic power field. BNX is a partnership between the four leading British nuclear power organisations. These are the three consortia—Atomic Power Constructions Ltd., The Nuclear Power Group Ltd., Nuclear Design and Construction Ltd., who design and build nuclear power stations, and the United Kingdom Atomic Energy Authority.

Arising from these discussions BNX agreed on behalf of its members to co-operate in these studies by providing information on the advanced gas-cooled reactor which is a development by the U.K.A.E.A. and British industry, from the earlier and successful graphite moderated gas-cooled reactors adopted by the U.K. for the first nuclear power programme. The AGR is being used for the second U.K. nuclear power programme of which so far three twin-AGR power stations are now under construction by consortia at Dungeness and Hinkley in England, and Hunterston in Scotland.

Under this agreement the U.K.A.E.A., acting on behalf of BNX, will provide information to allow a full technical and economic study of the AGR to be carried out, having regard to Norwegian conditions. The main purpose of this study is to build up the necessary competence in

Norway for the assessment and possible later construction of gas-cooled reactors.

In addition, the study will identify the components of such systems which can be manufactured by Norwegian industry. This latter part of the study is co-ordinated through IFA by Noratom Norcontroll A/S, which is a shareholding company owned by Norwegian industrial firms, banks and shipowners.

Discussions between BNX and Norwegian interests other than those specifically mentioned above are continuing with a view to ascertaining their power requirements and nuclear power interests.

1st April, 1968

Carbon fibres

Carbon fibres are one of the new materials of industrial significance now being worked at Harwell. Harwell has a development programme in this field integrated with the experimental and scientific work at the Royal Aircraft Establishment, Farnborough, where carbon fibres were originally invented.

It is proposed that patents resulting from the Harwell work shall be assigned to the National Research and Development Corporation for exploitation along with the R.A.E. patents that are already the subject of negotiations with industrial companies in the United Kingdom and abroad. The companies that the N.R.D.C. are proposing to licence in the United Kingdom are Courtauld's, Morganite Research and Development Ltd., and Rolls Royce.

Carbon fibres and material reinforced with carbon fibres offer a unique combination of high strength, low weight and high stiffness and the research work and the industrial programme could lead to the development of new materials of high value to the aircraft and related industries and in any application where stiffness is a prime need. The Harwell research programme, which extends earlier atomic energy collaboration between Harwell and Farnborough, will involve a total of about 17 professional staff for three years at an annual cost of about £250,000 per annum; the work will be reviewed annually.

Earlier work at Farnborough on laboratory-scale production of carbon fibres has been followed by chemical engineering development at Harwell to make possible commercial production on an industrial scale.

Work at Farnborough has shown that resin-bonded structural materials containing carbon fibres are twice as stiff and half as heavy as aluminium alloys and parallel work at Harwell has shown that fibres can be incorporated in magnesia, alumina glasses and aluminium extrusions offering the possibility of making toughened ceramics and metals. The research programme will make use of the Farnborough experience of fibre production and bonding and property measurement and the Harwell experience of graphite, ceramic and metallic matrices and of fabrication and non-destructive testing expertise.

The work done at Harwell is the subject of a direction issued by the Minister of Technology under Section IV of the Science and Technology Act 1965.

21st March, 1968

A.E.A. to reprocess fuel from Japan

[*A similar release was issued in Japan*]

On Wednesday, 10th April, the Japan Atomic Power Company (J.A.P.C.) signed with the United Kingdom Atomic Energy Authority, a contract for the reprocessing of spent fuel discharged from the Tokai nuclear power station. The signatories were Mr. Tamaki Ipponmatsu, President of J.A.P.C.; and Mr. T. Tuohy, Managing Director of Production Group, U.K.A.E.A.

Under this contract, 160 tons of spent fuel discharged from the Tokai power station during the first three years of its operation will be sent to the United Kingdom for reprocessing at the U.K.A.E.A.'s plant at Windscale, Cumberland. About 180 kilograms of plutonium, recovered from the fuel, will be returned to Japan for use in that country's power reactor development projects. The first consignment of spent fuel will leave Japan in the summer of 1969.

After being stripped of its graphite sleeves and stored under water for a few months to allow some of the radioactivity to decay, the spent fuel will be transported in 50-ton protective steel containers, each holding two tons of fuel.

Twelve such containers at a time will be shipped from the Japanese port of Hitachi to Barrow-in-Furness, Lancs. The containers, designed by the U.K.A.E.A., have been made to the standards set by the International Atomic Energy Agency for the safe transportation of radioactive materials.

The U.K.A.E.A. have transported many thousands of tons of spent fuel from nuclear reactors at home and overseas and since 1966 have been shipping spent fuel from the British designed Latina nuclear power station in Italy, the same type as the Tokai station.

Background Notes

The Japan Atomic Power Company was founded in 1957 to pioneer the development of commercial nuclear power generation in Japan. The shareholders in the Company are the nine Japanese Electric Power Companies, The Electric Power Development Co. (which is a Government investment corporation) and five atomic industrial groups. The Tokaimura power station has been in operation since 1966. The Company are also building another nuclear power station at Tsuruga, which is expected to go into operation late 1969 or early 1970.

U.K.A.E.A.'s plant at Windscale in Cumberland has a reprocessing capacity of over 2,000 tonnes of spent nuclear fuel per annum. It is capable of treating natural uranium metal fuels and also enriched uranium oxide fuels. It is currently processing the arisings from the reactors in Britain's nuclear power programme and also fuel from the Latina reactor in Italy and the Canadian N.P.D. reactor.

10th April, 1968

A.E.A. appointments

Dr. W. M. Lomer, Dr. L. E. J. Roberts, and Dr. J. Williams have been appointed Assistant Directors, A.E.R.E., Harwell, with effect from 1st April, 1968, the date on which Dr. W. Marshall takes up the appointment of Director.

Initially Dr. Lomer will be primarily responsible for nuclear programmes, Dr. Roberts for non-nuclear programmes, and Dr. Williams for reactor programmes. All three officers will be members of the Research Group Board of Management.

IN PARLIAMENT

Fuel and power policy

The following extracts are taken from the debate on fuel and power policy which took place in the House of Commons on 26th March, 1968.

MR. PETER HORDERN (Horsham): In my view there should have been a debate on the Government's White Paper on Fuel Policy several months ago, and, furthermore, it should have taken place on a Government Motion. However, I consider myself very fortunate in being able to raise this topic, even at this late hour, for it is of cardinal importance both for the economic and the social future of this country.

I do not for a moment quarrel with the way in which the Government's calculations in the White Paper are presented, but I quarrel with their conclusions. The reason I do so lies not so much in the findings of the White Paper, but in the seeming failure of the Government to co-ordinate the activities of different Ministeries. In short, the calculations in the White Paper are based primarily on the number of men the Government think can be retrained and redeployed from the coal industry.

The calculations that are supplied are that there will be room for 17,000 trained men in Government retraining centres by the end of this year, and that this capacity will be extended to 20,500 men by the early 'seventies. I regard this figure as simply ludicrous. In France the figure will be 74,500 by the same date, and I recently visited the Ministry of Social Affairs in France to study at first hand the operation of the National Employment Fund, and in particular to inquire whether there was any good reason why our retraining centres should not be expanded to retrain 70,000 men in 1970, or roughly three and a half times the number at presented proposed. There is none.

There are many hon. Members whose aim it is to improve the lives of miners. I hope that they will forgive me, though I doubt whether they will, if I say that the best way that this can be accomplished is to make it possible for more men to leave the mining industry. For many years the miners have lived and worked in conditions that are dangerous both to health and to life itself, and now, at last, through the discovery of North Sea gas, and through the development of nuclear energy, it is possible to reduce the number of men affected by these conditions. The folly of the White Paper is that it is a shabby compromise which fails to make the most of a cheap energy policy, and it fails to deal with the security and retraining of miners.

The Government claim that national considerations need to be taken into account, including the security of supply, the fullest use of resources, the balance of payments, and the economic, social and human consequences of changes in the supply pattern. But there is another major consideration. Power is a primary factor in the cost of production. Its price lies largely in the Government's control and it is essential therefore that power should be provided to industry at least as cheaply as it is to our competitors abroad, but this is not being done. The cost of electricity is markedly cheaper for our industrial competitors in the United States and Canada and the wholesale price of our coal rose by 20 per cent. between 1959 and 1965, by 10 per cent. in West Germany, and actually fell, by about 4 per cent., in the United States.

The increase in the price of coal is a continuous trend and we know that increases in some prices of other fuels are to come. It should be the Government's duty to provide energy to industry at a cheaper rate than it is available to our competitors, but this criterion has not been seriously considered.

The Government's fuel policy is such that, even by 1975, internal demand for coal, at 118 million tons, will still be larger than West German demand now and much larger than that for France, Holland and Belgium combined. If, as seems likely, there will be even greater advantages in cost for fuels other than coal by the mid-seventies, it is imperative that we should be able to benefit from them. What is more, the huge capital investment in nuclear energy by the Conservative Government in the 1950s, which put Britain first in the field, is too vital to be whittled away, because the coal industry needs special protection.

The present plans for nuclear energy are to provide 8,000 megawatts between 1970 and 1975 as the second nuclear programme. The first programme will provide 5,000 megawatts when completed by 1969, making 13,000 megawatts in all by 1975. In the United States, installed nuclear capacity will be 12,900 megawatts by 1970, but is expected to grow to 72,000 megawatts by 1975. Nuclear plants with a capacity of 12,500 megawatts were ordered in the first six months of 1967, yet coal in the United States costs less than half the pithead price in the United Kingdom.

We shall never be able to match this sort of progression in nuclear power, but it would be madness not to proceed with our own fast breeder programme, where we have a clear lead, as rapidly as possible.

Alcan has caused something of a stir by ordering a coal-fired power station at Invergordon for its new aluminium smelter. No details of price have been given, but it must be cheaper than anything offered to the C.E.G.B. In any case, as the White Paper pointed out:

> "Even if extra coal could be supplied to the C.E.G.B. at or below the break-even price, this cheaper coal should be considered to be available to dispense with a corresponding quantity of the coal being burned in existing stations, for which higher prices were being paid. It is thus the higher price coal that must be considered as being displaced by nuclear power."

As for the future of nuclear power, the White Paper considers it a reasonable assumption that, by about 1980, A.G.R. generating costs should be down to a level of at least 20 per cent. below those of the A.G.R. stations now under construction.

There are firm grounds for thinking that our energy is not being provided at competitive levels, compared with some of our overseas competitors, and that this relative position is likely to deteriorate because of the large sector of the energy market which is now provided by coal.

I turn now to the advantages given to our coal industry. The N.C.B. had £415 million written off its capital debt in 1965, yet, despite an increase in the price of coal in the spring of 1966, the Board was unable to afford to meet the difference between depreciation of assets at historic and replacement cost, for which its target is £10 million a year. It finished the year with a small surplus of £300,000. No coal is imported, yet our competitors in the E.E.C. import both American and East European coal. The Government's projections not only allow no coal to be imported until 1975, but will not even allow coal-fired power stations to be converted to oil. Coal is further protected by the tax of 2·2d. a gallon on fuel oil.

As for natural gas, the Goverment were surely right to authorise the construction of a nation-wide transmission system for natural gas by 1970. It was unfortunate that the Gas Council did not fix the rate with the producers before devaluation, as it is now certain to be more expensive. However, it is impossible to justify a policy of keeping one-quarter of the available supply of natural gas under the sea in 1970 so that the coal industry may be allowed to sell more coal to the C.E.G.B. Nevertheless, this is the Government's policy. The Parliamentary Secretary will see this set out in chapter and verse in the White Paper.

Thus, coal is being protected at great cost to our economy and to our competitive position. By 1970 the level of coal production will be held to 155 million tons, which includes 3 million tons of exports. Even with a continuance of the 2·2d. a gallon fuel tax and the present intention to use coal in power stations, inland demand should not be above 146 million tons in that year.

As it is, the C.E.G.B. and the Gas Council will have to use an extra 6 million tons of coal per annum up to 1970, which will cost the taxpayer about £45 million. Now the C.E.G.B.'s requirement of coal for power stations is expected to be 70 million tons in 1970, against 15 million tons coal equivalent of oil. As it takes five years to get a power station on stream, it is of cardinal importance to decide now what the level of coal protection, and of production, should be if we really mean to get a cheap fuel policy in the 1970s.

The Government have decided that the fuel tax of 2·2d. a gallon should remain until 1975. I believe this to be an indefensible decision. It is based on the social problem of having to deal with a planned outflow of 35,000 men a year, caused primarily by improved productivity. Yet this should not be a problem. It should be regarded as an opportunity to get our miners out of the dark, dangerous and degrading circumstances in which they have laboured for generations.

If we then assume that coal production were to be 100 million tons in 1975—instead of 120 million tons—could the oil industry fill the gap? There seems no doubt that it could. In 1967 oil demand was 120 m.t.c.e., so that a growth rate of 4 per cent. would be required to reach 165 m.t.c.e., much lower than past rates. Refining capacity is already being increased from 86 million tons of oil to 135 million tons by 1972, and should be sufficient to cover any reasonable increase in demand by 1975.

What of the effect of the balance of payments? Before devaluation, the net delivered cost of oil was about £300 million to our balance of payments. That was in 1965. Even if it were £500 million to £600 million in the 1970s, one should offset the considerable price advantage given to our exports which are largely fuel-intensive. One should also take into account the use of oil as a chemical feedstock which can often be substituted for more expensive natural imports such as textiles and rubber.

Then there are the strategic risks, but at present United Kingdom oil demand is less than 5 per cent. of the world total. Massive stocks can be built up. Whatever their political differences, there is a strong mutual interest between suppliers and users, besides the oil companies' flexibility, which was well demonstrated last year.

The Coal Board's problems are plain enough not to have to resort to speculation. There are 28 million tons stockpiled, and the industry has been run down for many years, and so it should be. On average, 30,000 men a year have left during the last decade. During the last three years the run-down has been 28,000, 41,000 and 26,500, but the level of unemployment has not risen by more than 1·3 per cent. within the industry. During the same period inland demand for coal has fallen from 188 million tons to 165 million tons last year.

The average cost of coal rose by 4·6 per cent. between 1964-65 and 1965-66 and by 6·4 per cent. between 1965-66 and 1966-67, despite increases in productivity of 3·4 per cent. and 1·4 per cent. in those years. We are told that, without any further fall in the level of coal demand, the expected improvement of productivity will lead to a reduction of about 105,000 in the number of miners by 1970-71—about 26,000 a year. Let us accept that figure. With the number of places available in Government retraining centres—17,000 at the end of 1967—it is impracticable to consider the run-down of coal production below 5 million tons this year and next. The N.C.B. is working on the assumption that 35,000 men will be released this year.

If, however, a really substantial effort were made to build retraining centres so that 70,000 men in 1970 could be retrained compared with the proposed 20,500, it should be possible in that year to release 50,000 men and thus to resume the normal rate of run-down of some 10 million tons a year and more thereafter.

Is it desirable that the coal industry should be run down so rapidly? In terms of cheap fuel, certainly. In human terms, which is by far the most important factor, abundantly so. I am sorry that the White Paper has not seized this opportunity.

Mr. Michael McGuire (Ince): I turn to the question of nuclear power. In the past some of my hon. Friends and I have expressed our doubts about carrying on with the planned programme for the second generation of nuclear power stations. We are often accused of being flat-earthers or Luddites, but my hon. Friends and I welcome nuclear power. We have said so here and elsewhere. We think that it is necessary for a nation as technologically advanced as Britain to keep in the forefront of this new development of energy generation. But we must remember that forecasts have been made in the past by people I call rosy-dawners, who always promised the rosy dawn with the new nuclear power, but whose forecasts have never come true.

We — the miners' M.P.s — questioned some of the figures based on experience. In 1955 the rosy-dawners said, "Here is a new way of generating energy. Fossil fuels are out. This will produce electricity at 0·6d. per unit as against the best conventional method at between 0·6d. and 0·7d." Those forecasts have never come anywhere near being true. Therefore, should not we ask my hon. Friend to admit that it is necessary to recast the nuclear programme, not merely in view of devaluation but because of the very optimistic forecasts which week by week are being proved wrong?

The White Paper is being made more out of date every time a Parliamentary Question is asked about the cost per unit sent out from A.G.R. stations. The White Paper could do nothing about Magnox. That is water under the bridge. The last of those will be in commission in 12 months, and we cannot do anything about it.

The coal industry knows, if its main customers run away from it, that it should be planning beyond the mid-1970s, and not take it from the Minister that it will have what he once said would be a rosy future. When I mentioned that on 18th July, he said that it was merely a good future. But how can the industry have a future with the C.E.G.B. whose needs will give us nothing like the demand we need in the mid-1970s? The coal industry wants a shot of confidence—that, if the industry can match its competitiveness within the targets generally laid down between 3d. and 4d. a pound delivered to the C.E.G.B., it is in the market for new power stations. But I ask the Minister how there can be a future without a conventional station planned beyond 1971. Drax is the last conventionally planned coal-fired station.

Yet, when on 5th March I asked the Minister to set out which coal-fired power station he estimated would produce the cheapest electricity in the years 1968 to 1971, and

> "what will be the cost per unit sent out; and if he will give similar information about the cheapest nuclear power in those years."

my hon. Friend replied that Ratcliffe-on-Soar, a coal-fired station now in commission, whose costs for coal purposes are anyway unlikely to increase, will be sending out electricity at a cost per unit of 0·54d. up to 1971. Even the much vaunted Dungeness B will not be doing anything like that. Its cost per unit will be 0·57d. per unit, which does not include a royalty of 0·014d. It will not be competitive and this is in the new generation of A.G.R.s, the second planned nuclear power programme.

Even up to 1972, despite forecasts to the contrary as recent as 1965, coal will still be the best fuel for power stations. It will still be competitive on a cost per unit basis. The nuclear power station sites are still to go on stream and the way costs are increasing makes one doubt whether the forecast of 0.57d. will prove correct. I should not be surprised to see an increase.

Mr. Arthur Palmer (Bristol Central): The hon. Member for Horsham (Mr.

Hordern) was right to draw attention to the importance of nuclear power to the economy of this country, and to the economy of any advanced industrial country, but I cannot follow the logic of his argument that for that reason the coal industry should fade almost into extinction. In the United States, where nuclear power has been strongly developed, 60 per cent. of the orders for new power stations are for nuclear-fired stations but the coal industry is still flourishing. There is no reason why a similar situation cannot exist here. To my mind there is no contradiction in advocating a strong nuclear programme, and at the same time recognising that there is room for a healthy and viable coal industry.

I asked the Minister a fortnight ago whether the White Paper still represented the policy of the Government: he said that it did and seemed rather surprised at the question. This is not the way to treat the House. It is not taking seriously all the hopes which were once held out. I look forward to a whole day's debate on fuel policy, in the full light of day, on the "day shift". I hope that my hon. Friend when he replies will avoid the obscurantist tactics which have been hitherto practised by the Government Front Bench. I hope he will tell us that he is anxious for all aspects of fuel policy to be fully debated.

Those of us who, as Members of the Select Committee on Science and Technology, examined the methods of relative fuel costing in the Ministry were not satisfied that it has the staff or resources for accurate work. We therefore suggested—though I do not want to anticipate any debate on the Select Committee's Report—an independent assessment outside the Ministry of fuel costs right across the board. This is badly needed. Few of us are satisfied, on recent performance, that the Ministry can do it accurately or objectively.

An adequate energy policy is basic to the needs of the economy and I agree with the hon. Member for Horsham (Mr. Hordern) that the continuing need of this country is for an abundant supply of cheap energy.

Mr. McGuire: I hope that my hon. Friend will not fall too much in love with the remarks of the hon. Member for Horsham because our present energy arrangements are adding no more than $1\frac{1}{4}$ per cent. at the very most to our exports. Generally speaking, energy prices in this country are, for the majority of industries, low, representing only about 2 per cent. of total costs.

Mr. Palmer: That is true, but it is equally true that if British industry is to be flourishing and competitive it must be based on abundant supplies of cheap energy. Given the right opportunities, I believe that it is possible to have a mixed fuel economy which is efficient and viable; although the main advance is bound to be towards nuclear energy, which is the fuel technology of the future. But there is still plenty of room for coal and oil on a proper competitive basis for a long time to come. But to achieve this we must have for the first time, a more accurate estimate of true costs.

The Parliamentary Secretary to the Ministry of Power (Mr. Reginald Freeson): By the leave of the House, I will comment on some of the matters that have been raised.

It is unfortunate that so much of the public discussion which followed the publication of the Fuel Policy White Paper was directed to the decline in coal, instead of to the technologically exciting fuel economy of the 1970s and what this could mean to our industries and urban living conditions in the future. I stress—I do so not for the first time—that coal has an important part to play. These are not chosen words but what the Ministry and the Government believe to be the case.

However, we should be looking at the positive side of a technologically advanced, highly mechanised industry, employing highly skilled technicians. The introduction of new and pioneering techniques of coal mining and of the reorganisation of the coal industry have led to a 50 per cent. rise in productivity in 10 years. The rise is still going on and there is considerable scope for further dramatic increases. Technologically, the British coal industry is among the most advanced in the world and we have plenty of visitors coming here, from East and West, to study our methods.

Increasing mechanisation in the coal industry means that fewer miners are required for any given level of coal production. Even if the present level were to be maintained in the years ahead there would be a major reduction in the industry's manpower. But in the two years preceding the White Paper, coal demand has fallen at more than 10 million tons a year. On the basis of the Government's policy as outlined in the White Paper the fall will now be only at an average of 5½ million tons a year between 1967, the year of the White Paper, and 1975.

Nor is the forecast average annual fall in mining manpower of 35,000 up to March, 1971, much in excess of the average of 30,000 a year in the past 10 years. Allowing for natural wastage and the movement from closing collieries to those with a future, the number of redundancies will, as in the past, be a small part of the total manpower reduction.

I make these comparisons simply to keep things in perspective and not by any means in a spirit of complacency. No one concerning himself with the industry can be complacent. Indeed, the measures taken by the Ministry of Power and more particularly by other Departments to help the older redundant miner, to help the industry itself with its social costs and to give special help to the areas specially hard hit by colliery closures, demonstrate our concern to reshape the industry in a civilised and economically sensible manner.

Oil as a fuel is cheap and convenient, but 40 per cent. of its use is for purposes such as transport for which there is no practical substitute at present. Yet in this country we are less dependent on it than continental countries where it represents 50 per cent. of total energy use, or in Japan, where it represents 60 per cent.—and those countries are expecting oil's share in their total energy use to increase as compared with our predictions in the White Paper. Here, together with the advent of nuclear and natural gas, we expect oil to remain fairly stable. Our anxiety to keep down direct balance of payments costs and the security disadvantages of oil must not lead us into so adding to the costs of our energy that we jeopardise our competitive standing *vis-à-vis* other countries. There is also the generally important point that, in growing into a major source of energy, the oil industry has contributed greatly to technological progress and has become the basis of quite new and extremely important industries, for example petrochemicals.

Natural gas will undoubtedly produce great resource savings for this country, particularly with the introduction of natural gas into the premium markets, those markets which the industry already supplies or into which it could readily expand over the years, and where its introduction will displace oil rather than coal. There will be some bulk sales to industrial users to assist rapid absorption of what is available from the North Sea and for load balancing.

The ultimate scale and pattern of use of natural gas cannot be settled until we have more knowledge of what the North Sea holds and more experience about how we can encroach into different markets.

Nuclear power presents another case where, on account of the major capital costs involved in nuclear stations, careful cost studies have been made to assess the likely balance of advantage or disadvantage entailed by the investment. It could not be otherwise with these huge expenditures. We are dealing here with stations which will come into commission from about 1974 onwards. There are bound to be uncertainties, looking so far ahead, as in other aspects of fuel policy; but, without undue optimism or undue caution, and remembering that the stations coming into service in the early 1970s are expected to produce cheaper electricity than even the most favourably sited conventional stations, there are grounds for confidence that the stations in the middle and later 1970s will have even lower costs. Cost estimates by the Ministry for that part of the second nuclear power programme which is still uncommitted suggest that the internal rate of return on extra investment involved will be about 13 per cent.; but these are not something done once and for all.

There is a constant watch kept on this because, inevitably, there are changes which come forward from time to time and will do so in the years ahead. The evidence available to us points towards greater economy with the introduction of power from this source. The Government envisage the completion of the second programme of 8,000 megawatts of nuclear plant coming into service between 1970 and 1975. This does not, however, prejudge the choice of fuel for individual power station projects coming forward as new capacity is required. Each will be considered on its merits. This applies to the C.E.G.B.'s proposal for a new nuclear station at Hartlepool which has again been referred to in the debate.

What the White Paper did was to settle the principles for making and dealing with new power station proposals such as this. It established first that the electricity generating boards should base their choice of fuel for power stations on an economic assessment of the method of generation which would enable them to supply electricity at the lowest system cost. It would, however, be for the Government, in deciding whether to give consent for new stations, to take into account wider economic considerations such as were set out in the White Paper and dealt with in questions and answers and debates since the White Paper was published.

Meanwhile, the electricity industry has many new coal-fired stations in existence or under construction. As the White Paper shows, no less than three-quarters of the capacity is coal fired and 25,000 megawatts out of a total of 35,000 megawatts of new capacity under construction is coal-fired. One has to get the right all-round balance on the basis of the soundest possible study of the industries in relation to each other and in relation to the prospective demand for energy. This the White Paper achieves.

We are dealing with market forces. The Coal Industry Act, passed last year, provides for over £130 million of extra help to coal, which is a sizeable sum by any standards and particularly at a time of general economic restraint. This is plain and sound economic sense and social justice. We are going to make the most, in terms of cheap, adequate and secure supplies of energy, of all the fuel resources available to us. This means that the newer fuels—natural gas and nuclear power—will take their proper places in addition to coal and oil.

Although I mention the last point briefly I consider it to be vitally important. We will continue inside the Department to develop the new study techniques in this field which were initiated during the 18 months' work leading up to the publication of the White Paper. This is as vital for sound economic planning as the White Paper itself. As is implicit in the White Paper, this will continue. The White Paper is not a once-and-for-all exercise. We will continue to study what changes can be considered from time to time.

Culham Laboratory

The following extracts are taken from the debate on Culham Laboratory which took place in the House of Commons on 26th March, 1968.

Mr. Airey Neave (Abingdon): This short debate arises out of the—in my view, unsatisfactory—decision of the Minister of Technology in July, 1967, to reduce the work of the Culham Laboratory of the Atomic Energy Authority at Culham.

Since 1962 this laboratory has been internationally famous for fusion research and its main object is a nuclear fusion power reactor. This involves important experiments with plasmas, and also studies of possible fusion power stations and their costs. It seems possible, from present experience, that such a station would be competitive with future fast fission reactors, over, perhaps, a fairly long period of time, though the latter are now at the prototype stage.

Fusion reactors have many advantages. They do not produce plutonium, and there is a negligible problem of radioactive waste. I do not want to go into the wider question of fusion power tonight, but there are great possibilities in this field.

For this reason it was an unpleasant shock to the staff and to many scientists in other branches when the Minister announced that a working party of the Atomic Energy Authority had advised him to reduce the programme over the next five years by 10 per cent. per annum. He has so far obstinately refused to publish the working party's report. The result is that no one outside the working party and those connected with the Authority and the Minister's Department knows what the scientific or budgetary reasons were for this decision. This seems to be extremely wrong, because the issues involved are major ones. The result would be that the £4 million or so spent at present each year on this laboratory will be cut by 50 per cent. in five years' time.

I should also mention that the Select Committee on Science and Technology, under the Chairmanship of the hon. Member for Bristol, Central (Mr. Palmer), went to the laboratory yesterday and is making certain studies in connection with its future. No doubt it will report to the House on it. For that reason, I will not raise the major matters of policy which it may have to consider. Instead, I shall stick to the point of my concern, which is the position of the staff who are leaving at the moment at the rate of about 10 per cent. per annum.

This is a matter about which the Institute of Professional Civil Servants gave evidence to the Select Committee in June, 1967. After the Minister made his announcement in July, I wrote to him asking what plans he possessed for the redeployment of the staff and what was being done about the resources which were being released as a result of this run-down of the laboratory. The Minister replied on 20th September, saying:

> "These are matters which will be worked out between the Authority and my Ministry."

That was not a helpful reply to a detailed series of questions about what was to happen to the staff.

I want to put one or two points to the Minister about the redeployment of the staff. First of all, it does not appear that the decision about Culham was part of any general plan for the redeployment of the staff of the Atomic Energy Authority. I do not know why the decision was made in isolation. It is very unsatisfactory that it has been made in isolation, because, as members of the Select Committee saw yesterday, Culham has a very wide range of skills in such matters as astro-physics, computers, plasma physics, and so on, and those skills could be exploited in activities outside that of fusion research. Are there plans for dealing with this point?

My next question relates to the interchange of staff between the laboratory, industry and the universities. This will be very important, because of the high quality of staff which has been working at Culham, and it would not be possible to bring it about without completely new salary scales and, above all, a settlement of the burning question of transferability of pensions. I have raised this matter several times in the House with the former Minister, Mr. Frank Cousins, and with the present Minister. Progress in the matter must be made if there is to be a satisfactory redeployment of staff into perhaps more productive fields of activity, assuming that that is the Government's intention.

Speaking as a director of a company which is engaged in the nuclear power programme, I know the necessity of keeping a good research team together, and it is essential that the very high quality of the Culham staff should be maintained. The position is not at all satisfactory at the moment. At present, Culham has 245 professional scientists and engineers and 188 scientific and technical auxiliaries, out of a total staff of 782. The apparent intention of the Minister is to run down the professional staff to 132 by 1972.

I repeat that I do not know the reasons for this decision. It is a very important national decision. I have a large number of constituents involved, and many of them are scientists of international repute. They do not know why this has been done. I think that this is a case where there should be far more public discussion of the reasons which have caused the Government to make this decision. I quite understand that any staff matters must be of a confidential nature, but surely it is possible to arrange for some kind of publication of the scientific reasons.

I do not like the decision, because it is competely negative. It does not seem to be part of any organised plan for the future of the Atomic Energy Authority staff as a whole. Speaking for myself, in the presence of the Chairman of the Select Committee, I hope that the Committee will inquire into the question of publication of the Report.

It is not as though we were spending an exceptional amount on fusion compared with other countries. We are responsible for 10 per cent. of the world effort on nuclear fusion at the present time, the Soviet Union 40 per cent., the United States 30 per cent., West Germany 10 per cent. and 8 per cent. in France. For reasons which the Minister refuses to publish, we are proposing to reduce our total contribution to world effort to 5 per cent. We cannot maintain a leading rôle in fusion research if this is done. One of the more remarkable things that the Minister said in July when he made his statement was that the Authority had assured him that we would be able to maintain a leading rôle in fusion research. I do not see how this can be done if we reduce proportionately the amount we contribute to world effort while at the same time Russia, France, Japan and America are increasing their contribution to this possible new source of power.

I have not been able to go into the broader question which the Select Committee will no doubt wish to consider. It is not right that I should at this time.

The staff were not consulted about this decision. The working party, according to the Minister, went there for only one day, and there was no consultation with the staff side. If the working party spent only one day there, it is in no better position than the Select Committee which spent a whole day there yesterday and went round the establishment. I do not feel that the matter has been handled satisfactorily, and I am worried that no alternative plan seems to have been prepared for the future of the staff.

What worries me is that no alternative plan seems to have been prepared to make use of the resources of Culham outside the fusion range. Plenty of skills abound there. It is a place of great international reputation. The Government should reconsider their decision.

The Joint Parliamentary Secretary to the Ministry of Technology (Dr. Jeremy Bray): In 1966 the Atomic Energy Authority set up this internal working party to look at the future programme of plasma physics and fusion research centered at Culham. The working party consisted of a highly competent body of experts. It examined the problems of providing cheap power by means of fusion and concluded that these problems were more difficult than was thought when the Culham Laboratory was set up in 1960.

The United Kingdom has spent about £40 million on plasma physics and research. Even so, we are not in sight of a fusion reactor capable of providing cheap electricity. Given the prospect of cheap electricity promised by other kinds of nuclear reactor—the fast breeder and the A.G.R. programme—it was logical to conclude that a substantial reduction should be made in the programme of research on plasma and fusion. One day fusion may come into its own, but for the time being it is right to limit our efforts on it. The United States, too, has recognised that the perspectives have lengthened, and it has rephased its objectives to emphasise the scientific nature of its fusion programme.

After considering the report of the working party the Atomic Energy Authority advised the Minister that its effort on this research should be reduced by about 50 per cent. over the next five years. I may say that there is a powerful body of opinion that the work should have been closed down altogether. This conclusion that the work should be run down to 50 per cent. was endorsed by the Minister, and a statement was made in both Houses on 26th July, 1967.

The hon. Gentleman must appreciate that there is a difference between what can be said in a published document, and what can be said in an internal working document of a public authority.

My right hon. Friend the Minister of Technology made a statement regarding the run-down of work at Culham on 26th July, 1967. Since that date nothing has changed and no evidence has come to light to justify reconsideration of the conclusion reached. I appreciate the hon. Member's wholly legitimate and most important concern for the staff and for his constituents, many of whom work at Culham. The position at the end of February was that the professional staff at Culham working on fusion was 245, which represented a reduction of 15 from last July. This is just about the planned rate of run-down.

The rate of staff turnover has increased in the past eight months. There was bound to be some reaction of this sort to the very difficult decision which had to be made last summer, but there will continue to be a substantial and challenging programme, particularly on closed systems, plasma production, computing and technological studies, providing a wide interest for those involved. The vitality of the establishment is being renewed and readers of the technical Press will have seen the figures regarding efforts which are being maintained to get the high-quality young staff to Culham working in this area. The parts of the programme which are being reduced are on open-ended systems, diagnostic techniques and basic physics.

As for future work at Culham, the development of fusion power is recognised world wide as a long-term programme. The reduced effort at Culham will still enable us to keep in touch with international effort in this field and provide a basis for expansion later if changed circumstances make that desirable. The volume of the work will be quite sufficient to provide that base for development whenever it is found to be needed.

One of the functions of the Ministry of

Technology is to foster major technological developments and to supply advanced technical information and research services for British industry. It sometimes happens that the required expertise and facilities for a particular project are available only in an Authority establishment, perhaps Culham, Harwell or elsewhere. Under Section 4 of the Science and Technology Act, 1965, my right hon. Friend is able to require the Authority to undertake scientific research in the non-nuclear field. Under this Section, work has already been directed to Culham, including some work on the large astronomical satellite for the European Space Research Organisation. The hon. Gentleman mentioned work being transferred to the Science Research Council. This is work on solar and stellar ultraviolet spectroscopy. It involves about 30 professional staff, and it will show a further reduction in the number of staff working on plasma physics at the laboratory when the transfer has taken effect.

There is also the development of the COTAN computing system, which is used in KDF9 computers, a number of which are installed in universities in a configuration similar to that at Culham. This work is being paid for by the Computer Board. It is a very good example of the way practical skills developed at Culham are being transferred into areas where they can be effectively used in the universities. It is a small-scale effort, but it is being done economically and efficiently, as it should be and as one expects from the Authority. It is none the less an extremely useful piece of work.

Although Section 4 work will continue to be authorised where appropriate, it must be made abundantly clear that such work will prove to be of real economic benefit to the nation, and there can be no question of authorising Section 4 work simply to absorb surplus staff. There can, therefore, be a question for the staff as to what they themselves wish to do. It is possible to arrange secondments to industry or to universities. Indeed, the Authority is anxious to take whatever means are possible to spread knowledge of the work which it has done to appropriate users.

Mr. Neave: Will the hon. Gentleman deal with the question of transferability of pensions?

Dr. Bray: I have examined this matter closely. I asked for the actual pension scheme of the Atomic Energy Authority, and it is a question to which I have given a great deal of thought.

It has been made clear to the staff that for scientific staff over the age of 30 there will be no difficulty about preserving their pension rights, where that is appropriate, about transferring their pensions rights, about single premium annuity schemes, or whatever is the choice of the individual concerned. Whether the pension rights can be put into an industrial scheme depends on how that industrial scheme is drafted. It is not a matter for the Atomic Energy Authority but the industry. If an Atomic Energy Authority scientist goes into a firm which does not offer this facility then his pension rights with the Authority can be preserved and when he reaches retirement age he will receive the value he has earned in the Atomic Energy Authority's pension scheme in addition to any pension he may have later earned in his new job.

I should be happy to look at any particular cases and particular kinds of career services on which problems may arise. If there are difficulties let us look at them. I think that the provisions here are highly favourable by comparison with those available virtually anywhere else. They are a great deal more favourable than those available anywhere else in the public service, and in the Civil Service in particular.

With this background of valuable work at Culham to keep people there and undoubtedly the ready demand for their work in employment elsewhere, I do not think that it can be said that there is any major problem of redeployment at Culham. If the Select Committee has observations to make on this matter, clearly they will be a matter of great interest to the Minister and we look forward to receiving them.

Meanwhile, of course, the work on the future of the nuclear engineering industry goes ahead. The hon. Member asked whether the redeployment at Culham was part of a larger pattern in the Authority as a whole. As the hon. Member knows, there are discussions under way about the future of nuclear engineering and the contribution that the Authority can make. This is a matter which has to be settled as part of the planning of the future work of the Authority, with Culham fitting into the pattern.

300 GeV accelerator

The following extracts are taken from the debate on the 300 GeV accelerator which took place in the House of Commons on 26th March, 1968.

SIR HARRY LEGGE-BOURKE (Isle of Ely): If I had to sum up what I have to say tonight, I could do it in two words—"Matter matters". We are dealing with the smallest known particles of matter. We are at the very far fringes of knowledge. We are probing into the future. We are now confronted with a situation in which an exercise in which we have been proud to participate through C.E.R.N. is in danger of being severely interrupted unless a far more powerful accelerator than C.E.R.N. yet possesses, or any nation possesses, is provided, and it will take a number of years to build it. Therefore a decision has to be taken.

Seldom have we been better equipped with knowledge of the most expert kind we could possibly wish for than in the evidence in this Report. Their Lordships have already had a very important debate on this matter on 28th February this year in which what I might describe as the Olympians uttered. A number of them suggested that this is not the sort of expenditure we should contemplate at a time like this, yet others still believe that the search for the knowledge of structure of matter is essential and that we should go on probing as we have done.

We have already discovered a third natural force, in addition to gravity and electro-magnetism, in the shape of nuclear force. We may be on the brink of finding yet a fourth. Who knows?

We may well find that the knowledge which we are using today, especially in microbiology and so forth, already owes something to knowledge acquired at C.E.R.N. We must be very careful before we say, or encourage the contributing nations of C.E.R.N. to say, "Let us pause". The Soviet Union will continue this work. So will the United States. The case is made unassailably in the Report that we cannot expect to keep in the field as we ought in the United Kingdom by relying on what the Americans or the Soviet Union are doing. This is undisputed.

But it is clear from the Report also that, while the distinguished scientists reporting to us believe that the exercise ought to go on, they believe that it ought to go on only if we can persuade enough countries to co-operate in it and if there are certain important safeguards. One of the most important safeguards, which everyone wants, is that, if the exercise is to continue, other disciplines must not suffer. There is an important minority Report submitted by Professor Sir Ewart Jones and a colleague. I had the opportunity at Oxford a week or so ago to have a conversation with him on the matter. Sir Ewart Jones is a distinguished chemist, and I can well understand chemists and other scientists feeling that nuclear physics is already getting more than its fair share of public expenditure. At more than 40 per cent today, it is a very big share.

There are two ways of solving that problem. One would be to reduce the amount devoted to nuclear physics. But there is another way. If there is—as there must be—a limit to Government expenditure, let us switch some of the expenditure on the technology front to the basic science front, thus keeping the share of nuclear physics at roughly the same figure as today but making it a smaller proportion of a larger total.

My purpose in raising this matter tonight is to beg the Government, before they come to a final decision, seriously to reconsider whether, important though the application of technology in industry is, they are already in danger of starving some of the basic research which is essential to our long-term future. In much that we do today we are living on the future indebtedness of our children and grandchildren. I have no doubt that we shall not see the full benefit of the work which I am now discussing, but it will be of the greatest importance to them.

So much for the general, international scene. There is only one other question I want to raise, namely, where should the new accelerator be if it is decided to proceed with it? The United Kingdom has put forward a site in Norfolk which I know well. I have had the advantage of seeing the proposals put forward by the Government to C.E.R.N. and I am grateful to the Secretary of State's predecessor for the opportunity of doing so. The proposals were revised as late as December 1966. I have seen that a great deal of trouble has been taken to answer the questions that C.E.R.N. asked.

The case is made in the Report for saying that if one becomes the host country for an exercise of this sort it militates to one's advantage economically. On the other hand, there is the special report from the economists in this document in which the economists do not quite agree.

I want to refer back to a Question I put to the Ministry of Technology on 11th April, 1967, when we were concerned about the number of orders which British firms have obtained from C.E.R.N. It is rather shocking to know that only 4·5 per cent of C.E.R.N.'s contracts have been placed with British firms, whereas the British contribution to C.E.R.N. is 23 per cent. I strongly suspect that this is a case of reluctance on the part of British firms, which one notices wherever one goes, to do what they call a "one-off" exercise. There is always the suspicion that it will be an expensive exercise for which they will not be fully recouped. It being a Government contract or a quasi-Government contract it may be rescinded in the middle, and they feel that it is not worth a candle.

If the decision of C.E.R.N. is to go ahead with this—and I hope that it will be—I hope that we have a fair chance of becoming the host country. It will be to our economic advantage and I believe that we will be able to revise the figures which I have quoted and see British firms taking a bigger interest in this matter.

Mr. Eric Lubbock (Orpington): I am sorry to have to disagree with the hon. Member for Isle of Ely (Sir H. Legge-Bourke), because generally speaking we think very much alike on scientific subjects. But I at least heartily endorse his statement that we have the advice of the Council for Scientific Policy in a very complete and detailed form, such as we have never had on a major decision affecting the future of science policy in this country.

I disagree with the hon. Member for Isle of Ely largely on the financial aspects of the proposal, which he did not refer to in great detail. It is worth looking at some of the figures for the expenditure by C.E.R.N., now and in contemplation, on the 28 GeV accelerator already in operation and see how they compare with the estimates made some time ago. In the table of figures on page 13 of the White Paper, we find the cost increased from 174·9 million Swiss francs in 1967 progressively to 226·4 million Swiss francs in 1970, representing £21·8 million at the present exchange rate. Those figures do not include the so-called intersecting storage rings which I now understand it is agreed by the parties to C.E.R.N. will come into operation some time during the early 1970s.

The Council for Scientific Policy has some very interesting things to say in commenting on those figures. It points out that

> ". . . the capital expenditure of the laboratory continued after the machine came into operation, in December, 1959 (partly because of improvements found possible after the initial operation and partly because this item includes capital items of experimental equipments) at a level comparable with that reached during the construction phase. Secondly, the operation and personnel costs continued to rise thereafter."

When the machine was first proposed in 1955 the total running cost was estimated at £720,000 a year, whereas the actual figure is about 30 times as large. The increase can be accounted for partly by the experimental equipment added on after the construction of the accelerator had been completed, such as the bubble chambers which had not even been thought of in 1953. Even now, I understand that the European Committee for Future Accelerators is asking for a 200-ton liquid hydrogen chamber which would come into operation in about 1977, the cost of which can be judged from the experience of a pilot model one-tenth the size, which costs £8 million. Then there are the intersecting storage rings I have mentioned on which expenditure is expected to rise to about 80 million Swiss francs annually. I understand that the United Kingdom has already agreed to allow this to go ahead.

Mr. Tam Dalyell (West Lothian): Is the hon. Gentleman sure that in giving these figures he is comparing like with like?

Mr. Lubbock: No, I am not entirely comparing like with like. What I imagine that the hon. Gentleman means is that when the project was first put forward in 1953 a machine as large as 28 GeV was not envisaged. It was not as closely defined as that. An increase in costs to about 30 times the original figure is still worthy of mention because we do not know the final design of the 300 GeV project and that it will not be altered in such a way as to make it vastly more expensive. Therefore, this historical experience is relevant and should be considered most carefully when we are looking at the estimated cost of the 300 GeV machine.

Paragraph 15 of the Council's Report says:

> "It is quite possible that new major experimental tools will be invented during the construction period of the 300 GeV machine and for this and other reasons we consider that escalation in the costs of experiments with this machine is the most serious factor."

We see that cost estimates show that the British share would be about £37 million, even before the accelerator begins to operate in 1977, and without taking into account the effects of devaluation, and before making any allowance for the type of additional equipment which might be found desirable later.

The Secretary of State, in his introduction to Cmd. 3503, says that the cost in sterling would not rise by the whole amount of devaluation since our share would be reassessed in due course, presumably in accordance with the Gross National Product of the member nations of C.E.R.N. I would like the Minister of State to say what estimate she has made, now that devaluation has been with us for some months of the final total which will replace the £7 million figure as our share of the production costs before the accelerator comes into operation.

The other factor which could make a big difference to the British share is the attitude of other nations like West Germany which has been lukewarm towards the project and may decide not to participate at all. I understand that the West Germans had suggested postponing a decision until it is possible to assess more fully the opportunities provided by the recent agreement between C.E.R.N. and the Soviet Union about collaboration on the 70 GeV Serpukhov machine. If Germany dropped out, our share of the project would have to be increased accordingly, and it would be much more than the 25 per cent indicated in the Report.

It is perfectly true, as the Council for Scientific Policy says, that the accelerator is not like a new aircraft project, where errors in forward estimating are sometimes 100 per cent. Our experience on NINA and NIMROD, built in this country, shows that escalation—to use a word I do not like, but which is used all through the Report—is something of the order of 25 per cent in real terms; but there is no room at all for an increase, let alone for an additional facility, such as the intersecting storage rings, for which provision is already made in the 300 GeV Accelerator project, for acquiring additional land over and above what is required for the accelerator itself.

The Member for the Isle of Ely said that he was concerned that this project should not have an effect on the rest of the science budget. If the S.R.C. Vote is allowed to grow by 9 per cent per annum up to 1973-74, and 8 per cent thereafter, the project can just be accommodated within the estimates made. The question must arise as to whether these rates of growth can be accommodated almost indefinitely, bearing in mind that the competing claims on science Vote expenditure will have to be accommodated, and the certainty that the figures mean an ever-increasing share of national resources going to the S.R.C. in general and to nuclear physics in particular. If one takes it to the extreme if Gross National Product grows by 3 per cent. and the S.R.C. Vote by 9 per cent., by the end of the century the whole nation would have to be engaged on research and development, and half the population would have to be nuclear physicists. Obviously, there must be some adjustment in the figures before we get to that stage. If there is any increase in the estimates for the 300 GeV accelerator the position is even worse.

The Council points out that if there were only a 20 per cent. rise in costs it would put up our share by £1·2 million a year, an amount comparable with the whole of the budget devoted by the Council to chemistry at the moment. No wonder the Council only recommends going ahead with certain qualifications. It wants an assurance that the science votes as a whole will go up by 9 per cent. a year for the next ten years. If this did happen, it would bring the amount up to no less than £2,270 million in 1977-78, if my arithmetic is correct.

I doubt whether this kind of undertaking could be expected from any Secretary of State. How can we say that the growth in our national product and in the amount we are prepared to devote to science over the next ten years will be sufficient to justify guaranteeing the Council an increase in its annual budget of 9 per cent. a year? It is a growth rate that many workers would dearly like to ask their employers for, but it is not one which it is reasonable to expect the Secretary of State to guarantee. He could not guarantee a figure of this magnitude.

Then, the Council wants limitation of the construction and operation costs of the machines and ancillary equipment by prior international agreement. Whatever may be put in writing beforehand, experience shows that once one reaches the point of no return beyond which one has already spent so much money that it is too late to back out it will be the decision to go ahead, even though if one had seen expenditure of this magnitude coming in the first place one would not have made the decision.

I think I have said enough to show that it is clear that the scientific community as a whole may not approve the advice given by the Council for Scientific Policy and that many scientists in other disciplines are desperately anxious about the effect that the 300 GeV accelerator might have on their own budgets. In its second Report, the Council says of science policy:

> "In this sense the rest of science is at a disadvantage, in that it does not yet need facilities on this scale and no way has been found to plan so far ahead on programmes composed of smaller projects."

There is the difficulty that we can see fairly clearly how much it would cost us to go ahead with the accelerator but cannot tell how much will be required by all the other disciplines as far ahead as 1981, to which the figures in the Report extend. Nevertheless, the Council foresees a rapid growth in other sectors, notably oceanography, many aspects of biology and the synthesising of complex organic substances. Is it not paradoxical therefore, for the Council to accept a significant increase in the proportion of resources going to nuclear physics during the early years of rapid growth in construction costs of the 300 GeV machine?

The next proviso made by the Council is that the commitment upon operations and equipment costs should be deferred until construction costs are clearly defined. This is an impossibility. According to *Nature* of 23rd March, the U.K. delegates at the 37th meeting of the Council of C.E.R.N. held the week before last:

> ". . . expressed itself completely satisfied with the answers given on design, cost, management and collaboration and said that there was no reason why these issues should be reopened."

The same article then went on to say that countries would have to commit themselves to the project before they knew where it was to be built. Yet C.E.R.N. has advised that the costs could vary by 5 per cent. or more, due to variations in the civil engineering costs, according to the site selected.

This brings me to the question of whether the accelerator should be located in the U.K., if it is to be built. If the site offered at Mundford in the U.K. is chosen it would be a mixed blessing. Although our balance of payments would be improved, we would be responsible as host nation for the site and infrastructure costs, including houses, roads, hospitals, schools and 300 megawatts of electrical power and so on. To repeat the words of the Report. None of these costs are included in the figures that I have quoted, and it is not clear how they would be financed if we succeeded in our bid to have the accelerator on U.K. soil. Bearing this in mind, it is difficult to see how that particular condition of the Council could be fulfilled.

Its last condition was that any increase in costs during construction should be met by corresponding economies in the nuclear physics budget as a whole, by cutting out something else. This condition indicates a lack of confidence by the Council in the estimates put forward, which is probably only too well founded. Secondly, it was said that it would be easy enough for the Secretary of State or the Nuclear Physics Board to agree with the best of intentions that they would allow these cuts, so as to keep the nuclear physics budget within an agreed percentage of the total S.R.C. Votes, and then, when the time comes, to find that there are perfectly good reasons for maintaining the whole of the nuclear physics sector in the style to which it has become accustomed.

When we examine the advantages of this project—and the hon. Gentleman has had little to say on this except that we could not afford to remain out of an advancing area of knowledge with such exciting implications—we find that the arguments in favour of it are extremely flimsy. The Report spoke of the:

> ". . . extreme scientific interest and importance of the results and the influence on other branches of physics."

When one looks at this in practical detail one finds that a very small number of Ph.D. graduates who have been engaged on the 28 GeV accelerator ever go into industry. It is something like three or four. We find that the benefit from the experience of the 500 professional staff who work at C.E.R.N. never comes back to the industry again. Only six a year on average go from C.E.R.N. to the whole of European industry in any one year. The hon. Member said there had been practically no work for British industry in the construction of ancillary equipment of the GeV accelerator.

Then there are the intangibles and general political benefits of participating in a European project. These ought to be calculated to appeal to me as a convinced European, if I felt that there would be any political fall-out from going ahead with them. I cannot really say that I do. I do not believe that our entry into Europe or the warmth with which we are received by the Germans, French or Italians is conditional upon our approval of this idea. It is not pretended in the Report that any direct commercial pay-off will be obtained for a long time, indeed if at all.

Lastly, I come to some alternatives. The first is to opt out altogether from this field. I know the hon. Member for West Lothian (Mr. Dalyell) will accuse me of sacrilege when I say this, but I doubt whether the living standards of anybody in this country who is alive today would suffer one iota if we made that decision. Secondly, we could pursue the idea of a world machine as the next stage beyond the 70 GeV machine at Serpukhov and the 200 GeV machine at Weston, Illinois. According to the Nuclear Physics Board of the S.R.C., it was only after international discussions had made it clear that proposals for a possible world machine of 1,000 GeV were premature that the Americans decided to go ahead with their very large national project. Professor Swann's group itself said that if we ever decide to build a larger machine than the 300 GeV, it would have to be done on a much wider base than collaboration within Europe alone.

The third possibility is to spend much smaller sums of money on a programme aimed at cheaper accelerators. In a footnote to the Working Group's report, the idea of less orthodox designs based on superconducting magnets is dismissed because the magnet development programme "would involve undue delays". Yet such a programme could have very attractive commercial applications in electricity generation, where the technology of conventional accelerators yields practically no commercial fall-out whatsoever.

The fourth suggestion is that we should wait till there has been time to evaluate the potential of collective ion accelerators, which, according to a symposium at Berkeley University in February, hold out the prospect of achieving very high energies at a much lower cost.

Finally, why not wait till we can benefit from the experience of the United States and the Soviet Union of building and operating very large accelerators, benefiting from this experience in the sense that we could construct our own more cheaply? This is what I think the Germans would like Europe to do.

The Minister of State, Department of Education and Science (Mrs. Shirley Williams): I shall endeavour to answer the questions raised and also to deal with the present situation with regard to the 300 GeV accelerator project. I think the first point to make is that the estimated cost of the project following devaluation is now set at £175 million for the cost of construction, with recurrent cost estimated at £30 million per annum. So the estimated cost at present of Britain's contribution would be something like £44 million over the period of eight to nine years which the construction period is expected to take.

Having said that, I think one must then qualify it by saying that C.E.R.N. contributions are based on estimates of gross national product. An estimate of Britain's gross national product as affected by devaluation, in general a reduction of one-sixth, will only be taken into account in the post-1967 period in about four or five years' time. So, with the best will in the world, I cannot be very helpful to the hon. Member for Orpington (Mr. Lubbock) there. However, I would make the point that the effect of devaluation on the gross national product would be balanced out to some extent by any improvement in G.N.P. following devaluation. So it is fair to say that one could perhaps estimate 20 per cent. to 25 per cent. still at the end of the period of construction about which we are speaking.

As the hon. Member for the Isle of Ely said, this would be, as it stands, the largest single project of its kind in the world. There is room, of course, for the American project to grow from the 200 GeV, the present estimated design and energy, to a 400 GeV, which would be its full capacity as at present designed. But, on the immediate basis of that and the Russian project which has been completed, there is no doubt that the European project would be the largest single one by the time at which construction had been completed. Apart from the costs, there will be a fairly heavy manpower requirement of approximately 2,500 in the first instance, rising to a steady level of about 4,000, as far as we know.

No one would question the desirability of the project, all other things being equal, since, as the hon. Member for Isle of Ely said and as my hon. Friend the Member for West Lothian (Mr. Dalyell) repeated, there are possibilities in nuclear physics of a kind that one can only begin to see over the distant horizons and which may well produce eventually a source of energy, the level of which we cannot begin to imagine.

Having said that, in a few moments I will deal with some of the points made by the hon. Member for Orpington in respect of the development of other sciences, the competition that this project will be to other sciences, and the effect on the science budgets of trying to take in this project. However, before that, I want briefly to sum up the present state of the negotiations.

On the original timetable, December was to be the Council meeting at which all those countries who wished to participate and who were members of C.E.R.N. would declare their positions. But, as the hon. Member for Isle of Ely will know, by the December meeting only Austria, Belgium and France, of whom France only has a substantial share of the C.E.R.N. budget, had committed themselves to participation. The other countries had not and, in particular, both West Germany and Britain had reserved their positions.

Several matters came up at this point. As the hon. Member for Orpington pointed out, there were suggestions for a further examination of the design of the project. There were suggestions that the sites should be more closely looked into and, if possible, alternative costs of those sites should be estimated. Although it has not been done in detail, the competition is extremely severe and, although the British project is in the running, it is true to say that there are at least seven other sites, and it would be impossible for me to say that there was a strong chance of the British site being chosen. I wish it were otherwise, but it is only fair to say that it is very much in the balance and that our site is only one of a number being considered by C.E.R.N.

There is then the question of escalation of costs, to which both the Council for Scientific Policy and the Science Research Council paid a good deal of attention in their advice to the Secretary of State. As the hon. Member for Orpington said, in the case of the Council for Scientific Policy, an attempt was made to link any acceptance of the project to what can only be described as very stringent conditions in respect of possible escalation. The Council recognised that possible escalation in a project of this kind which is moving into the advanced areas of science was almost incalculable and might mean that the ultimate costs of both construction and running were very much higher than the present estimates available to us. Nevertheless, as hon. Members have pointed out, the Council finally advised, on balance rather than indisputably, in favour of this country going ahead with its share of the project. It did so on the basis of the maintenance of a 9 per cent. average rate of increase for 10 years in the science budget.

The nearest that I can get in answer to my hon. Friend the Member for West Lothian is that, in 1967-68, the increase in the science budget was 11 per cent. In 1968-69, following various economies, it was 7½ per cent. In 1969-70, which is the latest year for which allocations have so far been made, the estimated figure is 7·8 per cent.

Although it is possible that there may be at least a levelling out or even an improvement in the budget, at the moment the 9 per cent. rate is only just being maintained, and it is difficult to commit oneself clearly to saying that it will be able to be maintained for a further 10 years, granted a rate of increase in scientific expenditure in absolute terms. It is impossible to say exactly what that figure will be, for the straightforward reason that the Council for Scientific Policy has not yet indicated its allocations. Within the present allocations for 1969-70, which is the last year for which allocations have been made, whereas the overall increase in the science budget is 7·8 per cent., the specific increase in the science budget for the Science Research Council, under which nuclear physics comes, is only 5·6 per cent., so it is well below the 9 per cent. to which the C.S.P. referred. Within this total in the present year nuclear physics amounts to 45 per cent. So the note of reservation of the minority report by the two chemists to the S.R.C.s recommendations is not far off the mark in suggesting that something of the order of 40 per cent. would be likely to be required for one branch of nuclear physics over the period of ten years about which we are concerned.

Reference has been made to competing areas of science. Unquestionably the 300 GeV project would maintain and possibly increase the European, and more specifically the British, position in high energy nuclear physics. This cannot be denied. But there is a considerable British lead at least in Europe—and some would say internationally—in other spheres of science. Molecular biology is one which was mentioned by the hon. Member for Orpington (Mr. Lubbock). There are others, such as plasma physics, where it may be said that the British position is very strong.

The difficult question—difficult for the Council to advise upon and difficult for my right hon. Friend to decide—is precisely what the scientific and perhaps technological returns on any given investment in scientific research are likely to be. It may be that a large investment in nuclear physics will prove to have been well made. But there is some feeling in the scientific community that the share that has gone to nuclear physics over the last ten years is rather high as against the requirements of other sciences.

Two other points were raised. The hon. and gallant Gentleman the Member for the Isle of Ely fairly said that the present commercial returns from C.E.R.N. have not been great, and he gave some figures. I should like to mention other figures. In 1966 our contribution to C.E.R.N. came to £3·16 million and our total contracts from C.E.R.N. came to £230,000. This is not the fault entirely of C.E.R.N. It is the case that perhaps because it is in Geneva there is a certain remoteness about industry taking up such contracts.

Finally, as the hon. Member for Orpington pointed out, there are major questions about whether technological breakthroughs are involved in the 300 GeV project. As matters stand the breakthroughs look as though they will be scientific rather than technological. It has been said, I think by the West Germans, that it is worth considering the possibility of whether there might be more advanced technology if one were to consider, for example, the American and Russian projects in slightly more detail. In other words, some people might think that there was some case for a little delay on this.

There has been a question of whether there might be some exchange of research projects between the Serpukhov accelerator, and later the Weston one, the project for intersecting storage rings in C.E.R.N. The hon. Gentleman will be interested to know that this has been put forward specifically. It has our support, and we would like to see forms of co-operation of this kind.

I think that my concluding words to the House must be that no decision has yet been made. There is still a number of outstanding matters to be considered carefully, notably some of the queries which have been raised by other member countries of C.E.R.N. We hope that a decision will be made before long.

Electricity industry review

12th March, 1968

Sir G. Sinclair asked the Minister of Power to what extent allowance is being made for possible changes in the structure of the Atomic Energy Authority in his review of the structure and organisation of the electricity industry.

Mr. Marsh: I am in touch with my right hon. Friend the Minister of Technology, on his consideration of the structure of the nuclear industry and if his conclusions are relevant to my examination of the electricity industry I will, of course, take them into account.

Siting

12th March, 1968

MR. URWIN asked the Minister of Power what is the maximum density of population near to which he will permit a nuclear power station to be built.

Mr. Marsh: I cannot lay down precise figures. Every site must be considered individually. Topographical features as well as population density need to be taken into account. But I do not yet contemplate licensing stations within a mile or two of developments of full urban density.

Power station costs

12th March, 1968

MR. DAVID HOWELL asked the Minister of Power what is his latest estimate of the trend of the overall costs of nuclear and coal-fired power stations, respectively, during the next 10 years.

Mr. Marsh: The latest estimates of the trend over the next 10 years were given in the Reports on Nuclear Power Costs published as Appendices 43 and 44 to the Report from the Select Committee on Science and Technology.

Mr. Howell: Does the Minister accept that those figures suggest that the economic advantages of nuclear stations are bound to be stronger and to increase in the future? Would he reassure the House that those advantages will be taken fully into account in the future fuel policy in both the medium and the long term?

Mr. Marsh: I find myself in the embarrassing position of agreeing with the hon. Gentleman.

Mr. Cronin: Will my right hon. Friend be aware that some of us have grave doubts about the figures available for nuclear power stations? Bearing in mind the already rapidly increasing capital and running costs of power stations, would not it be desirable at least to consider an independent inquiry into the matter?

Mr. Marsh: I appreciate that there is a great deal of controversy on the subject. But the investigation which has taken place so far has involved the A.E.A., the C.E.G.B. and the Department's Chief Scientist's Division. The matter has also been to the Select Committee on Science and Technology. I find it difficult to think of a body which would be independent of all those and be capable of doing the job.

Sir H. Legge-Bourke: Will the right hon. Gentleman bear in mind that the two Appendices to the Select Committee's Report which he mentioned contain the agreement of the Coal Board officials to the general calculations in them? Will he remind Lord Robens that the Coal Board officials agreed?

Mr. Marsh: I am sure that Lord Robens will note what the hon. Gentleman said.

Safety

12th March, 1968

MR. EADIE asked the Minister of Power what is the machinery in his Department for dealing with safety factors in nuclear power stations.

Mr. Marsh: Commercial nuclear power stations require a licence from the Secretary of State for Scotland or myself. Strict conditions, based on the advice of the Nuclear Safety Advisory Committee and the Nuclear Inspectorate, are attached to these licences to ensure that such stations are designed, constructed and operated with proper regard for safety. The installations are systematically inspected to ensure that these conditions are observed.

S.G.H.W.R.

13th March, 1968

MR. ALBERT ROBERTS asked the Minister of Technology what is the cost per unit sent out of electricity supplied to the grid from the steam generating heavy water reactor at the Winfrith Atomic Energy Authority Establishment; and what he estimates will be the cost from a commercial station based on this type of reactor.

Dr. Bray: Although the prototype steam generating heavy water reactor at Winfrith is designed as a power station, it is equipped and operated partly for development purposes. No meaningful figure can, therefore, be given for its generating costs.

The cost of electricity from commercial stations of this type will depend upon many considerations, such as size, customer requirements and rate of interest.

Chapelcross nuclear power station

13th March, 1968

MR. ADAM HUNTER asked the Minister of Technology when he expects the Chapelcross nuclear power station to be fully operating again; and what is likely to be the full cost, both in repairs and lost electricity sales.

Dr. Bray: I am advised by the Atomic Energy Authority that remedial work on No. 2 reactor is making good progress but that it is not possible at this stage to forecast a date by which the reactor will be restarted. It is likely to be some months.

The cost of remedial work to date has been about £100,000 and this sum is expected to increase by about £10,000 per month until the work is completed.

The loss of electricity sales up to the end of February is put at about £0·8 million and additional losses will accrue at about £90,000 per month until the reactor is brought back on power.

Nuclear marine propulsion

18th March, 1968

MR. HOOLEY asked the Minister of Technology if he will approach the Government of the Federal German Republic with a view to working out a joint programme of research and development into nuclear marine propulsion.

Dr. Bray: The nuclear research ship "Otto Hahn", now being fitted out in Germany, is an interesting national project in which EURATOM has participated, and from which some valuable experience will no doubt be obtained.

18th March, 1968

MR. IAN LLOYD asked the Minister of Technology what information he has on the actual and estimated operating costs of nuclear-powered surface vessels; and whether he will revise his estimates of the period within which conventional fuels will retain an advantage.

Dr. Bray: A very large power output is required to make nuclear reactors competitive for marine propulsion. A requirement has not yet been found for the combination of speed and size, either for tankers or container ships, which would require this power output. The matter will be kept under review.

Steam generating heavy water reactors

18th March, 1968

MR. GRESHAM COOKE asked the Minister of Technology what steps are being taken to encourage the export of steam generating heavy water reactors now that the reactor at Winfrith has reached full design power.

Dr. Bray: For the past two years the United Kingdom Atomic Energy Authority have been carrying out a promotion campaign overseas to make foreign buyers aware of the advantages and features of the Steam Generating Heavy Water Reactor, and this effort is now being stepped up following the successful commissioning of the Winfrith prototype.

Commercial designs based on the Winfrith prototype have been completed for a range of sizes and price indications have been submitted to fourteen potential purchasers. A firm bid is under consideration by the Finnish utility Imatran Voima.

Security

18th March, 1968

MR. GRESHAM COOKE asked the Minister of Technology what measures have been taken to improve security at Atomic Energy Authority establishments since the investigation into the damage to steam generating heavy water reactors at Winfrith was completed.

Mr. Benn· The Steam Generating Heavy Water Reactor project is unclassified and military security was not involved in this incident. The Authority have, however, carried out a comprehensive review of the arrangements for protecting unclassified projects at their sites. This has shown that the arrangements are generally satisfactory; but in future special attention will be given to certain aspects of them in cases in which intentional or unintentional damage would have particularly serious consequences.

Aldermaston

18th March, 1968

MR. DALYELL asked the Minister of Technology what steps he has taken to declassify work at the Atomic Weapons Research Establishment at Aldermaston.

Mr. Benn: It has always been the practice at Aldermaston to declassify work as far as possible and to publicise the results extensively. For the past five years a large part of the site has been an unclassified area. Work has been undertaken for civil departments and facilities made available to research workers from universities.

Mr. Dalyell: Is my right hon. Friend satisfied that although it may always be

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Nuclear fuel cycle services in the United Kingdom

This paper, by N. L. Franklin, Deputy Managing Director, Production Group, U.K.A.E.A., was presented originally to a meeting of the Japan Atomic Industrial Forum, Tokyo, 21st February, 1968.

It is not my intention in speaking under this title to catalogue the nuclear fuel cycle services as they exist in the United Kingdom. Instead, I hope to draw to your attention the problems of policy which I see in the establishment of the nuclear fuel services in Britain or, for that matter, in other countries with comparable size and comparable nuclear power programmes. I hope that I shall be able to show that there is a basic conflict between the desire to preserve maximum flexibility and the need for relatively firm planning decisions upon which to base capital investments leading to plants of large capacity.

I should like to divide my lecture into three parts, dealing first with the history of the establishment of the nuclear fuel industry in Great Britain and thereafter with a review of the present situation. From there I shall go on to examine the uncertainties and policy problems in relation to the choice of nuclear power systems and the decisions, particularly decisions to invest in development work or plant, which a fuel cycle contractor must face.

History of the U.K. industry

When it was decided in the early 1950s to establish in the United Kingdom a military programme for the production of materials for nuclear weapons, the knowledge of reactor safety and siting was less sophisticated than is now the case. It was thought that unless particularly remote and inaccessible parts of our country were chosen it would be necessary to restrict the sort of reactors which we could build to ones having a relatively low fuel rating. In the first instance we chose air-cooled reactors employing uranium metal rods clad in aluminium, and to provide for the fuel cycle services for these reactors we constructed batch-type chemical processes for uranium purification and reduction and primitive fuel element manufacturing lines. We also constructed a chemical reprocessing plant involving duplicate lines, the capacity of which we were subsequently able to work up until it could deal with the whole of the military programme resulting from our later Calder Hall and Chapelcross reactors. These reactors were designed after we had studied the possibility of using carbon dioxide under pressure as a closed cycle coolant. They employed ratings of only about $1\frac{1}{2}$ MW per ton of fuel, and we were able to utilise uranium metal bars with a rather simple magnesium alloy can and heat transfer surface. Eight reactors of this type were constructed and although each of them now operates at about 250 MW heat output, the original design target was 180 MW. When the reactors were used for the production of weapons grade plutonium the throughput of fuel was about 1,000 tons per year. In addition, by the time that all eight of the reactors were in operation the first phase of the United Kingdom's nuclear power programme had been decided upon by the Government, and it was clear that the annual requirements for magnox fuel would be as great as 2,500 tons. For this reason the original plant for the production of natural uranium metal fuel elements was scrapped and replaced by one which we had developed and which was based upon continuous processes up to the stage of metal reduction, and upon more sophisticated flow line operation for the production of metal bars and for their canning and inspection. The fuel for the civil reactors was intended to be irradiated for four or five years so that the corresponding increase in demands for capacity for reprocessing irradiated fuel arose at a later date and it was possible to continue to operate the old active chemical reprocessing plant until well into the 1960s. During the years from 1957 onwarbs we undertook a substantial programme of development and, in consepuence, we were able to adopt for our new active chemical plant a different flow sheet using different chemistry and different equipment. We were also able to have centralised instrumentation and those other features which are good practice on chemical plants when labour costs are to be minimised. Thus, by 1964 we had available relatively modern plants for the manufacture and reprocessing of magnox fuel. These plants had been constructed in part to meet the requirements of the United Kingdom's civil nuclear power programme, and the corresponding part of their capital costs and their costs of operation had to be charged against the programme.

Capenhurst

Returning for a moment to the early 1950s, it had been decided that for weapons purposes we should need to manufacture highly enriched uranium-235 and that a diffusion plant should be constructed. This plant was brought into operation as a full enrichment cascade by 1956 and shortly thereafter its capacity was increased by the additon of larger stages. Even at its largest, however, it was a small diffusion plant in comparison with any one of the three American plants, and furthermore at the time of its construction minimum capital investment rather than efficiency was sought so that the unit production costs of the plant were high. In the early 1960s the military demand for enriched uranium from the diffusion plant terminated and we were left with a "first generation" diffusion plant of low capacity and of inefficient design in the sense that its rate of electricity consumption per unit of separative work was high. At that time the United Kingdom Atomic Energy Authority was developing reactors using oxide fuel and enriched uranium, but this type of reactor had not been adopted by the generating boards in the U.K. so that there was no established demand for the services of our diffusion plant. Most of the plant was shut down, a small portion of it was retained in operation so as to preserve the technology and the skilled staff and to manufacture very modest quantities of slightly enriched uranium which we could use for development work. Because we believed that Britain would be adopting enriched uranium reactors, we undertook development work during this period for the modification of the larger stages in our diffusion plant cascade so as substantially to increase their output and electrical efficiency. As a result, when it became clear in 1964 that whatever type of reactor was adopted for the future U.K. nuclear power programme it would use enriched uranium, it was possible to secure Government loans for the modification of the Capenhurst diffusion plant. This modification is being carried out on behalf of the civil nuclear power programme and its costs will be recovered in the product which we sell.

The situation in 1965, therefore, was that the United Kingdom had provided for its civil nuclear power programme factories for the production and reprocessing of magnox fuel, each at a cost of around £15m., and was in the process of spending a further £15m. in order to modify the Capenhurst diffusion plant. It is interesting to consider the relationship between these investments and the domestic nuclear power programme. It can be assumed that the average cost per kilowatt of the magnox reactors in the United Kingdom was approximately £100 and therefore that the programme of 5,000 MW of magnox reactors, the construction of which is now almost complete, would cost approximately £500m. The capital provisions for the magnox fuel cycle were perhaps £30m., together with a few million pounds spent on the development of the processes and perhaps £10m.-£15m. of work in progress largely in the form of natural uranium materials. It is true that the detailed design of magnox fuel element differed from station to station, and the development costs associated with these differences were high. But the fuel was very much standardised in other respects. It could be produced in a common chemical plant and for the most part in common equipment for the assembly of the fuel element itself. It could be decanned, dissolved and processed in a common reprocessing plant. This standardisation resulted in a highly economical fuel cycle even though it was based on reactors which were themselves only marginally competitive with coal-fired stations in the United Kingdom.

Standardised fuel

In the early 1960s when the United Kingdom Atomic Energy Authority believed that the future for thermal reactors lay in the use of enriched uranium fuel, we assumed that there would be a further substantial programme of nuclear power based upon a single type of reactor. We thought that this would be the Advanced Gas-cooled Reactor. And from our previous experience of the cost of developing a variety of different types of magnox fuel element, we set out to standardise the design of fuel for A.G.R. reactors. We were also able to forecast the probable requirements for fuel for initial charges for such reactors, the needs for the manufacture of stainless steel cans and other components, the diffusion plant capacity which would be required and the way in which this would need to expand, and the time at which we should be justified in modifying our active chemical plant in such a way that it could accept enriched oxide fuel clad in stainless steel as a feed material. We set out in fact to repeat the type of planning exercise which we had undertaken six or seven years before for the magnox programme, with the expectation that we should make capital investment as required. It seemed clear at all stages that the economies of scale even for the fuel element lines were such that there was no justification for having more than one manufacturer of oxide fuel. Indeed, this matter was a subject of independent comment both by our customers, the home generating boards, and by the private nuclear industry in the United Kingdom, and neither of them disagreed with our conclusions. The same conclusion was true, in an overwhelming way, of the diffusion plant and the active chemical reprocessing plant at Windscale.

Production levels

It is useful at this stage in my lecture to study in an approximate quantitative way the levels of production which are needed for a programme the size of that in the United Kingdom. It is a fair generalisation to say that this problem is common to most advanced countries who intend to use nuclear power on a substantial scale, but it would not be proper, and I would not wish, to extend the conclusion to the United States where the scale of the power industry and therefore the volume of production required for the nuclear fuel cycle is much greater. The second phase of the nuclear power programme in the United Kingdom is expected to consist of about 8,000 MW of capacity brought to power over a period of six years. The mean fuel rating will be about 5 electrical MW per ton so that the total tonnage of enriched oxide fuel to be manufactured for initial charges during the six years will be about 1,600 tons. To this must be added perhaps 1,200 tons of replacement fuel, giving an annual manufacturing rate rising from 250 tons to 500-600 tons per year over the six-year period. It seems from our investigation and development work that an oxide fuel manufacturing line of 250 tons per year capacity may represent the proper combination of flexibility and low manufacturing costs so that the total fuel requirements of our power programme based on oxide fuel can be met by the use of a single fuel element line, increasing during the currency of the programme to two lines. This certainly does not afford a justification for diversification of fuel manufacture between several industrial enterprises. In the case of the diffusion plant, our needs for 1970 will not exceed 200 tons per annum of separative work output rising by 1975 to perhaps 600 tons per annum. This figure should be compared with the capacity of a single one of the United States diffusion plants which is reportedly about 6,000 tons per annum. It is a task of overwhelming technical difficulty to operate a diffusion plant for an output of only a few hundred tons per year of separative work and on the basis of fairly expensive power and yet produce separative work at a price which is even approximately comparable with the U.S. price scale. It is, of course, true that the incremental cost of manufacture from additional units of capacity as the diffusion plant is expanded may more easily be made comparable with the U.S. price. But even then the disadvantage of the cost of power and of the accounting conventions which have to be met on a plant installed for purely civil purposes, are considerable.

The oxide fuel which will be fed to the advanced gas-cooled reactors of the U.K. power programme will emerge progressively for reprocessing, the expected throughput reaching about 400 tons per year by 1975. This throughput is well within the capacity of a single active chemical plant. Indeed, as a result of development work on our existing plant we expect to have a sufficient amount of spare capacity so that all the oxide fuel after chopping and dissolving will be able to be processed on a campaign basis in the existing facility. Once again, no justification has appeared to us for diversification of reprocessing facilities inside the United Kingdom, where transport distances are not more than a few hundred miles at most.

Reactor choice

At this stage the listener might be led to suppose that I was a firm advocate of rigid planning for nuclear power programmes, of the adoption of a single type of nuclear reactor system and its installation over a substantial period of time, and of centralisation in the control of the facilities for the nuclear fuel cycle. I believe, however, that the situation is changing. It remains true that for countries other than the United States it is difficult to provide the national enrichment requirements with reasonable economy from a single plant, and the idea of constructing several plants would be ludicrous. But in other respects we see before us a number of avenues. In the United Kingdom, for example, the construction of our first large sodium-cooled fast reactor is well advanced and in parallel with it we are building at our Windscale factory, and at a cost of £2m., a facility for the manufacture of plutonium containing fast reactor fuel. We believe that it will be possible to adopt the sodium-cooled fast reactor in the United Kingdom nuclear power programme in the later 1970s, with the first one coming on power in 1975 or 1976, and if this is to be the case it is easily shown that to obtain satisfactory economy in a fast reactor-based power programme a close integration of the fuel cycle is essential. Indeed, a detailed study of this problem indicates that even if fast reactors were to be installed in the U.K. at 1,000 MW per year it would be five or six years before the fast reactor fuel cycle facilities could be sufficiently well deployed to make it possible to achieve the inherently low fuel cycle costs associated with this kind of reactor. On the other hand, and still in the United Kingdom, we see the prospect of the advanced gas-cooled reactor in its present form evolving into a helium-cooled unit utilising coated particle fuel, or possibly a carbon dioxide cooled unit utilising coated particle fuel support in silicon carbide cans. Or again, perhaps the steam generating heavy water reactor will prove to be so successful as to command a significant part of our future nuclear power programme. This is not, of course, a race in which only one horse can be the winner. The fast reactor will almost certainly take its place, but one or conceivably even two thermal reactors might be adopted for use in the U.K. If such an outcome is seriously possible then the assumption that large units of manufacturing capacity can be installed on the basis of firm long term programmes is inevitably brought into question. A careful study of the postulated costs of power from the various more advanced reactors indicates that they differ mostly in the cost of their fuel cycle, including perhaps the cost of initial fuel charges, and that for larger sizes of nuclear power units the differences in capital cost between units of different kinds is of decreasing importance. The reason for this is not difficult to understand when it is appreciated that the total cost of the nuclear steam raising unit for a unit of 1,200 MW electrical output, and exclusive of fuel, is probably no more than one half of the present worth value of the total fuel cycle cost for that reactor during its lifetime. It is, therefore, impossible to make a meaningful comparison between various types of reactor for adoption into a national electrical network unless the consequences of their adoption upon the economy of the nuclear fuel industry in the country is examined in detail. This detailed examination required a study on a year-by-year basis of the investment in development, capital plant and working capital, and of the resulting fuel cycle costs to the system as a whole. One is, therefore, led to the conclusion that for countries of the size of the United Kingdom, and with our resources and demands for new electrical capacity, it is more important to examine the way in which the fuel cycle requirements of a type of reactor will be accommodated and to study the associated costs and economics than it is to conduct a detailed study of the relative capital costs for various sorts of reactor systems. It may also reasonably be pointed out that this same logic leads to the conclusion that a country the size of Britain, or for that matter Japan or France, may not be a sensible economic unit on which to base the provision of nuclear fuel cycle services. It would almost certainly be cheaper from a purely commercial viewpoint, if it were possible to make arrangements for example to rationalise fuel cycle services within

Western Europe. There are, however, well known political difficulties which get in the way of a course of action which would appear eminently sensible on purely commercial grounds. This is true internationally and may be true within a given country when the history of establishment of the nuclear fuel cycle has differed from that in the U.K. because of the absence in past years of an atomic weapons programme.

Development

In my lecture this afternoon I have placed a great deal of emphasis upon the economies of scale associated with production plants and their operation. I should like to conclude by extending the range of the discussion to include the problems of development. These are not different in kind from the problems of plant investment decisions, but they involve greater uncertainties and risks. In general, it is necessary to initiate development work on process plant 3-5 years before the construction of the plant is expected to start. This estimate of the time required is certainly valid for a new type of active fuel reprocessing plant or for a new diffusion plant stage, even if the technology of a diffusion plant in general is already available. In the case of a diffusion plant if a new stage is required, it will involve the development of a unit of two or three times the size and electrical power consumption of the largest of the existing stages. It will require the sort of design development and demonstration which one associates with, for example, a large new gas turbine, and the degree of assurance required of its satisfactory operation will be high because when installed in production quantities a much larger investment in a nuclear power programme may be dependent upon its output.

The problem in the development of fuel manufacturing processes is no less severe because in many instances it will be necessary to test production-type fuel in advance of its general introduction into the new commercial reactors. This means that a prototype reactor will have been constructed and that in practice the development of the fuel and of the prototype fuel manufacturing plant may have taken place seven or even eight years before the main civil production facility is required. In the U.K. for example the development of the production process for fast reactor fuel containing plutonium is complete, and construction of the plant intended to supply the 250 MW prototype reactor will be finished in a year's time. But fuel for a commercial fast reactor in the U.K. will not be needed for six to seven years at least. Indeed, in this instance the cost of the plant for manufacturing fuel for the prototype reactor may be so great that it can only be justified if in some way the facility can be integrated into the subsequent needs of the power programme.

The decisions regarding investment in development must, therefore, be taken by the fuel cycle contractor some years before the utilities have decided to adopt a new type of reactor, be it a sodium-cooled fast reactor or an H.T.R. or something else, and the sums of development money which are involved are significant. The annual turnover inclusive of uranium of the fuel cycle industry in the United Kingdom will be about £30m. in 1970 rising to perhaps four times this figure by 1980. For comparison, the cost of developing the manufacturing process for fuel for the sodium-cooled fast reactor will, when complete, be £4m.-£5m. The cost of developing the fuel design and demonstrating it will be several times as great. Such a level of development expenditure cannot be supported by the fuel cycle contractor on the basis of the current level of commercial business in the nuclear fuel industry. But if it is to be recovered in the future the contractor will require an assurance for the security of his investment. He will require either that Government should take the risk or that Government should ensure that the system on which his development effort has been spent should be adopted by the electrical utilities. Once again, the scale of the market in individual countries is insufficient to support the costs of competitive development and one returns to the basic contradiction between the wish for flexibility and the need for a firm plan.

A.E.R.E. Post-Graduate Education Centre

THE following courses are due to be held at the Post-Graduate Education Centre, A.E.R.E., Harwell, Didcot, Berks. Further information and enrolment forms can be obtained on application to the Centre.

Introduction to Reactor Instrumentation and Control

23rd to 31st May, 1968

Held at Durley Hall, Bournemouth, and intended primarily for graduates who are new to the nuclear reactor field and who need a broad knowledge of these subjects. Participants should have some basic knowledge of nuclear reactors, electronics, the measurement of physical quantities and automatic feedback control. Fee: £36 15s. exclusive of accommodation.

Two-Phase Heat Transfer

10th to 14th June, 1968

Held at Durley Hall, Bournemouth. Of particular value to engineers and scientists working in the field but may also appeal to those requiring an introduction to two-phase heat transfer. Fee: £26 5s. exclusive of accommodation.

General Isotope Course with special reference to Biochemistry

17th June to 12th July, 1968

Designed to enable qualified biochemists to use radioisotope methods in their work. Includes basic lectures on nuclear physics, radiochemistry, detection and radiological protection and practical exercises associated with them. Fee: £105 exclusive of accommodation.

Summer School on Neutron Diffraction

1st to 5th July, 1968

There will be about 15 invited lectures on elastic neutron scattering given by leading workers in the field. The main topic will be the accurate determination of neutron intensities and structure factors; this will include nuclear and magnetic scattering from both single crystals and powders. Fee: £8 exclusive of accommodation.

A.E.A. Reports available

THE titles below are a selection from the April, 1968, "U.K.A.E.A. list of publications available to the public". This list is obtainable free from the Librarian, A.E.R.E. Harwell, Didcot, Berkshire. It includes titles of all reports on sale, translations into English, books, periodical articles, patent specifications and reports which have appeared in the published literature. It also lists the Depository Libraries in the U.K. and the countries with official atomic energy projects which receive copies of U.K.A.E.A. unclassified reports.

AEEW-R 558
A Comparison of the Accuracy of Some Correlations for Burnout in Annuli and Rod Bundles. By P. G. Barnett. January, 1968. 29 pp. H.M.S.O. 6s.

AEEW-R 583
Drift Correction of Binary Cross-Correlation Measurements. By J. D. Cummins. October, 1967. 13 pp. H.M.S.O. 2s. 6d.

AERE-PR/HPM 12
Health Physics and Medical Division Progress Report, January-December, 1967. Edited by J. E. Johnston. February, 1968. 61 pp. H.M.S.O. 12s.

AERE-R 5729
X-ray Microscopy Applied to Materials Science, Including Divergent Beam Analysis-Bibliography. By P. J. Baldock. February, 1968. 43 pp. 6s.

AWRE O-59/67
Manual for the S2 and S3 Dialects of Fortran 2. Edited by M. U. Thomas. March, 1968. 91 pp. H.M.S.O. 12s.

PG Report 826(CC)
Radiobiology Research Unit, Chapelcross. Annual Report, 1967. Presented by J. H. Martin. 1968. 6 pp. H.M.S.O. 1s. 9d.

PG Report 823(W)
Analytical Method for the Determination of Non-uranic Alpha Emitters in Uranium Products from the Reprocessing of Natural Uranium Fuels. 1968. 8 pp. H.M.S.O. 1s. 9d.

TRG Report 940(R)
'Style'—A general Digital Computer Code for the Analysis of Steam Cycles for Marine and Land-based Power Plants. By J. B. Love and W. R. Dines. 1968. 57 pp. H.M.S.O. 8s.

TRG Report 1059(C)
Determination of the Specific Activity of ^{14}C Labelled Carbon. A Critique. By M. F. Sheppard. 1966. Reprinted for sale, 1968. 11 pp. H.M.S.O. 2s.

TRG Report 1157(C)
Preliminary Investigation into Welding by Friction. By P. Lees. 1966. Reprinted for sale, 1968. 15 pp. H.M.S.O. 3s. 6d.

Depleted uranium in industry

This article, by K. G. Seedhouse, U.K.A.E.A., Production Group, appeared originally in Chemical Processing *and is reprinted here by permission of the editor.*

Introduction

DEPLETED uranium, a by-product of the nuclear industry, differs from natural uranium only in having an appreciably lower uranium 235 isotope content. It is produced initially as the gaseous hexafluoride, which can be converted, for sale, into more useful forms, such as the metal, the oxides, and the diuranates.

Thousands of tons of depleted uranium have already accumulated in the world, and this situation has led to the initiation of studies into possible non-nuclear uses. Reviews have been published that suggest many industrial applications. It has been found in the United Kingdom that the principal use at present, is for the metal as a shielding material against radiation, but in the long term it is expected that a major increase in the use of uranium compounds in catalysts will occur.

Although potential users may think that handling radioactive materials presents safety problems, it should be stated that uranium is only very slightly radioactive and good industrial hygiene affords adequate protection, as discussed later in connection with catalysts. Possibly more is known of the toxicology of uranium than any other element, and no case of toxic injury has been reported; the precautions required are similar to those adopted for other heavy metals such as lead.

Uranium metal

The metal can be cast and machined to close tolerances as easily as any conventional metal with standard equipment, but a coolant is used to prevent swarf from igniting during machining. Uranium can also be fabricated by rolling, forging, extruding, swaging or drawing, and the U.K.A.E.A. have extensive facilities available to meet individual requirements.

Uranium tarnishes in air due to oxide formation, but this can be avoided by plating, or limited by using uranium alloys. Corrosion by water or water vapour can also be satisfactorily reduced by using alloys.

Uses of depleted uranium metal

The high density of uranium metal, 18·77 g/cc on average, can be used to advantage when mass has to be supplied in minimal volume. It is much denser than lead (11·4 g/cc), and is also denser than tungsten alloys, which range from 16·8 to 18·0 g/cc. Uranium is thus used with advantage for protective shielding in equipment using gamma sources and X-rays, and for isotopic generators.

The absorption processes by which gamma rays are attenuated in matter vary with atomic number. Therefore, uranium with an atomic number of 92 is significantly better for shielding than tungsten (atomic number 74) or lead (82). Uranium is cheaper than tungsten but more expensive than lead, so its use can be justified in circumstances requiring the conservation of space.

Some uses in the aircraft industry are as aileron, rudder, and elevation counterweights for aircraft. A weight can be inserted into the leading edge of a wing to balance the weight of the engines, less mass being required with a denser metal to give the same balancing moment. Power-operated control systems on aircraft fitted with manual overrides also require balanced surfaces for easy operation. Shims for aligning the centre of gravity of a missile with the longitudinal axis can be made by cutting uranium rings into small segments; such components can be plated to prevent corrosion and sparking.

Other uses which have been suggested are in braking systems, balancing of rotating machinery, and counterbalancing large rotating structures.

Uranium alloys

Considerable work has been done on uranium alloys, and phase diagrams exist for uranium with most elements. Metals which form solid solutions with uranium are of particular interest, since they often greatly improve mechanical strength and corrosion resistance.

Conversely, most alloying elements will increase the strength and hardness of uranium when added in small amounts. Tardif has shown that 2 per cent and 3 per cent molybdenum alloys are very hard, and can attain Rockwell C hardness of 40 after quenching and 54 after quenching and precipitation hardening. Most of the more complex alloys which were examined hardened to about 52-57.

All alloying elements except titanium and zirconium will improve the corrosion resistance of uranium; chromium, nickel and molybdenum each seem to be particularly effective. Uranium-molybdenum alloys are used in many shielding applications by the U.K.A.E.A. for this reason. The 8 per cent molybdenum alloy is particularly valuable since it is easily cast and machined, and takes a very good surface finish due to its resistance to tarnish. The alloying operation does not involve extra cost to customers.

Certain intermetallic compounds, such as U_3Si, U_6Ni, U_6Fe and UAl_2, provide stable corrosion resistance at temperatures at which the resistance of gamma phase alloys declines. However, these materials are difficult to fabricate.

Lead-uranium alloys in the range 2-8 per cent by weight uranium have been studied in connection with possible anti-friction applications, since the combination of angular, cubic crystallities of UPb_3 in a very soft lead matrix may be acceptable for this purpose.

Uranium in ferrous metals

Between the two world wars, claims were made that the addition of uranium to steels conferred special properties. It is now widely held, however, that in general uranium has no decisive advantages over less expensive alloying elements. Although, for example, it can be substituted for tungsten and molybdenum in high speed tool steels, a larger mass is required to give the same atomic percentage.

Melting, casting, and forging methods for low alloy steels containing up to 1·5 per cent by weight have been developed. Vacuum melting and air melting can be successfully used, uranium recovery being about 80 per cent in both cases.

The high affinity of uranium for oxygen, nitrogen and sulphur has suggested its use as a scavenger for steel. Creep testing of steels indicates that small additions of uranium are beneficial. It is also an effective stabilizing element in austenitic stainless steels. However, for economic reasons, uranium would have to possess additional advantages for adoption in steel making.

Corrosion tests with steels indicate that uranium will reduce their corrosion in hydrochloric and sulphuric acids.

Uranium in non-ferrous metals

Investigations have been made into the possibility of using uranium to improve the properties of common metals such as aluminium, magnesium, zinc, copper and nickel. Only in the case of copper and nickel can uses be foreseen for uranium, namely in deoxidizing the molten metals and improving the malleability of certain alloys.

The high solubilities of hydrogen and oxygen in molten copper give rise to problems of porosity. These problems can be reduced by using a phosphorus-copper deoxidant. Unfortunately, this treatment leaves phosphorus in solution and markedly reduces electrical conductivity. It has been found that the addition of stoichiometric amounts of uranium gives complete deoxidation, without any appreciable loss in electrical conductivity. Careful teeming should prevent contamination of the product with UO_2. The presence of the copper-uranium eutectic phase should make the product stronger, more resistant to oxidation and more machinable.

It has also been shown that uranium can have a beneficial effect on the hot workability of alpha brasses containing lead and bismuth. These two impurities produce the low ductility characteristic known as hot shortness. At U/Pb ratios equal to or greater than one, it has been possible to hot roll brasses which would otherwise have been scrapped. Such a usage makes this process, like the copper deoxidation method, a commercial competitor to existing techniques.

Uranium compounds as catalysts

The first notable mention of uranium as a catalyst was by Haber, who suggested uranium carbide for the catalysis of ammonia production from nitrogen and hydrogen. It was thought that uranium

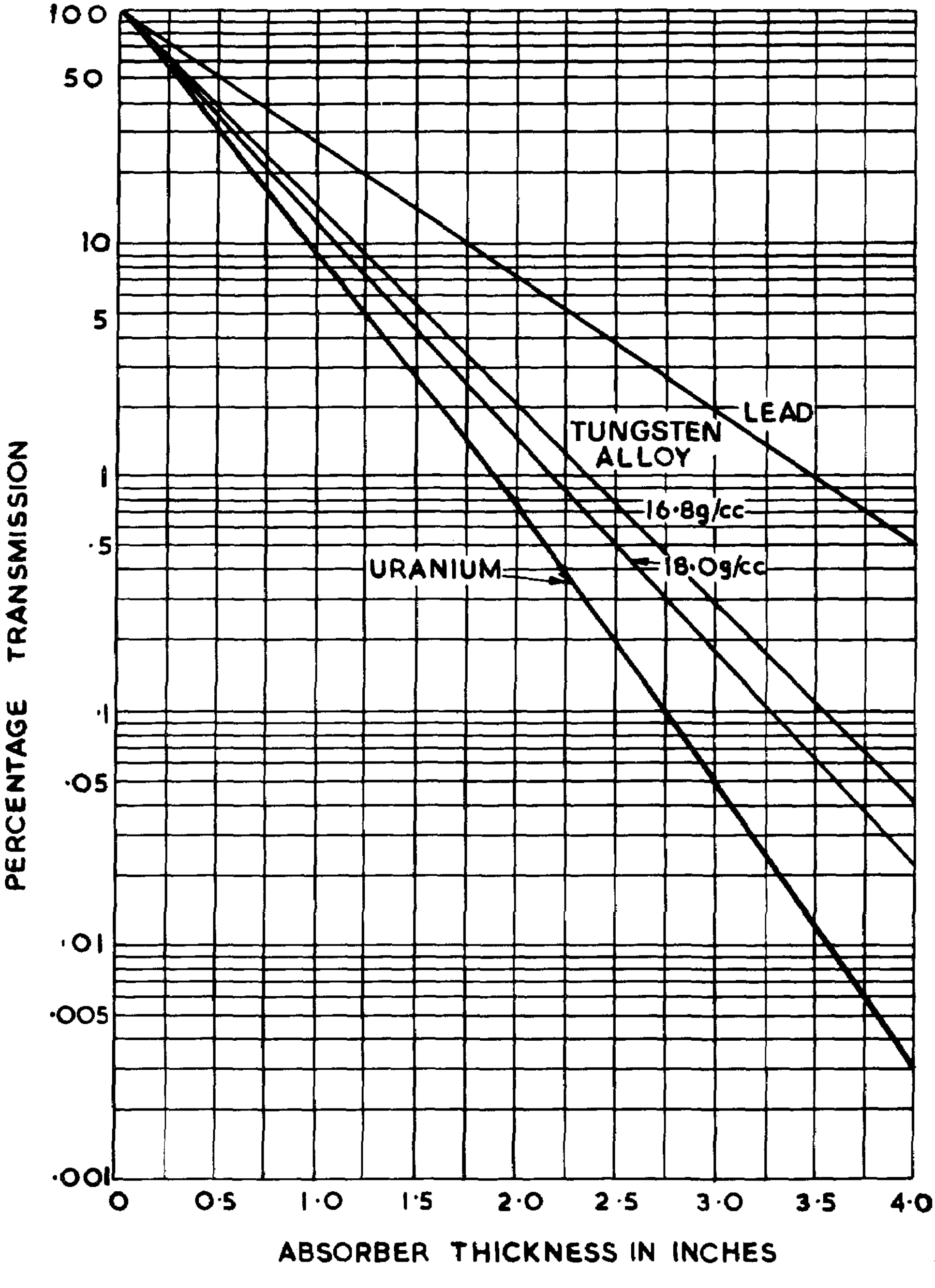


FIG. I BROAD-BEAM ABSORPTION OF GAMMA RADIATION FROM COBALT - 60 nitrides were formed as intermediates, and the nitride has now been investigated as a catalyst. A recent development in the same synthesis has been the addition of uranium to an iron-type catalyst.

The only large scale use in this country of uranic catalysts has resulted from the discovery by the North Western Gas Board that uranium oxide can materially improve the performance of conventional nickel catalysts in the steam reforming of naphtha to town gas or synthesis gas.

The catalyst consists of nickel and uranium, as oxides, supported on pure alpha alumina. This catalyst is outstandingly stable. It is notable for its resistance to the formation of carbon deposits, which is particularly valuable if the crude oil, as at present, contains a large proportion of the higher hydrocarbons since these have a greater tendency to deposit carbon than the lower hydrocarbons..

Sulphur removal

The North Western Gas Board have also found that sulphur can be removed from the naphtha, before reforming, by using a catalyst containing uranium oxide on alumina to decompose sulphur to H_2S, which is then removed conventionally, for example by absorption on zinc oxide. The catalyst can be regenerated with steam. This method could have wide application.

Another large scale development has been the replacement, by Standard Oil of Ohio, of bismuth by U_3O_8 for catalysing the production of acrylonitrile from propylene:

$$2\ C_3H_6 \times 2NH_3 + 3O_2 \rightarrow 2C_2H_3CN + 6\ H_2O$$

The catalyst consists of oxides of antimony and uranium, and can be employed with or without support. Such a catalyst can also be used for the production of methacrylonitrile from isobutylene, and the oxidation of propylene to acrolein, although the latter reaction has also been catalysed by uranyl nitrate. Uranium compounds can also be used for the dehydrogenation of propane to propylene.

Other organic syntheses in which uranium compounds have been used include the oxidation of toluene to benzaldehyde, methane to formalin, and toluene to benzaldehyde and benzoic acid.

Polymerization reactions promoted by uranium-based catalysts include the polymerization of ethylene in the presence of UCl_6, and the polymerization of olefins in the presence of uranium oxide and diborane. Various uranium compounds will catalyse ester interchange reactions, accelerate the condensation polymerization of the bisglycol esters, and accelerate the formation of polyesters of high molecular weight.

A catalyst consisting of uranium oxide on a carrier has been found to be very effective for purifying exhaust gas from cars, without combining with lead and without being affected significantly by sulphur and other poisons.

The use of uranic materials as catalysts will not present radiation problems on a chemical plant. For example, a man working in close proximity to the Gas Board catalyst for 200 hours a year would receive no more gamma radiation than the total dose from natural background in the course of a year. Although gloves would be used because of the toxicity of uranium, a worker who spent half his time handling catalyst with his bare hands would not receive more than 3/10ths of the maximum permissible annual dose. It is therefore unlikely that the use of uranic catalysts will give rise to extra costs for health and safety precautions, compared with conventional catalysts.

Uranium in glass

Uranium in quantities between 0·3 and 15 per cent has been used extensively to produce brilliant colours in glasses, ranging from black to red, Such glasses have been classified into three types.

(a) Fluorescent glasses containing uranyl groups, formed when uranium is added to soda-lime-silicate glasses under oxidizing conditions.
(b) Uranate glasses, such as the non-fluorescent yellow glasses formed under oxidizing conditions in very alkaline silicate and borates. Orange to deep red glasses are formed in high lead silicate glasses.
(c) Non-fluorescent brown and green glasses containing tetravalent uranium, produced under strongly reducing conditions.

Uranium oxides are readily incorporated into silicate, phosphate and borate glasses, up to about 50 per cent by weight UO_2. Very stable silicate glasses, comparable with commercial glasses, can be made which are insoluble in hydrochloric, nitric and sulphuric acids, aqua regia, and concentrated caustic soda; they are easy to fabricate and form. Borate and phosphate glasses are less satisfactory.

It has been suggested that uranium could also be used for the following purposes:

(a) to give special spectral absorption properties to optical glass;
(b) to confer a different refractive index to optical glass; and
(c) as a tracer, indicating refractory attack and solution paths in glass refractories.

Uranium in ceramics

Brilliant colours can be given to ceramics by uranium salts, particularly if the salts are impure. A very fine black is given to porcelain by 5-10 per cent of U_3O_8.

Crucibles made of UO_2 or US have been suggested for molten metals. UO_2 is stable to very high temperatures, except under oxidizing conditions. Some metal uranates and also UC are very refractory, and the former are stable to oxidizing conditions.

Uranium oxide has been suggested for the manufacture of grinding wheels. Greater strength and better oxidation resistance could be given if uranium oxide is incorporated into the melt used to bind the grains of silicon carbide.

Uranium in the electrical industry

Uranium targets have been used in X-ray tubes for producing hard X-rays of short wave length at a high efficiency. Uranium electrodes have also been used as a source of ultraviolet light.

The reactivity of uranium is used for removing gaseous impurities from vacuum tubes, and for extracting oxygen and nitrogen from argon. Resistors of UO_2, with a negative temperature coefficient of resistance, were developed to limit overshoots in incandescent lamps when circuits are closed. The resistance is fairly constant after many thousand hours service.

Conclusion

Uranium and its compounds should be considered for many economic applications in industry. The cost of materials and components, together with technical advice, can be obtained from the U.K.A.E.A. Commercial Branch, Production Group Headquarters, Risley, Nr. Warrington, Lancs.

New RCC publications

THE following are among new publications issued by the Radiochemical Centre, Amersham, Bucks. Copies are available on application to the Centre.

Enzyme assay

Radiochemical methods of enzyme assay by K. G. Oldham.

Radiochemical methods of enzyme assay are very sensitive and accurate. They are commonly used nowadays, but because details of such methods are to be found only in the "methods" section of most published work and no reference to their use is made either in the title or abstract, it is difficult for research workers to find the necessary information about the various techniques without searching through a vast amount of published work. This has resulted in many workers continuing to use complicated and tedious assay methods when quicker and simpler techniques are available.

This review booklet includes a critical examination of the present uses and potential of radiochemical methods of enzyme assay, and a bibliography of published work in this field.

Labelled compounds—storage and stability

Storage and stability of compounds labelled with radioisotopes, by R. J. Bayly and E. A. Evans,

Most users of compounds labelled with radioisotopes recognize that such compounds decompose on storage and that the decomposition is accelerated by self-irradiation. The degree of the decomposition in relation to the storage conditions of the compound, and the measures which can be taken to control and minimize the rate of self-radiolysis, are perhaps not always so well known. This review summarizes present knowledge of the decomposition of labelled compounds and methods of reducing it.

Purity of labelled compounds

Purity and analysis of labelled compounds, by J. R. Catch.

The booklet is written primarily to advise newcomers to tracer methods. Copies are available from The Radiochemical Centre, Amersham, Bucks., England.

continued from page 125

the practice, as he says, in fact there is progress-chasing at Aldermaston to see what can be declassified?

Mr. Benn: Over the last few years 40 reports have been published from Aldermaston by the Stationery Office and 100 to 150 scientific papers are published every year. Aldermaston was represented at EXPO 67 and two other exhibitions. Civil work on computers and for the Forensic Crime Laboratory and for medical and dental engineering are indications of the intention here.

Mr. Dalyell asked the Minister of Technology what steps he is taking to promote research for commercial purposes at the Atomic Weapons Research Establishment, Aldermaston.

The Joint Parliamentary Secretary to the Ministry of Technology (Dr. Jeremy Bray): With my right hon. Friend's support, the Atomic Weapons Research Establishment accepts a wide and increasing variety of orders on commercial terms from Government Departments, including the Ministry of Technology, and from private customers for research and development outside the atomic weapons field.

Mr. Dalyell: Is my hon. Friend satisfied that in fact the establishment itself takes the initiative in bringing work to the notice of what he calls this wide variety of customers?

Dr. Bray: Yes, indeed. There are constant meetings between the staff of the establishment and the Ministry of Technology headquarters—sometimes involving Ministers—with private concerns of various kinds seeking profitable outlets.

Radioactive waste disposal

18th March, 1968

MR. EADIE asked the Minister of Technology if he is satisfied that the methods of disposal of radioactive effluents from Atomic Energy Authority establishments and other bodies under his jurisdiction are effective; and if he will make a statement.

Dr. Bray: Radioactive waste from United Kingdom Atomic Energy Authority establishments can only be disposed of with the authority of my right hon. Friends the Minister of Agriculture, Fisheries and Food and the Minister of Housing and Local Government or the Secretary of State for Scotland. The approval of my right hon. Friends the Minister of Transport or the President of the Board of Trade, according to the method of transport, is required for the movement of radioactive waste in certain cases. Port authorities need to be notified in advance of the movement of some classes of goods.

Mr. Eadie: Is my hon. Friend aware that there have been various statements in the Press, which cast some doubts on the methods of radioactive waste disposal? Is he aware that the Soviet Union has complained that Britain is polluting marine life?

Dr. Bray: The reports derive from Russia, and, I think my hon. Friend will be aware that, as was pointed out in the article, Russia did far more to pollute the oceans by her last series of dirty hydrogen bomb tests than centuries of carefully controlled dumping could do.

Uranium

20th March, 1968

DR. ERNEST A. DAVIES asked the Minister of Technology if, in view of the rising demand for uranium following the world wide adoption of nuclear electricity generation, he will take steps to ascertain whether there are indigenous resources of uranium capable of economic exploitation, as a means of import saving and reducing the burden of foreign exchange.

Mr. Benn: Yes. Under Section 2 of the Atomic Energy Authority Act 1954, I have already authorised the Authority to search for uranium in this country. The Authority, through the agency of the Institute of Geological Sciences, are embarking on a reconnaissance prospecting programme in selected areas in the United Kingdom: the objective is to establish whether there is evidence of the occurrence of uranium sufficient to justify a subsequent more detailed investigation.

Power stations

25th March, 1968

MR. ADAM HUNTER asked the Minister of Power how many coalfired power stations, nuclear power stations and oilfired power stations, respectively, are in the United Kingdom.

Mr. Marsh: The figures are:

Coal fired	*Oil fired*	*Coal and oil fired*	*Nuclear*
163	34	17	8

U.K.A.E.A. SCIENTIFIC AND TECHNICAL NEWS SERVICE

Computer for Amersham

The Radiochemical Centre at Amersham, which is responsible within the UKAEA for the production and marketing of radioisotopes, and which recently received the Queen's Award to Industry for export achievement and for technological innovation, has ordered an ICT 1901 computer system.

The major use of the computer will be to assist in the handling of the increasing number of orders for the Centre's 3,000 products. More than 50% of the orders are for export. It is anticipated that up to 1,000 items of radioactive material will have to be despatched daily from Amersham during 1970. The 1901 computer is expected to facilitate the handling of these orders and to increase the speed and accuracy with which the customers' requirements are interpreted. It will enable a high percentage of orders received during the morning to be prepared, despatched and invoiced by the afternoon of the same day.

The configuration includes a 16K word store, backed by two high density exchangeable disc stores and two magnetic tape units. Input will be by paper tape and output is provided by a high speed line printer and a paper tape punch. The principal programming language will be Cobol. Delivery is to take place in the last quarter of 1968.

20th March, 1968

The Physics Exhibition

At the Physics Exhibition held at Alexandra Palace, London, 11th-14th March, 1968, the U.K. Atomic Energy Authority showed some of the new instruments and techniques developed at its establishments. The exhibits were:

Stored charge image reader (SCIR)

An electro-mechanical method of reading ultra-violet and visible light spectra non-destructively has been developed, which incorporates the advantages of the photographic plate and the scanning photomultiplier. The spectrum can be stored on any insulating surface by photo-emissive or photoconductive means. It is read off by scanning a vibrating conductor close to the surface containing the charge image. An image may be erased and the surface prepared for a fresh exposure by scanning it with a low energy electron beam.

Thermal diffusivity of very thin single or double layer samples.

The thermal diffusivity of very thin (0.005 in. to 0.050 in.) small samples can be rapidly and accurately determined by observing the transit time of a heat pulse through a parallel faced specimen. An infra-red detector is used and a laser produces the heat pulse.

Monitoring the electrical conductivity of heavy water in high radiation fields.

It has been found possible to use silica as an insulating material for conductivity probes in nuclear reactors at flux levels 10^{14} n/cm^2/sec. Probes using silica-to-tungsten seals with long paths of non-conducting material to compensate for conduction across the seal have been employed with a conductivity bridge to detect the presence of impurities in the heavy water moderator of materials testing reactors.

High speed facsimile display of flow signals or metrological readings from tubes.

This equipment, developed under contract by the University of Salford, Department of Electrical Engineering, uses a system of cathode-ray storage tubes to produce a continuous television type of raster display showing the results of tube inspection. It enables the inspection to be carried out at high speed.

The development of neutron convertors for research reactors.

A neutron convertor is a device for insertion in a reactor to create a relatively high flux of fast neutrons (2 MeV on average) by making use of the available flux of thermal neutrons (0.025 eV on average). The unit consists of an experimental facility surrounded by fissile material in which the thermal neutrons produce fission and create a region with a fast neutron flux.

A variable thermal insulation with a resistance dependent on the pressure of a gas.

This consists of an aluminium foil,

nominally 0.001 inch thick, wrapped a hundred times round a heated ¾ in. diameter copper bar. Alteration of the gas pressure within the wrapping markedly affects its thermal resistance.

Digital timer for plasma physics experiments

This timer gives a timing accuracy of 0.1% and yet is easy to adjust. This is because it generates time signals by counting pulses from a crystal-controlled oscillator until the count reaches a preset number which is set by an array of decade switches. The timer can be used to time intervals from a few microseconds to several hours simply by using different oscillator frequences; maximum resolution is 100 nanoseconds. Up to 30 timing signals can be generated.

30 kG superconducting solenoid with room-temperature aperture

Most large super-conducting solenoids work submerged in simple cylindrical cryostats, and experiments are limited to those which can be performed in liquid helium. This solenoid, however, has an unobstructed horizontal tube, 23 cm. in diameter, through the centre of the magnet.

60 kV multiple arc low inductance spark gap

This is used to discharge a 60 kV capacitor bank into a load of, for example, 20 nH inductance, to give peak currents of about 1MA rising in about 1.0 microseconds. Alternatively, it can be used to discharge a 60kV transmission line of about 1 ohm impedance in about 15 nanoseconds to give a rate of rise of current of 4×10^{12} A/sec. It has multiple arc channels between the two main electrodes.

Filament position stabiliser

This is a means of stabilising the filament in electron-probe microanalysers and possibly other electron beam instruments. The unit uses an annular diaphragm divided into four quadrants, which is placed in the electron optical column so as to sample the outer part of the beam emerging from the gun and condenser assembly. The current passing through each quadrant is measured and the out of balance signal from opposite pairs is used to maintain the filament in a central position.

Ion implantation doping of semi-conductors

The introduction of electrically active impurities into semi-conductor materials by ion implantation provides an alternative technique for manufacturing active devices. Some specific examples of devices made by implantation which cannot be easily fabricated by conventional diffusion technology were shown.

A computer orientated modular unit system

This new system of modular instrumentation was demonstrated in a simple nuclear counting system.

Cryogenic temperature meter and controller

This is a prototype capable of operating between 5°K and 330°K.

A high efficiency miniature tape recorder for the black arrow series of satellites.

This recorder employing the endless loop principle uses less than 0.5 watts of power at 12 volts. An earlier version was flown in the Ariel III Satellite which has been in orbit for over 10 months. The model uses full width saturation recording on ¼ inch wide tape; it is designed to store digital information at 64 bits per second with a tape speed of 0.234 inches per second. This information is then replayed at 2000 bits per second at a tape speed of 7.5 inches per second, on command from a ground station. Three separate heads are used: replay, permanent magnet erase and record; the tape passes over the heads in this order and thus the last 120 minutes of data is always stored on the tape.

Tritium/tritium-oxide in air monitor

This differentiates between tritium gas and the more hazardous tritium-oxide in a continuous flow of air drawn from a laboratory or workroom. The monitor contains two flow ionisation chambers, oppositely polarised and connected electrically in parallel to the input of an electrometer. The first chamber receives untreated air from the environment, while the second chamber receives air which has passed through a column of molecular sieves. Thus ionisation currents arising from the presence of tritium gas in both chambers are cancelled and not recorded while the ionisation current caused by tritium-oxide vapour in the first chamber is recorded.

Multibeam holography

In this a series of separate reference beams, not necessarily of the same wavelength or angle of incidence and curvature, are used to record each object beam separately. These exposures are all superimposed on the same plate and each object beam can be regained independently of the others, or combinations can be gained, with exact registration.

Low fidelity holography

A series of conventional photographs can be combined holographically to produce three dimensional constructions which are adequate for applications where reconstruction to wavelength accuracy is not needed, for example in three dimensional television.

Holographic velocity measurement

Holography is used to bring about interference between the reconstructions of waves which have never co-existed. The principle was demonstrated using an array of small spheres falling in a viscous liquid.

Dynamic testing of cellular materials

Materials with optimum energy absorption characteristics have been developed as a result of studies on rigid and semi-rigid polyurethane foams and cellular rubbers. Specimens of the material under test were impacted with a steel probe fired from a semi-automatic compressed air " gun "; the energy absorbed by the material was determined from the deceleration of the probe.

Scanning Fabry-Perot interferometers

These use piezo-electric and magnetostrictive effects to produce scanning, such systems being able to deal effectively with fast and slow scanning speeds.

Sputtering apparatus

A low energy sputtering system was demonstrated, constructed to ultra-high-vacuum standards, for thin-film deposition in a low impurity environment. Sputtering takes place in a separately-excited plasma provided by a magnetically-confined d.c. arc. Provision is made for both d.c. and r.f. sputtering and for r.f. bias of the substrate.

Data acquisition system for shock phenomena

During investigations into shock waves, a transient data recording system has been developed capable of recording over the bandwidth DC to 250 kHz and of producing clear and accurate results.

Ultrasonics in NDT

Exhibits describing advanced ultrasonic methods of measuring the wall thickness of tubes, grain size of metals, and the potential increase in resolution offered by using frequencies in the region of 100 MHz were shown.

On-line estimation of frequency response from random data

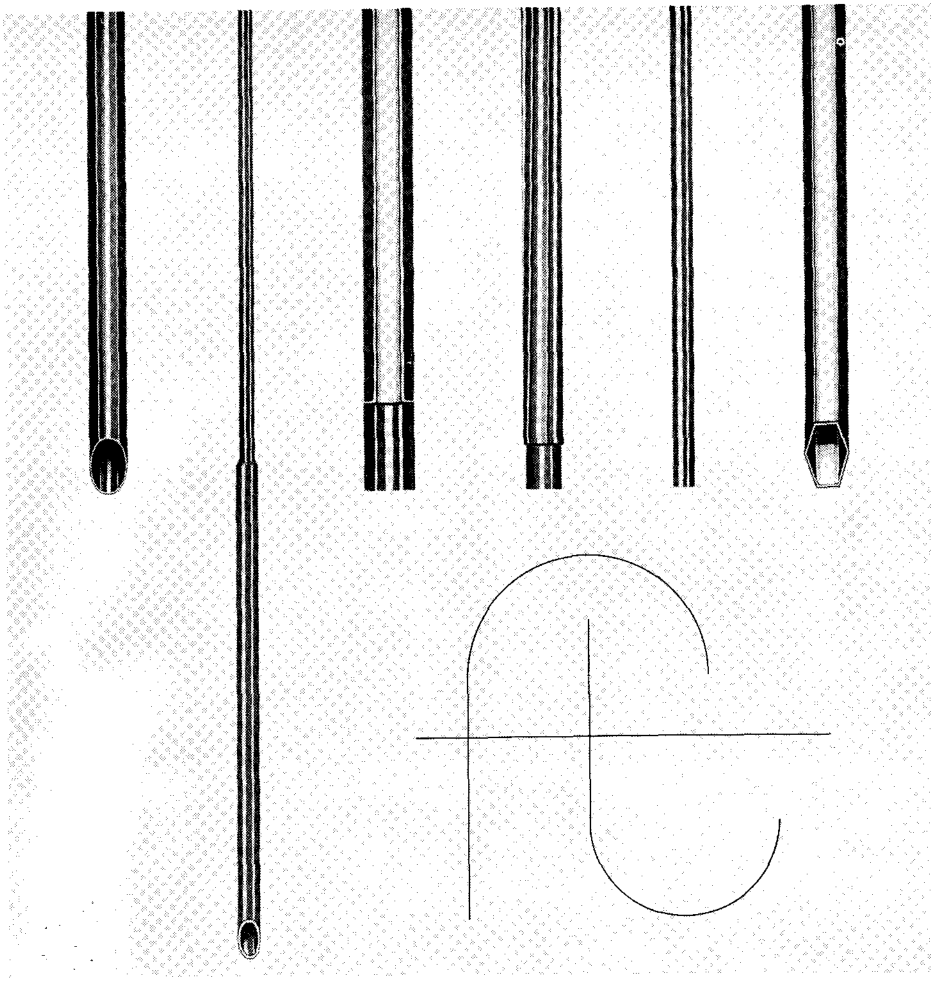
An adjustable model technique can be used to determine the steady-state frequency response of a linear system from measurements of its excitation and response, both of which are random.

RCC at FASEB

With total annual sales of radioisotopes now amounting to nearly £3 million—over half of them exports—The Radiochemical Centre, Amersham, took part in the exhibition held during the 52nd Annual Meeting of the Federation of American Societies for Experimental Biology (F.A.S.E.B.) from 15th-19th April.

The Radiochemical Centre has 27 years' experience in the processing and sale of radioisotopes. It supplies 180 radioisotopes in more than 1,200 chemical compounds and in over 400 kinds of radiation appliance. The current catalogue offers more than 2,000 items. The Centre sent out nearly 75,000 consignments in 1967, doing business with nearly every advanced country. Sales have increased five-fold in ten years.

In biology the main use for radioisotopes is in the form of tracer compounds usually in organic compounds labelled with carbon-14 or tritium, although sulphur-35, phosphorus-32, iodine and other isotopes are also used. These materials offer a method of unrivalled sensitivity for studying the chemical reaction mechanisms and physico-chemical transfers.



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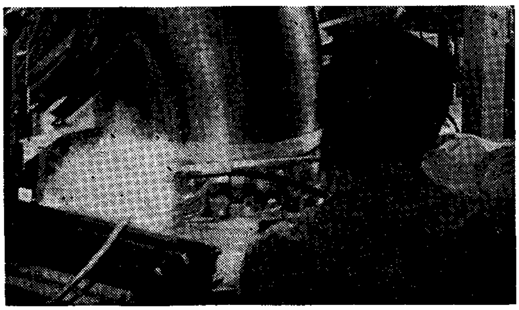

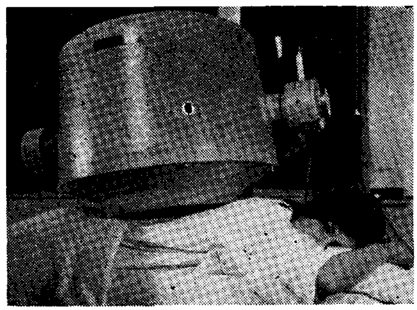

UKAEA/new films on atomic energy

WATER FOR LIFE A layman's guide to sources of water, in particular desalination — turning salt water into fresh. *15 minutes.*

RADIOISOTOPES IN MEDICAL DIAGNOSIS AND INVESTIGATION *30 minutes.*

TRANSPORTABILITY Bringing back irradiated fuel elements from overseas. *20 minutes.*

NUCLEAR POWER TODAY AND TOMORROW A film version of the Faraday Lecture in two parts. *76 minutes.*

ON THE SAFE SIDE Electrical safety in a high voltage environment. *20 minutes.*

Three films about the Steam Generating Heavy Water Reactor:

CALANDRIA AND SHIELD TANKS *18 minutes.*

CHANNEL TUBE ASSEMBLIES *18 minutes.*

THE PRIMARY CIRCUIT *10 minutes.*

These films are available free. Write for our catalogue to the Film Library, United Kingdom Atomic Energy Authority, 11 Charles II Street, London, SW1.

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