# ATOM

Number 145 / **November 1968**



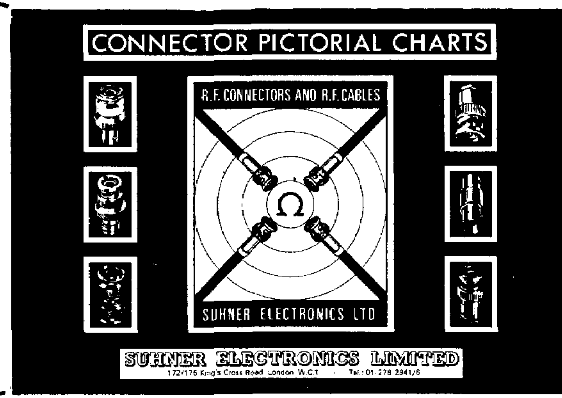
MONTHLY INFORMATION BULLETIN OF

THE UNITED KINGDOM ATOMIC ENERGY AUTHORITY

# SUHNER ELECTRONICS

37 individual Connector Pictorial Charts giving illustrations, descriptions, U.S. Mil. Numbers and equivalent NATO Numbers, where applicable.

Your Free Copy gladly sent on request.




Covering BNC, TNC, N, C, UHF, HIGH VOLTAGE, BNC Crimp, TNC Crimp, Miniature Connectors, Range-to-Range Adaptors, Banana Adaptors, Terminations, etc.

172/176 KING'S CROSS ROAD, LONDON, W.C.1.

---

Please send me ...... Copy/Copies of your Publication

**SEND FREE OF CHARGE TO:**

**Name of Company or Establishment:**

**Address:**

**for the attention of:** **Tel. No.**

**Department:** **Ext.**

R.F. CONNECTORS AND R.F. CABLES

SUHNER ELECTRONICS LTD

H.M. Government Contractors

INLAND TELEGRAMS & OVERSEAS CABLES: SUHNER LONDON WC1

**SUHNER ELECTRONICS LIMITED**

172/176 King's Cross Road, London, W.C.1.
Tel.: 01-278 2941/6
*Precision R. F. Connectors and Cables*

Dear Sir(s),

Re: New Suhner Electronics Publication.
''CONNECTOR PICTORIAL CHARTS''

May we have the pleasure of sending you a free copy of our NEW ''CONNECTOR PICTORIAL CHARTS'' Publication, which contains 37 individual Pictorial Charts, giving illustrations, descriptions, U.S. Military Numbers and equivalent N.A.T.O. Numbers, where applicable.

Our ''CONNECTOR PICTORIAL CHARTS'' Publication covers the following Connector types:

BNC, TNC, N, C, UHF, UHF TWIN, UHF TWIN POLARISED, BNC HIGH VOLTAGE, C HIGH VOLTAGE, NC HIGH VOLTAGE.
RANGE-TO-RANGE ADAPTORS, BNC CRIMP, TNC CRIMP, BANANA ADAPTORS, BNC TERMINATIONS, MINIATURE CONNECTORS.

Additional copies gladly sent on request.

Always with pleasure at your service,

We are,

Yours faithfully,

SUHNER ELECTRONICS LTD.

# ATOM

MONTHLY INFORMATION BULLETIN
OF THE UNITED KINGDOM
ATOMIC ENERGY AUTHORITY

NUMBER 145

November 1968

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.
Extracts from U.K.A.E.A. material from 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.

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

Public Relations Branch.
**U.K.A.E.A.**
11 Charles II Street
London sw1
Telephone 01-930 6262



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

## New Director of Dounreay

Mr. P. W. Mummery, at present Deputy Director, Technical Operations, Reactor Group, has been appointed as Director of the Dounreay Experimental Reactor Establishment, Reactor Group, from 1st October, 1968, in succession to Mr. R. W. Matthews.

Mr. Mummery will join the Reactor Group Board of Management on taking up his new appointment.

Mr. Matthews will continue as a Director and member of the Reactor Group Board of Management. He is being transferred to the Reactor Group Headquarters at Risley.

**Biographical note**

Mr. Peter W. Mummery, O.B.E., was born on 27th March, 1926.

He was educated at Rotherham Grammar School, 1936-44, Queens College, Cambridge, 1944-47. B.A. Science Tripos 1947. M.A. 1952. Fellow of the Institute of Physics.

Mr. Mummery joined the Authority in August 1947, as a Scientific Officer at the Atomic Energy Research Establishment, Harwell. On 1st January, 1952, he was promoted to Senior Scientific Officer, Harwell, and on 1st July, 1955, to Principal Scientific Officer, Harwell; 23rd March, 1957 Senior Principal Scientist, Harwell.

Mr. Mummery later became Head of the Power Reactor Branch, Reactor Division, Harwell, and afterwards Head of Industrial Power Reactor Division, Atomic Energy Establishment, Winfrith.

On 1st April, 1962, Mr. Mummery was appointed Deputy Director, A.E.E., Winfrith. He was appointed Chief Physicist Reactor Group, Risley, Lancashire, 1st October, 1966, and Deputy Director, Technical Operations, 1st May, 1967.

He was awarded the O.B.E. 1st January, 1959.

*30th September, 1968*

## Atom 68

An illustrated summary of the fourteenth annual report of the United Kingdom Atomic Energy Authority from 1st April 1967 to 31st March 1968 is available from the Information Bureau, U.K.A.E.A., 11, Charles II Street, London, S.W.1

# 14th Annual Report and Press Conference

*Dr. J. M. Hill, Chairman of the U.K. Atomic Energy Authority, made the following introductory statement at the Press Conference on the Authority's 14th Annual Report, held on 9th October, 1968.*

This is the first time that I have appeared at this press conference to give the opening statement as Chairman of the Authority. Perhaps I might take this opportunity of paying tribute to my predecessor Lord Penney who, as you know, is now the Rector of Imperial College in the University of London. The enormous contribution which he made to atomic energy is known to everybody, but it is only those who know him best, who fully realise the great loss to the Authority when he left us last year.

Now a great deal has happened in the last year, much of it in the last few months. I think it would be unnecessarily restrictive for me to confine my remarks to what has happened up to 31st March this year, which is the period covered by the annual report which is before you, and I propose to up-date my remarks to the present day. I would like if I may, to cover four distinct aspects of our activities and to comment upon them:—

(i) The changes in the structure of the British nuclear industry.
(ii) The highlights of the Authority's reactor development programme.
(iii) The requirements for further research and development in nuclear power.
(iv) The changes taking place within the Authority and its future role and responsibilities.

**Changes in the structure of the British nuclear industry**

Let me deal first with a matter which has been in people's minds for many months past:—the re-organisation of the nuclear industry.

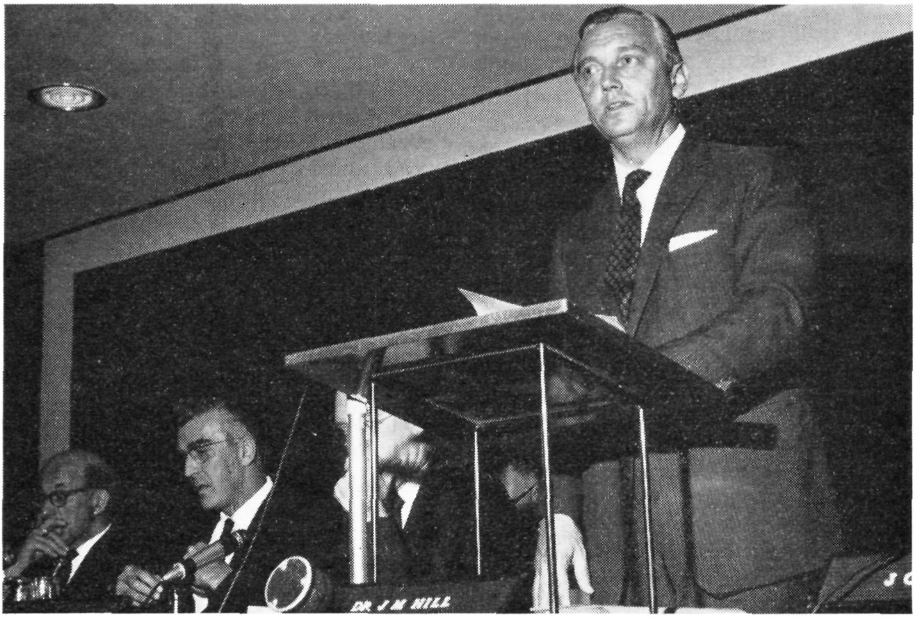
The Authority, together with the appropriate parts of British industry, have been working as rapidly as possible to form from our joint resources two new design and construction companies. These two new companies will undertake all the design and construction of nuclear power stations in this country and we hope also to secure substantial export orders from their latest designs. The first of these new companies has just been formed. It will have its headquarters at Risley. Its directors and staff are being drawn from the Authority, from N.D.C. and from the parent companies of N.D.C.—English Electric, Babcock & Wilcox, Taylor Woodrow and the Industrial Reorganisation Corporation. The Authority will have a 20% shareholding. We hope the new company will obtain the order for the Hartlepool station and we in the Authority propose to place a contract with it for the completion of the P.F.R. at Dounreay.

The details of the second company with T.N.P.G. and A.P.C. are still being worked out and it would be wrong for me to make any premature disclosure. However, it is no secret that the principles are virtually all agreed and an announcement can be expected any time now.

Although in 1955 there were good reasons for setting up the industry with four consortia, the turn of events and the rapid development of the technology has resulted in this structure being absolutely wrong for 1965 and even more so for today. It has resulted in under-loading of the firms' resources, wasteful duplication and costs being higher than they need have been. The new structure which has evolved is not exactly what was advocated by the A.E.A. last year, but I do not regard that as particularly important. The structure we have achieved now is very much better than we have had in the past and both industry and the Authority are wholeheartedly behind this new structure and determined to take the fullest advantage of the opportunities now presented to us.

**The Authority's reactor development programme**

I will now turn to the reactor development programme. First let me speak of gas-cooled reactors. These should be regarded as having a continuing evolution which started at Calder Hall and has now reached Hunterston "B". These reactors




which are the basis of our nuclear power programme at the present time, have performed, and, for that matter are performing, extremely well. Each year's new model has been better than the last. Furthermore they still have an enormous development potential and there are numerous ways in which the fuel, the heat transfer and the physics can be developed quite apart from engineering improvements. To suggest that development should stop now would be the equivalent to saying that the development of the motor car should have stopped after it had ousted the horse and cart. Let me illustrate what might be achieved. The Authority are working on silicon carbide as an alternative to stainless steel as a canning material. If successful this could give higher temperatures or greater output, lower neutron capture and longer fuel life. We are working on coated particle fuels similar to that used in the DRAGON H.T.R. concept. We are studying the problems of gas turbines in place of steam turbines as the prime movers. Let us not under-estimate what a long way there still is to go or the magnitude of the returns that can be obtained.

The S.G.H.W. reactor at Winfrith was completed on time and has worked well. H.R.H. Prince Philip did us the great honour of officially opening the reactor in February. For our part we had sufficient confidence in our plant for the ceremony to be undertaken only two months after steam was first passed from the reactor to the turbine. We are satisfied that the S.G.H.W. system is economically sound and that it should be a good reactor for export.

But is the S.G.H.W. better than the A.G.R. or vice-versa? It must be remembered that the two reactors are very different. The A.G.R. is a high temperature high thermal efficiency machine ideally suited to base load operation. The S.G.H.W. has the lower thermal efficiency characteristic of all water reactors but is very suitable for load following and frequent changes in power loading. It has a high specific production of plutonium and can readily be used for plutonium recycle. In my view both reactors are the best in their respective fields and I regard them as complementary.

The fast reactor programme continues to go well. We found the leak in the sodium circuit of the Dounreay Experimental Fast Reactor. Its cause was a substandard weld that failed after ten years of service. The leak was in a very difficult position in the active part of the reactor, but after it was found it was repaired using remote maintenance techniques, and the reactor is now back in service again testing fuel elements for the fast reactor programme. The Prototype Fast Reactor, with an output of 250 electrical megawatts is being built alongside. We have come across no unexpected problems, and

I have really nothing to add except to say that our fast reactor programme continues towards its original target.

**The requirement for further research and development of nuclear power**

Let us now turn our attention for a few moments to the future and the need for further research and development in nuclear power. It is thought by many people that the U.K. is the big spender in atomic energy and some ask why this should continue. It has been said that now that nuclear power is competitive with coal, no more government money should be spent unless it can be recovered in full in royalties. This would be to close one's eyes both to the reason for doing the development work and to what is happening in the world outside. The basic purpose in developing nuclear power is to create an efficient industry capable of building and using the most up-to-date plant based on modern technology so as to supply power cheaply and reliably to British industry in order to assist it in keeping up with the ever increasing pace of world trade and competition.

Other countries also see the great importance of this objective to the economy at large. It will be no surprise to anyone that the U.S. government spends many times more than we do on the civil uses of atomic energy. What is not so well appreciated is that both France and Germany are spending substantially more government money on civil nuclear power than the U.K. and that their expenditure, and that in Japan and Italy, who also have large government programmes, is still increasing. Incidentally none of these countries attempts to relate its development programme in any way to the recovery of royalties.

By comparison with what has been spent in other countries of the world, I think that this country has had remarkably good value for money from its nuclear power programme. Our programme is as good as anybody's and we are up with the leaders, but in this sort of international technological race you have to run very fast to keep level. Certainly nuclear power is rapidly becoming a fully commercial industry but arguments about "nuclear versus coal" are not relevant to determining our development programme. Our present development programme is aimed at assisting British industry in the world-wide technological race and maintaining its position in the huge nuclear power programme that will exist in the world in the 1970's and 1980's.

We, in the U.K., are reducing expenditure. We must of course be economical, we must cut out the frills where we can but in a modern technology where British industry is in the forefront, we must keep some breadth of vision and not lose sight of our real objectives.

**Changes taking place in the Authority and its future role and responsibilities**

Finally, let me say a few words on the future. It is the responsibility of any management to run an organisation as cheaply and economically as possible and to seek at all times ways of doing things more efficiently and with fewer people. During the past year we have made further reductions in the Authority's manpower. But the relatively modest change in overall numbers belies the quite fundamental changes that are taking place within the Authority. There is a steady growth of all our commercial activities. Amersham continues to expand at 15% per annum entirely on commercial account and predominantly for export. The activities of my old Group, the Production Group, are geared to the increasing nuclear power programme and they too are substantially expanding their export business. The Production Group also has an increasing programme of development and reconstruction of their factories which in turn has put an increasing load on the Authority's Engineering Group.

The Reactor Group and the Research Group have both reduced their overall numbers. In the case of Research Group, reductions in staffing have been achieved despite taking on an increasing programme of non-nuclear work. We have, during the past year, set out to deploy the resources and facilities of Harwell in support of British industry, and I am happy to say that this policy is meeting with ever-increasing success. It is plain that the continuing requirements of the reactor development programme, and the increasing programmes of non-nuclear work, will continue to provide a major role for the Authority's resources for many years to come.

# Review of the year*

### Introduction

The work of the Authority continued satisfactorily during the year. The steam generating heavy water reactor (S.G.H.W.R.) at Winfrith was completed to time and within the financial ceiling, and was formally opened by H.R.H. The Prince Philip Duke of Edinburgh on 23rd February, 1968. Over seventy overseas visitors attended the opening and a number took the opportunity to visit the London Office and other Authority establishments for talks. Construction of the 250 MW(E) fast reactor at Dounreay proceeded according to programme. The Authority's commercial activities, primarily the sale of fuel services, radioisotopes and electricity, continued at a high level. A number of new non-nuclear programmes was set in hand. The Authority continued to meet the requirements placed upon them by the Ministry of Defence, and pursued their programme of research into detection of nuclear explosions.

Nuclear energy is now a firmly established fuel for electricity generation, as recognised in the Government White Paper on Fuel Policy (Cmnd. 3438, November, 1967). As part of the review of fuel policy the Minister of Power arranged for a re-examination of likely trends in nuclear power costs. An initial study in which the Authority and Central Electricity Generating Board (C.E.G.B.) participated was followed by a second study in which Authority, C.E.G.B. and National Coal Board (N.C.B.) representatives took part. The reports (which were published as appendices to the Report on the Nuclear Reactor Programme from the Select Committee on Science and Technology) confirmed that nuclear generating costs estimated for the period 1970/75 were reasonable, and that there were sound grounds for assuming further considerable reductions in these costs after 1975.

During the year, C.E.G.B. placed an order for the 1250 MW(E) A.G.R. power station at Hinkley "B", and the South of Scotland Electricity Board (S.S.E.B.) ordered a similar station for Hunterston "B".

While the recent increase in the rate of ordering of nuclear stations in the U.S. has attracted much attention, the fact that the U.K. has more accumulated experience than any other seems to be still inadequately appreciated. The table below shows the installed nuclear capacity in the principal countries (excluding the Soviet bloc) at 31st March, 1968, and the cumulative nuclear electricity produced at that date. All figures are gross.

The British electricity boards at present operate their nuclear stations as base-load stations and the record of reliability has been so good that all seven (Berkeley, Bradwell, Hinkley "A", Trawsfynydd, Dungeness "A", Sizewell and Hunterston "A") were able to operate continuously over the winter months to meet the 1967/68 record demands. The C.E.G.B. stations each operated non-stop for 2,837 hours between November and March and the S.S.E.B. station for 3,024 hours. After the initial years of operation average yearly load factors for the British stations exceed 75 per cent and for lesser periods regularly reach 100 per cent.

After receiving a wide range of evidence, and visiting a number of Authority

*Copies of the Fourteenth Annual Report of the United Kingdom Atomic Energy Authority, from 1st April 1967 to 31st March 1968, are obtainable from H.M.S.O. price 13s.

| *Country* | *Capacity in Megawatts* | *Electrity in Kilowatt/hours* |
|---|---|---|
| U.K. | 4156 | 99,136,000,000 |
| U.S. | 2900 | 35,182,000,000 |
| France | 1101 | 8,746,000,000 |
| Italy | 631 | 13,999,000,000 |
| West Germany | 317 | 2,323,000,000 |
| Canada | 245 | 334,000,000 |
| Japan | 178.5 | 1,277,000,000 |
| Belgium | 11.4 | 221,000,000 |
| Sweden | 10 | 137,000,000 |
| | Total excluding U.K. | 62,219,000,000 |

establishments, the Select Committee on Science and Technology published their report on the nuclear reactor programme in October, 1967. At the end of the year under review, the recommendations were being considered by the Minister of Technology.

As part of their continuing interest in the nuclear programme, the Select Committee visited Culham on the 26th March, 1968.

During the year the three Authority research and development committees, dealing respectively with reactor research and development, general nuclear research and development, and non-nuclear research and development, became fully operational. All the Authority's research and development programmes have now been reviewed; decisions have already been taken in certain areas which will lead to redeployment of effort, while other important areas are still under consideration by the committees. The Programmes Analysis Unit also increased its activities during the year.

**Membership**

Lord Penney (who received a Life Peerage in the 1967 Birthday Honours) retired from the Chairmanship of the Authority on 15th October, 1967, to become Rector of Imperial College. He was succeeded by Dr. J. M. Hill, formerly Member for Production.

Sir John Cockcroft, who had retired from the Board of the Authority in July, died suddenly on 18th September at the age of 70. A tribute to his immeasurable services to the Authority, and to British science generally, was paid by Dr. Spence, Director A.E.R.E. Harwell, at a Memorial Service held in Westminster Abbey on 17th October, 1967.

**Financial and Commercial Activities**

The estimate for 1968/69 under the Atomic Energy Vote totalled £29.1 million net (£84.5 million gross). The Authority's cash expenditure in 1967/68 on civil nuclear research and development was £46 million and 2,355 qualified scientists and engineers were engaged on this work at the end of the year. In addition, some 90 qualified staff were doing work on repayment for other organisations. Cash expenditure on non-nuclear work totalled £1.35 million and an average of 100 qualified staff was employed on this work. In addition some 75 qualified staff were engaged on non-nuclear work on repayment.

The balance sheet value of the total net assets at £316 million shows a further large reduction of about £38 million from the total at 31st March, 1967.

An agreement waiving all royalties on the U.K. magnox nuclear power stations and fixing the royalties payable on the advanced gas-cooled reactor stations commissioned before 1975 was announced in the House of Commons in May, 1967. This will be reviewed in 1974 to determine the royalty payable on A.G.R.s to be commissioned after 31st December, 1974.

Because of the size of the stocks of uranium in hand, the full effect of devaluation in increasing the price of the uranium component in the fuel elements supplied to the electricity generating boards will be delayed for several years. A decision has now been taken to write down the value of some $U_3O_8$ supplies in about five years time. The Authority's actual stock position remains substantially unchanged from that reported last year. The first phase in the reactivation of the Capenhurst diffusion plant to provide enriched uranium for the power programme took place during the year when a section of the plant, which had been shut down since 1962, was successfully recommissioned.

The Authority's sales, primarily of nuclear fuel services, electricity and radiosotopes, totalled £37.1 million with a net surplus of £1.4 million. All the electricity sales, and the larger part of the fuel service sales, were to the U.K. electricity generating boards but substantial overseas fuel service business was maintained. Sales from the Radiochemical Centre increased by 17 per cent to £3.0 million with 58 per cent exported.

During 1967/68 the Trading Fund continued to be wholly self-financing and met all its capital expenditure requirements without borrowing from the Treasury.

Most of the electricity sold by the Authority is generated by the eight reactors at Calder and Chapelcross. One Chapelcross reactor was shut down for the greater part of the year. Nevertheless very high average load factors were achieved for the stations—79 per cent over the whole year with an 85 per cent average over the winter months. The Windscale advanced gas-cooled reactor averaged an 87 per cent availability over the year and continued to provide 25 MW(E) capacity for the national grid.

**The reactor programme**

A primary objective of the Authority's work in the field of reactors is to ensure the success of the advanced gas-cooled reactor and assist in the exploitation of the system overseas. An objective on a longer timescale is to develop a commercial fast reactor for adoption by the electricity generating boards in the 1970s. Although fast reactors are expected to have good economic performance, thermal reactors will continue to be installed during the 1980s because the rate of installation of fast reactors will be limited by the availability of plutonium. Therefore a third objective is to improve the economic performance of thermal reactors. In the shorter term, improved designs of A.G.R.s and commercial designs of S.G.H.W.R.s are already available; for the longer term, designs of gas-cooled reactors using coated particle fuel, based on DRAGON project technology, are being prepared.

The Authority gave extensive support to the efforts of the British Nuclear Export Executive and the nuclear industry to publicise and promote British advanced gas-cooled reactors. The Authority and Japanese industry have held discussions, which are continuing, on the possibility of licensing the A.G.R. for sale in Japan. A 500 MW(E) design study of a steam generating heavy water reactor has been used as the basis of the commercial bid, by the Authority, to Finland for a 1500 MW(H) nuclear steam supply system.*

*The second nuclear power programme*

The Authority work in support of the second nuclear power programme, which is based on the advanced gas-cooled reactor, is in two main directions: to confirm that the fuel and the graphite moderator will have satisfactory technical and economic performance for the required life, and will allow the reactors to meet the demands of the electricity supply system; and to assist in realising the development potential of the A.G.R. system foreseen at the time of the Dungeness "B" tender.

*Advanced thermal reactors*

In addition to improvements to the A.G.R. system, commercial designs of the S.G.H.W.R., a water-cooled thermal reactor system, have been prepared. In this reactor, the light water coolant is allowed to boil in the core, the steam is fed directly to the turbine and heavy water is used as the moderator.

The first S.G.H.W.R. power station was built by the Authority at Winfrith and became critical on 14th September, 1967. Operation at the full power of 100 MW(E) was achieved in January, 1968. This reactor and the commercial designs based on it use enriched uranium fuel. A design of S.G.H.W.R. using natural uranium fuel has been studied with staff seconded to the Authority from interested authorities in Australia and New Zealand.

During the course of studies of the further development of gas-cooled reactors, reference designs for several possible lines of development (Mk. III gas-cooled reactors) were produced by the consortia and the Authority and discussed with the generating boards. All the Mk. III reactor concepts use a new form of fuel based on the technology developed by the international DRAGON project. The fuel takes the form of small particles of uranium dioxide, or dicarbide, coated with graphite to provide retention of the fission products. Designs which use helium as coolant, instead of carbon dioxide, are being considered.

A further possible development of gas-cooled reactors is to use gas turbine generators for direct cycle power generation. The development of gas turbines for gas-cooled reactors is being studied in collaboration with the Commissariat à L'Energie Atomique of France.

*Fast reactors*

The first power station incorporating a sodium-cooled fast reactor (P.F.R.) is being built by the Authority at Dounreay in Scotland to come on power in 1971. It is expected that this reactor, which will have an electrical output of 250 MW, will be the forerunner of larger commercial stations to be built for the generating boards in the 1970s. Preliminary design work for these larger commercial fast reactor stations has started.

The design of the P.F.R. is based on experience gained from the smaller Dounreay Fast Reactor (D.F.R.) which has been operated by the Authority for several

*The Finnish Government decided on 25th July 1968 not to order a nuclear power station.

years. This reactor is now used to provide information on the irradiation behaviour of fuel and materials for fast reactors and other reactor systems. In May, 1967, a small leak of the liquid metal coolant from the reactor was discovered and in July the reactor was shut down for repair. The leak was located in a weld in the primary circuit pipework. At the end of March, 1968, the leak was being repaired and the reactor prepared for further power operation*.

*Small reactors*

A design of pressurised water reactor (burnable poison pressurised water reactor —B.P.W.R.) is being considered for applications where small power outputs are required. A market survey had indicated that there is little prospect of sales for land-based applications. However, a re-assessment of the application of the B.P.W.R. to the high speed, high utilisation requirements presented by container ships has led to further study for this use. A complementary analysis of the operation of a nuclear container ship by a ship-owner is awaited before the economics can be assessed.

*Supporting work*

The project development programmes are supported by background and exploratory studies particularly in the areas of fuel, materials, nuclear physics data and instrumentation. Some effort is devoted to studies of new reactor systems; the Authority are participating in an assessment of alternative-coolant fast reactors sponsored by the E.N.E.A. The potential benefits of the reactor systems being developed, and their relationship to the expenditure on the development programmes, are kept under review.

**Nuclear research and development**

The programme of general nuclear research and development is controlled by the Authority's Nuclear R. & D. Committee and can be divided into two main categories, underlying and applied nuclear research. An indication of the effort devoted to the programme is given by the approximate numbers of qualified scientists and engineers working in this field at 31st March, 1968. These were: 395 on underlying research, 130 on applied nuclear research and a further 190 on plasma physics and fusion research. The first category, underlying research, provides background information and broad support to the applied nuclear and non-nuclear research and reactor programmes, and information for future development; also new ideas are explored which may lead to significant improvements in nuclear processes and techniques or to new applied or non-nuclear projects. This underlying nuclear research will be reduced over the next three years to not more than 10 per cent of the Authority's total civil R. & D. effort and individual items will be judged against the criterion of their relevance to the applied programmes. Before projects for the second category, applied nuclear research, are approved, they will be subject to an analysis of their potential national economic benefit. The Programmes Analysis Unit and the Economics and Programming Branch are playing an important part in these analyses.

The underlying research programme is concerned mainly with the properties of materials, especially with the effects of irradiation, how these properties limit the performance of materials in reactors and with ways of extending their limits. The range of studies of radiation-induced damage processes has been greatly extended by having available very powerful superconducting magnets, the Harwell refrigerator (with which temperatures as low as $\frac{1}{10}$th of a degree above absolute zero can be obtained) and also the new Variable Energy Cyclotron. Some of the other particle accelerators at Harwell are being modified to study these effects at greater depths of penetration.

A substantial increase took place in the use, particularly by university research groups financed by the Science Research Council, of thermal neutron beams for studying structural defects in materials on an atomic scale. The use of this technique, well known to physicists, is extending to the chemical sciences and to industry. New beam equipment was developed and installed on some of the Harwell and Aldermaston reactors. Research into fundamental nuclear processes and the provision of accurate nuclear data have continued not only as support for the reactor and other nuclear programmes but also as an important part of the national effort on nuclear physics; the accelerators, as well

*The D.F.R. resumed power operation on 22nd June, 1968.

as the research reactors, are widely used by universities and other bodies.

Many of the industrial applications that have so far arisen from the nuclear programme involve the use of radioactive isotopes as sources of radiation or heat, or as tracers. Another four gamma-irradiation plants were built by Authority licensees to meet overseas orders and are now in operation for treating medical equipment or food. Industrial interest grew rapidly in the use of gamma-irradiation to produce wood-plastic composites and in the irradiation-chemical synthesis of mercaptans which are intermediates in the production of synthetic rubber. The isotope-heated thermoelectric generators, RIPPLE I and II, have operated continuously and completely unattended since first put into operation in navigational beacons in 1965. Isotope measuring techniques have been developed and are being used for such purposes as research on hydrological and ground water problems of national importance and for extremely accurate measurements of large turbulent flows as in the cooling water systems of power stations.

A pilot-scale processing plant for hardening paint and films by electron irradiation was built and is to be tested under industrial conditions. The techniques of ion implantation attracted increasing interest particularly for introducing impurity atoms into semi-conductors, and the manufacture of specific semi-conductor devices is being planned in collaboration with industry.

Research on plasma physics and fusion at Culham Laboratory was reviewed last year by an Authority working party. The resultant decision that the effort in this field should be reduced by 10 per cent each year for the next five years was announced by the Minister of Technology in the House of Commons on 26th July, 1967. The cuts are subject to annual review by the A.E.A.

Much of the fusion programme is affected by this decision, but the new series of studies on plasma confinement employing toroidal magnetic systems will continue as planned, as will theoretical and computing work. Supporting plasma physics research will have to be reduced. In November, 1967, the Science Research Council agreed to take over Culham's work on solar and stellar ultra-violet spectroscopy.

Theoretical methods have been advanced for investigating the stability of plasma confinement in practical configurations. The present generation of confinement experiments has provided valuable data which are being used in the design of the new series of stellarator and multipole experiments now being commissioned. A report has been published on a design study for a conceptual 5000 MW(H) deuterium-tritium fusion reactor.

**Non-nuclear research and development**

The Authority continued their programme of research and development into matters not connected with atomic energy following the Requirements issued by the Minister of Technology under section 4 of the Science and Technology Act 1965. Five new Requirements were issued during the year and extensions to the existing desalination and fuel cell projects were approved.

The effort devoted to these activities has risen as follows:—

| | | |
|---|---|---|
| 1965/66 .. | 42 man/years | (qualified |
| 1966/67 .. | 81 ,, | scientists and |
| 1967/68 .. | 175 ,, | engineers) |

A further increase is expected.

Projects are developed by identifying areas of work for which there is a good prospect of substantial industrial application and to which the specialist expertise and resources of the Authority can make a substantial contribution that cannot be achieved in other ways. The projects are assessed through detailed discussion with the Ministry, research associations, industrial firms and other interested bodies. Wherever appropriate, Advisory Committees, representing all those concerned, are formed to advise the Authority on the nature and scope of the work. Programmes are also subjected, where practicable, to an economic benefit assessment in which the costs are compared with the benefits likely to accrue to the nation.

The programme of work on desalination has been extended from 1968 to 1971 at an estimated cost of some £4 million; almost half this sum will be spent under contract by the Authority's principal industrial collaborators, as compared with only one-fifth in the original programme approved in 1965. Of the four desalination systems under development (flash distillation, electrodialysis, reverse osmosis and freezing), only the first two are as yet commercially viable; detailed design improvements resulting from the programme are being incorporated in commercial designs with marked success in export markets.

Following the commissioning of the 1,600 ton hydrostatic extrusion machine at Springfields, tests for metal-working firms are being conducted on repayment terms.

The Ceramics and Non-Destructive Testing Centres at Harwell have dealt with hundreds of enquiries and concluded a variety of agreements for collaborative or sponsored work on commercial terms. The Heat Transfer and Fluid Flow Service, also at Harwell, and the National Tribology Centre at Risley, commenced operations at the beginning of 1968. All these services deal with their customers in commercial confidence.

The extended programme of work on high temperature fuel cells now aims towards the design study of a prototype cell.

In collaboration with the Royal Aircraft Establishment, the Authority are assisting industry to develop and produce improved and cheaper carbon fibres, and to extend their application in the reinforcement of metals and ceramics.

In the computer field, the Aldermaston project for the application of computers to engineering (APACE) has been enlarged to meet growing industrial demand; a complementary service to provide assistance to industry in scheduling and similar optimisation problems is operating at Harwell, where several successful applications have been devised for industrial customers. Improved micro-circuitry is under development at Aldermaston; the multi-access on-line system (COTAN) developed at Culham is being installed at six U.K. universities.

### Manpower

The contraction in the Authority's manpower, which has been in progress since 1962, continued. This contraction was due partly to changes in the Authority's programme and partly to measures taken to ensure the most efficient use of manpower. A productivity agreement applicable to industrial employees was concluded during the year and close attention continued to be given to the development of management services, including the use of efficiency techniques applicable to all categories of staff.

## New nuclear power company board.

THE title and board of directors of the new reactor design company announced by the Industrial Reorganisation Corporation in September (ATOM No. 144) have now been published. The joint company, formed by Babcock & Wilcox Limited, The English Electric Company Limited, Taylor Woodrow Construction Limited, the United Kingdom Atomic Energy Authority and the Industrial Reorganisation Corporation, is to be called Babcock English Electric Nuclear Limited.

The chairman of Babcock English Electric is Mr. Hector McNeil, chairman of Babcock & Wilcox Limited, and the directors of the new company are:

Mr. E. B. Banks—deputy chairman and joint managing director of English Electric.

Mr. T. Carlile—managing director of Babcock & Wilcox Limited.

Mr. H. V. Disney—managing director engineering group, U.K.A.E.A.

Dr. N. L. Franklin—Authority officer (special duties) U.K.A.E.A.

Mr. A. J. Hill—chairman, Taylor Woodrow Construction Limited. Mr. A. R. Morton—executive, Industrial Reorganisation Corporation.

Mr. E. M. Price—managing director power generation group, English Electric.

Dr. R. B. Sims—managing director, Nuclear Design & Construction Ltd.

Mr. J. C. C. Stewart—Board member for reactors, U.K.A.E.A.

### Conference on fast reactor irradiation testing

An International Conference on the use of fast reactors as irradiation test facilities will be held at Thurso, Caithness, from 14th-17th April, 1969.

The conference, arranged by U.K.A.E.A. Reactor Group, will have as its aim:

(a) To disseminate information on the methods used for irradiations in fast reactors, and the problems involved.
(b) To discuss the problems of standardisation of techniques between different countries.
(c) To discuss future requirements and the adequacy of the present facilities.

During the conference delegates will visit Dounreay.

# Fast reactors and the full utilisation of uranium in the U.K.

*An address by Mr. J. C. C. Stewart, Member for Reactors, U.K.A.E.A., in presenting a paper on The Full Utilisation of Uranium in the U.K. to the World Power Conference, held in Moscow, from 20th-24th August, 1968.*

Two factors are often considered to be of paramount importance in considering the strategy of nuclear power development: these are economics and nuclear fuel utilisation. They are of course inter-related and the implications of particular nuclear fuel utilisations should be reflected in the economics. Our paper shows that for the U.K. a comprehensive systems analysis indicates that the strategy of early development and exploitation of fast reactors yields both maximum economic benefit even at present uranium prices, and maximum nuclear fuel utilisation.

The facts, with respect to nuclear fuel utilisation, are well established. Once the inventory has been provided, the fast reactor can be maintained with a supply of uranium (and depleted uranium is adequate) of the order of a hundred times less than that for thermal reactors. The advantages of the fast reactor, in terms of nuclear fuel utilisation, are therefore unique, the variations between different thermal reactors being relatively trivial. The use of heavy water reactors instead of graphite reactors would not make a significant difference in our overall uranium requirements.

A consequence of high uranium utilisation with fast reactors is that the contribution of uranium ore costs to generating costs is negligible at present prices and would still be acceptable, i.e. less than 0.1 mil/kWh even if the uranium were produced by extraction from sea-water. Shortage of uranium supplies or a high ore price cannot be used therefore as arguments for developing other sources of nuclear energy such as fusion or the use of high energy accelerators.

The other key factor is economics. This requires consideration of a subtle interplay between plant and fuel costs, availability requirements and maintenance aspects, plutonium logistics, and the load factor requirement for nuclear power stations over their lifetime, as determined by the overall method of system operation. It is for these reasons that a systems analysis is essential to determine and justify a reactor development and installation strategy, to optimise the appropriate reactor system parameters, and to give guidance on whether plutonium should be bought or sold.

We in the U.K. see no reason to purchase thorium as an alternative nuclear fuel. It contains only fertile material and is therefore similar to depleted uranium. The depleted uranium which will become available from the ore we have already imported will, if used in fast reactors, be sufficient to meet our energy requirements well into the next century.

Our position depends of course on our belief that fast reactors will be economic. I would mention two points that are of significance: breeding gain and fast reactor operating experience.

During the last year or so there has been world-wide speculation on the implications of the longer doubling times which have been suggested from zero energy and nuclear data experiments. We in the U.K. were, I think, the first to be convinced that these longer doubling times were realistic; we are now equally convinced that a linear doubling time in the region of fifteen to twenty years can be produced with comparatively minor modifications to existing reactor designs and that the penalties for exceeding this criterion by a modest amount are small.

Most of the fast reactor operating experience has been concentrated in the U.S.S.R., U.S.A. and U.K., although experience is now being obtained or is planned in other countries. The U.S.S.R. B.R.5, has generated electricity over the longest period of time, some ten years. The U.S.A. has built the largest number of fast reactors, three, i.e. EBR-I and II and Enrico Fermi. The U.K. has generated most electricity from its fast reactor, D.F.R. (over 200,000 MW/hrs). This reactor became operational again in June of this year, following a shut-down to identify and repair a leak in the primary coolant circuit. Prior to that time it had operated for five years at power. Our 250,000 kW(E) plant at Dounreay is proceeding well and should be at full power by 1971. All of this experience gives me confidence in the acceptability of fast reactors to electric power utilities.

# A.E.A. Reports available

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

AEEW-M 790
*Winfrith Nuclear Data Group Notes on Topics in Nuclear Data Evaluation*, 1964-1968. By M. F. James and J. S. Story. May, 1968. 63 pp. H.M.S.O. 9s.

AEEW-R 448
*Slip. A Dynamics Programme for the Thermal-Hydraulic Behaviour of Boiling Loops.* By D. Moxon. August, 1968. 46 pp. H.M.S.O. 7s.

AEEW-R 510
*Erosion of Common Structural Materials and the Degradation of Suspended Particles in Flowing Suspension of Graphite Powder in Carbon Dioxide Gas.* By D. A. Garton, R. I. Hawes and P. W. Rose. June, 1968. 23 pp. H.M.S.O. 5s.

AEEW-R 582
*Hambo. A Computer Programme for the Sub-channel Analysis of the Hydraulic and Burnout Characteristics of Rod Clusters. Part* 2. *The Equations.* By R. W. Bowring. January, 1968. 60 pp. H.M.S.O. 9s.

AEEW-R 607
*Reading Equipment for Thermo-Luminescent Dosimetry.* By K. E. G. Perry. July, 1968. 13 pp. H.M.S.O. 2s. 6d.

AERE-R 5724
*The Treatment of Low Level Radioactive Effluent by a Ferric Hydroxide Precipitation.* By J. H. Clarke, R. F. Cumberland and M. J. Smyth. April, 1968. 19 pp. H.M.S.O. 3s.

AWRE/LIB/BIB/17
*AWRE Library Bibliography No.* 17 *List of Unclassified Publications and AWRE Reports by Staff of the Weapons Group Published During the Year* 1967. Compiled by R. S. Every. April, 1968. 38 pp. H.M.S.O. 5s. 6d.

AWRE 0-3/68
*The Value of Trace Analysis in the Comparison of Glass Fragments. A Preliminary Study.* By R. F. Coleman and G. A. Wood. April, 1968. 17 pp. H.M.S.O. 3s. 3d.

AWRE 0-9/68
*The Analysis of Recoil Proton Spectra.* By P. W. Benjamin, C. D. Kemshall and A. Brickstock. March, 1968. 49 pp. H.M.S.O. 7s.

AWRE 0-22/68
*The Krypton*-85 *Leak Test.* By J. L. Murgatroyd. March, 1968. 27 pp. H.M.S.O. 4s. 6d.

AWRE 0-28/68
*The In Vivo Distribution of Plutonium in Rat Liver Homogenates.* By G. Boocock, D. S. Popplewell and D. M. Taylor. May, 1968. 28 pp. H.M.S.O. 4s.

AWRE 0-38/68
*Experiments to Improve the Mechanical Properties of Wrought Uranium.* By P. D. Tilbury. June, 1968. 8 pp. H.M.S.O. 1s. 9d.

AWRE 0-39/68
*The Production of Fine Metal Powders Using Grinding Aids.* By R. A. Knight and C. A. Calow. April, 1968. 13 pp. H.M.S.O. 2s. 6d.

AWRE 0-43/68
*The Use of Scanning Electron Microscopy in Composite Materials Research.* By C. A. Daldus and R. E. Cooper. July, 1968. 14 pp. H.M.S.O. 4s.

AWRE 0-72/68
*Holographic Measurements of Vibration Amplitudes Using Powell and Stetson Fringes. Interim Report.* By M. R. Wall. September, 1968. 21 pp. H.M.S.O. 4s. 6d.

TRG Report 1950(S)
*The Design and Construction of Acoustic Transducers for Use in A.G.R. Simulation Loops.* By J. Rooney. 1968. 20 pp. H.M.S.O. 5s.

TRG Report 1681(W)
*The Behaviour of Fission Gases in Irradiated* $UO_2$. *A Resolution Process.* By A. J. Manley. 1968. 31 pp. H.M.S.O. 4s. 6d.

---

## New British Standard

A new British Standard, based on OECD publication C (66) 79 has been published at the request of the Ministry of Technology: BS 4333 : 1968 Radioluminous time measurement instruments: Part 1: Instruments bearing radioactive luminous materials.

The standard specifies the radionuclides to be used in luminous compounds and the levels of radioactivity in respect of both general-purpose time indicators on sale to the general public and special time indicators having a higher degree of luminosity for some specific purpose.

Copies of BS 4333 : Part 1 : 1968 may be obtained from the BSI Sales Office at 101/113 Pentonville Road, London N.1. Price 6s each (postage 9d extra to non-subscribers).

# A broader approach to benefits from nuclear power and associated social and other costs

*by M. Phillips, Economics and Programming Branch, U.K.A.E.A.*

*Mr. Phillips*

**Introduction**

In their Annual Report for 1967-68 the Authority discuss the direct benefits accruing to the nation from the lower costs of generating electricity that nuclear power makes possible. Some estimates of what these direct economic benefits might be (as compared with the most economic alternative form of electricity generation) are given in paragraphs 193 and 194 of the Report. However, the Report also refers to the fact that with nuclear power "there are a number of secondary benefits both social and economic" (paragraph 190). And one must also consider whether any corresponding costs arise.

Paragraph 98 of the White Paper on Fuel Policy (Cmnd. 3438) says that, while the Generating Boards should base their choice of fuel on an economic assessment of the method of generation which will give them the lowest system cost, the Government will have to take into account, in giving consent to new stations, "such wider economic considerations as may be relevant".

Similarly, while the Authority satisfy themselves that their reactor development programme is adequately justified on grounds of direct national economic benefit, they must also take into account these secondary costs and benefits to the nation.

A study has therefore been carried out by the Authority's Economics and Programming Branch of these wider implications of the nuclear reactor development programme and an attempt has been made where possible to express some of these costs and benefits in direct economic terms. It is recognised that in many cases such a quantification is necessarily an incomplete reflection of the overall costs and benefits to the community, but it is believed that the order of magnitude of the figures produced is sound. As will be seen, both costs and benefits can be identified, and the study indicates that the benefits from nuclear power substantially outweigh the costs. The conclusion of the study therefore is to strengthen the direct economic case for the development of nuclear reactors for electricity production.

The economic benefit from nuclear power is normally assessed by comparison with the most economic alternative form of generation so that the study does not consider the costs and benefits associated with the choice between the cheapest form of conventional generating plant and a more expensive form which may provide social or other benefits. However, it is not clear at this stage whether the conventional station against which nuclear power will have to compete in the long term will be fuelled with oil, natural gas or coal—all these industries are making long term cost forecasts which if realised would make them contenders. So the study has examined the situation where the construction of a nuclear power station leads to a reduction either in the level of output in the coal industry or in the consumption of oil or natural gas. The country can, of course, secure only one or other of these sets of benefits and costs. For example, the benefits from reduced expenditure of foreign currency if nuclear replaces oil cannot be added to the benefits from reduced injuries in coal mines if nuclear replaces coal: these benefits are necessarily alternative not additive in an individual case, though both may be present to some extent where a programme of nuclear power stations is concerned.

In the case of coal, it is appropriate, in the circumstance of competitive costs envisaged, to assume that this reduction takes place in an industry centred mainly on the East Midlands and Yorkshire pits which are likely to be the ones which would produce the 70–80m. tons or more of coal which the National Coal Board hope* will be available at a cost of about 3¼d/therm ex-pit. Thus the costs associated with the present transitional stage of the coal industry as a whole are not included in this study, since they arise primarily from the fall in demand for coal now taking place and the measures taken to close high cost pits and to increase productivity. Nuclear substitution has played a minor part in these developments. However, a new nuclear power station chosen rather than a coal-fired one (where the coal-fired one is the most economic alternative) could involve the transfer of miners to other work, because of the reduced level of output in the relevant coalfield. So the costs of this, so far as they can be quantified, are included where appropriate.

The various factors affecting these wider benefits and costs are accordingly discussed against this background in subsequent paragraphs. The Appendix attempts to summarise these factors in tabular form. This necessarily involves abbreviation of the argument and, where necessary, reference back to the detailed analysis should be made.

**Effects on national resources**

*Demands on manpower*

The more efficient use of labour is a national economic objective of considerable importance. The movement of workers into occupations of higher productivity would allow total output and income to expand at a faster rate than would otherwise occur.

Different types of power station do not differ greatly in their own manning requirements. There has been a big drop in labour requirements for all types of stations with their increase in size. Large modern stations employ well under one man per megawatt. Nuclear power stations probably need more labour during construction (including labour in the manufacturing industries). The big differences in manpower lie in the methods of obtaining and fetching the respective fuels, coal making by far the biggest demand upon the nation's manpower. The difference between 1,000 MW of A.G.R. capacity and equivalent coal capacity is that if both operate on base load the coal plant will require support by perhaps 4,000 more men in the U.K., both in mining and (to a much lesser extent) in transport. On the basis of present East Midlands productivity it would require some 4,800 men to provide the coal needed (upwards of 2½m. tons a year) whereas only some 600 men are needed to produce the equivalent amount of nuclear fuel. The number needed for the necessary coal production will decline as output per man in the coal industry continues to rise with increasing mechanisation, etc.

The manpower saved by installing nuclear power instead of coal is reflected in the main economic assessment, through fuel prices, at the value of its existing productivity. There are, however, two side effects not so reflected. First the manpower may not be merely re-employed but re-employed in due course more productively, not least because it is employed more safely. Fresh capital formation may be required for this, possibly demanding bigger resources than those released by not replacing mining equipment. But it can be assumed that such fresh capital will earn its own sufficient return. Moreover, if labour shortage is a constraint in some industries—the East Midlands and Yorkshire levels of unemployment have been consistently under the national average for the last ten years—labour released elsewhere may be absorbed without the need for fresh capital. There may therefore be in due course an increase in the gross national product not reflected in the main benefit calculation. This is the general effect to be expected from moving towards less labour-intensive industry. Second, the manpower saved by installing nuclear stations will be wasted until new employment can be found for it. The period of waste will depend upon local circumstances.

* See, for example, Select Committee on Nationalised Industries Sub-Committee B evidence, 15th May, 1968, Q.434.

Given the substantial ageing in the coal-mining labour force during the past decade, it could average a few years in areas with high unemployment and cost upwards of £1,000 p.a. per man in lost productivity. Elsewhere, the period could be very short. Redundancy payments, unemployment benefits, loss of tax and other transfer payments do not represent resource costs to the nation, but they are accounting losses with their own intrinsic worth.

The effect on manpower of adopting nuclear power instead of oil or natural gas stations will be much less. There should be little difference in power station manning requirements. Requirements for fuel supply are difficult to compare. But the effect of losing a power station outlet on industries which are thriving and expanding will be marginal, and any differences between them and nuclear power will be reflected in principle in the fuel prices.

*Demands on capital*

The demand of a nuclear power programme for extra capital is reflected like other costs in the main economic calculation leading to its adoption. Nevertheless, it has been argued that the need for extra capital, particularly as it is in the public sector, is an adverse factor, given the many competing demands for a limited supply, and the problems posed by the call on resources.

However, it is important to consider and appraise this as an investment decision, using criteria applicable to either the private or public sectors. It has been estimated* that the internal rate of return on the extra capital required for the 1970–75 nuclear power programme would be about 14 per cent assuming that the cost of coal at the power stations was reduced to 3.7d/therm. The rate of return normally required by the Treasury for investment in the nationalised industries is 8 per cent.† This could still be secured on the extra capital for nuclear plant even if the cost of coal at the power station fell to 3d./therm (which not even the N.C.B. are forecasting). The extra capital required by the Generating Boards for the 1970–75 programme is well under one per cent of gross national capital formation, and in itself has no effect on interest rates generally. The extra capital required for a nuclear powered station as compared with a fossil-fuelled one is being reduced all the time and may not be particularly significant for nuclear stations ordered in the seventies.

It is sometimes argued that nuclear substitution is "wasting" serviceable capital assets in other fuel industries. Serviceable capital assets, whether amortised or not, are, of course, worth keeping in use as long as the avoidable cost of doing so is below the full cost of superseding them. Calculations of the economic benefit of nuclear power are customarily based on the delivered price of (say) coal to the power station. To take due account of existing serviceable assets such as mining machinery and special railway trains, the calculations ought, however, in strictness to be based on the coal's avoidable cost (together with appropriate interest and surplus, as required to meet the coal industry's financial targets). In practice, this refinement may be safely ignored, because the assumptions in the main economic benefit analysis about conventional fuel prices are varied over a range, and because the unavoidable costs appear to be only a few per cent of the prices. Any serviceable assets which have been wholly amortised are not reflected in the prices at all. Moreover, the cost of providing for the replacement of coal mining machinery and merry-go-round trains is avoidable if the construction of a coal-fired station would necessitate their replacement when they would not otherwise have been replaced.

*Foreign exchange*

For the main economic calculation, foreign exchange is reflected in system generating costs at its sterling equivalent. This ignores the fact that the money cost of foreign exchange may be less than its resource cost to the nation. Shortage of foreign exchange puts a brake on economic growth in the United Kingdom, and is likely to remain a limiting factor. So, from the national standpoint, foreign exchange may be deemed to have a value greater than its sterling equivalent at the current rate of exchange. Various figures are put on this "additional" value by economists, 25 per cent being illustrative. It will tend to vary with the balance of payments situation, but it is not likely to disappear and should be kept in mind in comparisons between different fuels (and fuel industry exports).

*Appendix 44 to the Report of the Select Committee on Science and Technology 1967.
† Cmnd. 3437.

In plant comparisons the percentage of foreign exchange costs as between nuclear and fossil-fuelled stations is not significant. In fuel, foreign exchange requirements represent about 10 per cent of the generating costs of an AGR station before taking account of the by-product plutonium. With a sizeable installation of commercial fast reactors using plutonium, the foreign exchange element in nuclear fuelling will shrink and ultimately be negligible. The comparable figure for oil is about 45 per cent, whereas coal is indigenous. There are foreign companies involved in the exploitation of North Sea gas. The White Paper on Fuel Policy indicated that the foreign exchange involved would be somewhat greater than for nuclear power. In fact it would seem that foreign exchange will account for about 25 per cent of the landed beach cost.

*Assurance of supplies*

An extra cost for all fuels is the need to maintain buffer stocks and emergency reserves. In principle, the cost of these is reflected in fuel costs and therefore in the main economic calculation. As regards security of supply, the White Paper on Fuel Policy has stated that "nuclear power and North Sea gas are hardly less secure than coal and the security of our fuel supplies will be enhanced to the extent that they take up markets which would otherwise have gone to oil". Development of more advanced nuclear plant like fast reactors, which are almost independent of imports, will bring almost complete security of supply to nuclear power.

In one sense nuclear power has a definite advantage. It is not as vulnerable as other forms of generation to political disturbance overseas or to industrial disputes at home. Fuel replacement has a very different timescale, the fuel is easily transportable and contains large energy reserves. The seamen's strike in 1966 halted seaborne coal and reduced seaborne oil supplies to C.E.G.B. stations in the South of England for two and half months and led to higher operating costs of at least £2m. Nuclear stations were not affected. Similarly nuclear power is not affected by exceptionally bad weather conditions.

**Other economic activities**

*Technological spin-off—creation of intellectual capital*

So long as nuclear power development continues, it will encourage the application of many physical sciences and technologies at the most advanced levels. It must therefore be a fruitful source of technological "spin-off" and intellectual development. One can categorise this into tangible spin-off—the transfer to commercial use of well-defined products, processes or materials; and, potentially as important, intangible spin-off, in the form of new information which is diffused outside the strictly nuclear industry under the special arrangements made for industrial and scientific collaboration. Among the areas of technology that have benefited from the nuclear programme are standards of welding, high vacuum technology, materials purity, improved instrumentation, computer design and software, pumping technology and the maintenance of clean conditions for production and operation. There will continue to be subsidiary benefits here, e.g., from nuclear materials. One of the most significant fields in science and technology generally in the years ahead will be that of materials, since the application of scientific knowledge can proceed only as fast as the development of materials technology allows.

*Secondary benefits of cheaper electricity and regional implications*

Whereas economic considerations point to the siting of fossil-fuelled stations near the coalfield or oil refinery, nuclear power stations are much more flexible in siting requirements. The comparative ease of siting nuclear power stations and the cheaper electricity from them can have obvious beneficial implications for regions which are either remote or "depressed", and for the introduction of new industries. These advantages might be regarded as reflected in the main cost benefit calculation through the reduced generating costs fed into it; but only in relation to the electricity demand assumed. The ultimate advantages stimulated by plentiful cheap power are a good deal wider.

**Environment**

Modern industry as a whole is necessarily concerned with the effects it may have on the physical environment both of its employees and of the public. In considering whether different methods of power generation, and the fuel supplies necessary for them, have different effects in this respect, it is important to avoid emotional statements that merely serve to obscure the issues. In many respects it may be impossible to ascribe a cash value to the relevant considerations. But costing the undesirable event is a first step to seeing what expenditure is justified to secure its prevention. In the process a value is ascribed to what has hitherto been regarded as unquantifiable. In other fields such as road accidents a beginning has been made in this respect, and it is reasonable to think that a start can be made in power comparisons also.

It is proposed to consider these aspects in relation to sickness and injuries in employment; the safety of the general public; and waste, including air pollution.

*Sickness and injuries in employment*

Although the amount of absence due to sickness, industrial disease or accident may, to some extent at least, be related to psychological factors, industrial disease and accidents can clearly be related to working environment. Some aspects of sickness, including psychological aspects may have a similar association. In power station comparisons there is no evidence to suggest that the incidence of sickness or industrial disease is any different as between the various forms of generation. The nuclear industry has been aware from the start of the vital need to take every possible precaution in relation to radiation, and has spared no expense in this regard. The standards of radiation safety are a model for other industries handling potentially dangerous materials.

In the accident field information so far available suggests that accident rates in nuclear power stations are lower than in coal-fired stations, and it is reasonable to to think that this situation will continue. The high standard of safety-consciousness, housekeeping, and self-discipline has its effect on the accident rate, while the absence of high level fuel bunkers, and fewer cat-walks and exposed stairways help to keep down the number of accidents from falls. However, the numbers involved in any comparison are small—typically 30 accidents per year for a 350 MW(E) coal-fired station and about a quarter of this for a nuclear station. Thus the difference in lost output is correspondingly small (perhaps £2,000 for the comparison given).

In terms of fuel supply, comparisons are again difficult because for coal one is concerned with an indigenous industry, relatively well-documented in terms of statistical information, while natural gas in this country is as yet in its infancy, and oil and uranium are imported from overseas. Moreover the continuing efforts being made on a world-wide basis to improve the safety of all types of mining make it certain that what is true today will not be true in five or ten years' time.

Nevertheless it is worth considering how the picture looks in this country now. The U.K. coal mining industry has a very high rate of both voluntary and other absenteeism. The factors causing this are complex. But sickness (including social factors as well as ill-health), industrial diseases, and accidents, all play a part. Miners as a class seem to have about twice the average number of days of sickness incapacity of all occupations. The economic consequences of this are to a large extent covered in the price of coal. However, it is worth isolating one part of this cost.

It is possible in the light of past experience to estimate the cost of industrial accidents likely to be incurred yearly in the fuel supplying industries to maintain a 1,000 MW(E) station operating at 75 per cent load factor. For a coal-fired station—and leaving aside fatalities—there might typically be 1,500 accidents per year, each involving the loss of at least three days work, in an East Midlands pit. For a nuclear station there might be 14 lost time accidents in the U.K.A.E.A. for A.G.R. fuel. The value of production lost as a result of these accidents could be about £300,000 per year in the coal mining industry (in terms of opportunity cost this figure might be halved) against £1,500 for A.G.R. fuel. The figure for the oil industry in the U.K. seems to be even less than in the nuclear industry, and is about £650 per year. No comparable figure for natural gas is available, but since it will include accidents involved in prospecting for gas in the North Sea, the tapping of gas fields and the laying of pipelines to land, it is likely to be somewhat higher than for oil.

The figure for coal is calculated on the assumption that the shortage of miners in the central mining areas continues. If, however, the shortage is overcome, the N.C.B. would be able to employ a larger number of miners to allow for absence through injury. In this case the loss of national output would be equivalent to the opportunity cost of the spare labour (that is its wages in alternative employment) which could be about £160,000; and the spare labour, if released and absorbed into local industry, might incur production losses through industrial accidents of about £8,000 p.a. If, then, a 1,000 MW(E) A.G.R. were built in preference to a power station fired with East Midlands coal, the productivity of the manpower involved might rise appreciably through a reduction in accidents, the net gain on this score being upwards of £150,000 per annum. A small part of this, representing a reduction in payments of sick pay, would be reflected (through fuel prices) in the main calculation of generating cost savings. But the rest would be an extra benefit. Some of this benefit from reduced accident rates may be achieved by the coal mining industry itself, through mechanisation. But it should be noted that the estimate is based upon comparison with a coal-fired station in the highly productive East Midlands coalfield. In assessing the benefit to the nation, a sum of perhaps £75,000 should be added for savings on hospitalisation, etc.

The net savings in industrial accidents from installing a nuclear plant in preference to a coal-fired plant therefore appears to be between £0.2 and £0.3/kW per annum or £2 to £3/kW, as a shadow saving on the capital cost of the nuclear station.

Accidents occurring in uranium mines overseas do not of course affect productivity in the U.K., but the accident rate per ton of mined material would have to be about 18 times as high as that obtaining in the U.K. coal mining industry for the rates to be equivalent.

In all the foregoing, fatal accidents have been left out of the reckoning. These also are much more common in the coal mines than in other fuel supply industries. The economic effect in the other industries is very small, but current data suggests that in economic terms the net loss of output* to the nation from coal fatalities is upwards of £750,000 per annum—or about £12,000 p.a. for supplying a 1,000 MW power station. An appropriate allowance for subjective costs could double this figure.

In the analysis so far Industrial Injuries Benefits have been ignored. They are transfer payments and do not represent a resource cost to the nation. Nevertheless, they are a mechanism whereby the population at large helps to maintain the living standards of those affected. A major part of the payments under the Industrial Injuries Scheme goes to the coal industry; the proportion greatly exceeds the proportion of the industry's own contributions to the scheme. Beveridge's original plan envisaged a special levy on hazardous industries, though this was never followed up. As it is, the degree of support being received by the industry from elsewhere in this respect deserves to be highlighted.

*Safety of the general public*

The nuclear power industry has a unique record in having achieved its major development without causing any public health dangers. Radioactivity and radiation are a natural part of man's environment, and quantitatively the additional exposure from a nuclear power station or from radioactive waste disposal is not significant.

There is clearly a theoretical risk to the public from nuclear power, as there is from disused mineshafts, subsidence, unstable tips, road transport of coal and oil, coal ash, large oil tankers, and gas and oil fires. It is, however, difficult to quantify a comparison. Nominally it is reflected in the main economic calculations through insurance costs. But in relation to both nuclear power and coal there is a significant public underwriting of responsibility in terms of government arrangements for inspection, safety research, etc.

*Waste including air pollution*

The U.S. Joint Committee on Atomic Energy has suggested that one factor in the rush by utilities in the U.S.A. to order nuclear power stations has been the fear that public authorities with air pollution control responsibilities may react with an excess of zeal to pressures for clean air, and impose corrective measures on fossil-fuelled plants that are unrealistic or prohibitively expensive in the present state of technology. Nevertheless preliminary U.S. studies suggest that a comparison of the environmental effects of nuclear plants compared to fossil fuel plants could result in a report favourable to nuclear plant from a health standpoint. In this country the problems of clean air have received much attention. While the total cost to the

*Discounted loss of earnings for rest of working lives, reduced by discounted consumption saved.

community of air pollution is thought to be some £350m. a year, the main source of both smoke and sulphur dioxide at ground level (where the damage is done) is the domestic user. The contribution of fossil-fuelled power stations, especially modern ones, is comparatively small. The main air pollutants from coal-fired stations are fly ash and oxides of sulphur and carbon, and the Generating Boards are at pains to reduce the escape of such substances to a minimum. This adds about £1.5 per kW to the cost of a coal-fired station in the U.K., and is reflected accordingly in the main calculation of the benefit from substituting nuclear stations. A practical basis for eliminating the pollution from coal stations entirely has not yet been found. There is, therefore, a small additional benefit to be had from substituting nuclear power and avoiding any material or other damage this residual discharge may cause. But the damage could probably be represented by adding only a few shillings per kW to the cost of the coal-fired stations (and if the fluidised combustion of coal ever became an economic proposition the sulphur would be retained in the ash). Oil-fired stations also produce sulphur dioxide and their position is similar. On the other hand, the sulphur content of North Sea gas is very small.

Much of the damage caused by air pollution is from the effect it has on materials and buildings, and in the cleaning and repairs that follow as a consequence. In terms of health the effect is less certain, although occasions can occur when effluents accumulate in concentrations sufficiently high to cause distress from respiratory diseases or even death for old and infirm people. But it is primarily in the domestic field that further action is still necessary in the implementation of the policy for clean air.

In the nuclear field the regulatory control of the release of gaseous radioactive waste is such that no pollution problem arises. Indeed fossil-fuelled stations could be discharging relatively greater quantities of radioactive material. Coal contains trace quantities of naturally occurring radioactive materials, and the combustion process (as with oil and natural gas) involves the release of quantities of radium through the stack (though here too the amounts involved are insignificant in relation to background radiation).

Solid and liquid waste is a problem for both the nuclear and coal industries, but one that should be kept in perspective. Radioactive waste disposal is carried out under close regulatory control, and in comparison with natural background makes a negligible contribution to the estimated average radiation dose to the population. The costs involved are reflected in the main economic calculations. It has been argued that expanding nuclear power programmes in a small island will eventually involve the sterilisation of large areas of land to receive radioactive waste. In fact the whole of the highly active liquid waste arising from the U.K. nuclear power programme up to the mid-1980s could be accommodated in a small number of tanks occupying about one acre of land at the Authority's Windscale site. At the end of their working life the disposal of nuclear reactors can be achieved with due regard for the aesthetic appearance of the countryside. Experience in this respect will be accumulated on a world-wide basis in the years ahead. Radioactive fuel will be withdrawn to be reprocessed in the usual way and the reactor structure containing some residual radioactivity can if, necessary, be dismantled at an estimated cost, discounted to the date of commissioning, of only a few shillings per kW.

In the coal industry coastal pollution from colliery waste is a problem attracting attention in, for example, the Durham area, while the disposal into rivers of underground mine waters in their natural state, which is often of high acidity, is normally exempt from regulatory control. Mine waters containing ferrous iron can be a particular problem.

The direct compensation paid by the N.C.B. for subsidence amounted to over £5m. in 1966–67. It may be deduced that 1,000 MW(E) of nuclear generating capacity which displaces equivalent coal-fired capacity may save around £80,000 p.a. in payments for surface damage caused by mining the coal. In principle these payments are reflected through coal prices in the main benefit calculation. But it is arguable whether this adequately represents the social gain from avoiding subsidence. There may be other hidden costs in making structures resistant to possible subsidence. Other forms of electricity generation would, of course, be as beneficial as nuclear in avoiding these losses.

## Conclusions

Nuclear power already has significant cost advantages in comparable circumstances when compared with fossil-fuelled stations. If account is taken of other relevant economic and social factors, it is reasonable to conclude that the margin of advantage for nuclear power, certainly over coal, will widen. It is clear that nuclear power involves less labour overall than coal-fired capacity. Once the transitional problems of the coal industry are over, this should enable a more productive use of labour in the fuel industries and the nation generally. The extra capital now required by nuclear as compared with fossil-fuelled stations can be fully justified on normal investment criteria. In the seventies with capital reductions in the cost of nuclear stations the difference in the demand for capital will have narrowed considerably.

In terms of foreign exchange requirements nuclear power comes second to coal, ahead of natural gas and oil, and with the advent of plutonium-fuelled fast reactors the foreign exchange content will be reduced even further, while security of supply will be enhanced. Nor is nuclear power as vulnerable to industrial disputes as other fuels.

The valuable technological spin-off into a wide range of other industries, with the use of new processes and materials, will continue and should help in meeting the challenge of other advanced technologies in the future.

In the effects on the environment of employees and of the public the nuclear power industry has established working conditions in which standards of both radiation and conventional safety are of the highest. This contrasts with the continuing unhappy record of the coal industry in accidents, occupational diseases and ill-health which is reflected not merely in the price of coal but in the loss of national output and in the subsidies received under the industrial injuries scheme. All the fuel industries are, of course, conscious of their responsibilities to the general public. While pollution from fossil-fuelled power stations in this country is a problem that is under control, a greater use of electricity domestically, helped by the cheapness of nuclear power, would assist in reducing the major contribution made by the domestic open grate to the material and physical damage caused by pollution.

## APPENDIX

### Associated benefits and costs of nuclear power

This appendix summarises relevant factors in tabular form. It excludes the *direct* benefits arising from lower electricity generating costs.

Abbreviation is inevitable in this presentation. The main text should be consulted for elucidation.

| BENEFITS derived from Nuclear Power | COSTS arising from Nuclear Power |
|---|---|
| 1. *Manpower* | |
| Fuel supply for nuclear stations is far less labour intensive than for coal-fired. | |
| The redeployment of redundant men must ultimately lead to a net gain in national productivity. This will be particularly apparent in areas where labour shortages are a major brake on industrial expansion. | Men displaced by loss of 1,000 MW(E) coal-fired station could be unemployed for varying periods, with consequent loss of national output. Transfer payments covering redundancy, and unemployment are another factor. |
| 2. *Capital* | |
| Benefits are included in the main economic assessment, but note that: | Nuclear power stations require extra capital for construction in a time of limited financial and other resources. |
| (i) Internal rate of return on the extra capital required for the 1970/75 nuclear power programme has been estimated at about 14%. | |
| (ii) While nuclear capital costs are steadily being reduced, conventional station costs are increasing, to extent that the gap between them will narrow significantly in 1970s. | Nuclear power substitution can waste serviceable assets of B.R. and the N.C.B. |
| 3. *Foreign exchange* | |
| The foreign exchange element is about 10% of nuclear power costs and should be reduced | Coal is an indigenous fuel. |

with the introduction of the Fast Reactor. About 40% of fuel oil costs are foreign exchange. The landed price of natural gas may include about 25% foreign exchange.

Uranium must at present be imported and the value of the foreign exchange involved could be greater than its sterling equivalent.

4. *Assurance of supplies*

Nuclear power and North Sea gas are hardly less secure than coal and both enhance the national fuel supply situation by reducing the reliance on oil.

Uranium is less bulky, contains huge energy reserves and is less vulnerable than coal or oil to exceptionally bad weather conditions, domestic industrial disputes.

Supplies of coal are wholly within national control.

5. *Technological "spin-off"*

Stimulus to advanced science and technology with transfer to commercial use of well-defined products, processes or materials.

Standards of welding, high vacuum technology, materials purity, improved instrumentation, computer design and software, pumping technology and clean conditions techniques have all benefited from the nuclear programme.

6. *Sociological "spin-off"*

Nuclear stations have greater siting flexibility: they offer an opportunity to improve the economy of remote and "depressed" areas. This cheap nuclear power will encourage the industrialisation of development areas.

7. *Sickness, injury and death in employment*

The incidence of sickness or industrial disease among employees in power stations is no different as between the various forms of generation.

Accident rates in nuclear power stations are lower than in coal-fired stations.

The supply of coal for a 1,000 MW(E) station operating on base load might involve each year:

(i) 1,500 lost time accidents in the mines;
(ii) about £300,000 in productivity lost through injury absences. (About half in terms of opportunity cost.)
(iii) the social consequences of prolonged illness or permanent disablement are substantial.

Fatal accidents in the U.K. nuclear fuel industry are virtually non-existent.

Fatal accidents in the coal mining industry could cost the country about £750,000 a year in lost production. An equivalent sum might be involved if subjective costs in terms of distress caused etc. were included.

A major part of the payments from the Industrial Injury Scheme go to the coal industry—an amount which greatly exceeds its total contributions.

To fuel a 1,000 MW(E) A.G.R. might cost each year:

(i) 14 lost time accidents in the U.K.A.E.A. and in industry;
(*ii*) about £1,500 in lost production.

To fuel a comparable oil-fired station could be even safer than the nuclear fuel service with U.K. lost production of only £650 a year.

These losses, of course, ignore the costs of accidents etc. occurring overseas.

8. *Safety of the general public*

The first-class public health record of nuclear power is probably unique in the history of advancing technology.

Super tanker incidents can be widespread in their economic effects and bulk fuel transport by road is not free from risk. There are also potential hazards from disused mineshafts, coal tips, and subsidence and from oil and natural gas fires.

For both nuclear power and coal there is a significant public underwriting of responsibility through government arrangements for inspection, safety research, etc.

9. *Disposal of waste products*

Gaseous and particulate discharges from modern conventional stations are being steadily reduced, but the burning of fossil-fuel releases significant quantities of pollutants to the atmosphere.

Radioactive gaseous discharges are subject to strict legislative control and authorisation and are of no environmental significance.

There is virtually no control over the disposal of undergound mine waters in their natural state, which is often of high acidity.

Low radioactive effluent is discharged under strict legislative control. Arisings of highly active liquid waste are small in quantity and can be stored in a few tanks of long life.

10. *Land subsidence*

Nuclear power is at a theoretical disadvantage in that an incident could have a widespread effect on public health. This is reflected in insurance costs.

The direct compensation paid by the N.C.B. for subsidence amounted to over £5 million in 1966/67 and is included in the cost of coal, but the necessity in coal mining areas to include special structural safeguards against subsidence damage is a large hidden cost.

---

# 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.

**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.

**Introduction to Production Control by Computer**

*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.

**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.

**Two-Phase Heat Transfer**

*6th to 10th January, 1969*
*9th to 13th June, 1969*

The subject will be approached in a fundamental way and although the problem of nuclear reactors will have some emphasis, the material presented will be useful to those requiring a knowledge of problems inherent in two-phase heat transfer and of current solutions, theories and developments. Fee: £40.

**Pulse Techniques in Nuclear Particle Counting**

*27th to 31st January, 1969*

Subjects covered by this course are requirements for nuclear pulse counting systems; linear and non-linear pulse-shaping circuits; transistors; the use of transistors as circuit elements; linear pulse amplifiers for nuclear particle counting; low-noise head amplifiers; pulse discriminator circuits—pulse shaping prior to scaling; scaling circuits and counting-rate circuits; fast timing circuits; multi-channel pulse data analysis; logic circuits; automatic recording for counting systems; practical design aspects of electronic equipment. Fee: £40.

**Radiological Protection**

*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.

**Nondestructive Testing Appreciation**

*3rd to 7th March, 1969*

The purpose of this course is to give a broad view of nondestructive testing in Great Britain and to show how the Nondestructive Testing Centre at Harwell fits into this picture. It has been designed to give management, design engineers and senior inspectors an appreciation of the nondestructive testing facilities available to them and to show how the Harwell Nondestructive Testing Centre supplements existing facilities by providing a research, development, information and advisory service. Fee: £40.

**Radioisotope Methods in Chemistry**

*3rd to 21st March, 1969*

This course is arranged in three one-weekly parts, each consisting of lectures and practical work.
Part I—Introduction to radioisotope work.
Part II—Radioisotope methods in analytical chemistry.
Part III—Specialised and advanced applications to chemistry.
Fee: £120 or £40 for each part.

**Process Instrumentation**

*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.

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

## Nucleonic instrumentation

The U.K.A.E.A. exhibited at the Nucleonic Instrumentation Exhibition, organised by S.I.M.A. in support of the I.E.E. conference on nucleonic instrumentation, at Reading University, 23rd-25th September.

The following instruments from Harwell and Aldermaston were shown:—

*Semiconductor nuclear radiation detectors for medical and biological applications*

These can be used to monitor phosphorus-32 activity in melanomas on the surface of the skin, to locate intestinal bleeding of unknown origin, to measure the absorbed dose distributions produced by high energy radiation therapy sources, to monitor X-ray beams, for counting in tissue and body cavities during tracer investigations, etc.

*Measurement of photon spectra from X-ray sets*

A spectrometer system has been developed for the measurement of photon spectra from a variety of X-ray machines. The system comprises a collimator which can be readily set up at any location, a sodium iodide crystal with a thin window (.001 inch of Al) and electronics to handle the high counting rates. The photon spectrum is required for calibrating dosimeters and for assessing the dose and radiographic effect in diagnostic radiography.

*Germanium gamma ray spectrometer*

Lithium drifted germanium detectors have found many applications, in nuclear physics, fuel element studies, activation analysis and reactor physics. Their success is primarily due to the very fine energy resolution obtained. Current research is aimed at improving the sensitivity of these detectors. The exhibit demonstrates a small detector with a response which is approaching the theoretical limit; the sensitivity is nearly twice that normally associated with a detector of this size.

*Instrumentation for radiological protection*

This was a display of some general purpose instruments for survey and contamination control.

*Neutron soil moisture probe* (*NIS* 374)

This portable, lightweight instrument uses a slow neutron detection system for the measurement of the water content of various materials in bulk such as soils, slag heaps and construction materials. Fast neutrons emitted by the Am/Be source enclosed in the sealed probe are moderated and back-scattered to a degree dependent on the moisture content of the surrounding material. The moderated neutrons are detected by a $BF_3$ proportional counter which is part of the integral probe assembly and are counted by an external ratemeter.

*Integral beta probe* (*NIS* 377)

The integral beta probe is a transistorised surface contamination monitor with a single quasi-logarithmic display covering the range 10 cps to 30,000 cps. 30 cps corresponds to $10^{-4}\mu Ci/cm^2$ of uniformly distributed thallium-204 (maximum beta energy 0.8 MeV) measured at approximately 0.75 cm from the probe face. The instrument weighs approximately $3\frac{3}{4}$ lb. and has a detector area of 100 sq. cm. The integral assembly provides convenience in handling and an easily readable display.

*Portable beta/gamma dose-rate meter* (*NIS* 501)

This instrument measures gamma dose-rate over the range 0.1 to 1000 rad/h and indicates the presence of beta contamination (mean energy 0.7 MeV) down to $0.3\mu Ci/cm^2$ in a gamma background of up to 1 rad/h.

*Semiconductor detectors for use in the current mode*

In current mode applications, one requires the detector output current to follow faithfully rapid variations of the input ionization. No commercial source of surface barrier detectors which satisfy this requirement has been found. The detectors which were shown have been made by including a copper plating process within the standard preparation method. Measured rise times have been found to agree with simple predictions for a wide variety of conditions.

*Concorde radiation warning system*

The system monitors the ionizing and neutron radiation received at high altitudes from galactic and solar radiation. Continuous meter indication is provided at the aircraft flight deck. Audible and visual warnings are given when radiation levels are such that a decrease in aircraft altitude may be required.

*Feasibility studies of semiconductor gamma cameras for medical research*

Non-destructive studies of various organs and glands (for example, thyroid, spleen, heart, brain, lungs, kidney, liver) can be made by an intravenous injection of the appropriate gamma-emitting radio-pharmaceutical, such as $Tc^{99m}$, and studying the resulting radioactive take-up of the organ. The gamma rays emitted are detected by a suitable device and processed to give a visual display of the organ of interest. Semiconductors have several advantages as the sensing device in preference to more conventional detectors such as scintillators, spark chambers, and image intensifiers.

*17-channel disc recorder*

In experiments to obtain nuclear data, an underground nuclear explosion is sometimes used as a source of bombarding neutrons. The method offers advantages over using an accelerator since it saves time and also enables highly radioactive samples to be employed. Individual events cannot be recorded by this method, but current outputs from semiconductor detectors are measured. A specialised recording system has been developed in which the signal is recorded by causing it to deflect the spot of a CRT, the deflection being photographed on a moving film. In the recorder which was shown, a disc of film which rotates in a horizontal plane is used, the signal appearing as a radial deflection near the periphery of the disc. Seventeen channels are available, and these produce 17 traces in a band on the disc which is about $1\frac{1}{4}$ inches wide.

## AEA at Farnborough Air Show

The UKAEA had several exhibits at the SBAC show at Farnborough, 16-22nd September.

On the Ministry of Technology's stand Aldermaston showed some applications of beryllium for possible use in gyroscopes, and in space—as X-ray windows, mirrors for satellite telescopes, and as a honeycomb structure having a beryllium skin and aluminium cells. Also on show

*The Atomic Energy Research Establishment, Harwell, has installed the world's first isotope powered generator to be used with an airfield marker beacon. The beacon has been installed by the Board of Trade at a site 7 miles from Benbecula airfield in the Outer Hebrides and marks high ground. It beams a vertical radio signal which is received by aircraft when overhead and indicates that it is safe to start the descent.*

*The beacon is powered by RIPPLE IX (radio isotope powered prolonged life equipment) which will supply not less than 4 watts (electrical) power over a period of at least five years.*

was the Concorde radiation warning system which was developed by Aldermaston and is being produced by S. Davall & Sons Ltd. A display by Submarine Cables Ltd. showed how a RIPPLE isotopic generator (a thermoelectric device powered by heat from a radioisotope) is used in the Hebrides to power a ground-to-air radio beacon—the first of its kind in the world. Submarine Cables Ltd. build RIPPLE generators under a licence from Harwell.

The payload of a Skylark sounding rocket was exhibited by the Culham Laboratory's astrophysics research unit on the Science Research Council's stand. It is similar in design to the eight Culham payloads fired from Woomera, Australia, since 1964. The solar corona and chromosphere have similar properties to plasmas produced in the laboratory for research into thermo-nuclear fusion. The nature of this plasma is studied by observing the emission spectrum in the U.V. and soft X-ray region. Solar emission in these wavelengths are strongly absorbed by the earth's atmosphere and therefore stabilized Skylark sounding rockets are used to carry spectroscopic instruments to heights of more than 100 miles.

## Plutonium for Sweden

The UKAEA has lent plutonium fuel to the Swedish A.B. Atomenergi for experiments which will produce information of use to both organisations.

The fuel consists of 160 fuel plates of the type used in the ZEBRA reactor at Winfrith. Each plate contains 50 grammes of plutonium, making a total of 8 kilogrammes of plutonium. The fuel will be used in experiments in the fast zero energy reactor FR-O at Studsvik and returned to the Authority by 1st March, 1969.

The experiments will provide information on temperature coefficients of fast reactors.

The loan is taking place under the UKAEA/A.B.Atomenergi fast reactor agreement and is fully covered by the terms of the UK/Sweden bilateral agreement on the peaceful uses of atomic energy.

*13th September, 1968*

## Accelerator accessories

The U.K.A.E.A. have licensed Vacuum Instruments and Products Ltd. to manufacture the following accelerator accessories:

Gas flow control devices.
High compression-ratio pumps.
Accelerator targets.

Various types of accelerators utilise ions or charged particles extracted from the gas plasma formed in an ion source. To achieve the required gas density in the ion source bottle, very accurate metering of the gas flow to it is necessary, this being of the order 1 to 20 atmospheric millilitres per hour. A typical system comprises a small high pressure cylinder, supplying gas to a regulator which reduces the pressure to a sufficiently low value for metering by the flow controllers. This controller may be a nickel or palladium diffusion barrier, a thermo-mechanical device utilising thermal expansion for control purposes, a refined type of needle valve, or a unit utilising the change of gas viscosity with temperature to vary the impedance of a fine capillary tube in the gas feed line.

In certain cases, where very expensive gas is supplied to the source, it may be necessary to recover that gas which is not usefully converted to ions—usually the major portion as ion sources are not very efficient. If the system is evacuated by a four-stage mercury vapour pump, this may be backed up by a high compression-ratio piston pump, free of oil, which is capable of producing the necessary vacuum of a few Torr whilst exhausting the gas collected into a recovery cylinder at pressures up to one atmosphere.

The ions when accelerated, are shot at targets of the element or isotope under study. The nature of such targets may vary from a gas to a substantial sheet of metal or a very thin transparent metallic foil. Carbon, for example, is commonly produced as a membrane supported across an aperture 1 cm in diameter and 5 millionths of an inch thick or less. Despite the fragile nature of many forms of targets, special packaging permits shipment by normal air freight to all parts of the world.

These accessories were developed at A.W.R.E. Aldermaston, which during some twelve years of active participation and support of nuclear physics research utilising Van de Graaff and Cockcroft-Walton accelerators, has developed considerable "know-how" in the manufacture of specialised devices and components used in this field.

More recently, equipment has been supplied to many external users of such components, from universities and research bodies in the United Kingdom to organisations as far afield as South Africa, Australia and the American continent.

Further information is available from Vacuum Instruments and Products Ltd., Bone Lane, Newbury, Berkshire. (Tel.: Newbury 4506).

*17th September*, 1968

## New tritium labelling service

The Radiochemical Centre has started a service for labelling chemical intermediates by reaction with tritiated methyl iodide. Molar specific activities up to 500 millicuries per millimole can normally be achieved.

Customers supply their own intermediates but leave the technical problems of handling small amounts of labelled methyl iodide *in vacuo* to The Radiochemical Centre.

This new service has been started because although The Radiochemical Centre can supply more than 250 tritium labelled compounds from stock and many others may be prepared to special order, it is impossible to meet every conceivable demand of the individual user of labelled compounds.

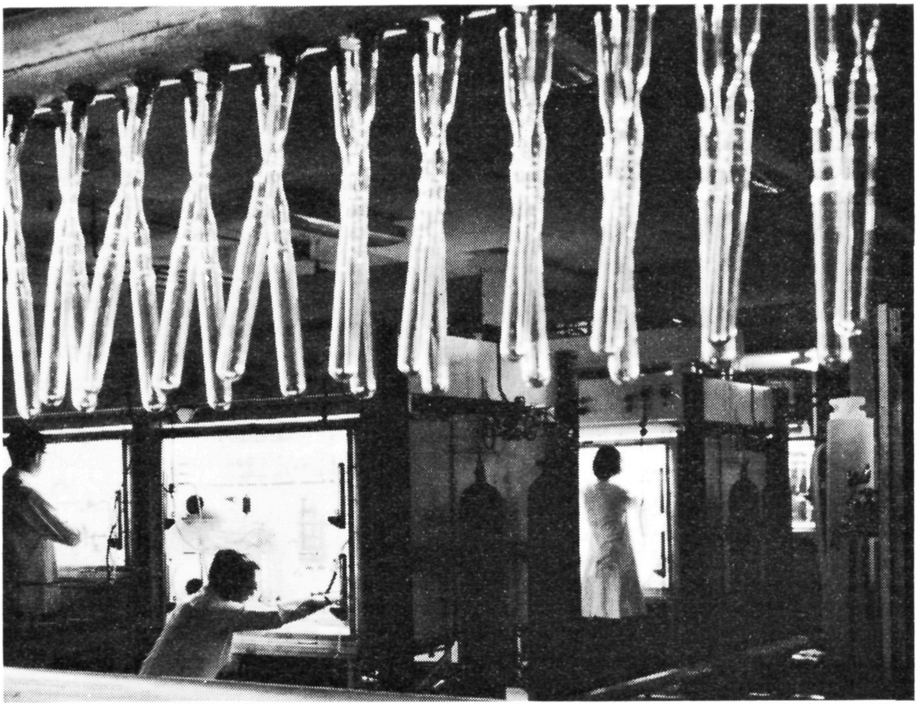
The charges for the service are:

| | |
|---|---|
| Reactions with 10 mc methyl iodide-T .. .. .. | £95 |
| Reactions with 100 mc methyl iodide-T .. .. .. | £175 |
| Reactions with 1 c methyl iodide-T .. .. .. | £350 |

Special quotations will be given for larger quantities or when more than three intermediates are submitted at one time.

These charges include measurement of the total activity of the product supplied. Purification and analysis of the product may be undertaken by special arrangement for a minimum additional charge of £100.

Carbon-14 labelling is also offered, involving similar reactions with methyl iodide-C14.



*General view of the tritium compounds laboratory of the Organic Department at The Radiochemical Centre, Amersham.*

These new services are in addition to the following established services:

- Labelling by catalytic exchange in aqueous media.
- Irradiation of organic compounds with tritium gas.
- Hydrogenation of unsaturated compounds with tritium gas or catalysed halogen-tritium replacement.
- Reductions with tritiated metal hydrides.

Further information is available from The Radiochemical Centre, Amersham, Bucks., (Telephone No.: Little Chalfont 2701).

25*th September*, 1968.

## High-pressure pipe couplings

A new design of bolted flanged pipe coupling has been developed in the Reactor Engineering Laboratories (REL) of the United Kingdom Atomic Energy Authority.

The coupling is of all metal construction. It employs a thin soft metal gasket which is compressed plastically between controlled finished surfaces on the mating hubs. With the right choice of materials the coupling can be designed for use in almost any environment at temperatures up to 600°C and at high pressures. Typical examples of current applications are low pressure, liquid metal loops, operating at 600°C and high pressure water loops operating at 400°C and 4,000 lb./in$^2$.

The couplings are generally available in sizes up to 6 in. diameter and larger sizes can be designed and made to special order. Sizes up to several feet in diameter have been made successfully.

Full particulars regarding development and performance of the couplings are given in U.K.A.E.A. report No. TRG 1208(R) *Bolted flanged joints for high temperature service* by W. P. White and N. A. C. Bromidge. The design is protected by patent.

The couplings are manufactured under licence by the Willaston Engineering Co., Willaston, Wirral, Cheshire. Enquiries should be addressed to Technical Operations Directorate, U.K.A.E.A., Reactor Group, Risley, Warrington, Lancashire, England, or to the licensee.

1*st October*, 1968.

# Science experiments for schools

The U.K.A.E.A. exhibited at the School's Science and Technology Committee's "Applications of Science" exhibition at Imperial College, London, from 24th-27th September.

The experiments were within the capabilities of a well equipped school to carry out and for "O" and "A" level science students to understand. Brief descriptions of the experiments are given below.

*Electro-optical properties of crystals*

The essence of this experiment is to show how certain crystals change their optical properties when an electric field is applied to them. An ammonium dihydrogen phosphate crystal is used, and it is made to change from a uniaxial to a biaxial crystal. The change is observable as attractive patterns, and this should help to fix the experiment in the mind of the student.

Useful applications of such crystals are as light modulators and light shutters. Specifically they are used for "Q-spoiling" pulse lasers; that is, for producing giant pulses of light. Hence the interest of the student can be directed towards a growing branch of physics.

*Fluidics*

Fluidics is the technology of performing amplification, switching and other operations usually found in electronics, by using fluid powered devices with no moving parts. These devices can operate at extremes of temperature and irradiation where electronic or moving part devices would fail, and are often more elegant than their electronic counterparts.

*Electrodialysis*

This process removes dissolved salts from solution and is used industrially for the production of drinking water from brackish ground water and industrial effluent. Other applications are in the food industry, e.g., in the processing of milk whey.

The feed solution flows through a cell with an electrical potential across it which causes the ions to move towards the electrode of opposite charge. The cell walls (termed a cell pair) are formed by ion selective "membranes" so arranged that ions which have passed through the membrane are trapped in the adjoining cell. Anion membranes only allow anions to pass through and similarly cation members only cations. A number of cell pairs are termed a "stack". This experiment was presented in conjunction with William Boby and Co. Ltd.

*Sonic detection of nucleate boiling*

Experiments with water have shown that considerable sonic energy is liberated by nucleate boiling. This energy can be used to detect boiling—mechanical wave guides are used to carry the acoustic signal out of the liquid to a conventional piezoelectric device. The experiment shown was actually developed from work on the Dounreay Fast Reactor but has other applications in work on boiling liquids.

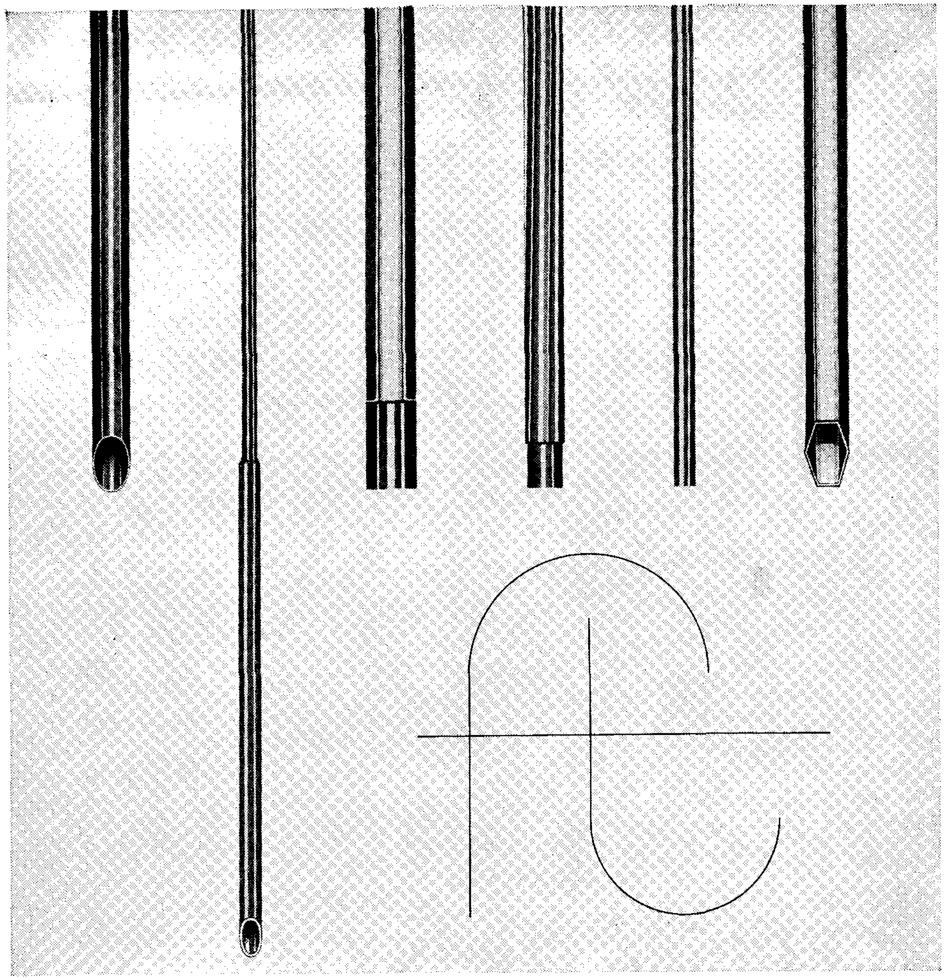
*Pressure and density measurement by dynamic means*

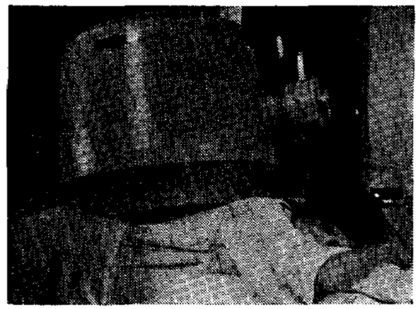
The principle that the resistance of a body moving in a fluid is proportional to the density of the fluid and independent of the fluid viscosity is used as the basis of two complementary methods of gas pressure or density measurement; both methods were developed for use where the environment prevents the use of orthodox transducers. The first uses a falling piston and the second is a comparator method and employs two vibrating reeds, one of which is subjected to a reference pressure and the other to the unknown pressure.

*Propagation of shock waves in bubbly mixtures*

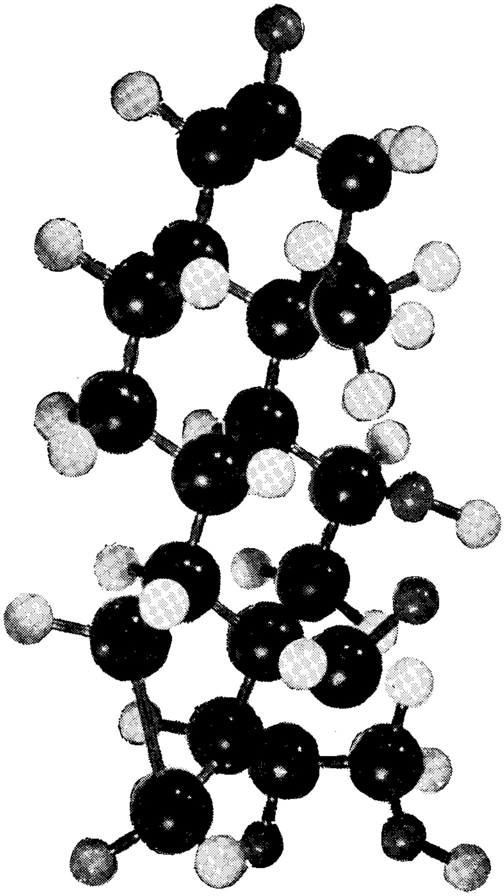
The presence of a small number of bubbles in a liquid causes a dramatic decrease in the velocity of propagation of a wave through it. The velocity decreases from 1,500 metres/sec for pure water to 150 metres per sec for a volumetric air concentration of about 2%. With a two phase medium however (say water and water vapour) the fall in velocity is even greater because of condensation and evaporation effects. This was demonstrated in the experiment.

"Do-it-yourself" leaflets, describing how schools can make their own equipment for these experiments, are available from Public Relations Branch, U.K.A.E.A., 11, Charles II Street, London, S.W.1.





# Labelled Steroids



The Radiochemical Centre offers a wide range of labelled steroids of high purity, high specific activity and at competitive prices.

Many carbon-14 compounds are available from stock at an isotopic abundance often over 90% of the theoretical maximum (100% isotopic abundance ═ 62·4 mc/mA carbon labelled).

For example:
Aldosterone-4-C14 56.7 mc/mM ═ 91%
Cortisone-4-C14 58.0 mc/mM ═ 93.5%

Other important compounds supplied from stock.

**CARBON-14**
Cholesterol-4-C14
*Cortisol*-4-C14
Oestradiol-4-C14
Oestriol-4-C14
Oestrone-4-C14

**TRITIUM**
Cholesterol-1α-T
Oestriol-6, 7-T

Ask for free batch analysis sheets providing details of purity, notes on preparation and recommendations for storage from:

**The Radiochemical Centre**
**Amersham England**

TAS/RC174

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