Number 155 / September 1969



#### MONTHLY INFORMATION BULLETIN OF

#### THE UNITED KINGDOM ATOMIC ENERGY AUTHORITY

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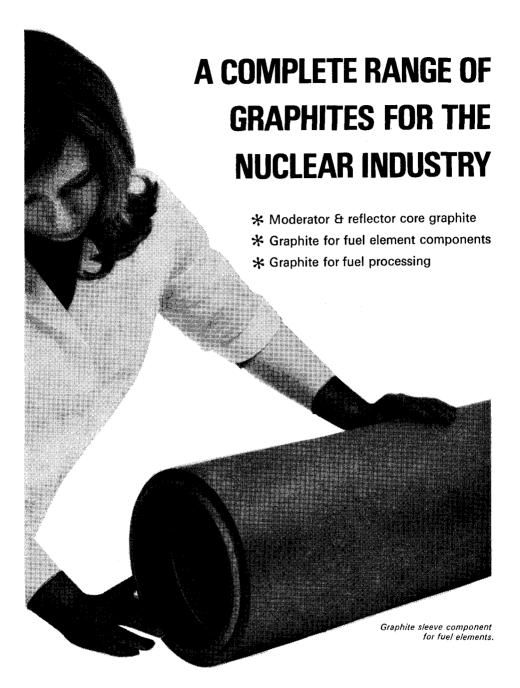
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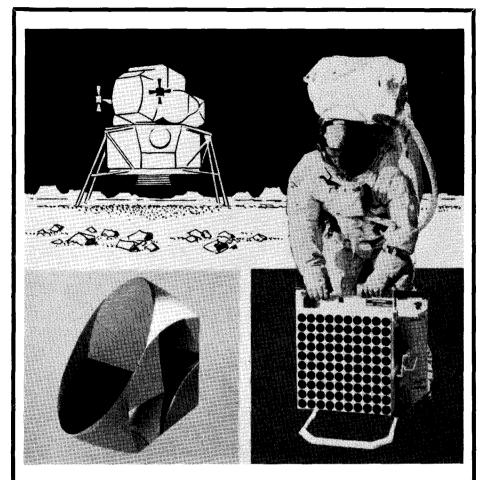




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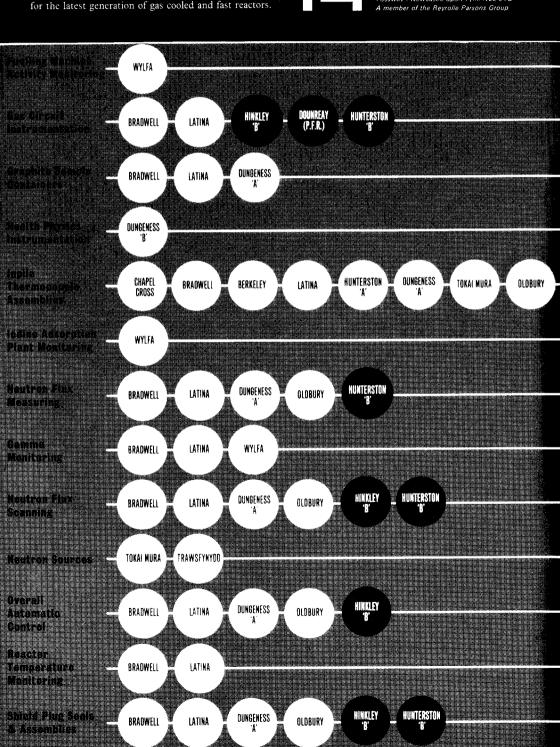
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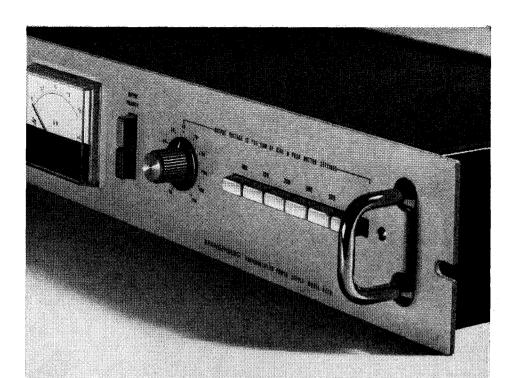
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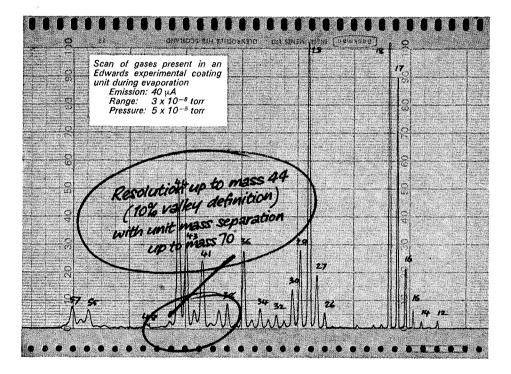
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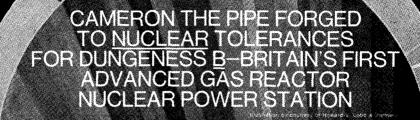
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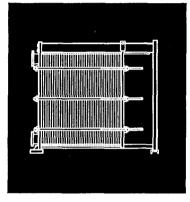


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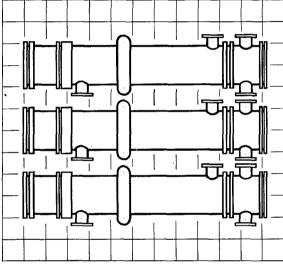
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MONTHLY INFORMATION BULLETIN OF THE UNITED KINGDOM ATOMIC ENERGY AUTHORITY

#### NUMBER 155

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#### **ATOM**

monthly bulleting of the UKAEA 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 Extracts from UKAEA material form the bulletin may be freely published provided acknowledgment is made. Where the attribution indicates that the source is outside the Authority, permission to publish must be sought from the author or originating organisation.

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#### U.K.A.E.A. PRESS RELEASE

# A.E.A. nuclear fuel for the Netherlands

A contract has been signed between N.V. Gemeenschappelijke Kernenergiecentrale Nederland and the United Kingdom Atomic Energy Authority for the fabrication of reload nuclear fuel elements required for three years' operation of the Dodewaard 54 megawatt (electrical) direct cycle boiling light water reactor. The fuel elements consist of sintered pellets of enriched uranium dioxide clad in zircaloy-2. M.M.N. Dessel will act as sub-contractors to the Authority for the assembly of the fuel.

## **Background** notes

Dodewaard reactor

The Dodewaard direct cycle boiling light water reactor is fuelled with enriched uranium and moderated and cooled with light water. The reactor commenced operation in 1968 and is presently operating at full power.

The Authority's nuclear fuel services

The Authority offers a fully comprehensive service for the design, supply and reprocessing of fuel elements for all types of reactors including pressurised water reactors and boiling water reactors.

M.M.N. Dessel

Metallurgie et Mecanique Nucléaires, Dessel, Belgium, are manufacturers of nuclear fuel elements,

24th July, 1969.

### Group technology seminars

Many engineering companies machining components in batches can effect significant improvements in production efficiency by the adoption of group technology principles. The Group Technology Centre has been set up by the U.K.A.E.A. to assist British industry to take advantage of the techniques, and offers one-day appreciation seminars for senior management.

One-day seminars will be held at the Centre on 23rd September, 1969; 21st October, 1969; 25th November, 1969.

Fee: £12, including lunch and light refreshments.

Further information may be obtained from Group Technology Centre, U.K.A.E.A., Blacknest, Brimpton, Reading RG7 4RS. Tel: Tadley 4111, Ext. 5951/5873.

# A.E.A. plutonium for the European Community

A contract was signed on 4th August between Nukem, of Wolfgang, near Hanau (acting on behalf of the Government of the Federal Republic of Germany), EURATOM Supply Agency and the United Kingdom Atomic Energy Authority for the supply of 200 kilogrammes of fissile plutonium for delivery during 1973. Under the terms of the contract the plutonium will be purchased by Nukem, and EURATOM safeguards will apply as provided for in the EURATOM/United Kingdom agreement for co-operation. The material will be used by Alkem, also of Wolfgang, near Hanau, in the manufacture of fuel for the prototype of a sodium cooled fast reactor (SNR) to be constructed in Germany by an international consortium formed by Siemens, Interatom, Belgonucléaire, Neeratom and Luxatom. The work for the SNR-project is supported by the governments of Belgium, Germany Luxembourg and the Netherlands.

# CAMAC units sale to U.S.A.

A \$160,000 order just received by Nuclear Enterprises Ltd. for units in the new CAMAC compatible modular data transfer system marks an important breakthrough for British industry in the American nuclear and data handling instrument field.

The Nuclear Enterprises development team, based at the Company's Beenham laboratories, has co-operated from the earliest stages in the design of CAMAC compatible modules with AERE Harwell, as well as sponsoring its own extensive development programme. Over forty different units are currently available.

CAMAC was originally designed to meet computer-based measurement and control requirements in the nuclear field and has been adopted as standard by most of the major laboratories in Europe. It is also of wide general value in many other fields where a controlling computer is used, so international marketing prospects are excellent. Nuclear Enterprises has already supplied CAMAC equipment to major high energy laboratories in Europe, including CERN and Daresbury.

#### IN PARLIAMENT

# Civil science

The following extracts are from the debate on civil science which took place in the House of Commons on 21st July, 1969.

THE MINISTER OF TECHNOLOGY, Mr. Anthony Wedgwood Benn: The Ministry of Technology was set up to concern itself with the uses to which science must be put to meet our personal and national objectives. We should be judged by the objectives that we have identified and by the extent to which we have succeeded in realising them.

Within MINTECH, we have developed new priorities after very full discussion, and I will explain what they are. First, we have set it as a major objective of our policy—I am speaking of my Department—that science should be harnessed to the job of earning our living as a nation and overcoming the curse of a continuing balance of payments problem that has afflicted this country, under all Governments, for many decades.

Looking at the consequences that have flowed from this, I am sure that this is the right approach. We have, therefore, adopted a frankly commercial approach to our funding of science, and I make no apologies for having done so. It is absolutely no good spending hundreds of millions of pounds on self-generated science projects or those which earn Nobel prizes and world acclaim if industrial competitiveness is neglected in the process, with all the restrictions on domestic growth that we know that to involve.

Indeed, industrial stagnation inevitably leads to the curtailment of science spending, just as industrial success allows its growth. Thus, even in this area of taking a commercial approach to science we are making possible the opening up of options which are of benefit to science.

This involves the development of a capability for making judgments involving new techniques that have not previously been available to government. This is why we have set up the Programmes Analysis Unit, which does good systematic forward analysis forecasting. This is why, in evaluating many projects for which we are accountable to the House, we use extremely complicated D.C.F. calculations based on forward market analyses of a kind which

are as good, if not better, than those to be found in many firms and industries. This is why the techniques of value engineering and the other methods which have been developed in the better companies are now in use by the Government.

This is certainly not to say, of course, that pure or fundamental science, designed to meet long-term needs, is irrelevant. Science seen as an arm of economic advance must be demand-orientated and not self-generated. It may be that, as a result of having a demand put on one by industry or by the Government, it becomes necessary to cater for certain fundamental problems. However, that is different from regarding this as an extension of the academic process which we think later might lead to some application.

We have brought to the task of formulating civil science the many thousands of qualified scientists and engineers who work for and under the supervision of the Ministry of Technology. These people-there are 9,000 qualified scientists and engineers, including 6,000 working in 22 establishments-are a priceless national asset and we have tried to make it our business to refocus their effort more directly than in the past to meet our primary economic The policies which we have objective. developed to achieve this have reflected some very important and significant changes in emphasis, and I want now briefly to deal with them.

First, we have tried to reinforce the Government's general policy decision to relate defence spending to our general capability by securing a shift from defence research to civil research.

The second shift of emphasis has involved moving away from the old exclusive Government support of aerospace and nuclear work—both of which are, of course, products of defence—towards a far wider range of industries upon which our economic future depends. A country of our size cannot aim to do everything; if it tries to do so it will store up difficulties for itself. Choices have to be made, and we have been making them, painful as some of them have been.

For example, in the nuclear field at Culham we are cutting down fusion research by 50 per cent., just because its pay-off is so far ahead, if it ever comes, and we cannot spare the funds or the people for it.

It may seem slightly odd that a Minister should highlight the things that he has stopped so as to illustrate a positive policy, but a positive policy must mean concentrating on where we can succeed and not in dissipating our efforts in the endless financing of work that is undertaken simply because it lies within the intellectual capability of the scientific community.

The third change of emphasis has been from intramural to extramural research. This has been done wherever it has been appropriate, because Government research establishments—and reference has been made in broad terms to them—in part reached their present size to compensate for the research deficiencies in British industry.

As this happens, the role of Government intramural establishments will tend to change, and we must be ready for that change. Some of the work will be so specialised, so occasional, so expensive or so fundamental that it will need to be done outside industry. But the problems of transfer from innovation to exploitation, and the problems of making research programmes responsive to market needs are immediately more difficult if research is conducted under auspices separate from the needs it meets. The best transfer of technology is by the transfer of people or the establishment of joint teams, jointly funded, and this we aim to achieve.

The final shift of emphasis is a shift away from research to the exploitation of science in world markets, because here is where we have failed dismally over the last 100 years. A recent study has compared the development of gross national product per head of population in the major industrial countries from 1840 to 1968. It shows this country well ahead of its competitors until America overtook us in the 'nineties.

The next to get ahead of us was West Germany, in the 'fifties. The author of the study, Angus Maddison, has suggested that projections on the basis of growth rates over the last 10 years indicate that by 1983 France could be well ahead of us, itself having been overtaken by Japan, with Italy edging up almost to the United Kingdom level.

In the past, we have allowed science to develop in a watertight compartment manned and guided by an elite, and we have, for a long time, failed to recognise in our schools and universities that science must be a part of life spreading across the whole industrial field and applied intelligently by millions of people who are not Ph.D.s but technicians and even semi-skilled workers, by managers and market men, designers and production engineers, to raise our living standards and open up fresh options by creating new resources we can use as we think best.

It is also the policy that I have been describing that led us to try to reintegrate science with industry by, amongst other things, reorganising the nuclear industry to put our research programme under the management of committees upon which industrialists dominate, to keep within the overall manpower strength in our civil establishments and run down the strength of our defence establishments.

This is why we gave the Atomic Energy Authority freedom to move into non-nuclear fields like desalination, ceramics and non-destructive materials testing, started industrial applications units at Farnborough and Malvern, and sponsored industrial units in universities and as at Strathclyde; to build bridges between science and industry.

Anyone who thought that this would have a bad effect on the morale of scientists has been proved completely wrong. My case is that the morale of a scientist, like the morale of everybody else, ultimately depends on whether he feels that his work is wanted. The old doctrine that one must keep scientific teams together, even if necessary by thinking up new projects, is totally wrong. We will get the best out of people not by that method, nor by telling them what to do, but by engaging their interest in a problem that has to be solved. It is the function of Parliament, the Government and industry to see to it that our needs are formulated and presented so that scientists can help us to solve them.

I wish to say a few words about the development of our own research policy. First, I will look ahead to see how we can use the men and facilities in the A.E.A. and our own civil establishments now that the design construction companies have been set up, the fuel company is to be started, and now that Harwell has so successfully broadened its capability. It is too early to say exactly what form we shall adopt, but over the years, talking to people who have faced the same problem

in other countries, it has become clear that the relationship between civil scientific research and the needs to which it has to be put is increasingly being seen as one embodying a contractual relationship. The customer, whether it be Government, local government, nationalised or private industry, pays for what it wants and, by paying, shapes the research programme itself and thus acquires an added interest in applying its results more quickly.

Mr. Airey Neave (Abingdon): If one looks at our attitude to America in general, the Financial Times today has an annual review of industry and gives an account of the average load factors achieved during the last three years by nuclear power stations. The Minister will probably know why I refer to this and that I have an interest in the nuclear power industry. The average load factor achieved for British nuclear power stations has been 87 per cent., and the average for United States power stations has been 78 per cent. Therefore, at this moment of congratulation of the Americans on their tremendous effort, do not let us get too world-weary about these matters and think that because we do not have the same resources as America we cannot achieve very great results as well.

Some of my hon. Friends who are not here today have been heard to say, and many middle-sized firms have ideas on this subject, that we can transfer a great deal of research now done in Government establishments to private enterprise. I think they are very optimistic and unrealistic in many of the things they say.

Certainly, no one engaged, like myself, in the nuclear power industry would take this view when we are beginning to realise how much designers must be supported by the research done by the Atomic Energy Authority. The reorganisation, to which the Minister referred, of the design and construction group is a great move forward. It is also true, of course, in other fields, where pioneer work is being done by the Government research establishments. I refer particularly to carbon fibres, of which we have heard something this afternoon. I was on the Sub-committee of the Select Committee on Science and Technology which went into these matters, and this is a very good example. The announcement which was made by the

right hon. Gentleman that I.C.I. is to go into this work is very welcome to the House. For those who think that all can be done by private enterprise I suggest that they see what R.A.E. and Harwell are doing. Of course these establishments are not involved in production, and success in this does depend on private enterprise, but neither can do without the other.

I think the industrial pay off to which I referred has greatly improved. I was unfortunately unable to attend the Maurice Lubbock Memorial Lecture this year, which Dr. Walter Marshall, the head of Harwell and director of the research group of the A.E.A. gave. I believe it was extremely interesting. He was reported to have said that 25 per cent. of Harwell's budget—£4 million—and 30 per cent. of his staff are now engaged on industrial projects ranging over a very wide field. I hope that this will go on. I find it of enormous value to industry. There are now 300 firms working for Harwell, and they hope to sign one substantial agreement each week next year, according to Dr. Marshall's report. He instanced tangible commercial benefits-the right hon. Gentleman referred to this—of joint development on the programme with Weir Westgarth on the multi-stage flash distillation system of desalination, which has greatly improved Weir Westgarth's exports. I am glad the Minister referred to that. I think the cash returns to Harwell in the form of royalties will increase, but no one doubts that the work of such establishments should be kept under continuous review, and I think the Minister is doing that.

I should like to conclude by asking how these reviews should be conducted and whether Ministerial committees and Ministerial control are the best way.

The Minister pointed out in a recent speech at Imperial College that the barriers separating research from production should be broken down, and he also said that it would be quite wrong to undertake work inside Government establishments for its own sake just to keep scientists and engineers employed. I do not think the House will disagree with that. But can co-ordination and future progress best be done by the Minister or by an independent authority? This is not a new argument. I have heard it in this House over a great many years. I think the problem really is: Can one really bring industry into an

independent research authority, and can one thus co-ordinate more easily? On the whole I think this is true. I think such a research authority would need an operational analysis unit such as the programmes analysis unit at Harwell.

There is a case for an independent research authority which should be studied further. It is not easy in the short time available in the debate to say much more about it, but I am referring to establishments administered by the right hon. Gentleman's Ministry and by the A.E.A. We should need to know what were the original terms of reference when we studied the role of these establishments, whether their missions have been accomplished and whether the terms of reference were for projects which needed a temporary home and which have now become permanently installed. as seems to be the case, judging from our investigation of defence research establishments.

In particular, the work done by Government research establishments, should in my personal view, be work which cannot be done by universities and private industry or which may be done in financial partnership with them. I think that my hon. Friends were right to point to the lead for some taxation incentives to be provided to help industry to do more research, as Dr. Jones suggested. I am in favour of decentralising to a considerable degree control over the spending of the Government research establishments and giving them much more independence.

The Minister was slightly surprised when I commented upon the role of the N.R.D.C. in the carbon fibre programme and said that it was acting as middle man. I realised that that was an over-simplification, but I ask whether it would not be much better if the Government research establishments had more direct responsibility in their dealings with industry and a much wider degree of financial authority. Whether that could not best be done by having an independent research authority co-ordinating their activities rather than Ministerial control is a matter for debate. I am beginning to favour that view.

This is an issue which we can shirk no longer. I do not think that there are any extreme solutions. Indeed, I am against extreme solutions in this field. But if we do not find some answer, Britain will be admired for brains and pure research but

the danger is that she will be regarded as ineffective. There is no reason why that should be so. We have the industry and the science. It is for politicians and the Government to decide how it can best be organised.

Mr. Eric Lubbock (Orpington): I believe that computers will be controlmost industrial processes streamlining the flow of information. I believe that power by thermo-nuclear fusion will be a practicality, in spite of the fact that the Minister has reduced expenditure at Culham by 50 per cent., which may prove a short-sighted decision. In medical science, I believe that artificial hearts will be inserted in the human body as a minor routine operation almost. believe that unlimited supplies of water from huge desalination plants will enable us to grow food in the deserts and that techniques of under-water engineering will enable us to recover valuable raw materials from the depths of the ocean bed.

I think that the right hon. Gentleman is right in general in putting out more research to industrial companies, having more extra-mural and less intra-mural research. but research on this must be a controlled process, and in many respects it may be preferable to have co-operative research programmes going between private and public organisations, such as those, mentioned by the hon. Member for Abingdon (Mr. Neave), which have been undertaken by Harwell. He was right to mention that example, and we should consider how this can be extended, because a great deal of pioneering work has been done in this field. By that, I do not mean so much the character of the projects, exciting though those may be-the techniques of nondestructive testing, heat transfer fluid flow and, of course, the desalination programme.

What I mean is the development of new types of machinery for co-operative ventures between public and private enterprise on a far more flexible basis than we have managed hitherto. I think that the hon. Member for Abingdon was right to pursue the Minister's thoughts in this respect and to see whether one could extend the techniques of management developed by Harwell into these areas.

The hon. Member spoke of the possibility of having an independent research authority which would manage these programmes on behalf of the Ministry of Technology and I should like to hear whether the right hon. Gentleman thinks that the Atomic Energy Authority, shorn of its reactor responsibilities and of its fuel production and processing side, should be the nucleus of such an independent research authority which would be engaged over the whole spectrum and not just on the nuclear side.

I agree with the right hon. Gentleman entirely that we should consciously direct our programmes away from pure research towards exploitation. Again, I think that the Atomic Energy Authority has been very successful in this respect as one looks at some of the programmes which have been going on at Harwell.

#### Carbon fibres

9th July, 1969

MR. NEAVE asked the Minister of Technology what is his policy for the future of carbon fibre technology; and if he will make a statement.

Mr. Benn: Discussions are already in hand between I.C.I. and N.R.D.C. on the possibility of I.C.I. building a large carbon fibre plant.

I expect very shortly to reply officially to the Select Committee, outlining my policy for carbon fibre technology in the light of its report.

#### Uranium demand

9th July, 1969

MR. EADIE asked the Minister of Technology what is the estimated demand for uranium by the nuclear power industries in this country during the next five years; what source it will come from; and at what anticipated price.

Mr. J. P. W. Mallalieu: Demand for uranium for the nuclear power programme in this country over the next five years is expected to rise from some 2,000 to some 3,500 short tons uranium oxide per annum.

It will be met from stocks and from current imports from Canada and South Africa under long-term contracts.

For commercial reasons prices paid under the Authority's long-term contracts are not disclosed.

#### Nuclear shipping

9th July, 1969

MR. BROOKS asked the Minister of Technology what progress he has made in

his discussions with the shipbuilding and maritime interests over the possibility of constructing nuclear-powered container and bulk cargo vessels; and when he will make a statement about the technical and financial aspects of such a venture.

Mr. Fowler: The study of the probable costs and benefits of a nuclear ship project, of which I informed the House on 15th April, is now proceeding. Information is being sought from shipbuilders, shipowners, the Shipbuilding Industry Board and others. We hope to have the first results of the study by the autumn.

## Nuclear feasibility study

9th July, 1969

MR. PALMER asked the Minister of Technology if he will make a statement on the decision of the Atomic Energy Authority to refuse a request to support a nuclear feasibility study for developments in the Rotterdam port area of the Netherlands.

Mr. J. P. W. Mallalieu: This is a matter for the day-to-day business of the Atomic Energy Authority in which my right hon. Friend is precluded by Statute from intervening.

## Nuclear industry reorganisation

9th July, 1969

MR. NEAVE asked the Minister of Technology when he now expects to introduce legislation to give effect to proposals for reorganisation of the nuclear industry announced on 17th July, 1968.

Mr. Benn: Work on this legislation is proceeding, and I hope to introduce it as soon as possible.

#### Mineral and geological surveys

16th July, 1969

MR. EADIE asked the Minister of Technology what assistance his Department gives in the technology of mineral and geological surveys.

Mr. Fowler: Mineral and geological surveys are the responsibility of the Institute of Geological Sciences, a component body of the N.E.R.C., the responsibility of my right hon. Friend the Secretary of State for Education and Science. The U.K.A.E.A. have been able to offer them some assistance in the development of prospecting techniques and instruments and the Laboratory of the Government Chemist also assists the Institute by providing an

analytical service for geological specimens. At the request of the Committee on Marine Technology, U.K.A.E.A. are also making a study of possible equipment for mineral prospecting on the sea bed.

## **Atomic Energy Authority**

17th July, 1969

MR. Hooley asked the Minister of Technology, in the Atomic Energy Authority at the most recent convenient date in 1969, what were the total numbers of employees of all grades, the aggregate value of capital assets including land and buildings, the annual income and expenditure, and the commercial or industrial activities, giving for each separate activity the value of assets employed and the number of employees.

Mr. J. P. W. Mallalieu: The Accounts to 31st March, 1969 are not yet available. This answer therefore gives figures for 1967-68, based on the accounts to 31st March, 1968, which were published in the Atomic Energy Authority's Annual Report for 1967-68:

The total number of employees of all grades was	31,653 £ million
The aggregate value of the Capital	
Assets including Land and Buildings of £71.7 million was	140.4
The income (excluding military contracts) for 1967-68 was	36.1
The expenditure (excluding military	
contracts) for 1967-68 was	105.2

The commercial and industrial activities of the authority comprise the trading fund, which had capital employed of £36.3 million and 6,410 employees.

The three main activities of the trading fund and the number employed in each were as follows:

			Number of Employees	
Nuclear fue	el serv	rices	 1	4,759
Electricity	٠.		 	1,068
Isotopes			 	583

For commercial reasons, the capital employed on each separate activity of the trading fund cannot be disclosed.

# Combined A.G.R. and desalination plant

23rd July, 1969

MR. GREGORY asked the Minister of Technology what progress has been made by the Atomic Energy Authority and the

continued on page 262

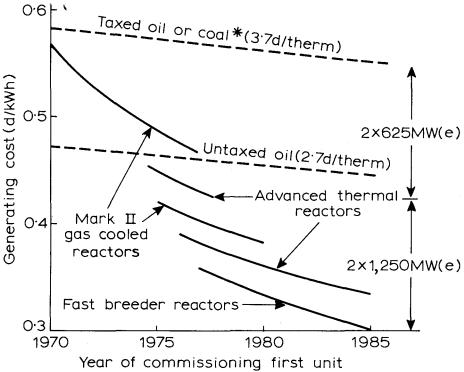
# The future operating role of nuclear power stations

This article by G. R. Bainbridge and C. Beveridge of Reactor Group, United Kingdom Atomic Energy Authority, originally appeared in the Electrical Review and is reproduced here by permission of the editor.

During the 1950s primary reasons for the development of nuclear power for electricity generation in Britain¹ were to provide for the forecast future need to supplement coal resources and to ensure a measure of independence from imported oil. Low cost coal seemed unlikely to be available in the quantities required and the direct oil supply routes were subject to political intervention.

A decade later<sup>2</sup> the energy situation has been at least temporarily transformed with large stocks of coal above ground, supertankers delivering oil via the South African Cape route and natural gas being landed into an expanding national grid. In that decade, however, the safe, reliable and economic application of nuclear power for base-load generation has been demonstrated and it seems likely that advanced nuclear designs will be able to increase the favourable margin established in generating cost, even if competing with coal from low cost mines or with untaxed oil, Fig. 1. The graph is based on the following assumptions:—

		Nuclear	Fossil	
Capital cost,		-		
1970-1985	(£/kW)	80-60	60-54	
Thermal		į į		
efficiency	(%)	42	37.5	
Amortisation				
period	(years)	25	30	
Load factor	(%)	75		
Interest rate	(% p.a.)	8		
		1		



**Fig. 1.** Generating costs for nuclear and fossil-fuelled power stations in the period 1970-1985. \*Coal costs based on low cost mine including transport and handling.

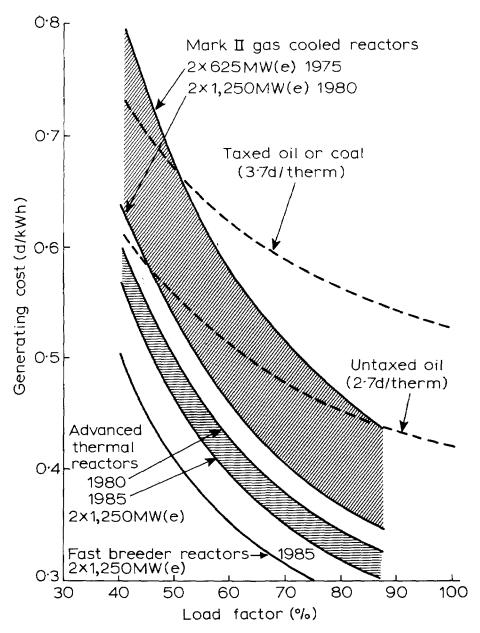


Fig. 2. Variation of generating costs with load factor for nuclear and fossil-fuelled power stations in 1970-1985. The graph is based on the assumption used in Fig. 1 with the exception of the capital cost of fossil-fuelled power stations. In this case, the forecast cost in the period 1970-1985 is taken as £57/kW-£54/kW.

In these circumstances nuclear stations will progressively supply not only all baseload power but, because of their competitive generating cost, Fig. 2, and low fuel cycle cost compared with fossil stations, Fig. 3, a substantial part of requirements at lower load factors.

# Likely nuclear installed capacity and load factors

With future nuclear power stations operating flexibly within the electricity grid system, an estimate of the economic benefit to the nation compared with an all fossil fired power station programme

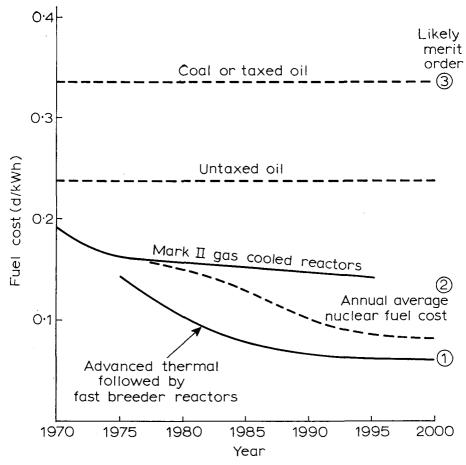


Fig. 3. Fuel costs for nuclear and fossil-fuelled power stations from 1970 to 2000.

indicates that at least 70% of all the new generating capacity installed should be nuclear, Fig. 4. This would lead to over 60% of the electricity generation being derived from nuclear energy in the 1980s, Fig. 5, and over 90% at the end of the century.

This implies that if the distribution of power station plant load factors stays much as it is today (which it will unless the consumers' daily demand pattern is radically altered by tariff or industrial restructuring, or the method of operating the grid system is modified) some of the earlier nuclear plants will on merit order be operating at down to below 40% load factor in 1990-2000 compared with the present 80%, Fig. 6.

If all nuclear stations were to be operated as a block, then the nuclear station load factors would all be about 65% at the end of the century. This would have quite

important grid system and generating plant advantages but the overall financial implications would have to be carefully considered.

#### Grid system requirements

The present daily variation of demand for electricity on the grid system, Fig. 7, is characterised by a rise during a period of about two hours in the early morning from the relatively low night level to the higher day level. Strong and fairly predictable peaks occur during the day, but there are many less predictable variations which plant must be organised to meet. The daily pattern is traced at a lower level during each weekend and holiday period, and at a higher level during the winter.

High merit order (low fuel cost) nuclear and fossil plants supply most of the steady night and day loads and "two-shifting" plant is brought up to high output to supply

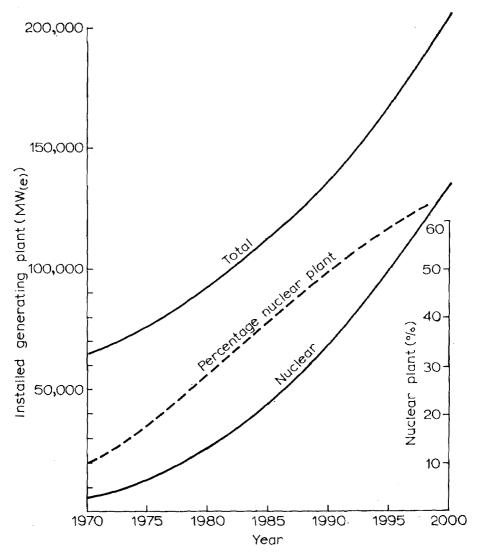


Fig. 4. Forecast total and nuclear generating plants in Britain, which takes account of the plant load factors each year during the amortisation period, where plant load factor  $\frac{\text{Units generated in year} \times 100}{\text{Rated output} \times \text{Hours in year}} \%$ 

the extra day load. Two-shifting here includes severe load reductions during the night without necessarily implying shutdown. Extreme peak load demands are supplied by low merit (high fuel costs) plants, i.e. gas turbines and old fossil and pumped storage hydro plants. There is a part of the day and night load provided by certain "immediate standby" plants running at reduced load and therefore able to change load rapidly to meet any demand occasioned by plant or grid system faults.<sup>3</sup> As more nuclear plant is installed part of it

will have to operate in the two-shifting and immediate standby roles.

To ensure that the nuclear plants may be designed to be fully capable of performing their future role, and that any development work required can be set in hand, the grid system requirements must be specified. For the two-shifting role the rate of output change is relatively leisurely, some 5% per minute for the plants when called into service from hot standby or low power. Such power changes would be required around 300 times each year.

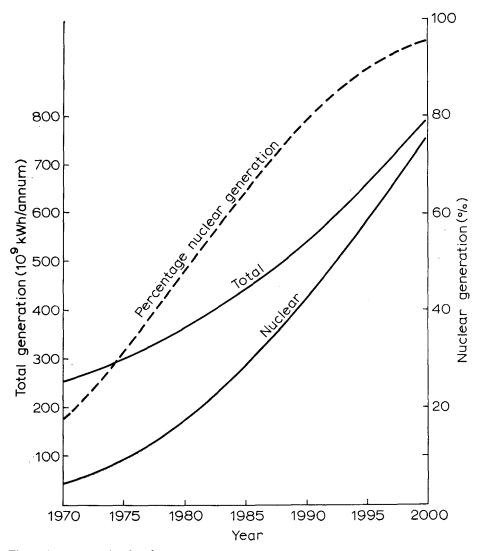


Fig. 5. Forecast total and nuclear generation in Britain.

The immediate standby role requires a more rapid response. On the grid system at any time sufficient plant capacity must be held operating at a lower power than it would merit, so that if a large plant unit or a grid line should fail, the output from this immediate standby capacity can be rapidly increased to make good the deficiency. The total plant involved in providing standby capacity can be in the region of 7 to 10 times the capacity of the largest generating unit for which deficiency cover is to be provided. Because undue delay could lead to an irrecoverable system frequency collapse, Fig. 8, the time allowed for a large part of the power

raising in these incidents is generally of the order of a few seconds.

A typical immediate standby plant response specification would be for a 15% increase in power from a level of about 75% maximum continuous rating in 2 to 4 seconds and thereafter a steady rise to full power output if required, Fig. 9. On average 100 events of this kind requiring a large response might occur each year on the grid system. The magnitude of the response needed depends on the size of the loss and the amount of running plant.

A larger number of slower (ramp) load increases are required additionally to supply abnormal customer demands, for

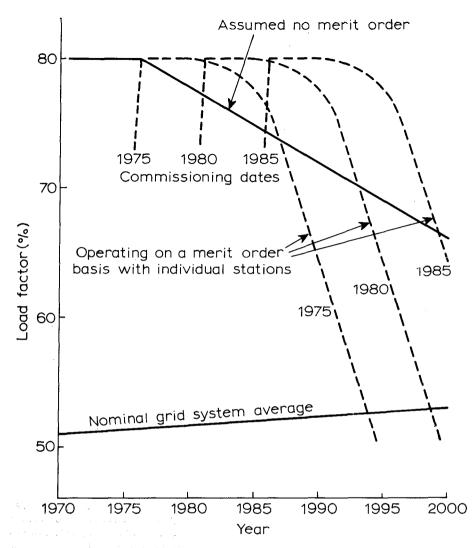


Fig. 6. Progressive annual load factors of nuclear power stations commissioned in the period 1975-1985 assuming stations operating according to (a) merit order and (b) without regard to merit order.

example, following popular television programmes.

In addition to the above operating roles, there is a fairly regular cyclic power changing pattern which plants generally are fulfilling in the grid system, unless they are for some special reason protected from it. This amounts to power increases and decreases of some 5% of the maximum continuous rating with approximately a one hour period.

The system requirements outlined will not, of course, only have to be met by nuclear plants, indeed new large fossil stations will have to be capable of fulfilling the various roles several years ahead of nuclear stations. Consequently many of the problems will be solved before the nuclear stations have to face them. This is particularly true for the solutions which lie in the operation of the turbine hall and "conventional" plant outside the boiler-house.

#### Nuclear implications in design

Nuclear power stations are not all alike, though there are obviously common features between different designs. Consideration of the various designs can lead to different solutions to the problems of

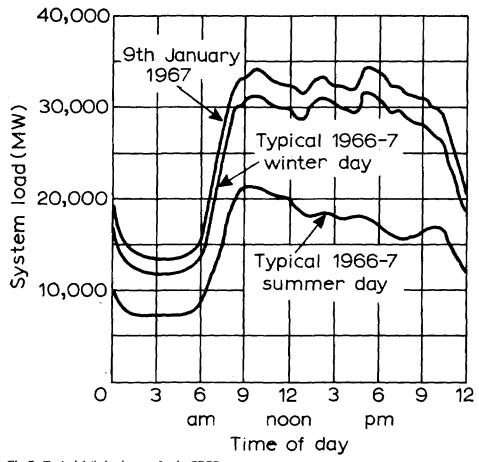


Fig. 7. Typical daily load curves for the CEGB system.

power changing. The same solutions will not necessarily be equally appropriate, for example, in stations having saturated and superheat turbines, nor should it be expected that gas-cooled, water-cooled and sodium-cooled reactors will be equally good in meeting the system requirements; what is necessary is that the designs are assigned to the roles they can best fulfil. It is the power station as a whole that must respond to give the demanded output change; the major duty to ensure the response may fall on the turbine or on the nuclear boiler, but it is more likely to be shared by both.

To assist in ensuring security of supply in their region, some nuclear power stations in Britain have already been called upon to operate at lower power output than they economically merit but by about 1980 all the power stations installed during the 1970s will be required to fulfil two-shifting and immediate standby roles.

In the case of fossil stations, with relatively costly fuel, the economic routine for two-shifting is to take some plants down to very low output each night and run the few remaining ones at high, peak efficiency, output. For nuclear stations with low fuel costs this method may not be followed as the most economic technique could be to reduce output slightly on all nuclear plants. Because there would be less accumulation of neutron absorbing fission products, particularly xenon, in the fuel this system of operation would reduce the initial capital expenditure by decreasing the control rod and fuel enrichment requirements. Towards the end of the century larger daily power station output variations will be required and these will necessitate some extra plant and fuel margins with consequent small cost increases. The rate of power increase for which gas-cooled reactors might be designed (say 20% per

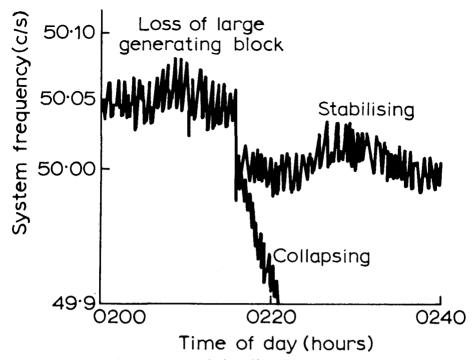


Fig. 8 Typical system frequency transient for loss of large generating set.

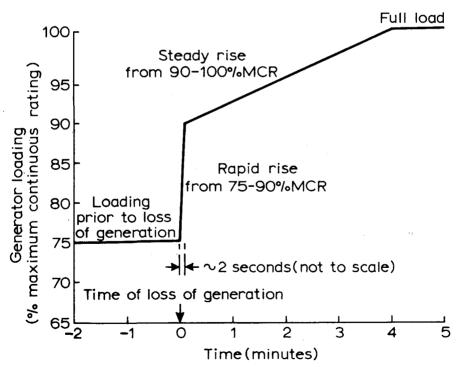


Fig. 9. Power station ideal load response requirement. The ideal response requirement is that when a system fault occurs, generating units running as a spinning reserve at 75 per cent m.c.r. should pick up two-thirds of the generation loss in 2 to 3 seconds and the remainder in 4 minutes.

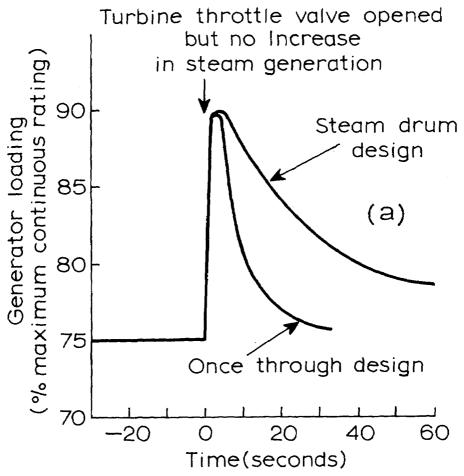


Fig. 10. Transient capability of nuclear stations: (a) shows that a thermal reactor with a steam drum would need less rapid heat and steam make-up from the reactor for immediate standby duties than for a once-through boiler design, (b) a longer permitted time to make-up steam generation by an increase of thermal reactor heat can be obtained by reducing the steam flow normally going to the feed heaters, and (c) shows the response which could be obtained from a sodium-cooled fast reactor.

minute) is adequate for the morning system demand increase, bearing in mind that several stations would be working up power together.

For immediate standby duty the rate of response for raising electricity output depends on the replenishment of steam instantaneously drawn off from the boiler system to increase the turbo-generator output. In a reactor employing a steam drum the store would need less rapid heat and steam generation make-up from the reactor than for a "once-through" boiler design, Fig. 10(a). A technique available for increasing the turbine output without drawing to the full extent required on steam from the boiler is to reduce the steam flow normally going to the feedwater heaters,

Fig. 10(b). This effectively gives a longer permitted time in which to make up the steam generation by the increase of reactor heat, shown in Fig. 10(b) as 20% of the maximum continuous rating per minute.

Fig. 11 shows a possible arrangement for feed heater switching on a gas-cooled reactor design. The additional h.p. feed heater shown may be economically justified, giving increased efficiency at part load operation. From the point of view of control the gas-cooled reactor seems to be capable of application to the two-shift and immediately standby roles. Development work for the fuel is being directed to ensuring that regular power and temperature changes will not lead to any reduction in fuel life.

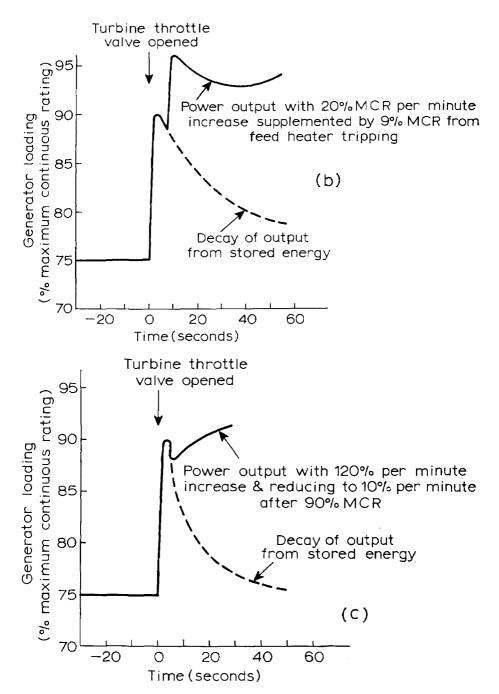


Fig. 12 shows a possible water reactor arrangement in which, with the lower steam conditions, the top two existing feed heaters may be sufficient for switching purposes.

#### Dumping excess steam

A further possibility might be to run the

nuclear stations at full power and to dump the excess steam until required, thus reducing any power cycling demands on the reactor. The economic and technical viability of such a scheme is receiving detailed consideration.

Water-cooled reactor power station designs installed during the late 1970s

Fig. 11. Modified gas-cooled reactor steam cycle for feed heater switching (dotted) for immediate standby duty capability.

would also be required to two-shift and provide immediate standby within a few years of commissioning. In several respects they might in principle be expected to be well suited for these roles. The steam reservoir with a direct cycle arrangement is readily available for transfer of reactor heat to the turbine and in some water-cooled designs there is further steam capacity in the steam drum. The feed heater trip arrangement could additionally be available to reduce the nuclear boiler duty. Temperature changes are small in the turbine for a given output change and so reliability should be good. The whole plant operates at relatively low and uniform temperature and the fuel is only slightly changed in temperature at the surface cladding for quite large core power changes. The fuel can is free standing from the fuel so it would seem suitable to withstand the required cycling. Nevertheless continuing power cycling proving work will be required to confirm these advantages.

Sodium-cooled fast reactors will probably be required to share grid system load changing duties from the date of introduction. Design and development work is being directed to this end. For example, fuel cycling experiments are being planned from the outset within the fuel development programme and this is generally less costly than having to add such experiments on to an already well advanced development programme.

From the outset also the characteristics of the fast reactor heat output control circuits can be specified, along with the necessary rates of change of coolant flow which the pumps have to provide, to transfer extra heat to the steam raising boilers. The sodium-cooled fast reactors seem likely to have better nuclear boiler characteristics in these respects, Fig. 10(c), than either gas- or water-cooled reactors. In the steam circuit and turbine hall arrangements the fast reactor stations will of course be closely similar to the superheat steam cycle equipment of the second generation gas-cooled reactors. The design possibilities overall seem likely to be adequate for two-shifting and for immediate standby operation without recourse to steam dumping, though if for any reason this proved necessary (perhaps to provide extra plutonium for the national or international fuel cycle economy) the fuel cycle cost should be so low that this reactor design would be the most suitable for this purpose.

#### Reliability and maintenance aspects

The duties of non-base-load operation will place upon large plants, fossil and nuclear, a requirement for high standards of maintenance and reliability. Outages of high merit-order plant are generally costly and this will particularly be so for low fuel cost nuclear plants during the years while they are at the top of the merit table and fossil units have to be called in to provide replacement electricity, Fig. 13. It will therefore be advisable to assess all new nuclear plants carefully to ensure that power cycling will not reduce their anticipated high standards of reliability and also to ensure that the component designs are suitable for speedy maintenance, including convenient access for adjustments, repair and replacements.

#### Outage costs

The cost of a week's outage for a 1,000 MW(e) nuclear plant in the mid-1970s is estimated at around £200,000 (summer months) and £400,000 (winter) and in the mid-1990s these figures could have fallen to £40,000 and £125,000 respectively due to the large scale installation of nuclear stations. Thus a period of two weeks' outage each year could average over 20 years (1975-1995) the equivalent of at least £4/kW capitalised to the commissioning date, giving a measure of the value of careful planning for reliability at the design stage to reduce such outage.

# Prospects and problems of arranging peak load operation

The expanding nuclear capacity discussed above leads to economic operation of nuclear stations down below the region of 40% load factor. The time will be reached when some nuclear stations will be shut down during the summer months at times other than those required for planned maintenance. During the winter these same stations may be on line at high output for 20 hours each day substantially on base load. Even the best fossil stations at that time may by comparison be operated little if at all during the summer and for only about 12 hours each day during the winter weekdays.

For peak lopping purposes very low first cost plant which can be brought rapidly

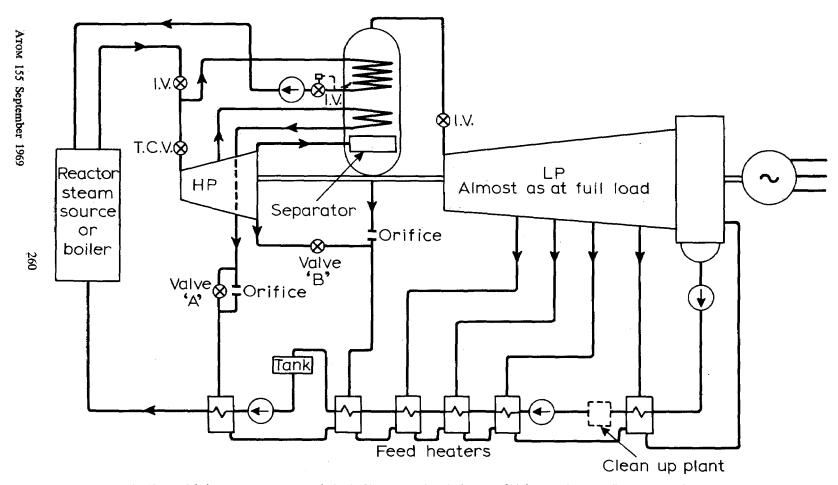


Fig. 12. Modified water reactor steam cycle for feed heater switching (valves A and B) for immediate standby duty capability. The orifice is used to maintain a minimum flow at all times.

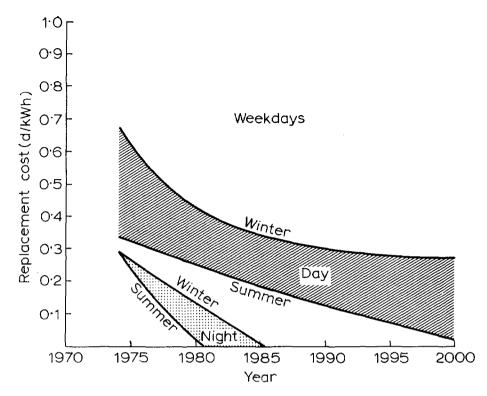


Fig. 13. Replacement electricity costs for a 1974-75 nuclear power station.

on-line is required and for this purpose gas-turbine plants4 continue supreme in the foreseeable future, (see table above). There is the possibility of designing into large plants short term overload base-load capacity<sup>5,6</sup> at relatively low cost, and increasing use may be made of disconnectable loads in, for example, aluminium, steel and chemical or desalination plants. Otherwise for the limited operation required of peak load plant each year (about 600 hours) clearly the most economic, independent plants, almost irrespective of the fuel costs, are those with lowest capital investment.

Various ideas for suitably low first-cost generating capacity have been proposed. For example, use of mine shafts to supple-

# Relative power station capital costs

Nuclear	1.0
Fossil	0.9
Pumped storage (80% of fossil)	0.7
Gas turbine, diesel	0.5

ment natural pumped storage where this is limited in amount by topography; construction of high pressure air accumulators formed in rock caverns<sup>7</sup>; and development of other forms of energy storage including fuel cells<sup>8</sup>. But none of these have so far shown any clear cost advantage at their present stage of development over the gas turbines for peak lopping purposes.

Because of their development potential future nuclear power station plants will continue to reduce in capital costs. Britain is particularly well placed in this respect with the SGHW (pressure tube) reactor advanced gas-cooled (possibly with the reactor coolant circuit coupled directly to gas turbines) and the sodium-cooled fast breeder reactor. Longer term concepts for study are the molten salt reactors from which the bred fissile fuel and the fission product poisons can be extracted continuously in a chemical plant coupled to the reactor, the possibility of direct electric generation reactors, pulsed power reactors and designs working with the fusion of atoms rather than fission. But again, none of these gives promise of the capital cost reduction by a factor of two compared with the present nuclear power stations which is needed to give them the required advantage over gas turbines for peak lopping.

#### Conclusions

The competitive economic position of nuclear power stations for base load operation is fully established and increasingly they will be called upon to fulfil load changing demands, both automatically and to the requirements of the grid system controllers, as immediate standby and two-shifting plants. Until the end of the present century fossil power stations will in the main provide for the detailed variations in consumer demand but nuclear stations will be increasingly required to take over this flexible operating role in addition to the daily two-shifting operation.

When the specifications and designs are adopted for these new reduced load factor operating roles near future nuclear power stations will maintain their economic advantage even at annual load factors in the region of 40%.

The major object for nuclear plants is to increase further standards of reliability and maintenance in service, particularly in their future flexible operating role.

Gas turbine plants are well suited for very low load factor peak-lopping generation. No other generating equipment seems likely to better their low first cost, robustness and fast response characteristics which are already leading to a general introduction of gas turbines into the grid system as about 5% of all new plant. Nevertheless improvements should and will be made in grid system operation to meet peak load requirements by increasing use of tariff structures to encourage storage and industrial process applications which can be considered as disconnectable loads.

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### IN PARLIAMENT

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Central Electricity Generating Board in the design study for a combined advanced gas-cooled nuclear reactor and distillation plant capable of producing 400 megawatts of electricity and 60 m.g.d. of water, including the costs of producing from such sources units of 1,000 gallons of water.

Mr. J. P. W. Mallalieu: The Atomic Energy Authority undertook a design study in 1965, in collaboration with the Nuclear Power Group Limited for this specific size of plant. A more recent study undertaken by the Atomic Energy Authority and Central Electricity Generating Board was based on  $2 \times 600$  MW(E) A.G.R. station linked with  $4 \times 10$  m.g.d. desalination units; the cost of water produced by this plant was estimated at approximately 5s. per thousand gallons.

# Nuclear power station for Greece

23rd July, 1969

MR. WILLIAM HAMILTON asked the President of the Board of Trade what further progress has been made in the negotiations with Greece on the sale of a nuclear power station.

Mr. Crosland: Negotiations are continuing between the various interests concerned, and I hope that they will be concluded successfully in the course of this year.

Mr. Hamilton: Can my right hon. Friend answer two questions? First, is the agreement inevitably tied up with the purchase of Greek tobacco by the United

Kingdom, and, second, will he make it clear that, whether this agreement goes through or not, Her Majesty's Government in no way condone the bestial activities and practices of the military regime?

Mr. Crosland: On the first point, the two sets of negotiations are not inevitably linked, but they are certainly very closely linked. On the second part of the question, I make it clear again, as I have made it clear many times before, that the fact that we encourage trade with Greece does not in any way alter the very strong feelings which I and my colleagues have about the nature of the Greek Government.

#### Desalination

23rd July, 1969

MR. PETER M. JACKSON asked the Minister of Technology whether he will publish in the OFFICIAL REPORT information regarding the potential applications in the United Kingdom of research being undertaken by the Atomic Energy Authority and others into the flash distillation, freezing and reverse osmosis systems of water distillation including any available information on costs per 1,000 gallons of fresh water.

Mr. J. P. W. Mallalieu: The Water Resources Board "Report on Desalination for England and Wales" published on 3rd July stated that the most likely application in the United Kingdom of the desalination processes being developed is in conjunction with conventional water supply and the provision of high purity water for industrial processes.

The Board report indicated that high purity water, using present distillation technology, would cost between 5s. and 8s. per thousand gallons, depending on whether produced from a dual purpose nuclear power plant (i.e. producing electricity and water) or from a water producing plant only.

Present research and development within the United Kingdom Atomic Energy Authority and by its industrial partners indicates a further reduction in the cost of water from improved distillation processes of up to 20 per cent. The freezing process for sea water desalination, which is at an early stage of development, gives projected water costs of 3s. to 4s. per thousand gallons for United Kingdom sea water conditions. It is too early to quote costs for water produced by the reverse osmosis process.

# 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. The fees shown are exclusive of accommodation.

### Introduction to Radioisotopes

22nd September to 3rd October, 1969 27th April to 8th May, 1970 14th to 25th September, 1970

A general theoretical and practical introduction to the principal techniques used in tracer applications of radioisotopes in research and technology. There is reference to the use of higher levels of radiation. It is not intended that the course be directed towards any particular discipline or application; but it is designed to be followed by a specialist course or to stand alone as a general introduction.

Time is available for alternative practical work to suit special needs. This work may include gamma radiography, measurement of neutrons, autoradiography or additional radiochemical work. Fee: £80.

#### Pressurised Equipment

29th September to 3rd October, 1969 9th to 13th March, 1970

For designers of graduate level who are concerned with pressurised equipment in a research and development environment.

Covers the following broad aspects of the subject:

Design of vessels, seals, joints, flanges; other practical aspects of design; materials and the effects of special environments; recent work on fracture mechanics and high pressure engineering.

Lectures are given by specialists from U.K.A.E.A. establishments at Harwell and Risley, from Government and industrial research and design establishments and from a University. Fee: £40.

#### Critical Path Methods

15th to 17th October, 1969 13th to 15th October, 1970

An introductory and largely non-mathematical course for management staff of graduate level who wish to make use of Critical Path Methods but are too busy to study in detail the larger commercial programmes.

It is based on Harwell's own CPM computer programme "CAPSTAN" of which the main advantages are its simplicity in use and its range of optional outputs. It is available at data centres.

Fee: £30.

# A.E.A. Reports available

THE titles below are a selection from the August, 1969, "U.K.A.E.A. list of publications available to the public". 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, periodiarticles, patent specifications which have appeared in reports published literature. It also lists the Depository Libraries in the U.K. and the countries with official atomic energy proiects which receive copies of U.K.A.E.A. unclassified reports.

## **AERE-R 4506**

Film Thickness Measurement in Annular Twophase Flow using a Fluorescence Spectrometer Technique. Part II: Studies of the Shape of Disturbance Waves. By G. F. Hewitt and B. Nicholls. May, 1969. 8 pp. H.M.S.O. 2s. 6d.

#### **AERE-R** 6083

The Gamma Ray Spectra of Large Volume Aqueous Sources. By J. E. Slade. June, 1969. 18 pp. H.M.S.O. 3s. 6d.

#### AERE-R 6105

Alumina Formation on the Dido-Pluto Class of Reactors. By E. T. Smith, G. F. Aitchison and J. Monahan. May, 1969. 38 pp. H.M.S.O. 5s. 6d.

#### AHSB(S)R 169

Revised Fission Cross Section Evaluations for the Energy Range 1 KeV to 15 MeV. By W. Hart. 1969. 34 pp. H.M.S.O. 5s. 6d.

#### AWRE 0-24/69

Glazing Defects in the Construction of Multilayer Circuitry for Computers. By R. H. Buck. May, 1969. 21 pp. H.M.S.O. 5s.

#### CLM-R 96

On Strong Transverse Magnetogasdynamic Shock Waves. By. L. C. Woods. May, 1969. 19 pp. H.M.S.O. 3s.

#### CLM-R 98

A Thermionic Lithium Plasma Source for Drift Wave Experiments. By J. Burt, P. F. Little and P. E. Stott. January, 1969. 15 pp. H.M.S.O. 4s.

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

# Tribology symposium

A two-day symposium and demonstration to explain the principles of tribology and to show how they can be applied in industry, will be held at The National Centre of Tribology, Risley, on Tuesday, 30th September, and Wednesday, 1st October, 1969.

The National Centre of Tribology was set up by the Ministry of Technology in January 1968. Since that time, through its consultancy, development and information services, it has provided solutions to a wide range of industrial problems. Knowledge of the relevant aspects of design, friction, lubrication and wear has been applied to produce such benefits as increased reliability, higher efficiency and longer life, with resultant financial savings.

The programme for the first day includes an introduction to the subject by Dr. D. Tabor, F.R.S., Deputy Director of Surface Physics Laboratory, Cavendish Laboratory, Cambridge, followed by a broad review of fundamentals given by Dr. J. F. Archard, Reader in Mechanical Engineering Leicester University. Professor J. Halling, Department of Engineering Tribology at Salford University, will bridge the gap between fundamentals and design, and Mr. M. Neale, an independent consultant, will consolidate design aspects and extend the subject to practical levels involving materials and the design aspects of industrial consultancy.

On the second day, conventional lubrication will be discussed by Mr. I. Palmer-Lewis of Shell Mex and B.P. Ltd., and the special expertise of the Centre on problems where conventional lubricants cannot be used will be outlined by the Manager, Dr. W. H. Roberts. Various examples of failures will be dealt with by Dr. R. Wilson, of Shell Thornton Research Centre, to be followed by case histories from the work of the Centre.

There will be ample time for discussions and for viewing the facilities of the Risley Centre, where there will be demonstrations of its work.

The symposium registration fee is £22 10s. 0d. and early registration is advised as attendance will be limited.

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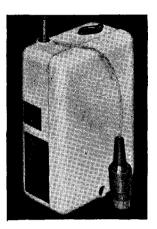
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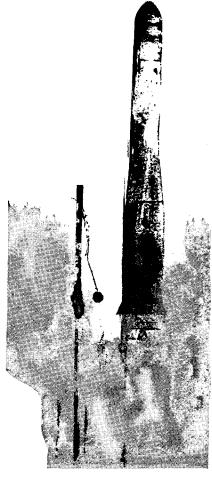
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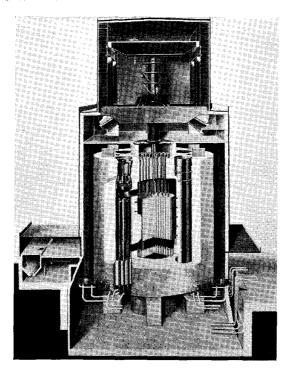
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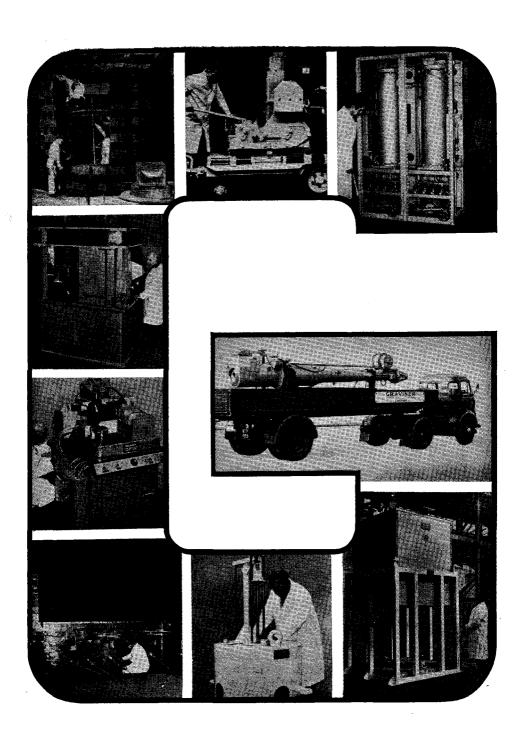
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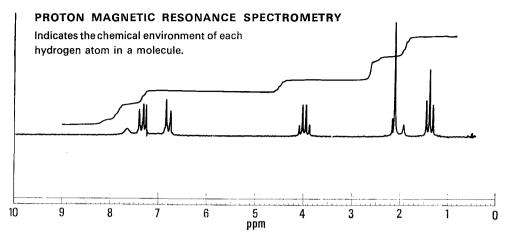


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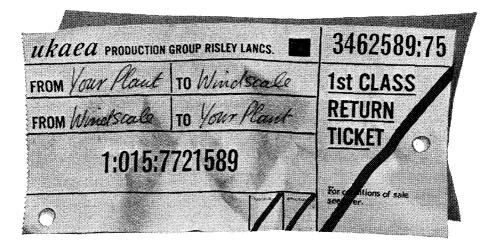
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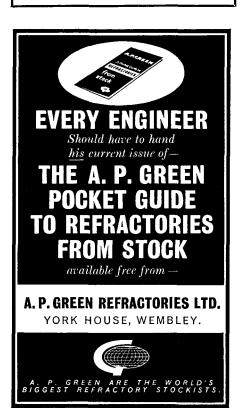
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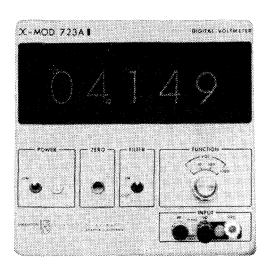
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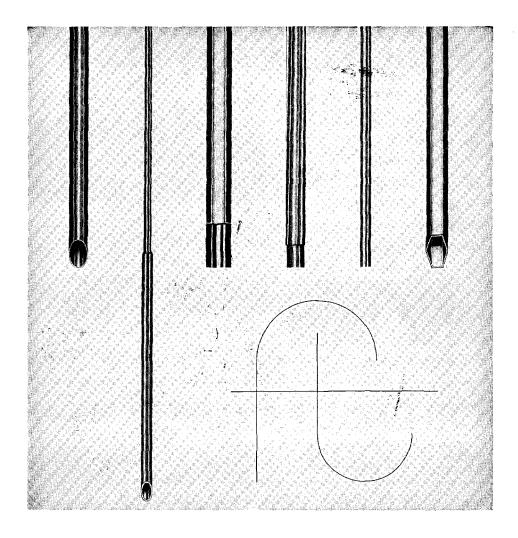
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