ATOM

Number 143 / **September 1968**

MONTHLY INFORMATION BULLETIN OF
THE UNITED KINGDOM ATOMIC ENERGY AUTHORITY

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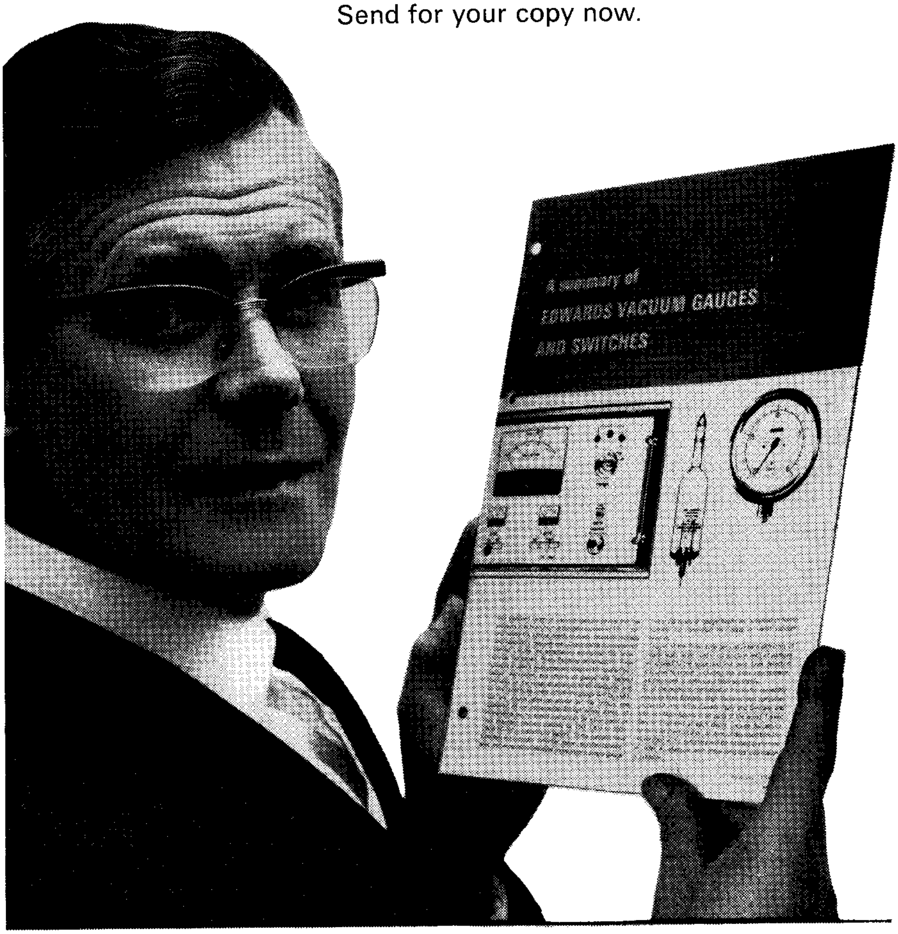

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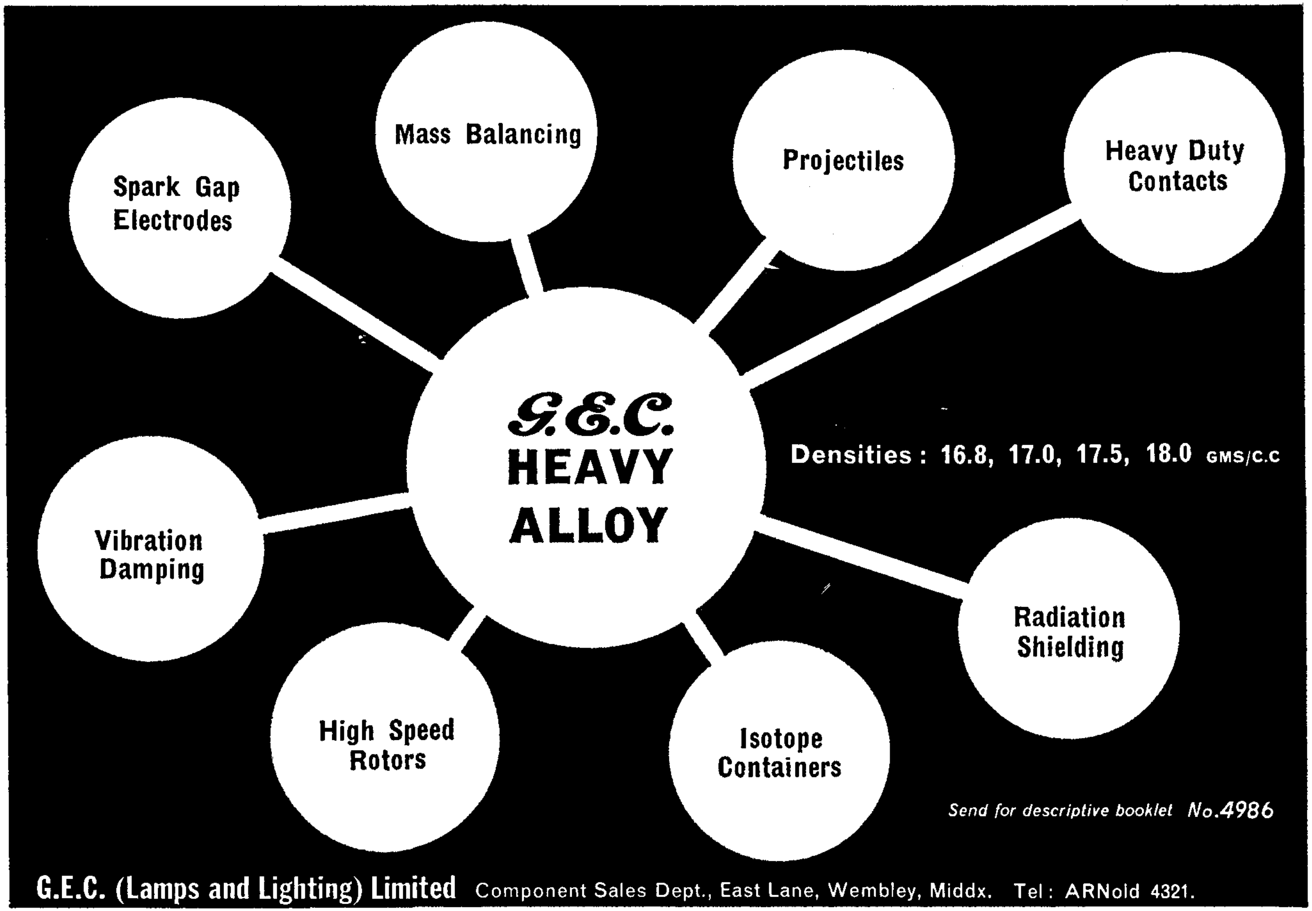

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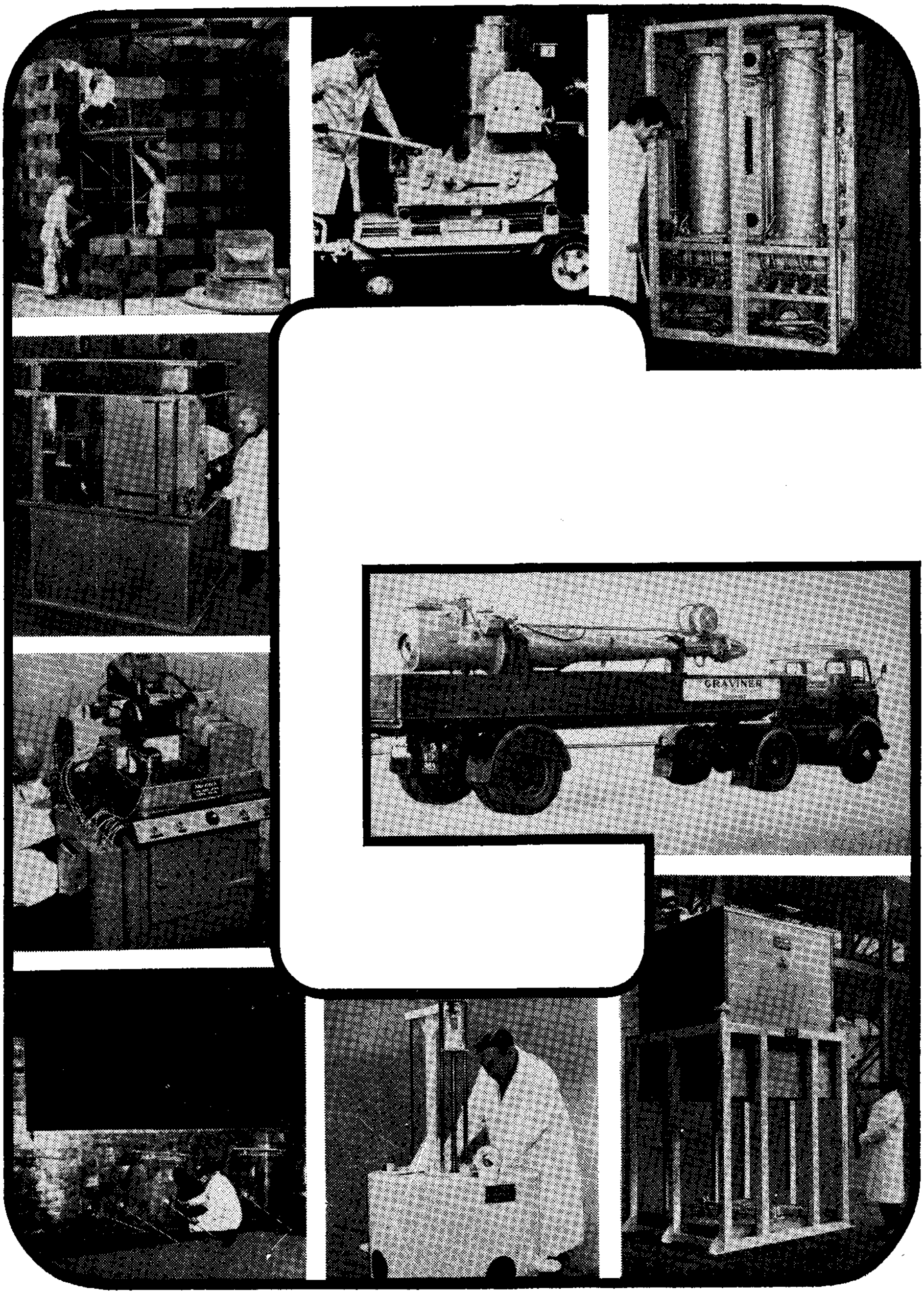
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ATOM

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OF THE UNITED KINGDOM
ATOMIC ENERGY AUTHORITY

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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.
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IN PARLIAMENT

Kincardine and Hunterston A power station unit costs

17th July, 1968

MR. EADIE asked the Secretary of State for Scotland what is the latest estimate of the cost per unit of electricity sent out from the high-pressure section of the Kincardine coal-fired power station; and what is the latest estimate of the cost of electricity from the Hunterston A nuclear power station.

Mr. Ross: I am advised by the South of Scotland Electricity Board that the average cost of electricity sent out from the high-pressure section of the Kincardine coal-fired station in 1967-68 was 0·83d. per unit and from Hunterston A during the same year 1·01d. per unit. Capital costs of nuclear plant are depreciated over 20 years, and of conventional plant over 25 years.

Computer industry

18th July, 1968

MR. PALMER asked the Minister of Technology if he will give a breakdown of the figure of £11·6 million for the total of Government support for the computer industry.

Dr. Bray: The figure of £11·6 million was composed as follows:

	£m.
S.R.C.	
Research grants in computing science (including allocation for awards to September, 1968)	2·5
N.R.D.C.	
(*Excluding* £4m. lent to I.C.T.) ...	3·0
Mintech	
Advanced Computer Technology Project (authorised ceiling to March, 1969)	2·6
Atlas C.A.D. Centre, Cambridge ...	2·5
University Research Contracts ...	0·5
U.K.A.E.A. sponsored work (mostly Aldermaston Project for the Application of Computers to Engineering)	0·5

Government expenditure in direct support of computer manufacture since the beginning of computing has been as follows:—

	Committed £m.	*Spent to date £m.*
Through N.R.D.C. ...	6·60*	6·60
Advanced Computer Technology Project	2·05	1·08
University contracts ...	0·21	0·04
	8·86	7·72

*Expenditure.

The above refers to expenditure in direct support of the computer manufacturing industry, either by way of capital assistance or support for research and development. It does not, however, include the cost of work in Government establishments, expenditure on computer development purely for military purposes, nor the cost of any support on projects aimed at furthering the application of computers, nor purchases of computers.

The main items of expenditure by the Ministry of Technology in support of projects aimed at furthering civil applications of computers are the following:

	Committed £m.	*Spent to date £m.*
Computer Aided Design (Cambridge)	2·50	0·58
Contracts with Universities	0·30	0·15
Aldermaston Project for the Application of Computers to Engineering (A.P.A.C.E.)	0·35	0·11
Cold Rolling Mill Automation (jointly with A.E.I. and Imperial College) ...	0·28	0·02
Warehouse Automation (C.W.S.)	0·15	—
N.C.C.	1·59	1·14
	5·17	2·00

Neither set of figures above includes expenditure on computers or computer projects by Research Associations, either from their own funds or by way of capital grants from Mintech.

300 GeV nuclear accelerator

22nd July, 1968

MR. FORTESCUE asked the Minister of Technology what studies he has made of the implications for British nuclear technology of the decision to withdraw British participation from the proposed CERN 300 GeV nuclear accelerator.

The Minister of State, Ministry of Technology (Mr. J. P. W. Mallalieu): The decision not to participate was taken only after the most thorough examination of all relevant factors, including the industrial implications of the project.

Mr. Fortescue: Does the Minister agree that without a healthy foundation of fundamental research applied research cannot exist at all, and that ultimately the whole work of his Department depends on full participation by British scientists in fundamental research on a European or even a world scale?

Mr. Mallalieu: Fundamental research is vitally important, but it is a question of priorities.

A.W.R.E. projects

22nd July, 1968

SIR H. LEGGE-BOURKE asked the Minister of Technology if he will make a further statement on the figures relating to rechargeable and non-rechargeable projects undertaken by the United Kingdom Atomic Energy Authority and the Atomic Weapons Research Establishment under Section 4 of the Science and Technology Act, 1965, including those conducted under special Ministerial approval.

Mr. Wedgwood Benn: The following table gives revised figures relating to expenditure or rechargeable work at the Atomic Weapons Research Establishment.

The other data given in my Written answers to the hon. Member on 13th May remain unchanged.

Approximate Date Started	*Description*	*Expenditure to 31st March, 1968 £'000*	*Estimated Expenditure 1968-69 £'000*
April, 1963 ...	Space Technology	305	250
October, 1966 ...	A.P.A.C.E.	133	185
April, 1963 ...	M.O.H. Medical Engineering and Services ...	139	180
April, 1963 ...	The Home Office—various forensic science projects	186	55
October, 1966 ...	Mintech—Advanced Computer Interconnections	76	65
August, 1967 ...	M.P.B.W.—Glass Fibre Reinforced Plaster ...	14	25
October, 1966 ...	M.O.H.—R & D on Dental Materials	24	20
April, 1963 ...	Other Civil Work for Government Department*	463	180
April, 1963 ...	Minor Works for Universities, Industry, etc† ...	94	40
	Total‡	1,434	1,000

*Includes 8 contracts in hand over £5,000 each.
†Includes 2 contracts in hand over £5,000 each.
None of the above projects forms part of any international project.
‡*Figures of expenditure cover full cost, including depreciations and similar notional overheads.* Full cost is recovered from all customers.

Prospects for nuclear energy in Western Europe: illustrative power reactor programmes

Some comments by P. J. Searby, Economics and Programming Branch, U.K.A.E.A., on a report by a Study Group of E.N.E.A.

History

At the end of 1964, shortly after the Third Geneva Conference, the Steering Committee of the European Nuclear Energy Agency (E.N.E.A.) set up a Study Group on " Nuclear energy as a long term resource in Western Europe ". It was considered that a common study of such problems as the availability of nuclear raw material reserves and possible long-term energy demands, including the anticipated contribution from nuclear reactors of various types, could provide an agreed set of assumptions valid for the Western European region as a whole which might prove useful for future planning on a national basis in E.N.E.A.'s member countries.

The author of this note has been a member of this Study Group since shortly after it was set up, and is thus not in a position to express an unbiased view of the extent to which the Group's activities have justified the Steering Committee's decision to set it up. The Group has, however, not been idle. With the assistance of the Working Parties it has set up, it has produced authoritative estimates of the resources and price category of uranium and thorium minerals in the world (excluding U.S.S.R., China and Eastern Europe), and obtained general agreement on the characteristics of power reactors, both current and envisaged in the foreseeable future. The estimates on mineral resources were first published in August, 1965[1], and have since been revised (in collaboration with I.A.E.A.) in a report published in December, 1967[2]. The work on establishing agreed power reactor characteristics was first published in September, 1966[3]. The object of this report was to provide data suitable for establishing the fissile material and fuel cycle requirements of a nuclear power system over a long period of time. This was facilitated by the setting up of five groups, each concerned with a particular reactor system, who endeavoured to collate the data available and agree on a single recommendation as to the data to be used for a particular reactor type. The different reactor data were published in a standard form to facilitate future long-term studies and the report included a prediction of the nuclear load growth in Western Europe from 1970 to 2009.

The latest report from the Study Group[4] brings up-to-date, where necessary, the data in the 1966 report on " Power Reactor Characteristics ", and then aims to go one step further and to illustrate, on the basis of these data, some of the long term effects which could result from the eventual application of nuclear reactor technology along broad alternative lines of growth over the next forty years. Obviously there must be an appreciable element of speculation over any conclusions to be drawn from a study covering such a long period in the future, but studies of this nature are clearly required in forward planning and this particular report is a good illustration of the international co-operation within E.N.E.A. It must be appreciated, however, that although the hypotheses and assumptions employed in the calculations are generally recognised as being realistic in the light of present-day knowledge, the report is concerned mainly with only one of the factors which determine the performance of a nuclear reactor—i.e., the utilisation of fissile material—and ignores the most important factor concerned with the establishment of particular reactor types, which is clearly the achievement of minimum costs of electricity generation.

Nuclear demand forecast

The nuclear demand forecast for Western Europe used in the report is given in Table 1. Specific assumptions were made for the types of reactor installed to provide the 1970 capacity of 10 GW(e) (1 GW = 1,000 MW) and the

1975 estimated capacity of 40 GW(e). Allocation of fixed reactor types from 1975 onwards was not considered appropriate and the report concentrates on the comparison of alternative reactor programmes beyond this date. Furthermore, the nuclear demand situation beyond 1980 was considered to be equally uncertain and this led to the adoption of high, mean and low demand programmes with the range of uncertainty increasing with time. This wide variation in possible demand by the end of the century and beyond seems essential in view of all the uncertainties on the rate of growth of demand for energy in Western Europe and the extent to which (taking account of costs, etc.) this demand will be met by nuclear means; it thus provides perhaps the most important of the variants which the study considers.

Illustrative reactor programmes

Though the " reactor mix " up to 1975 can be guessed with reasonable accuracy, it is clearly impossible to select the correct mix for Western Europe for the remaining 35 years up to 2010. The report, therefore, considered, for comparative purposes only, twenty-one possible reactor mixes from 1975 onwards. Ten of these cases postulate the installation of single power reactor types for the 35-year period covering both uranium and thorium reactors, and allowing for either the " export " or recycling of plutonium. All of these clearly depict hypothetical situations, but they give a measure of the effects of an overwhelming preponderance of any one reactor type and some indication of the material savings to be made by recycling plutonium when no plutonium-fuelled breeder reactor is available, as well as acting as a base line to illustrate the benefits of the fast reactor or thorium breeder introduced in later cases. Because precise data relating to the recycling of plutonium in LWR's and HWR's were not available, several simplifying assumptions were necessary concerning the uranium and separative work savings due to the use of plutonium. For the LWR, these were that natural uranium requirements would be reduced by 150g. and separative work requirements by 200g. S.W. for each gram of plutonium 239 equivalent recycled. In the HWR case, some data were available and these were in good agreement with a saving of 150g. natural uranium per g. Pu-239 recycled.

The remaining eleven cases attempted to cover the more complex and likely situations where the overall power requirements would be met by two or more reactor types. These, of course, required the adoption of further simplifying assumptions relating to the date of introduction of particular types of advanced reactors, the allowable rate of build-up of fast reactors on their first introduction and the minimum level of plutonium stocks needed to maintain the programme. For computing purposes, therefore, it was assumed that fast breeders or converters would not be introduced before 1980, and liquid fuelled reactors not before 1990, whilst the plutonium stockpile was never allowed to fall below 15 tonnes.

Apart from the simplifying assumptions mentioned above, three further major assumptions, which radically affect the results and conclusions of the exercise, were adopted for the main calculations in the study:

(i) it was assumed that no nuclear stations needed to be withdrawn from service (being then replaced by more advanced designs) throughout the period considered, even though this meant in some cases a working life of 35 years or more;

(ii) reactor parameters were kept constant from 1975 onwards (i.e., no development potential was allowed for); and

(iii) all reactors would operate in a given year at the average load factor shown in Table 1 (i.e., no attempt was made to apply an order of merit for operation).

The effect of these on the results is discussed later in this article.

Although the twenty-one cases considered do not exhaust all possibilities or, indeed, represent, apart from the multi-reactor strategies, anything approaching reality, the overall results from these cases and interpolation between the results gives a good indication of the potential of practical programmes.

Computer techniques

The bulk of the computing work for the study was carried out under the guidance of the Swedish and Dutch mem-

Table 1—Nuclear demand forecast for Western Europe (July, 1967)

	High GWe	Mean GWe	Low GWe	Mean load factor
1970	10	10	10	0.80
1975	40	40	40	0.80
1980	110	110	110	0.80
1985	242	230	218	0.77
1990	432	392	352	0.73
1995	656	580	504	0.68
2000	978	800	622	0.67
2005	1,350	1,060	770	0.65
2010	1,800	1,350	900	0.65

bers of the Study Group though some Italian results are also reported. It is now planned to carry out some calculations using the U.K. Discount programs; these will enable useful comparisons to be made and should make it easier to carry out new calculations relaxing the unreal assumptions on load factor and plant life referred to above.

Discussion of results

Uranium requirements

The results clearly demonstrate that the introduction of advanced converters or breeders achieves a major reduction in uranium requirements over the 40-year period. Fig. 1 (which is derived from Table 5 and Fig. 2 of the E.N.E.A. report) compares the estimated total uranium requirements up to 2010 A.D. for a number of illustrative cases:—

(a) Continuation of "proven reactor" types only after 1975—the figures are not very different whether the system adopted is AGR or LWR.

(b) As (a) but recycling the plutonium produced.

(c) Introduction of a good advanced converter—a natural uranium heavy water reactor is taken as the illustration because it has the lowest uranium consumption, but the figures are not very different for an enriched heavy water reactor (e.g., S.G.H.W.).

(d) Introduction of fast reactors from 1980 (subject to the availability of plutonium) supplemented as necessary by either continued installation of proven reactors or by an advanced converter using heavy water as moderator.

The figures are given both for the high growth assumption and the low growth assumption. It will be noted, as the E.N.E.A. report points out (paragraph 46), that on the assumptions used the natural uranium heavy water reactor with plutonium recycling needs less uranium up to 2010 than the adoption of fast reactors with either AGR or LWR to complement them. However (quite apart from the cost factors not considered in this report) it would be wrong to deduce too much from any single set of figures of this type. As is shown in the report (Fig. 4), the trend of annual uranium requirements is very different in the different cases and, except for the high growth cases, annual requirements of uranium at the end of the period under consideration are less for the fast reactor plus proven reactor case than for advanced converters with plutonium recycling. Thus the fact that the investment in fast reactors provides for a continuing improvement in the overall utilisation of uranium (thanks to its breeding characteristics) is already being reflected in annual requirements. (Not to take advantage of the possibilities that breeding presents would be to deny to the future a large part of the benefit from the fission reaction that earlier generations will already have enjoyed.) Moreover, as the report itself stresses, actual programmes in Western Europe will be more complex than the illustrative cases studied, and significantly lower requirements can be achieved by a judicious blend of fast reactors with both proven reactors and advanced converters.

For these reasons the report is careful to supplement its discussion on total uranium requirements over the period with a discussion of annual requirements. To illustrate the effect on these of different assumptions the report discusses a number of programmes in which a proven reactor type (the LWR was in fact chosen) was:—

(a) the only type installed after 1975;

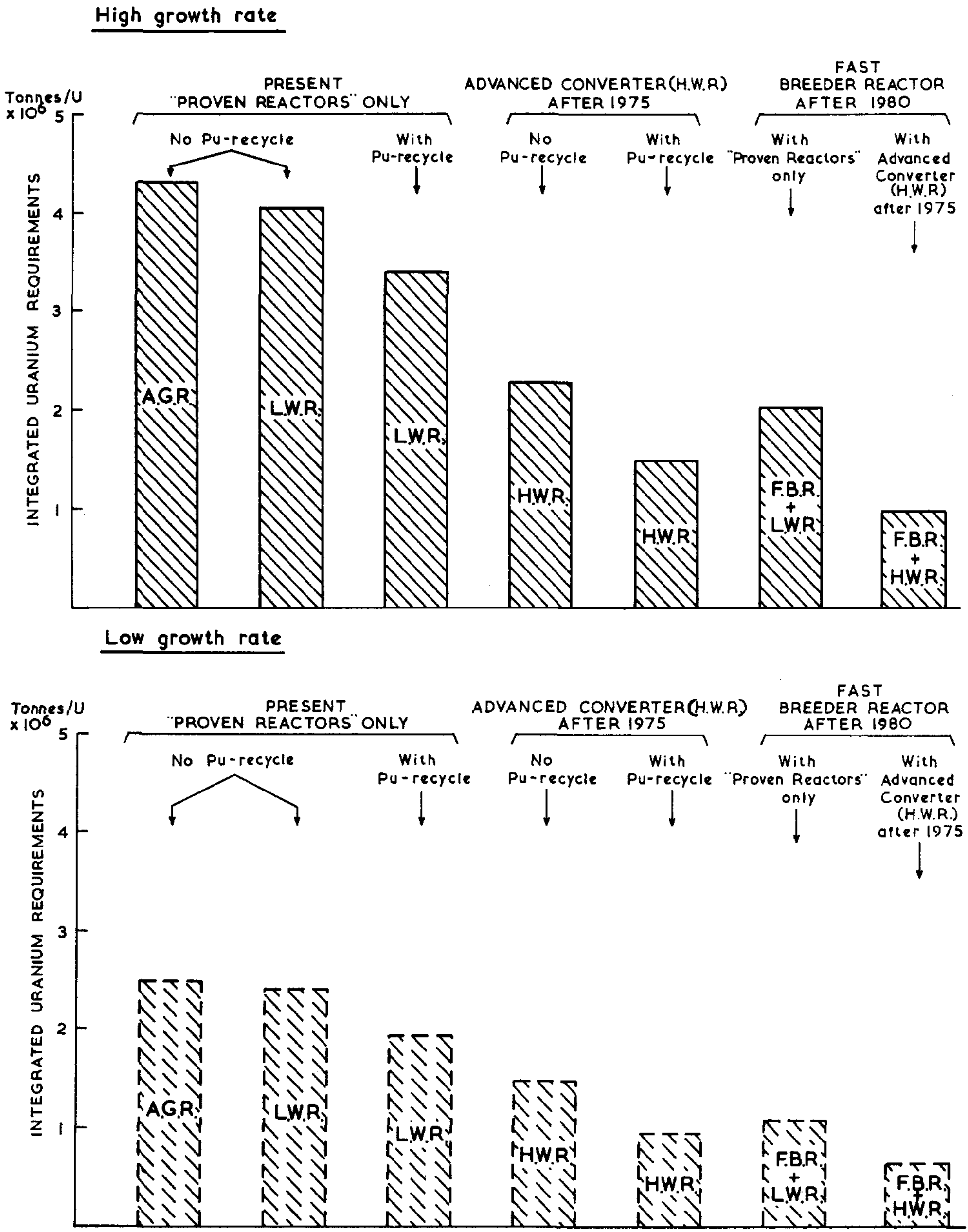

Fig. 1. *Integrated uranium requirements to 2010.*

(b) accompanied by fast breeders from 1980—subject to plutonium availability;

(c) replaced by fast breeders plus fast converters from 1980, the fast converters (initially fuelled with U-235) being installed and fuelled with U-235 for so long as plutonium requirements limited the introduction of fast breeders.

Fig. 2 (derived from Figs. 3, 4 and 5 of the report) shows the effect both of

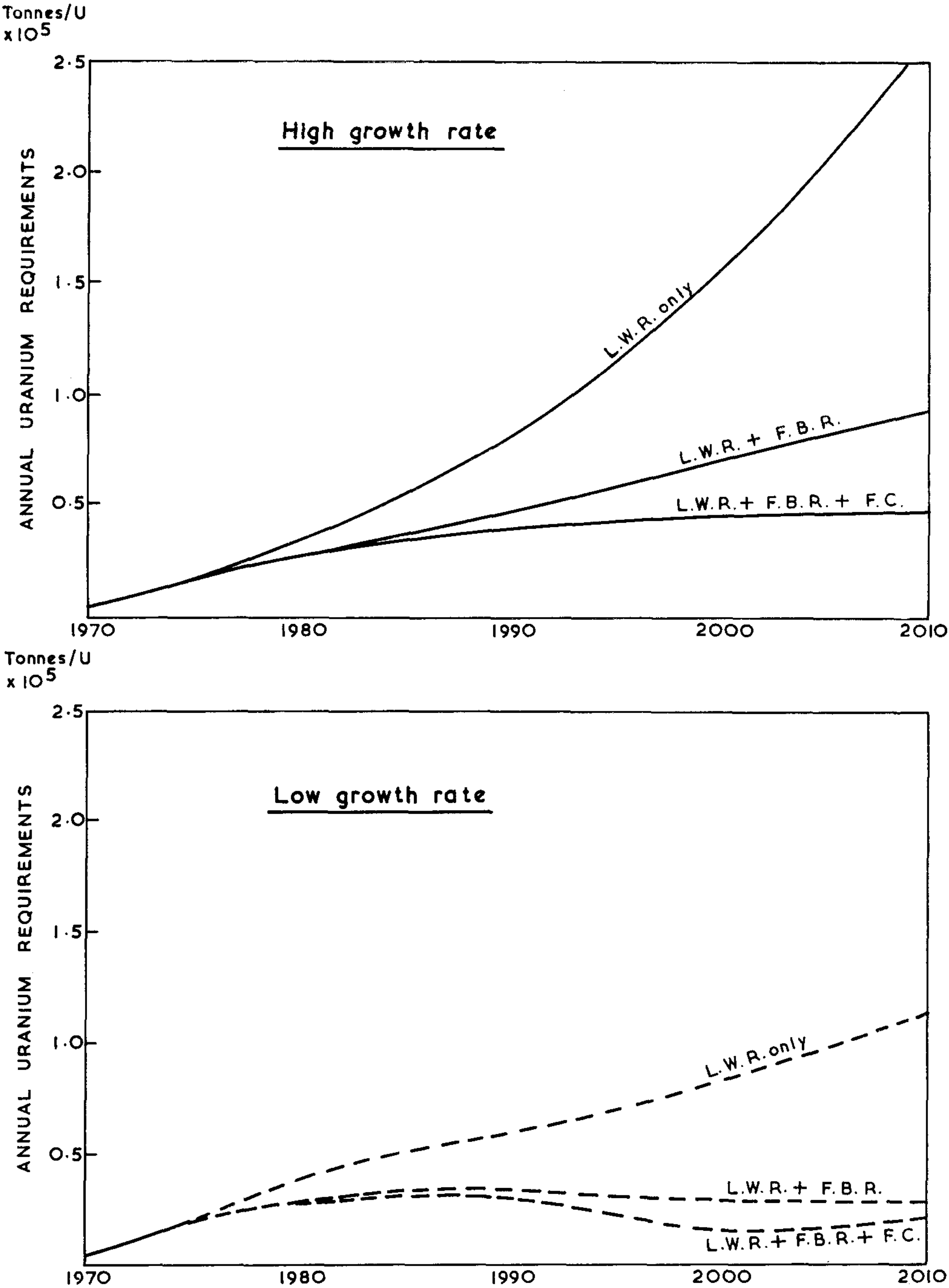

Fig. 2. *Annual uranium requirements—illustration of effect of alternative assumptions.*

variations in the assumed growth of demand and in types of reactor installed. A much more comprehensive presentation of these effects, for a larger number of illustrative reactor programmes, is given in Fig. 4 of the report. Both figures show that while a continuing increase in demand for uranium into the 1980s is highly probable there are many factors which will slow down and perhaps halt that increase in demand during that decade. However, we do not find, in any of the illustrative programmes considered, any rapid subsequent fall-off in demand for uranium such as has sometimes been predicted. This is partly due to the simplifying methods adopted for this study in relation to life-time, load factor and technical advance. However, some appropriate allowance for these factors can be made where appropriate, i.e., where on the basic assumptions of the study plutonium stocks start to accrue in the 1990s, by (for example) assuming the replacement of the earliest stations (with their heavy annual consumption of uranium) by up-to-date fast reactors fuelled with the surplus plutonium. Allowing for this would lead to a reduction in demand but the figures show that this would be gradual and occur over a long enough period to enable uranium producers adequately to plan the production capacity to match forecast needs. The figures in the study suggest (see paragraph 50) that the most these factors would in practice do would be to reduce uranium requirements for the year to 2010 to about half the level reached in 1990—say 20,000 tons of uranium metal a year for Western Europe compared with the figure of 40,000 tons a year which may be a reasonable estimate for a number of possible programmes in about 1990. These forecasts of the trend of demand will, of course, as the figures show, depend to a considerable extent on the assumptions made regarding the demand for electricity and, in particular, the characteristics of the breeder reactors which are introduced; it would appear that the particular sets of assumptions which at one time led to fears of a sharp collapse in the market are no longer regarded as being within the probable range of uncertainty.

Requirements for fuel services

Similar comparisons can be made of the requirements, for different illustrative programmes, for separative work (to provide enriched fuel) fuel fabrication plant and reprocessing plant. Not surprisingly, the general trend of requirements for fuel services follows closely the annual requirements for uranium though there are important differences of detail for individual programmes which can be studied in the detailed Appendices prepared as part of the study and to be issued separately. These Appendices also contain a wealth of valuable information on thorium requirements and plutonium stocks appropriate to the cases under consideration. Some of these figures are also given in the main report but space does not permit any discussion here of the figures, though further study both within E.N.E.A. and by individual countries will undoubtedly be well worthwhile.

The report gives particular attention to the requirements for diffusion plant and notes that, in addition to the obvious effects on capacity required if natural uranium reactors are introduced in quantity, there are important consequences in cases where a fast converter (capable of being operated on plutonium, once plutonium supplies are adequate) is included in the programme. Fig. 6 of the report shows that in certain circumstances if the rate of growth of nuclear installation is *high* the introduction of fast converters can significantly improve the utilisation of enrichment plant, but if the rate of growth is *low* a fast converter would increase requirements for separative work in the short term but soon lead (because the fast converter could be switched over rapidly to plutonium fuelling) to an under-utilisation of this capacity. This is an interesting conclusion, but perhaps needs to be tested against alternative assumptions to check whether it is valid generally or is dependent on particular features in the assumptions used or the techniques of analysis adopted.

Sensitivity analysis

The basic cases considered above made some attempt to allow for uncertainties in estimates of forward nuclear capacity by taking into account three alternative levels of demand. In addition, it was also thought advisable to test the sensitivity of the results to deviations in reactor characteristics from the reference assumptions used. The reactor parameters selected for this sensitivity analysis were: increased rating in converters and fast breeders (resulting in reduced inventory requirements); increases and decreases in the breeding/conversion ratio of fast breeders and thorium reactors, and hence in fissile material production from such reactors; delays in the introduction of fast breeders, fast converters and liquid fuelled reactors; increase in out-of-pile residence time for fast reactor fuel; varying load factors; and simultaneous application of all the favourable variations.

Apart from some brief comments in the main report, the analysis on the above lines has, as yet, only reached the stage of tabulating (in the separately available Appendices) the rather large number of results, with a few illustrative figures given in Table 5 of the main Report. Much work still needs to be done and it is hoped that the Study Group will be able to assess these results in more detail, possibly extending the analysis if this seems justified, and perhaps issuing a separate report detailing their findings. While it is therefore premature to draw any definite conclusions from these results, some mention should be made of the material now made available; some tentative comments based on that material may be appropriate. These comments are based on the results, given in Table 5 of the Report, of the deviations in total uranium requirements to the year 2010, which arise from the variations in assumptions considered:—

(a) Increased converter rating (+24%) has only a minor effect on requirements except for the A.G.R. and the thorium reactor cases.
(b) Increased rating in fast breeders (+30%) has a marked effect which averages a reduction of about 20%-30%.
(c) A 5-year delay in introduction of the fast breeder increases demand up to 15% in most cases but is particularly serious where plutonium production from thermal reactors is high (e.g., from Magnox).
(d) Making allowance for the operation of different types of reactor at different load factors (order of merit operation) can reduce requirements by up to 20%—this appears to be of least significance in the case of LWRs, which implies that in the simplified cases discussed above the LWR looks better (relative to other types) than it would be in reality.
(e) Simultaneous application of all favourable variables could give a reduction in requirements of at least 20% and up to 50% in some cases.
(f) Running through all the results is an indication that the medium programme is in some way out of line with the high and *low programmes with respect to the effect of changes in parameters—this will need further detailed investigation.

Conclusions

Though this is made quite clear in the E.N.E.A. report it should again be stressed that the results given in the report, some of which have been reproduced here, are *illustrative* figures based on a simplified form of analysis and clearly defined assumptions which are recognised as arbitrary and themselves also oversimplified. Any conclusions drawn from the figures must therefore be carefully qualified and interpreted, but they will, it is believed, help in an appreciation of the possible trends in requirements for fuel plants in Western Europe.

As already pointed out, the report notes that although the study has concentrated on requirements for fuel and fuel plant it is not designed to suggest that minimisation of these requirements should be adopted as the decisive criterion for policy; minimum costs of generation can be expected to be the paramount consideration. However, it is useful to be able to examine in a wider context than an individual national programme the effect of possible developments both in demand for nuclear power and in the development of both proven and the more advanced reactor systems.

To the author it has also been valuable to participate in this completely international study which has undoubtedly enabled those participating to obtain a better appreciation of the viewpoint of their colleagues from other countries, and the factors which underlie those points of view. While recognising that there are

* It should be noted that some of the results for the low growth cases are spurious since the analysis adopted could not re-optimise in cases where plutonium stocks were being built up.

limits to the areas in which completely free and uninhibited international collaboration is possible, the author hopes that there will be scope for continued discussion in these areas of long-term planning and techniques of analysis which could be beneficial to all taking part.

Acknowledgments

Though the U.K. participants in the discussions leading up to the Study Group's published reports have been the author and Dr. M. Davis (as Chairman of the Working Party on Uranium and Thorium Resources and also a participant in the Working Group carrying out the studies referred to above), considerable assistance to the U.K. representatives has been given by other members of the Authority in the course of this study. The author and Dr. Davis would like, therefore, to take this opportunity to acknowledge the contribution made by Mr. J. A. Chitty and Mr. D. A. Roper (of the Economics and Programming Branch, London Office), and by members of the Central Technical Services at Risley under Mr. C. E. Iliffe. Their assistance, both in the presentation of the detailed data required for the study and in the subsequent analysis, has been invaluable.

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2 "Uranium Resources: Revised Estimates". E.N.E.A. and I.A.E.A. December, 1967.
3 "Power Reactor Characteristics". E.N.E.A. 1966.
4 "Illustrative Power Reactor Programmes". E.N.E.A. May, 1968.

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The Radiochemical Centre has 28 years' experience in the processing and sale of radioisotopes. In 1967, it sent out 75,000 consignments, doing business with most countries, and its current catalogue offers more than 2,000 items. Copies are available from The Radiochemical Centre, Amersham, Bucks., England.

12th July, 1968

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.

Radiological Protection
30th September to 4th October, 1968
4th to 8th November, 1968
24th to 28th February, 1969
9th to 13th June, 1969
This short course aims to give users of radioactive substances and radiations in industry, research or teaching a broad introduction to the principles and practice of radiological protection, with a strong emphasis on practical considerations. Fee: £40 exclusive of accommodation.

Critical Path Methods
8th to 11th October, 1968
This course is intended for staff of graduate standard who are or will become users or managers of the system rather than for mathematicians already working in the field. Lectures are given by managers who have first hand experience with the system. Harwell has developed its own C.P.M. computer programme (CAPSTAN) details of which will be given during the course. Fee: £30 exclusive of accommodation.

Medical Radioisotope Generators
15th to 17th October, 1968
Arranged in collaboration with the Radiochemical Centre, Amersham, this course aims to give users and potential users of radioisotope generators practical experience of established and newly introduced systems. Fee: £24 exclusive of accommodation.

Commissioning, Use and Maintenance of Reactor Instrumentation
21st October to 1st November, 1968
This course is intended for commissioning, operation and maintenance engineers working on nuclear reactor instrumentation. Participants should have some knowledge of the basic principles of nuclear reactions and reactors, electronics and the measurement of physical quantities. Fee: £80 exclusive of accommodation.

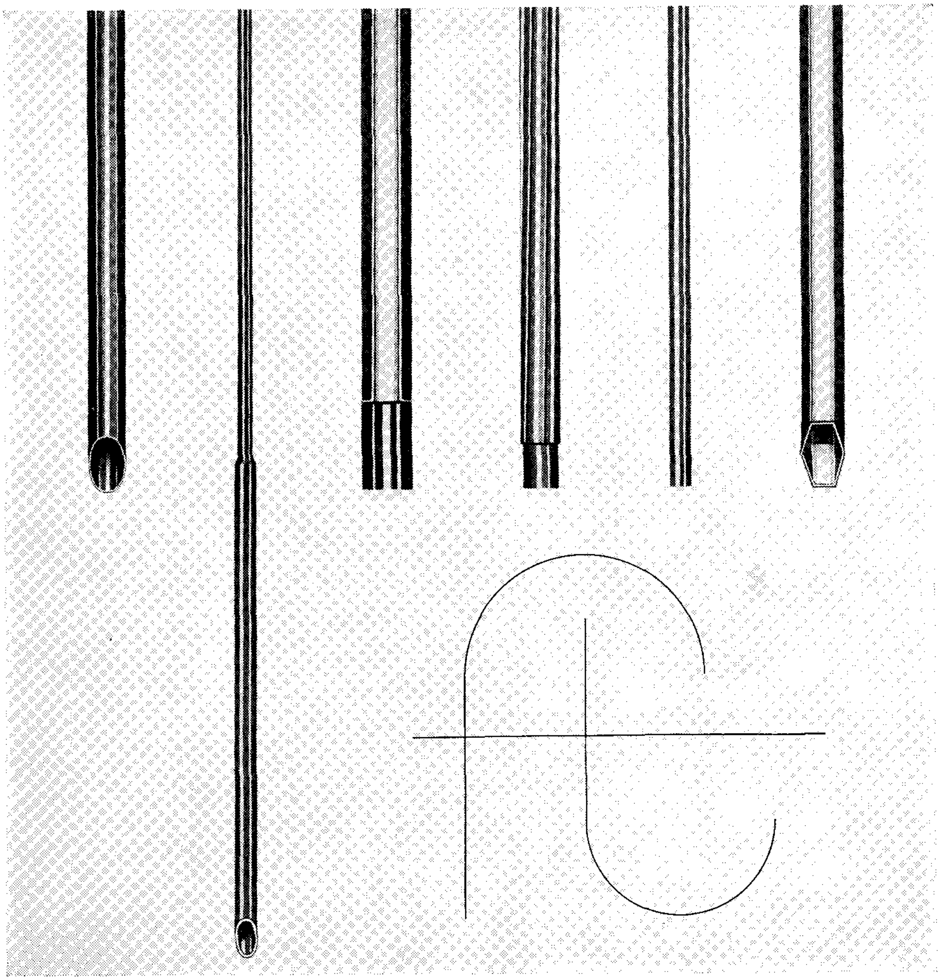
Process Instrumentation
21st October to 1st November, 1968
10th to 21st March, 1969
This course is intended for graduates who are working on the instrumentation of process plant, nuclear reactors and scientific apparatus or who have a direct interest in the subject. A visit will be arranged to a process plant or a power station where modern control techniques are being applied. Fee: £80 exclusive of accommodation.

Introduction to Production Control by Computer
30th and 31st October, 1968
4th and 5th December, 1968
31st March and 1st April, 1969
A new system of production control (WASP) which ensures better loading of machine tools has been devised at Harwell. The course will show how "WASP" may be used on its own, or in conjunction with other computer control systems. Fee: £25 exclusive of accommodation.

Magnet Design
18th to 22nd November, 1968
14th to 18th July, 1969
This course is intended to be suitable for both design engineers and scientists with or without experience in the field.

It will cover basic theory, magnetic materials, Fabry factors for coils, forces on coils, digital and analogue computation and computer calculations; field-measurement techniques, technology of low temperature and cryogenic magnets, practical winding design and construction techniques, superconducting magnets and pulsed magnets. Fee: £40 exclusive of accommodation.

Seminar on Harwell's Multi-access Computing System
10th and 11th December, 1968
The objective of the seminar is to describe and discuss the multi-access computing facilities developed at Harwell for use on the IBM system/360 computer. The system is designed to operate efficiently with conventional batch-processing. Participants will be given the opportunity to use it. Lectures will describe how it is implemented, giving particular emphasis on what is required for similar systems to be implemented on other computers. Fee: £16 exclusive of accommodation.



Printed by Straker Brothers Ltd., 194-200 Bishopsgate, London, E.C.2.