# ATOM

Number 157 / **November 1969**



MONTHLY INFORMATION BULLETIN OF

THE UNITED KINGDOM ATOMIC ENERGY AUTHORITY

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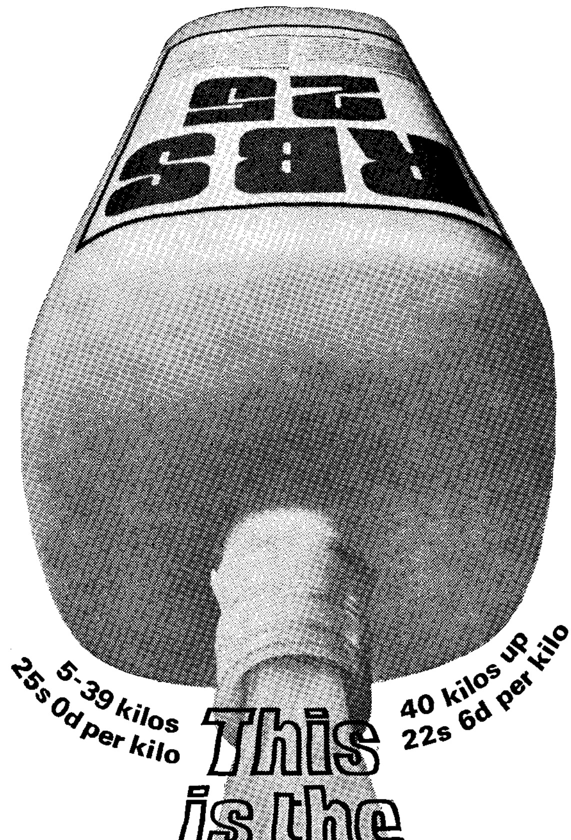
# SURFACE CLEANING PROBLEMS?

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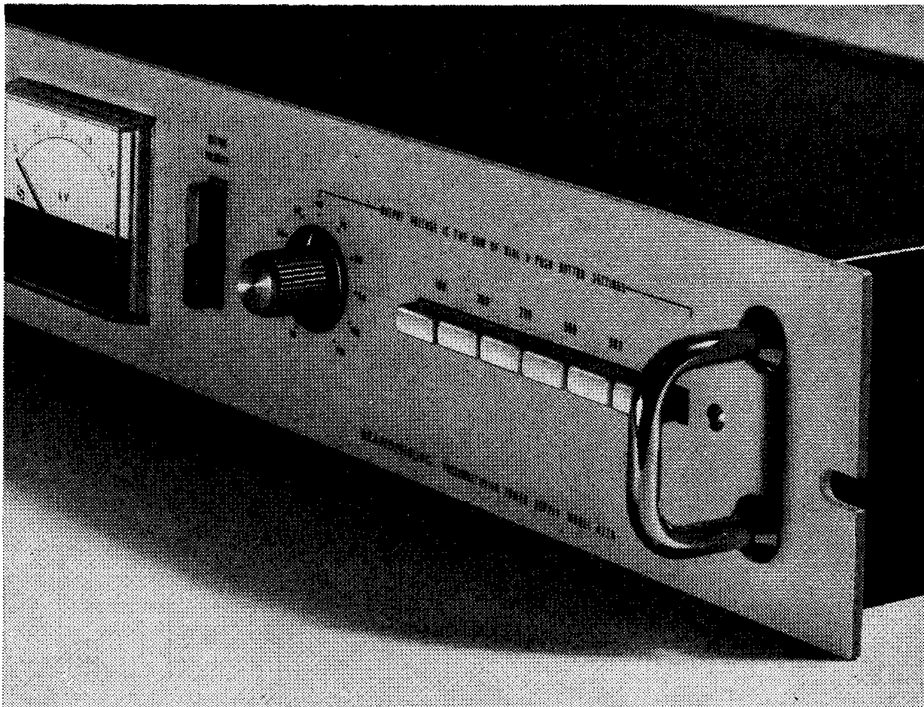

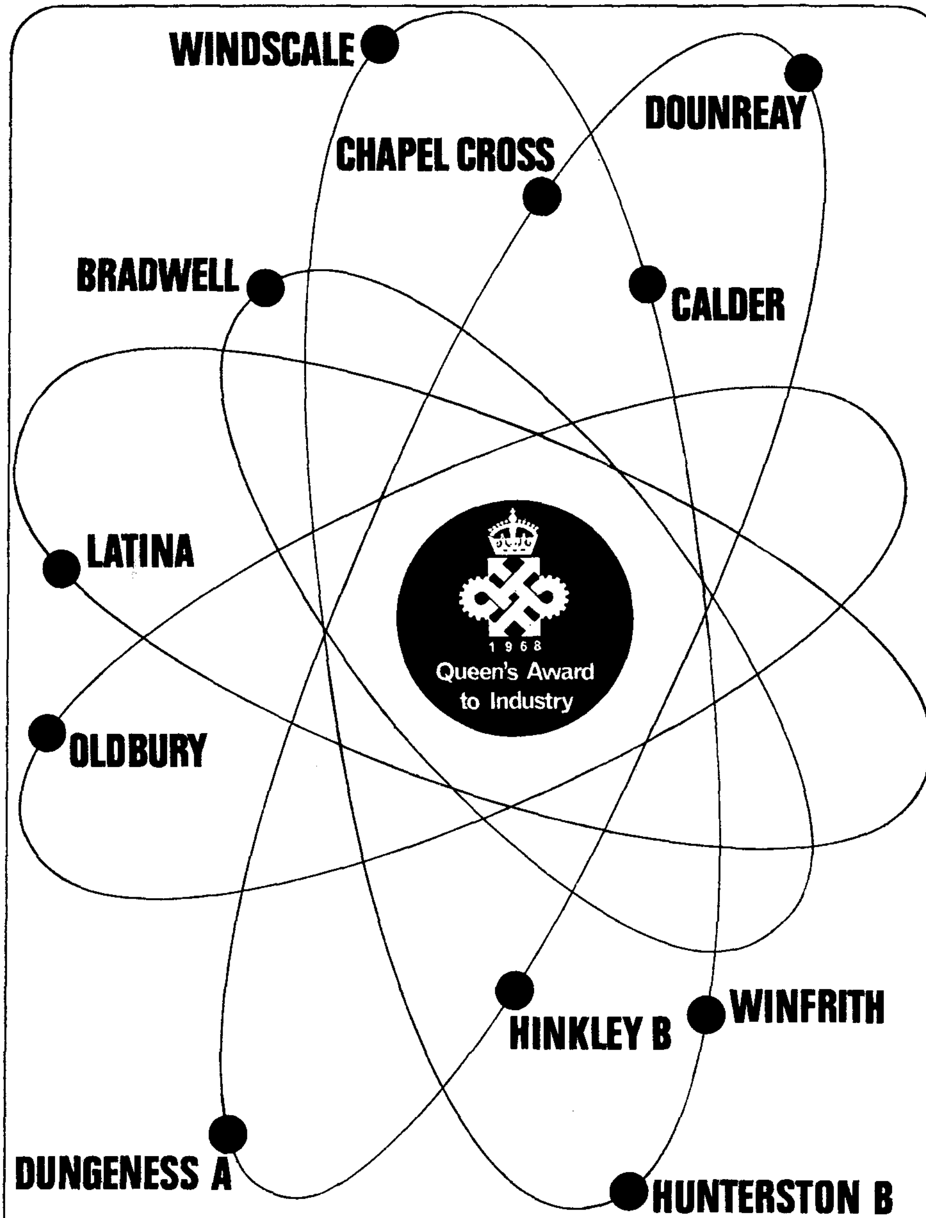
WINDSCALE
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1968
Queen's Award
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DUNGENESS A
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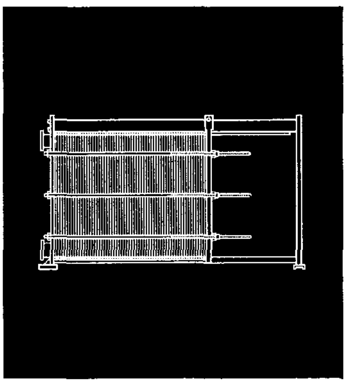

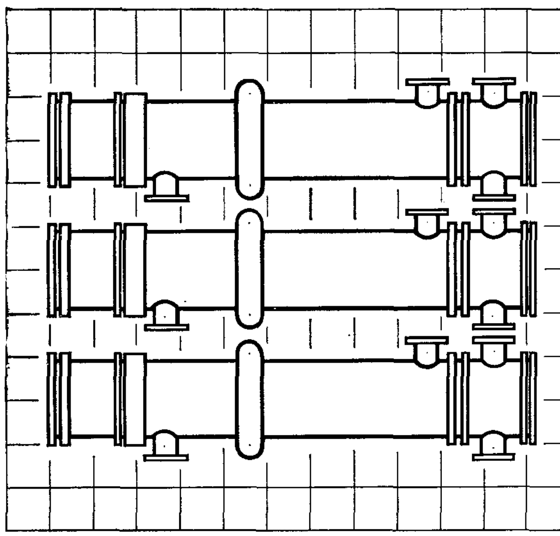

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OF THE UNITED KINGDOM
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**ATOM**
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# 15th Annual Report: Press Conference

*Sir John Hill, Chairman of the U.K. Atomic Energy Authority, made the following introductory statement at the Press Conference on the Authority's 15th Annual Report, held on 1st October, 1969.*

When I spoke to you at this time last year there was a great deal of uncertainty about the restructuring of the nuclear industry in this country. I had to try to outline to you what was likely to happen before we were sure ourselves and in fact not everything worked out in the way we expected.

But let me first tell you of the changes on the Board of the Authority. Mr. J. C. C. Stewart, who had been with the Authority since 1946, and was Member for Reactors, left last December to become Deputy Chairman of B.N.D.C. His move is a great loss to the Authority, but I am sure is as great a gain to B.N.D.C. Dr. J. B. Adams, the Member for Research, left us at the end of March to become head of the new European project for the 300 GeV accelerator. It is, I think, an enormous tribute to Dr. Adams that an Englishman should be selected to head this great European project even though the U.K. has not found it possible to participate and contribute.

**New members**

Two new Members have been appointed. Dr. N. L. Franklin, who took my previous position as Member for Production, and Dr. H. Kronberger, who became Member for Reactor Development. We now have a smaller Board than we have had in the past, but it does permit tighter integration of the research and development activities in our northern and southern establishments.

To return now to the nuclear industry. Although the outcome is well known to you I think I should recall it here as a background to the way the Authority is adapting itself to the changing circumstances of nuclear energy in this country and in the world. Last year we had four separate design and construction teams, three in private industry, and one in the Authority's Reactor Group. Now we have made substantial progress towards

*On the platform at the Press Conference on the U.K.A.E.A.'s 15th Annual Report are (left to right): Mr. M. I. Michaels, Under Secretary, Atomic Energy Division, Ministry of Technology; Mr. T. Tuohy, Managing Director, U.K.A.E.A., Production Group; Sir Charles Cunningham, Deputy Chairman, U.K.A.E.A.; Sir John Hill, Chairman, U.K.A.E.A.; Dr. H. Kronberger, Member for Reactor Development, U.K.A.E.A.; Air Chief Marshal Sir Denis Barnett, Member for Weapons Research and Development, U.K.A.E.A.; and Dr. W. Marshall, Director of Research Group, U.K.A.E.A.*

the concentration of effort and resources into two teams, B.N.D.C. and T.N.P.G. The Authority is a shareholder in each company to the extent of 20 per cent. and we have Dr. Franklin as a Director on the Board of B.N.D.C., and Dr. Kronberger and Mr. Allday, the Commercial Director of the Production Group, as Directors on the Board of T.N.P.G.

As far as staff transfers are concerned, I have already referred to Mr. Stewart's appointment as Deputy Chairman of B.N.D.C. and you will know that about forty of the design and construction staff on the fast reactor project have joined the new T.N.P.G. Group.

On the proposed new Fuel Company, the Authority has been assisting Government departments in formulating the necessary draft legislation for consideration by Ministers and Parliament. I should say that I regard the formation of a nuclear fuel company as the logical extension of the process by which the Authority set up the Trading Fund to allow its commercial activities to be conducted on a normal commercial basis.

**Future programme**

But the whole purpose of the reorganisation has been to get a closer integration of the various parts of the nuclear industry. Our future programme, and by this I mean the whole U.K. nuclear power programme, is discussed at regular meetings of the Reactor Policy Committee. This Committee is composed of equal numbers of the most senior engineers and technical people from the Electricity Authorities, the design and construction companies and the Atomic Energy Authority. I chair this Committee and we try to thrash out our future development and engineering programme between us so that we are all working with the same objectives and to the same timescale. I believe it is working well and all parties are in full accord with the programmes and policies that are being pursued.

Perhaps I should add that the two design and construction companies now have full access to any information they require on any reactor system under development in the Authority. I would also like to say that the Authority is giving, and will continue to give, every aid and assistance to the firms in support of their proposals for nuclear power stations for the Electricity Boards at home, and in support of their efforts to sell nuclear power stations abroad.

Let me turn now to the work of the Authority itself, and let me start by describing the commercial and production side. Activity has increased in every sector and all plants are working close to capacity. The Radiochemical Centre at Amersham has increased the range of its products and has increased its turnover by 10 per cent. to £3.15M. 57 per cent. of its production was exported. It has set up a new joint company in the United States with the Searle Corporation to expand further its activities in that vital market.

**Fuel output**

The Springfields factory produced over 2,200 tons of natural uranium fuel during the year, the highest output yet achieved. It also commissioned and is now operating a new plant for the manufacture of 2,000 tons per annum of uranium hexafluoride for the extended diffusion plant at Capenhurst, and a new line for the manufacture of A.G.R. fuel.

At Windscale the main active separation plant continued to operate at near full capacity and the new head-end plant for reprocessing enriched uranium oxide fuel was commissioned and is now operating. A start was made on the commissioning of the new fuel plant for the manufacture of plutonium fuels for the fast reactor. The Calder Hall reactors have continued to operate at very high load factor.

At Capenhurst, the first stages of the reconstructed diffusion plant were recommissioned and output is increasing steadily as additional stages are brought on line. Development on the centrifuge continues to make encouraging progress.

Finally, at Chapelcross, the reactor which was badly contaminated when a fuel channel melted two years ago, has been cleaned up and recommissioned.

**Exports**

Exports of nuclear fuel services have again been buoyant and orders received exceed £11M.

Although most of these increases in output have been achieved by increases in productivity, some increase in numbers has been required. The total strength employed on these commercial activities during the year under review increased from 9,215 to 9,585, a total increase of 370, of which 225 were transferred from other parts of the Authority as part of the overall rationalisation plan.

On the research and development side of the Authority, including weapons research, we have carried out a further streamlining and reorganisation in the interests of efficiency and economy. The Orfordness Establishment in Suffolk is being closed and its activities transferred to Aldermaston. The Research Laboratory at Wantage is being closed and the activities transferred to Harwell, and we are proposing to close the Culcheth Laboratories in Lancashire over the next year or two and transfer the activities to the Risley Engineering Laboratories and to the Springfields Establishment near Preston. The Engineering Group has been disbanded as a separate Group and those staff engaged principally on production matters have been transferred to the Production Group, and the remainder have become the Engineering Division of the Reactor Group. This reorganisation will bring a significant reduction in overhead costs and will also result in closer integration of the work with the activities of the larger establishments. The total number employed by the Authority on all activities outside the commercial field has been reduced from 22,310 to 21,380, a reduction of 930 (including the 225 transferred to production activities).

**Gas-cooled reactors**

Now let me turn to our development programme. Our programme on gas-cooled reactors, and by our programme I mean the programme agreed by the Electricity Boards, the design and construction companies and the Atomic Energy Authority, is in the shorter term to ensure the satisfactory operation of the A.G.R.s. (Mark II gas-cooled reactors) now under construction and still to be ordered by the Electricity Boards and, in the longer term, to base development on helium cooling with graphite coated fuel (the H.T.R. or Mark III reactor). Gas-cooled reactors improve year by year and some years they make bigger advances than others.

**Fast breeders**

Let me now turn to the fast breeder reactor. You will remember that the aim of this reactor system is not only to reduce generating costs from nuclear power still further, but also to reduce our dependence on imports of uranium.

The Experimental Fast Reactor at Dounreay, D.F.R., continues to work well, amassing information on the behaviour of large numbers of fuel pins: a key item in Fast Reactor development. We have now taken over 400 pins to a burn-up in excess of 5 per cent. of heavy atoms

(50,000 MWD/T); well over 200 have reached 7 per cent. burn-up and some have reached 10 per cent. burn-up, or nearly 100,000 MWD/T. Many of these fuel pins were in fuel sub-assemblies characteristic of those to be used in fast reactor power stations. This performance is, so far as I know, more advanced than that achieved anywhere else in the world. Emphasis has been moving for some time to determine limits of fuel performance. Fuel pins have been taken to failure and the effect of such failure on the operation of the reactor has been investigated. We have been greatly encouraged by the fact that when failure occurs it has been of a more limited nature than might have been expected and has had no effect on the subsequent use of the reactor.

**Test bed**

The D.F.R. is a very versatile irradiation test bed and a number of other countries are using it to test their own designs of fuel elements. This test work is carried out on a commercial basis and currently earning approximately £1M. a year.

In any large power station or in a complicated machine like an aircraft where safety is such an important factor, it is necessary to have a very large amount of instrumentation to detect any slight abnormality in operation so that appropriate remedial action can be taken immediately. The fast reactor is no exception to this rule and a great deal of ingenuity has gone into designing and developing instruments to detect any abnormality in the operation of the reactor, particularly the reactor core. Traces of fission products can be detected in the highly radioactive sodium coolant; traces of gas or vapour can be detected, as can voiding, in the highly turbulent core. Temperatures are of course recorded everywhere. I mention this simply as an illustration of the range of activities that have to be undertaken in the development of these projects.

As you know, it has been necessary to put back the completion date of the prototype fast reactor. There have been delays in the delivery to the site of some of the heavy fabricated components. I should say, however, that these items were not easy to fabricate. They presented new problems which took longer than expected to overcome. Naturally we would not consider any erosion of standards which could affect our safety margins in the interests of quick delivery.

I reported last year on the early operation of the S.G.H.W. reactor at Winfrith Heath. The reactor has operated well and has very attractive features, particularly in the 300 MW-500 MW range. The two design and construction companies are vigorously pursuing the commercial exploitation of this reactor system at home and abroad.

**Harwell programme**

Perhaps I should now turn to Harwell, where big changes have taken place under the direction of Dr. Marshall. In the last year Harwell has increased the amount of work it is doing in direct support of the main reactor projects. It has also increased substantially the amount of work it is doing in general support of British industry, both inside and outside the field of atomic energy. The response of the Harwell staff to these new and exciting fields of work has been such that the demand from industry for services, joint programmes or contract R. & D. work has tended to exceed the rate at which staff could be released from other work. The manner in which Harwell works with industry places the main emphasis on the need to carry out R. & D. as an integral part of the innovative process (marketing, design and production), and on the need to provide both Harwell and the firm with a common purpose.

The objective of the industrial R. & D. programme is first to use our resources in the national interest but, within this remit, to maximise cash and royalty returns to the Authority. There will be successes and failures—as in all R. & D. projects—and we are adopting the same practices as do industrial firms. Projects which show success are being vigorously pressed forward; those which show little or no industrial promise will be stopped as quickly as possible. Many of Harwell's activities —in carbon fibres, non-destructive testing, ceramics—have been described elsewhere, and I will not repeat them to-day. However, it is worth noting that Harwell gave assistance to a mining firm over the Whitsun holidays in assessing a new overseas development. As a minor digression I would like to say how pleased we are that Dr. Smales has been selected as a NASA principal investigator to assist in analysing lunar material. This analysis is currently under way.

The work done by the Authority in association with industry is beginning to show results. For example, in desalination, where work is carried out in more than one Authority establishment, British firms have secured three large overseas contracts this year. An increasing proportion of Aldermaston's activity is allocated to non-nuclear projects mainly on behalf of government departments but also on industrial projects such as APACE and high temperature chemical technology. In all this I am sure that the most important fact is the way in which the Authority is swiftly adapting to the changing needs of to-day.

Turning finally to Culham and the fusion programme, the recent conference at Culham showed that good progress is being made there towards the objective of a fusion power reactor. There is still a very long way to go before an economic fusion reactor can be envisaged, but I am sure that the Culham conference marks an important stage in the way ahead. A long-term technological project like that is well suited to international collaboration and Culham is playing its full part in this exciting development.

# The Authority: 1968-1969

*(The following is an extract from Chapter I of the A.E.A. Fifteenth Annual Report)*

By the end of the year under review, the first steps in the planned reorganisation of the nuclear power industry had been accomplished.

The recommendations of the Select Committee on Science and Technology on the United Kingdom nuclear reactor programme and the decisions of the Minister of Technology (announced in the House of Commons on 17th July, 1968) were printed in the Authority's annual report for 1967/68.

In accordance with these decisions, the Minister asked the Industrial Reorganisation Corporation " to assist in the creation of two design and construction organisations to be established in place of the three commercial firms and the design teams working within the Atomic Energy Authority."

Two such companies—British Nuclear Design & Construction Ltd. (B.N.D.C.) and The Nuclear Power Group (T.N.P.G.) —have now been established. The Authority have a 20 per cent. shareholding in each company and are represented on its board. In pursuance of the Ministry's policy that the design and the later development stages of nuclear reactors should now be the responsibility of the two new companies rather than of the Authority, T.N.P.G. have been given contracts for managing the completion of the Dounreay prototype fast reactor (P.F.R.) and for certain development work on the fast reactor system. Some 40 members of the Authority's design and engineering staff have accepted offers of employment with the company; and the Authority, in order to secure continuity of effort on fast reactor work, have seconded a further 100 officers to serve temporarily with T.N.P.G. on work covered by the two contracts.

Early in 1969, the Authority initiated discussions for the conclusion of licensing agreements with the two new companies (when established) covering all the reactor systems developed by the Authority, both thermal and fast. It is intended that these agreements should supersede the existing agreements which are confined to gas-cooled reactors.

The Minister's statement of July, 1968 envisaged the transfer of the Authority's fuel business to a publicly-owned company under the Companies Acts. This transfer of part of the Authority's functions will require legislation, and discussions concerning the form of the legislation were in progress at the year's end.

Of the Authority's civil research and development expenditure, by far the larger part (currently over £40 million per annum) is in aid of reactor development and there seems no possibility that the design and construction companies could accept responsibility for any substantial part of this work in the short term. It is clearly in the general interest that major facilities now provided by the Authority—e.g., the fast reactor at Dounreay (D.F.R.), the Prototype Advanced Gas-cooled Reactor (A.G.R.) at Windscale, the Steam Generating Heavy Water Reactor (S.G.H.W.R.) at Winfrith, the Materials Testing Reactors at Harwell—should continue to be operated in the interests of both companies; it would be impracticable for each company to duplicate them. Various statements which have been made concerning reorganisation seem to have created the impression that the Authority was on the verge of fragmentation. On the contrary, the principal responsibility of the Authority has always been to undertake research and development into all aspects of atomic energy and this responsibility is unchanged. Furthermore, with the rapid increase in investment in new nuclear power stations that can be expected during the next few years, the importance of a soundly-based supporting programme of research and development will be enhanced rather than diminished.

Further modifications in the organisation of the Authority were forecast in the Minister's statement. These will no doubt take some time to effect. Meanwhile, it is essential for the Authority to press on with the important research and development work which lies ahead.

**Main programmes**

The Authority's main programmes have been well maintained during the year under review. 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. The Trading Fund had another good year. Seven of the eight Calder and Chapelcross reactors operated at high load factor; the blocked fuel channel in Chapelcross No. 2 reactor was cleared and the necessary measures to bring the reactor back to power were set in hand. The Windscale A.G.R. continued to perform satisfactorily, as did the S.G.H.W. reactor at Winfrith, apart from fuel troubles due to early malfunctioning of the water purification plant. The Dounreay Fast Reactor (D.F.R.) was restored to power operation on 22nd June, 1968, after the sodium leak had been remedied. Construction of the P.F.R. continued, though it was necessary to set back the completion date by about 12 months because of difficulty which had been experienced in fabrication of the radiation shield roof.

In May, 1968, the Authority announced their intention to close down two research reactors, BEPO at Harwell and the Materials Testing Reactor at Dounreay. This decision, reached as a result of a review designed to ensure the most efficient use of the Authority's materials testing facilities, will reduce annual operating costs by £¾ million. BEPO, the second oldest of the Authority's reactors—it had been in operation since 1948—was finally shut down on 13th December, 1968; D.M.T.R. was closed on 12th May, 1969.

In June, 1968, the Radiochemical Centre, Amersham formed a joint company with G. D. Searle & Co. (Inc.), one of the leading manufacturers of pharmaceuticals in the United States, to market Radiochemical Centre products in North and South America.

**Gas centrifuge**

Satisfactory results of the Authority's gas centrifuge development programme led the Authority early in the year under review, to conclude that in European conditions the gas centrifuge would probably be the most economical method of uranium enrichment. Accordingly, if development continues satisfactorily, further expansion of U.K. enrichment capacity necessary to fuel the $UO_2$-fuelled nuclear power stations will be provided by the centrifuge route. Centrifuge development has already been carried on in Germany and Holland, and negotiations were begun between the three Governments towards the end of 1968 with a view to establishing joint enterprises for the construction and operation of centrifuge enrichment plants.

**Cost advantage**

Two developments concerning the nuclear power programme should be noted. First, the Central Electricity Generating Board (C.E.G.B.) have now increased the assumed life of A.G.R. power stations from 20 to 25 years in the light of satisfactory experience of the Windscale A.G.R. Second, whereas the capital costs of the earliest magnox stations were some three times higher than those of their fossil fuel equivalents, the difference between the Hinkley 'B' A.G.R. and the coal-fired Drax is narrowed to some 25 per cent. When account is taken of the very much cheaper fuelling costs, this establishes a decisive cost advantage for nuclear power.

The estimates for 1969/70 under the

# U.K.A.E.A. Reactors

| | | |
|---|---|---|
| 1 **GLEEP** | *Harwell* | Routine testing of the quality of graphite and uranium. Research with oscillator. Biological irradiations. |
| 2 **LIDO** | *Harwell* | Thermal reactor studies including shielding and neutron spectra measurements. |
| 3 **DIDO** | *Harwell* | Studies of nuclear reactor materials. Isotope production. Neutron and solid state physics. Radiation chemistry. |
| 4 **PLUTO** | *Harwell* | Studies of nuclear reactor materials. Isotope production. Neutron and solid state physics. Radiation chemistry. |
| 5 **FAST REACTOR (DFR)** | *Dounreay* | Fast neutron irradiation testing of advanced fuels, structural materials, etc. Development of fast reactor technology. |
| 6 **ZENITH** | *Winfrith* | Reactor physics investigations for advanced graphite-moderated reactors. |
| 7 **HERALD** | *Aldermaston* | Studies in neutron physics, radiochemistry and nuclear reactor materials. |
| 8 **HORACE** | *Aldermaston* | To obtain basic nuclear information for HERALD. |
| 9 **VERA** | *Aldermaston* | Experimental studies of fast reactor systems. |
| 10 **NESTOR** | *Winfrith* | Source of neutrons of sub-critical assemblies. |
| 11 **DIMPLE** | *Winfrith* | Testing of a wide range of lattices. |
| 12 **HERO** | *Windscale* | Reactor physics studies for the advanced gas-cooled reactor system |
| 13 **DAPHNE** | *Harwell* | To simulate DIDO or PLUTO; to provide basic physics information in support of these reactors. |
| 14 **ZEBRA** | *Winfrith* | Reactor physics studies of the PFR and other large fast reactors. |
| 15 **HECTOR** | *Winfrith* | Oscillator reactor reactivity measurements on materials and fuel elements. |
| 16 **JUNO** | *Winfrith* | Testing of a wide range of liquid-moderated lattices. |
| 17 **VIPER** | *Aldermaston* | Pulsed reactor. Experimental studies of the effects of intense, transient bursts of neutrons and gamma radiation. |
| 18 **ADVANCED GAS-COOLED REACTOR (AGR)** | *Windscale* | To study the advanced gas-cooled power reactor system and to test fuel elements for commercial AGRs. |
| 19 **STEAM-GENERATING HEAVY-WATER REACTOR (SGHWR)** | *Winfrith* | To obtain experience with the SGHWR concept and to test fuel for commercial SGHWRs. |
| 20 **PROTOTYPE FAST REACTOR (PFR) (under construction)** | *Dounreay* | To obtain the information necessary for the design of high power, commercial fast reactors. |
| 21 **CALDER HALL (Four reactors)** | | Power and plutonium production; process steam supplied to Windscale site services. |
| 22 **CHAPELCROSS (Four reactors)** | | Power and plutonium production; experimental work in aid of the UK power programme. |

Atomic Energy Vote total £27.9 million nett (£94.79 million gross) and show a reduction of £2.3 million. The Authority's cash expenditure in 1968/69 on the civil research and development programme was £48 million and 2,380 qualified scientists and engineers were engaged on this work at the end of the year. In addition, 265 qualified staff were employed on other nuclear and non-nuclear work on repayment.

## Sales

The Authority's sales, primarily of nuclear fuel services, electricity and radioisotopes totalled £41.7 million with a net surplus of £1.5 million. All the electricity sales and the larger part of the fuel services sales were to the U.K. electricity generating boards; overseas fuel service sales totalled £1.9 million, and outstanding export contracts totalled £19 million at the year's end. Sales of radioisotopes from the Radiochemical Centre increased by ten per cent. to £3.15 million of which 57 per cent. were overseas.

The first priority of the Authority's reactor programme is to ensure the satisfactory operation of the Mk. II commercial gas-cooled reactors (A.G.R.'s) now under construction. The scope for further development of the gas-cooled system is being exploited by improvements to the fuel for the Mk. II reactors under construction and to be ordered. The S.G.H.W.R. is being pursued as a complementary system for home and overseas markets with particular emphasis on the intermediate output stations (about 450 MW(E)). Designs for commercial fast reactors are being studied, since they are expected to give the lowest generating costs, though the rate of installation is likely to be limited for a time in the late 1980s by the availability of plutonium from thermal reactors. Improvements to thermal reactors are also being considered. The considerable experience of gas-cooled reactors is being exploited further by development of a Mk. III gas-cooled reactor, using low-enriched coated particle fuel and helium coolant, exploiting the new technology evolving from the DRAGON project.

During the year the C.E.G.B. signed a letter of intent for the 1250 MW(E) A.G.R. power station at Hartlepool. This brings the total capacity of Mk. II gas-cooled reactor stations ordered under the second nuclear power programme to about 5,000 MW(E). It was previously estimated that capacity totalling about 8,000 MW(E) of these stations might be in commission by 1975, but electricity peak demand has been growing rather more slowly than expected and the Government have indicated in " The Task Ahead " that the growth of nuclear power is also likely to be slower.

The nuclear fusion research programme at Culham Laboratory continues to be organised and implemented with the advantage of a full exchange of information among the principal world laboratories engaged in this field. Overall plasma confinement times continued to increase and show promise that the confinement needed for a fusion reactor can be realised.

The Chairman of the Authority, Dr. J. M. Hill, and the Director of Culham Laboratory, Dr. R. S. Pease, gave further evidence on the nuclear fusion programme to the Select Committee on Science and Technology on 28th November, 1968, and the Chairman reaffirmed the Authority's intention to maintain a viable fusion and plasma physics programme.

## Non-nuclear work

The effort devoted by the Authority to applied research and development with industrial objectives outside the nuclear power field is steadily increasing. Some of the work is classified as applied nuclear R. & D.; the remainder is classified as non-nuclear R. & D. In both cases the objectives are to achieve national benefit, either economic or social. These benefits are assessed by the Programmes Analysis Unit (P.A.U.) or by the Authority's Economics and Programming Branch.

The Authority continued their programme of research and development into matters not connected with atomic energy. During the year, five additional Requirements were issued by the Minister of Technology under Section 4 of the Science and Technology Act, 1965: quality control; water renovation by reverse osmosis; high temperature chemical technology; electrotechnology; and marine technology. Extensions to existing programmes of research into hydrostatic extrusion and the improved utilisation of steels were under consideration at the year's end.

The effort devoted to these activities continued to increase as follows:

| | | |
|---|---|---|
| | | (qualified scientists |
| 1965/66 | 42 man/years | and engineers) |
| 1966/67 | 81 " | " |
| 1967/68 | 175 " | " |
| 1968/69 | 264 " | " |

A further increase is expected in 1969/70.

The Authority's R. & D. programme on nuclear reactors and in the applied nuclear and non-nuclear fields are supported by underlying research in the relevant scientific disciplines. All these research and development programmes require the support of special major facilities such as research reactors, computers, particle accelerators, mass spectrometers, electromagnetic separators, as well as radiochemical laboratories and post-irradiation examination cells for handling and studying highly radioactive materials.

The reduction in the Authority's expenditure on reactor research and development consequent on the achievement of economic nuclear power necessitated a re-assessment and reduction of the underlying research and a change in emphasis in many of the programmes. This re-assessment has now been completed, taking into consideration not only the long term needs of the reactor programme and other applied programmes, but also the need to maintain a strong and coherent scientific base from which the country can exploit the new scientific and technical opportunities that arise in the nuclear field. At the end of the year, approximately 290 qualified scientists and engineers were deployed on underlying research.

The principal aims of this programme are to study the properties of materials used in the Authority's programmes, and to devise and explore new processes and techniques which may have application in research or production.

The major research facilities (e.g., reactors, accelerators, mass spectrometers, electromagnetic isotope separators) also provide the means of studying and developing new ideas and applications such as the uses of radioisotopes and radiation sources.

Notable progress has been made in physical and chemical studies of all the types of nuclear reactions of importance in reactor technology.

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

## A.E.A. to reprocess Oskarshamn fuel

The United Kingdom Atomic Energy Authority has received from the Swedish company, Oskarshamnsverkets Kraftgrupp AB (OKG), a letter of intent for the reprocessing of a minimum of 70 tonnes of nuclear fuel from the Oskarshamn nuclear power station. The fuel will be reprocessed at the Authority's reprocessing plant at Windscale, Cumberland, from 1972 onwards.

**Background notes**

1. The Oskarshamn nuclear power station is situated on the peninsula of Simpevarp on the Baltic coast between the towns of Oskarshamn and Västervik. A 440 MW(E) reactor of the boiling water type is being constructed by ASEA-ATOM who were also awarded a contract earlier this year for a second reactor of 580 MW(E) capacity on the same site.

2. The fuel consists of slightly enriched uranium dioxide which at equilibrium will achieve a burn-up of over 20,000 MWD/tonne U. Some 15 tonnes of fuel will be discharged each year from the first unit.

3. The U.K.A.E.A. reprocessing plant at Windscale has a capacity of over 2,000 tonnes of fuel per annum and can process both natural uranium metal fuels and enriched uranium oxide fuels. Apart from fuel from nuclear power stations in the U.K., the plant also reprocesses fuel from the Tokai-mura reactor in Japan and the Latina and Garigliano reactors in Italy. It will in future reprocess fuel from the NOK Beznau reactor in Switzerland, and the Zorita reactor in Spain.

Note: 1 tonne is 1,000 kilogrammes, and in this case refers to the quantity of uranium contained in the nuclear fuel, not to the gross weight of the fuel elements.

*6th. October 1969*

## Atom 69

An illustrated summary of the fifteenth annual report of the United Kingdom Atomic Energy Authority from 1st April 1968 to 31st March 1969 is available from Public Relations Branch, Room 102, U.K.A.E.A., 11, Charles II Street, London, S.W.1.

# The growth of demand for energy and the role of nuclear power

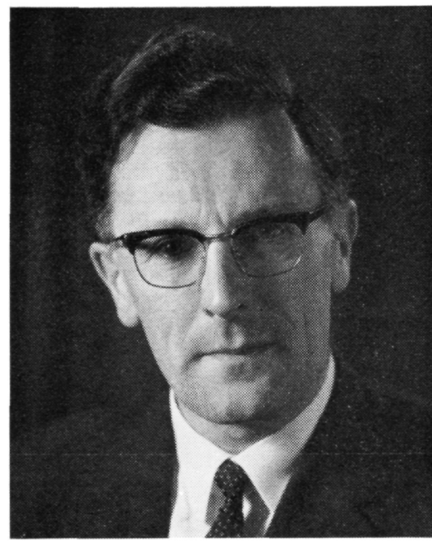
*The following paper by P. J. Searby, Principal Officer Economics and Programming, U.K.A.E.A., London Office, was presented to the International Atomic Energy Agency Symposium on nuclear energy costs and economic development, held in Istanbul, 20th to 24th October, 1969.*

Energy provides the power to progress. However great may be the natural resources of a country, they can only be turned into wealth if they are developed, used, and exchanged for other goods. This cannot be achieved without energy—but with a sufficiency of energy properly applied, a people can rise from subsistence level to the highest standard of living.

**Evolution of energy consumption**

More than half the world's primary energy is consumed in North America and Western Europe, but more than half the world's population lives in Asia where energy consumption is barely 7% of the world's total[1]. The contrast between the high level of and sharp increase in per capita energy consumption in North America and that of the developing countries is brought out in Figure 1, while Figure 2 shows each region's share in the world's primary energy consumption and how that consumption is made up. These figures, and indeed world statistics, are necessarily incomplete in failing to include that major source of energy in certain parts of the world, human and animal muscle. They ignore wind-power and solid fuel sources such as wood and animal dung, and that forerunner of hydro-electric power, the water-wheel. All these sources of primary energy, however, are already declining in significance. At the other extreme, the latest " industrialised " source of energy—nuclear power—though by 1965 providing some 10mtce of energy in the form of electricity, was then making too small a contribution to register in these figures.

Of particular interest is that from 1960 solid fuel ceased to provide over half the world's total energy and, as Figure 3 makes clear, its share has now dropped below that of liquid fuel. As we discuss later, these trends can be expected to accelerate, and Figure 3 also shows the possible changes in the shares of the main primary fuels in meeting the world's energy requirements to 2000 A.D.



*Mr. P. J. Searby*

An interesting demonstration of the inter-relationship between energy usage and the development of a country is given in Figure 4 which shows per capita growth of energy consumption against GNP (Gross National Product) per capita. Countries whose national output is mainly agricultural and whose people live mostly in rural communities fall at the lower end of the curve. Typical is East Pakistan with a population density of 922 persons per square mile (about the same as the Netherlands), 95% of whom live within the narrow ribbons of cropland alongside the distributaries of the Ganges delta. Apart from some natural gas, mineral and other resources are negligible, coal has at present to be imported, and hydro sites are scarce. Cloth and sugar mills provide some industry, but their effect on a population of 55 million is insignificant[2]. Although the

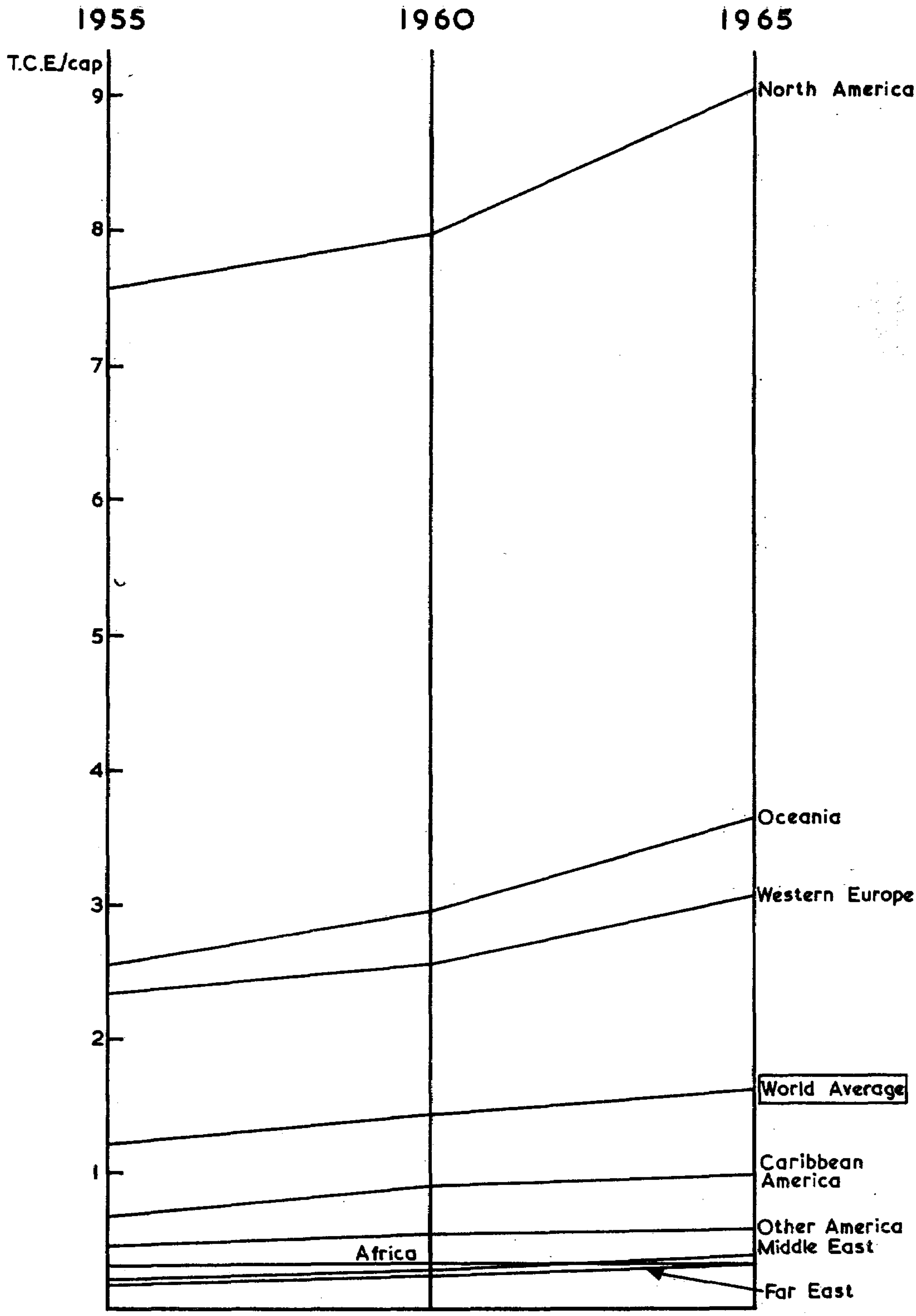



**Fig. 1** *Per capita energy consumption*

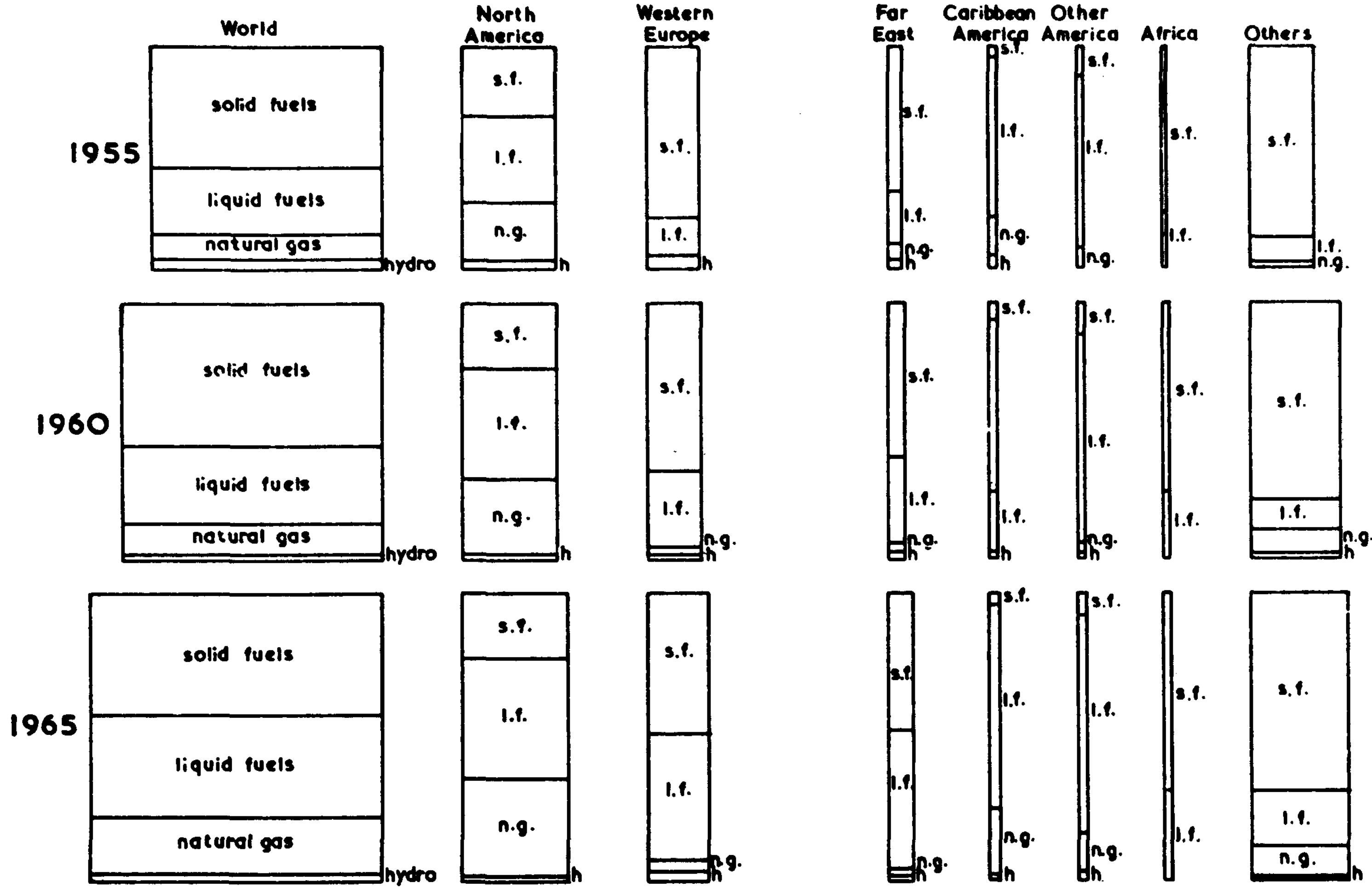



**Fig. 2** *Regional shares of the world's total energy consumption (imported gas is included under natural gas; nuclear and imported electricity under hydro)*

position in West Pakistan is somewhat better, the two regions combined show a very low energy usage and income per head for the country as a whole. The figures for India's GNP per capita differ little from Pakistan's but energy usage is considerably higher because of better resources—India is the world's sixth largest coal producer—and more industrialization. However, industrial activity forms only 16% of India's GDP (Gross Domestic Product) and employs less than 10% of the 500 million population while agriculture comprises 49% of the GDP (1966 figures). For statistical purposes India is taken as an economic whole and consequently comes near the foot of the curve in Figure 4, but were the country broken down into smaller economic entities, there is little doubt that some regions, e.g. Bombay, would come very much higher.

As a country (considered as an economic unit rather than a political area) develops, the pattern of its energy usage undergoes a distinct change. In a simple society, energy is almost entirely a consumer good, and although muscle, wind and water may provide some motive power, the effective use of the available energy is small and its contribution to the development of the economy negligible. However, once energy is made available in excess of domestic needs, e.g. by building hydro-electric dams, generating plants, and steam engines, it is not used solely as a consumer good and becomes a factor of production. Transport facilities and factory units multiply rapidly and the energy usage per worker rises sharply. The innumerable small workshops employing labour at very low wages which often characterize countries with abundant labour and little capital resources begin to be displaced by more efficient productive units. Income per head rises with the important consequence that purchasing power and savings both start to grow.

Overall, the correlation between energy consumption per head and GNP per head is very good, but clearly there will be differences from one country (or economic area) to another. Partly this may reflect history and tradition, partly it will reflect economic circumstances such as the availability of natural resources and the efficiency with which the energy available is used. For example, compare in Figure 4 the position of Japan and Italy. Their energy consumption per head is almost identical, but in the years 1955, 1960 and 1965 industrial activity (including construction) accounted for 30%, 36% and 37% of Japan's GDP, but 39% for each year of Italy's. Similarly, industrial activity (including construction) in 1960 and 1965 formed 29% of Chile's GDP, but 32% and 36% of Spain's, although energy consumption in both countries was almost the same.

The natural resources of some countries will lead them to develop energy-intensive industries and in others energy will play a less important role in national output. The former will lie above and the latter below an 'average' curve drawn through Figure 4. We must, of course, be careful not to deduce too much from a single series of generalised figures, especially where the degree of statistical reliability will necessarily vary from country to country—and where the need to combine (by means of conversion factors) a variety of different energy forms can distort the picture. For example, for reasons elaborated later, it seems highly probable that the internationally accepted conversion factor for hydro-power reduces the useful energy consumption per head attributed to countries, such as Norway, which rely heavily on hydro-power. It is, however, clear from Figure 4 that when the stage of rapid development is passed, the *rate* at which energy consumption increases in order to achieve a given increase in GNP per capita begins to slow down. It is outside the scope of this paper to examine whether, as present indications suggest, primary energy consumption will ultimately stop growing while GNP per head continues to rise because the efficiency of using energy will still be increasing.

Such a development, however, is likely in any case to be a long time ahead, even for the more advanced countries, especially since ample supplies of energy can contribute to those non-quantifiable advances which enhance the quality of life. Moreover, it must be remembered that the transition of societies from simple to advanced was not effected in a decade or so and for some countries it has taken almost two centuries. We are celebrating in the U.K. this year the two-hundredth

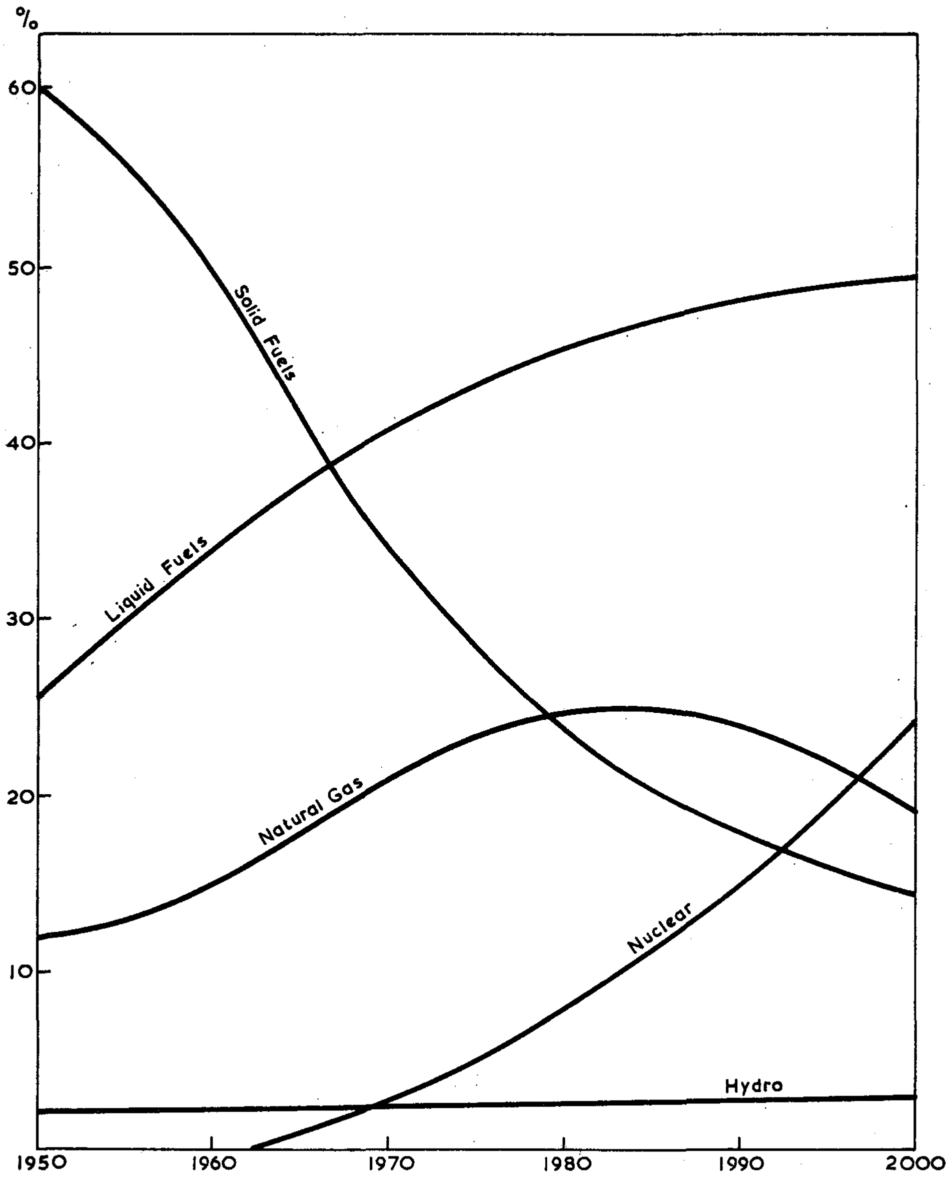



**Fig. 3** *Possible changes in percentage shares of primary fuels in meeting the world's energy requirements.*

anniversary of James Watt's first patent for his steam engine. But, whereas today's advanced countries had to rely on their own efforts to make the transition, the abundance of their accumulated experience, know-how, capital and financial resources can be made available to help developing countries build up a balanced economy. Developing countries may thus reap much sooner the benefits of the economies inherent in large-scale projects and those arising from the adoption of advanced technologies, and thereby enjoy much more quickly a higher standard of living. Yet the growth of their demand for energy may still be expected to follow the pattern described above.

### Investment in energy

Much has been written about the investment strategy of the developing coun-

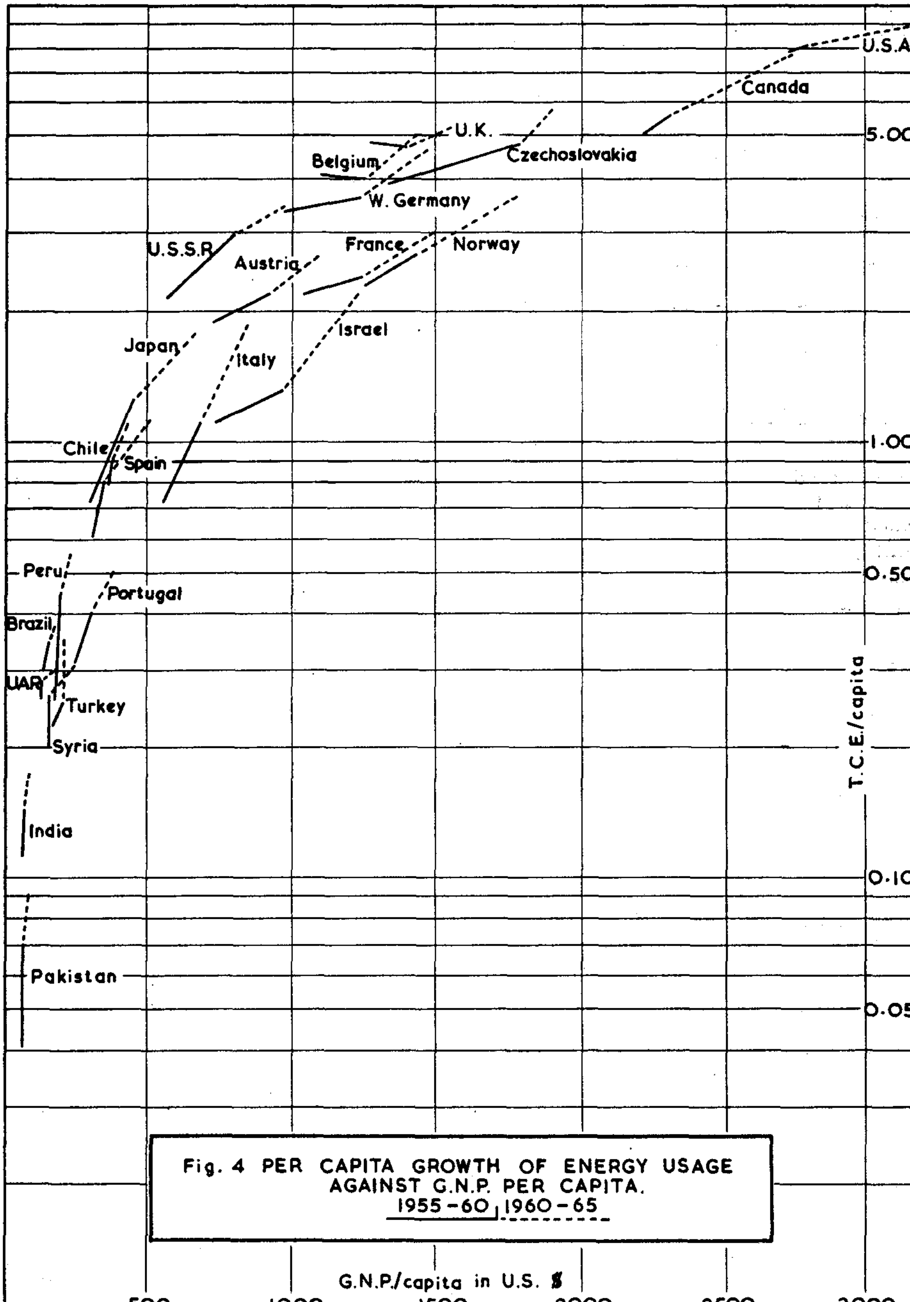



Fig. 4 PER CAPITA GROWTH OF ENERGY USAGE AGAINST G.N.P. PER CAPITA. 1955–60 | 1960–65

tries; investment in large integrated steel mills in areas where agricultural productivity is low, and in elaborate motorway systems that lead nowhere, has been criticised—and the reasons for it explained. Rapid advance is bound to create some temporary imbalances and apparent irrelevancies, but however priorities are assigned, it will be clear from the analysis above that a place must be found for both the provision, and the proper exploitation, of energy.

Similarly, just as the provision of energy must take its place within an integrated scheme of development, *it is* important that proper attention be given

**Table I** *Efficiency in the use of energy sources—U.K.*

| | Efficiency in Use Factor | |
|---|---|---|
| | In industry | By private consumers |
| Coal | 25 % | 40 % |
| Gas | 35 % | 67 % |
| Petroleum | 30 % | 62 % |
| Electricity | 85 % | 80 % |

to the form in which that energy is made available. Energy may be needed as heat, as light, as motive power, or for electric processes such as electrolysis (such direct uses of electricity in industrial processes are growing rapidly): it may be needed in large amounts or small: continuously or intermittently: in locations readily accessible to its primary sources or to means of transportation, or in remote or inaccessible areas; thus, what is most economic in one set of circumstances may be quite inappropriate in others. In comparing the alternatives available, proper attention must be given to these factors.

In this connection it is interesting to note recent studies on the efficiency with which various forms of energy are in fact used. Working on the basis of the analysis done by Adams and Miovic[3] we have deduced that in U.K. circumstances the efficiency of use of the energy sources available in the U.K. is as given in Table I. These figures, and the original work referred to, both indicate that the present, necessarily simplifed, factors used for equating different forms of energy (generally in terms of calorific value), almost certainly understate the rate of growth of the *utilisation* of energy, and that a major reason for this is the rapid increase in the proportion of total energy consumed as electricity. We turn therefore to specific consideration of the demand for electricity.

## Electricity demand

The relationship between population and electricity consumption in different parts of the globe is represented in Figure 5 which highlights the disparity between industrialized and developing regions. However, even if in absolute terms the gap between industrialized and developing regions in consumption per head is still widening, in relative terms it is less wide than it was; a growing proportion of energy requirements is being met by electricity—a trend which the increasing availablity of cheap electricity will itself stimulate—and, as suggested by Figure 6, this is expected to continue. This may apply especially to developing countries because their industrial progress will be based on modern technologies which are generally electricity-intensive. (No doubt different countries will have different views on the validity of the projections in Figure 6; they are generally based on published information from the countries concerned, and their main merit perhaps is that they reflect a consistent appraisal of statistics and information from many different sources.)

The absence in developing countries* of a stabilised electricity supply system such as exists in industrialized countries limits the value of projecting historical data, where these are available and reliable. Nevertheless it is useful to apply the annual growth rate of about $6\frac{1}{2}$% of the free world's generating capacity to some developing countries in order to obtain an indication of their possible generating capacity in say twenty years' time. The result is given in Table II. (A slightly higher growth rate would have included Bolivia, Cameroon, Costa Rica, Ecuador, and Kuwait among others.)

However, in each developing country it will be necessary to build up the likely pattern and size of electricity demand by careful analysis of requirements on a country-wide basis even if, for a time, each district will develop its own network. Demand will be influenced by competition from other forms of energy, income levels, and the degree of urbanization. There will need to be reserve capacity to cover divergences from the assumptions made about demand and the risk of breakdowns in supplies. The process of estimating future requirements is

* The term "developing country" includes all countries of Asia except Japan, mainland China, Mongolia, North Korea, and North Viet-Nam; of Africa except South Africa; of Latin America and the Caribbean area except Cuba; and the southern European countries of Cyprus, Greece, Malta, Portugal, Spain, Turkey and Yugoslavia.

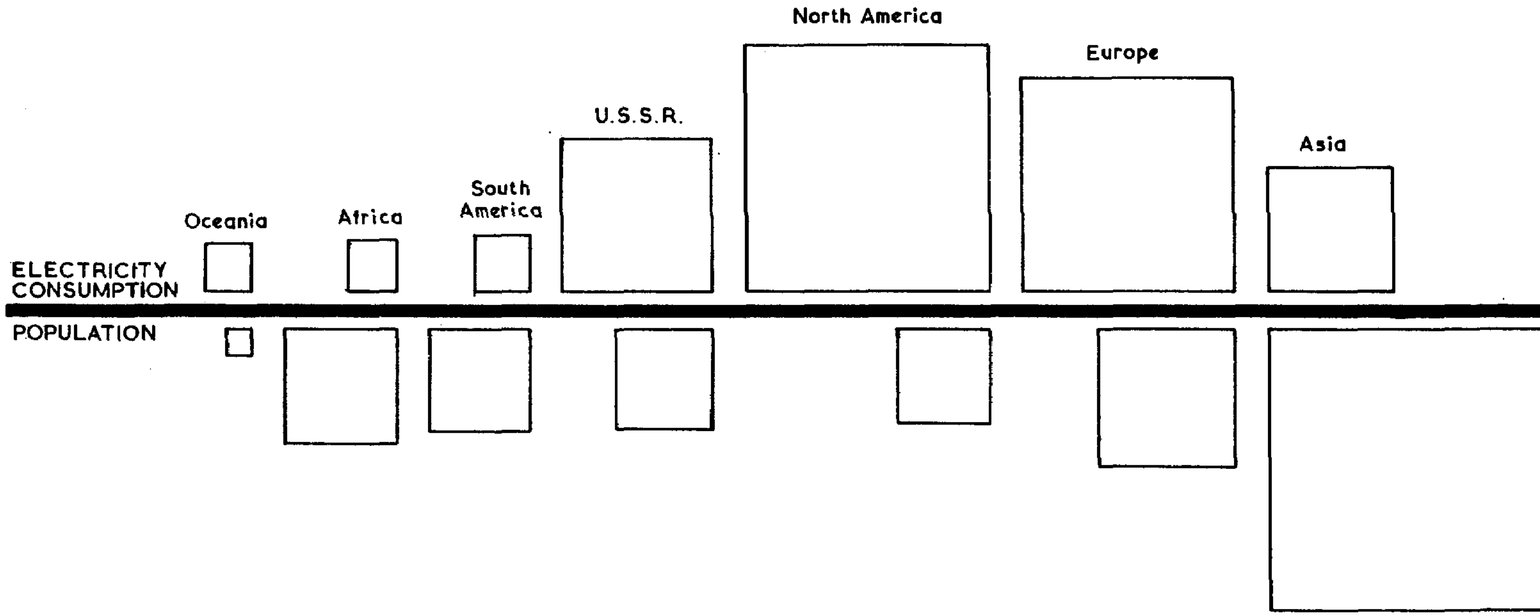



**Fig. 5** *1966 electricity consumption in relation to population*

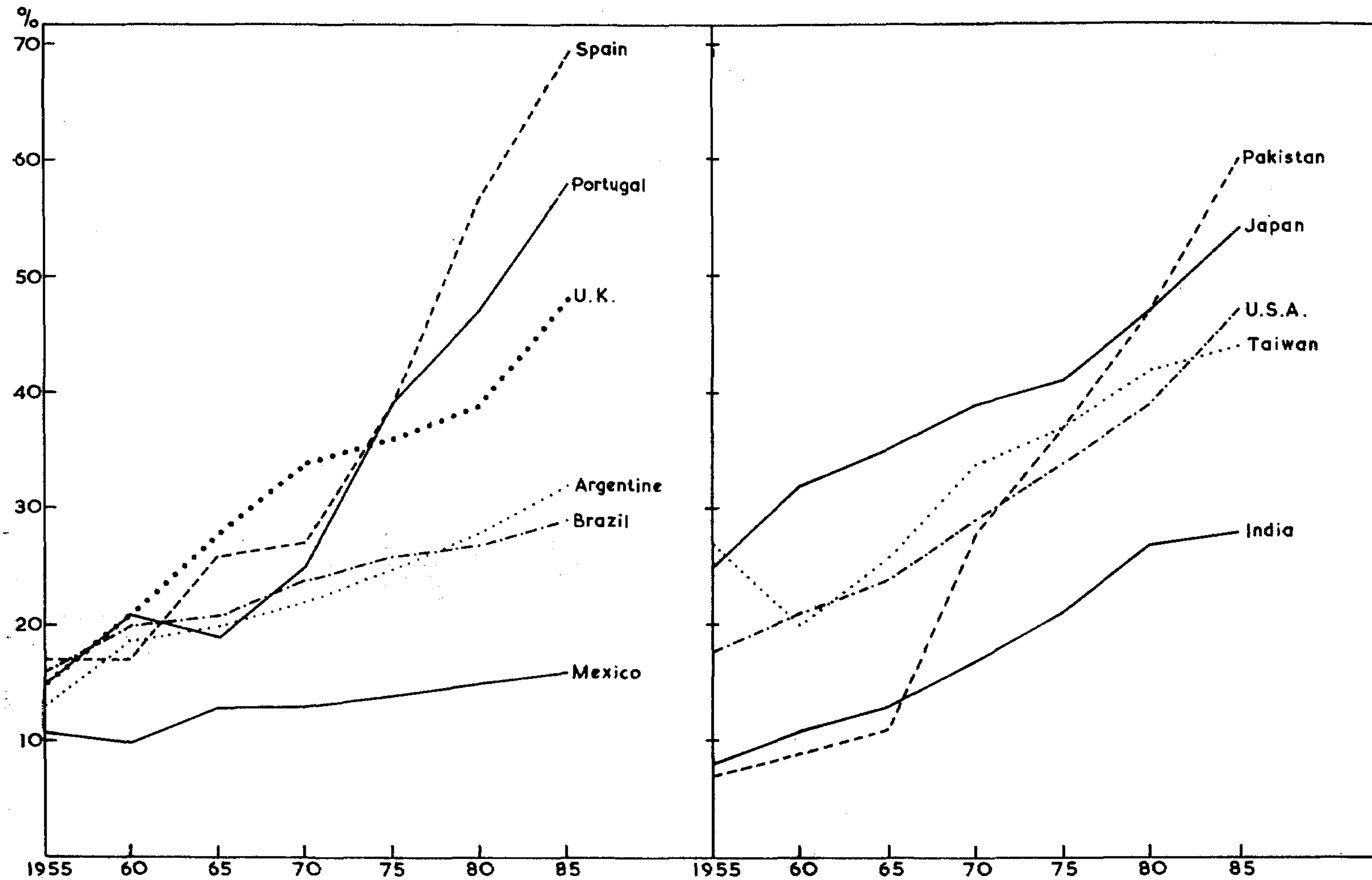



**Fig. 6** *Percentage of energy requirements met by electricity*

**Table II** *Possible generating capacity in* 1990

| MW 1-2,000 | | 2-5,000 | 5-10,000 | 10-20,000 |
|---|---|---|---|---|
| Algeria | | Ghana | Chile | Portugal |
| Angola | Ryuku Is. | Hong Kong | Colombia | |
| Burma | Singapore | Indonesia | Greece | |
| Ceylon | Surinam | Iran | Taiwan | |
| Ethiopia | Syria | Israel | U.A.R. | |
| Jamaica | Trinidad & Tobago | S. Korea | Venezuela | 20-50,000 |
| Lebanon | Tunisia | Pakistan | | Argentina |
| Morocco | Uruguay | Peru | | Brazil |
| Mozambique | S. Viet-Nam | Philippines | | India |
| Nigeria | Zambia | S. Rhodesia | | Mexico |
| Puerto Rico | | Thailand | | Spain |
| | | Turkey | | |

a continuing one and, as the economy expands, unforeseen demands will arise, particularly from technological advances, which will present considerable problems if industrial production is not to be curtailed for want of electricity. Against this, scarcity of resources makes it important that generating capacity is not wasted for lack of demand.

**Electricity supply**

Although statistics and other data on energy, electricity, industry, etc., are compiled on a national basis, natural resources are not confined by political boundaries. Coal mines and oil and gas fields may straddle frontiers and the frontiers themselves may be marked by a river or mountain range having hydro potential. In such circumstances, joint exploitation by neighbouring countries of the available energy resources may prove advantageous to both.

It is, however, essential to plan electricity supplies in relation to the generating system taken in its entirety if maximum benefits are to be secured. Planning will usually cover requirements up to twenty years ahead, and it will examine the alternative strategies which may be adopted with the object of achieving minimum total system costs, e.g. the proportions of the types of generating plant (oil or coal-fired, hydro, nuclear, etc.) in the system, or the effects of obsolescence, retirements, and transmission distances. Much will depend on the accuracy with which requirements can be forecast and accuracy will diminish into the future. The demand for electricity changes continuously and lowest system costs are obtained by running plant with the cheapest running cost first, duly allowing for transmission costs. But, changes in fuel costs will affect total system costs through existing as well as future plant, and it is accordingly necessary to consider the effects of possible rises in fuel costs.

The generating costs of large nuclear power stations now compare favourably with those of contemporary fossil-fuelled stations, while their running costs are significantly lower. In many industrialized countries, therefore, despite their refineries and networks of pipelines, highly mechanized coal mines and well developed transport systems, competitiveness has been achieved, since large nuclear stations operated at or near base load can be economically absorbed within the large and integrated electricity generating systems such countries possess. For countries with smaller systems nuclear power has a more difficult target to hit, but even so some developing countries may find the installation of nuclear power stations in smaller sizes more economical than developing their oil and coal industries. This will depend on their particular economic circumstances and the current developments for nuclear power. All countries will, I believe, find it essential to consider the overall effect on the electricity system of the phased installation of nuclear power, using techniques such as those for assessing system costs discussed at the 1967 I.A.E.A. Symposium on International Extrapolation and Comparison of Nuclear Power Costs[5]. In this way it will be possible to relate the costs of introducing each nuclear power station to the circumstances appropriate at the time to the developing country concerned and to avoid the difficulties of trying to translate data suited to conditions in another country.

**Prospects for nuclear power**

Utilisation of the energy released by nuclear fission to generate electricity was realised in the mid-1950s by the U.K., U.S.A., U.S.S.R., France and Canada, who all had reactors working within a short time of one another. Since then there have been large technological advances in nuclear reactors and a very substantial investment has been made in nuclear technology by the advanced countries.

The broad advantages of nuclear power stations are:

(i) low fuel costs per unit sent out;
(ii) high availability, especially where stations are designed for rapid refuelling;
(iii) flexibility of siting, especially since the introduction of pre-stressed concrete pressure vessels;
(iv) reducing capital costs with increasing size;
(v) negligible atmospheric pollution;
(vi) very low transport costs for fuel and waste materials.

The U.K. has always considered that the gas-cooled graphite moderated reactor system has considerable potential and has accordingly devoted much effort to its development. The Calder Hall reactors began to generate electricity for the U.K. grid in 1956. The knowledge and experience gained from the operation of Calder Hall formed the foundation for the first nuclear power programme of 5000 MW and the stations built under this programme all used natural uranium fuelled, gas-cooled, graphite moderated reactors (the " Magnox " stations). Between the start and finish of the programme, station sizes had increased from Berkeley and Bradwell, at about 300 MW(e) each, to Wylfa, which is scheduled to produce 1180 MW (e) from two reactors. With the increase in size has come a decrease in generating costs so that power from Berkeley costs 1.25d/kWh sent out, compared with the anticipated 0.70d/kWh sent out from Wylfa. The later Magnox stations incorporate pre-stressed concrete pressure vessels, a feature which reduces capital costs and which permits large nuclear power stations to be installed much nearer to large urban centres than was previously envisaged. This, in itself, is a noteworthy feature increasing, as it does, the flexibility of nuclear station siting and permitting the reduction in capital outlay on distribution networks which may be necessary when the siting of other types of power stations is dictated by the location of natural resources.

As a successor to the Magnox series of power stations, the U.K. is now introducing the Mk. II gas-cooled reactor system (A.G.R.) and a 100 MW(th) prototype has been successfully run at Windscale since 1962. This reactor system takes advantage of all Magnox design and operational experience and also utilises those materials, such as graphite and carbon dioxide, which are already available and whose properties are known and tried. The fuel is uranium dioxide, slightly enriched in U-235, clad in stainless steel; because of the high melting points of these materials, coolant operating temperatures some 200°C above those prevailing in Magnox reactors are possible. The fuel is sub-divided into clusters of rods and high fuel ratings can be achieved, of the order of four times that of Magnox fuel. These factors lead to high station efficiencies and about 41% is anticipated for those Mk. II stations being built. Because of the higher fuel rating the Mk. II stations are much smaller in size than a Magnox station with the same electrical output and so station capital costs are reduced. The higher operating temperatures result in superior steam conditions to those prevailing in Magnox reactors, and steam turbines of the type employed in most up-to-date fossil-fuelled stations capable of operating at advanced conditions can be used with subsequent reduction in capital costs. The high fuel burn-up which can be attained with uranium dioxide, of the order of 18 000 MWd/t, results in reduced fuel costs and high station availability results from the provision of on-load refuelling. As part of the second U.K. power programme four Mk. II stations are under construction, the latest of which is situated near a sizeable town and in the vicinity of a large conurbation. Each station will have an output of about 1250 MW(e) from two reactors and at this size the generating costs anticipated, 0.56d-

0.52d (5.6-5.2 mils)/kWh sent out, on U.K. standard ground rules, are lower than those from a contemporary coal-fired station, 0.64d (6.4 mils)/kWh sent out, with fuel at 39 cents per M Btu. For countries outside the U.K., total station capital costs (including utilities' on-costs and interest during construction) of single reactor Mk. II A.G.R. stations are likely to be in the region of $250/kW at the 400 MW(e) size and in the region of $200/kW at the 600 MW(e) size, the actual figures depending on the site conditions that obtain, the engineering and amenity standards required, and the year of ordering (since with more development some further reduction in costs can be anticipated); generating costs would be likely to lie in the range 5-6 mils/kWh sent out and 4½-5 mils/kWh respectively, depending on the accounting and financial ground rules adopted. Twin reactor stations could be expected to achieve costs about 8% below those indicated above.

The potential of the gas-cooled, graphite moderated concept does not end with the Mk. II system and reactor characteristics superior to those achievable in commercial gas-cooled reactors in operation or under construction in the U.K. are confidently expected from the Mk. III system, employing concepts based on the DRAGON reactor, developed and built in the U.K. as a joint international venture and now being operated primarily for the irradiation testing of fuel for the system.

The main characteristics of the Mk. III or H.T.R. are:

(i) use of coated particulate fuel, contained in graphite pins;
(ii) helium gas-cooling;
(iii) high fuel burn-up;
(iv) operating temperatures well in excess of A.G.R.;
(v) high power density;
(vi) the ability to use thorium in the fuel cycle if desired.

The U.K. Mk. III H.T.R. design will use the U-235-Pu cycle so avoiding the new and difficult fuel cycle processes which would be necessary if the Th-U-233 fuel cycle were to be used.

Great interest is being shown in the H.T.R. not only in the U.K. where the C.E.G.B. have indicated that they are likely to adopt it in their system as the successor to the Mark II A.G.R. but also by West Germany and the U.S.A. and elsewhere. Considerable reductions below Mk. II reactors in capital costs and initial fuel costs are expected. In the sizes then likely to be appropriate to the U.K., and for U.K. conditions and ground rules, stations employing Mk. III reactors ordered in the early 1970s are expected to give generating costs in the range 0.48d-0.42d. (4.8-4.2 mils)/kWh. For countries outside the U.K. the total station capital costs of single reactor Mk. III stations are likely to be in the region of $235/kW at the 400 MW(e) size, decreasing to about $185 at the 600 MW(e) size, actual costs being governed by site conditions, desired station standards and the year of ordering: probable generating costs are in the range of 4.5-5.5 mils/kWh sent out and from say 4-4.75 mils/kWh sent out, respectively. The Mk. III system is capable of yet further development and these costs will fall with time. One promising possibility for this system is the use of a direct cycle with gas turbines; this could reduce generating costs by 5-6% at least.

The U.K. interest in thermal reactor systems is not confined to the gas-cooled, graphite moderated concept. Considerable effort has gone into the development, construction and operation of the Steam Generating Heavy Water Reactor, S.G.H.W.R., and a 100 MW(e) prototype reactor has been in operation at Winfrith Heath since early 1968. Several characteristics of this system are of interest to those developing countries about to introduce, or considering the introduction of, nuclear power stations.

These are:

(i) a simple design, leading to a low cost system;
(ii) simple construction which is within the capabilities of conventional fabrication methods;
(iii) good neutron economy;
(iv) low fuel inventory;
(v) good plutonium production;
(vi) a design which is attractive in small unit sizes.

The S.G.H.W.R. is described in much greater detail, and capital and generating costs are given, in a paper presented at this Symposium*. Although in very large sizes this reactor is not seen as having any

* S.A. Ghalib, "The steam generating heavy water reactor"

advantage over Mk. III, in the lower sizes it is expected to give significantly lower capital and generating costs than A.G.R. and to have a somewhat smaller advantage over the Mk. III H.T.R.

It is, however, the fast reactor system which has been seen, in the U.K. especially, as the prime goal of nuclear power development because it holds out the promise of the lowest generating costs of any system and is capable of breeding more fissile material than is burned. The study of fast breeder reactors began in the U.K. in about 1950/51, construction of a sodium-cooled reactor was commenced at Dounreay in 1954 and in 1963 full power of 60 MW(th) was reached, thus demonstrating the practicability of the system. Since then the Dounreay Fast Reactor has been used as a test bed for irradiating advanced fuel concepts and for development of sodium technology. This has facilitated the next step to power from commercial fast reactors, which is the design and construction of a prototype fast reactor. Construction of a 250 MW(e) prototype at Dounreay was started in 1966 and is expected to be on power in 1972 with the possibility of power from a commercial reactor in the later 1970s. The prototype will be sodium-cooled and will be fuelled initially with plutonium-uranium oxide. Commercial fast reactors are in general likely to be rated at upwards of 600 MW(e). The fuel requirements of a fast reactor may be taken typically to be as follows[4].

Fuel inventory (including hold-up) at 80% load factor:
tPu/1000 MW(e) yr 2.8
tU/1000 MW(e) yr 40.0

Plutonium production rate:
tPu/1000 MW(e) yr 0.26

Uranium usage:
t U-238/1000 MW(e) yr 30

Doubling time (i.e. time to generate sufficient Pu to start up a further identical fast reactor): years 14

The low cost potential of the fast reactor system may not be fully realised with the initial stations but subsequent economies of scale, resulting from expanding production facilities, and increase in experience will undoubtedly enable the full benefits of the system to be achieved and, in large sizes, capital costs similar to those of contemporary thermal reactor systems should result. Developing countries should be able to enjoy the benefits of being part of a larger programme and so get the advantage, almost immediately, of cheaper power when they can take large size stations. Fast reactor generating costs are therefore expected to be of the order of $\frac{1}{2}$ mil/kWh lower than those of the best contemporary thermal reactors and thus generating costs substantially below 4 mils can be envisaged. The fast reactor is being developed primarily as a plutonium burner and as such is complementary to the U.K. thermal reactor programmes because it will enable the plutonium which they produce to be utilised to the best economic advantage. Countries which possess thermal reactor installations will similarly be in a position ultimately to install fast reactors. The time interval before this can be achieved depends, of course, on the size and nature of the existing thermal reactors. For example using the figures in the paper by Stewart et al. referred to above, a country with an installation of 1000 MW(e) of S.G.H.W.R.s (using slightly enriched fuel) would be producing some 400 kg of plutonium every year (on full load) and would thus be able to install a similar amount of fast reactor capacity after those S.G.H.W. reactors had been operating for some $7\frac{1}{2}$ years. Countries who wished to benefit from the progress with fast reactors achieved elsewhere, and who had a large enough electricity distribution system to enjoy the full benefits of fast reactors operating at a high load factor, but who did not want to wait until they had enough of their own plutonium supplies from previously installed thermal reactors, could start with a U-235 reactor system and breed their plutonium in these reactors. Alternatively, these countries could seek to obtain plutonium on a commercial basis from countries, such as the U.K., with a substantial thermal reactor installation; these countries would by then possess substantial stocks of plutonium and might be prepared to make some of this plutonium available for sale rather than retain the whole of it for their own fast reactor installation programmes.

**Conclusion**

The extensive knowledge and experience of the U.K. can be made available to developing countries wherever nuclear power is likely to help meet their energy requirements. The introduction of nuclear power must, however, proceed step by step as the electricity system, looked at in its entirety, is developed. It is a question of deciding what nuclear power can contribute, and the circumstances will be different for each developing country. Some, such as Argentina, India, Pakistan, and Spain, have already started to use nuclear power; for others the step lies in the future. Nuclear power is of no virtue in itself (except perhaps as a source of radioisotopes) but serves as a means of meeting, as electricity, the increasing demand for energy which occurs when a country develops, and it is for each developing country to work out when this role of nuclear power will most fittingly provide the power to progress.

### References


1 United Nations Statistical Yearbooks.

2 TAYYEB, A., Pakistan: A Political Geography, Oxford University Press (1966).

3 ADAMS, P. Gerard, MIOVIC, Peter "On relative fuel efficiency and the output elasticity of energy consumption in Western Europe".

4 STEWART, J. C. C. MARSHAM, T. N., FRANKLIN, N. L., "Full utilisation of uranium in the U.K.", 7th Plenary Meeting, World Energy Conference, Moscow 1968.

5 I.A.E.A. "International Comparison of Nuclear Power Costs", published 1968. See especially BERRIE, T. W. and BETTS, P. E. "Assessment of costs of alternative plant proposals on the C.E.G.B. system" and ILIFFE, C. E., SEARBY, P. J. "Problems associated with the integration of different types of reactor within a generating system".


## A.E.A. Reports available

THE titles below are a selection from the October 1969, "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 889
*A Coarse Mesh Correction for Collision Probabilities.* By J. R. Askew. June, 1969. 10pp. HMSO 2s. 6d.

AEEW-M 896
*A Description of the Equipment for Time-of-Flight Spectrum Measurements on the Fast Reactor Zebra.* By L. H. Gibson, D. Jakeman and J. E. Sanders. May, 1969. 10pp. HMSO 3s.

AEEW-M 897
*Wintof—A Program to Produce Neutron Spectra from Zebra Time-of-Flight Experiments.* By J. Marshall. June, 1969. 16pp. HMSO 2s. 6d.

AEEW-M 903
*Toffee. A Fortran Programme for Calculated Directed Flux Spectra.* By J. D. Macdougall. August, 1969. 7pp. HMSO 2s.

AEEW-M 921
*An Evaluation of the Neutron Cross-section Data Zirconium and its Stable Isotopes in the Resolved Resonance Range.* By J. S. Story and A. L. Pope. July, 1969. 33pp. HMSO 5s.

AEEW-R 560
*Experimental Physics Studies of Steam-cooled Fast Reactor Lattices.* By M. J. Arnold, A. C. Aldous, W. N. Fox, G. D. Burholt, C. F. George, D. J. Skillings, R. Richmond and R. C. Wheeler. April, 1969. 142pp. HMSO 25s.

AEEW-R 631
*Methuselah III. A Fortran Program and Nuclear Data Library for the Physics Assessment of Liquid-Moderated Reactors.* By M. J. Brinkworth. January, 1969. 26pp. HMSO 4s.

AEEW-R 639
*Newlin: A Digital Computer Program for the Linearisation of Sets of Algebraic and First Order Differential Equations.* By A. Hopkinson. May, 1969. 30pp. HMSO 4s. 6d.

AERE-AM 110
*Determination of Carbon in Stainless Steels.* By D. J. Wicks and I. G. Jones. July, 1969. 12pp. HMSO 2s. 6d.

AERE-Bib 150/Rev
*Bibliography of Reports on Two-Phase Heat Transfer Issued by A.E.R.E., Harwell.* By L. B. Cousins. June, 1969. 34pp. HMSO 4s.

AERE-M 2230
*The Structure of Data Files 78 and 79, for Niobium, and File 81 for Molybdenum, in the U.K.A.E.A. Nuclear Data Library.* By S. Blow and B. A. Lipscombe. June, 1969. 12pp. HMSO 2s. 6d.

AERE-R 6098
*Bonded Structure Testing 1968.* By G. J. Curtis. June, 1969. 44pp. HMSO 7s.

AERE-R 6117
*The Influence of Heat Flux, Subcooling, Wall Thickness and Type of Heating on Film Flow in the Evaporation of Water in a Vertical Tube.* By G. F. Hewitt and D. J. Pulling. June, 1969. 15pp. HMSO 3s.

AERE-R 6118
*Determination of Rate of Deposition of Droplets in a Heated Tube with Steam-Water Flow at 1000 p.s.i.a.* By G. F. Hewitt, H. A. Kearsey and R. K. F. Keeys. June, 1969. 9pp. HMSO 2s. 6d.

AERE-R 6027
*Some Aspects of Heat Transfer in a Gas Fluidised Bed* By G. A. Henwood. July, 1969. 13pp. HMSO 4s.

AERE-R 6127
*The Photochemistry of Sulphur Dioxide and its Relation to Atmospheric Chemistry.* By R. A. Cox. June, 1969. 17pp. HMSO 2s. 6d.

AERE-R 6153
*An Improved Phosphate-Ferrocyanide/Vermiculite Treatment for Harwell Medium Level Effluent.* By J. H. Clarke, R. F. Cumberland and M. J. Smyth. August, 1969. 13pp. HMSO 2s. 6d.

AERE-R 6154
*Yields from the Thermal Neutron Induced Fission of $^{241}Pu$.* By I. F. Croall and H. H. Willis. August, 1969. 6pp. HMSO 1s. 9d.

AWRE/LIB/BIB/19
*Shock and Vibration, A Selected Bibliography.* By J. E. Goodall and L. Corbett. August, 1969. 32pp. HMSO 4s. 6d.

AWRE 0-47/69
*Measurement of (n,2n) and (n,3n) Cross Sections at 14 MeV Incident Energy.* By D. S. Mather and L. F. Pain. August, 1969. 27pp. HMSO 4s.

AWRE O-56/69
*Surface Spray From Explosively Accelerated Metal Plates as an Indicator of Melting.* By W. F. Bristow and E. F. Hyde. September, 1969. 31pp. HMSO 9s.

PG Report 916(W)
*Index and Abstracts of Analytical Methods Used at Windscale.* By J. Barraclough. 1969. 37pp. HMSO 5s.

TRG Report 1850(C)
*The Gas Chromatographic Analysis of Carbon Dioxide Based Gas Mixtures Using Molecular Sieve 13X and Temperature Programming.* By H. L. Robinson and J. A. J. Walker. 1969. 4pp. HMSO 1s. 2d.

# 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.

**Radiological Protection**

*8th to 12th December, 1969*
*16th to 20th March, 1970*
*8th to 12th June, 1970*
*9th to 13th November, 1970*

Lectures, demonstrations and practical work designed to give some experience in the safe handling of radioisotopes. While it is assumed that students are normally graduates in science or engineering, or hold equivalent qualifications, such qualifications are not considered essential to attendance. This course is intended to be of use to "competent persons" since it contains information about safety precautions when using x-rays, industrial use of radioisotopes, instrumentation and the regulations applicable to the use of ionising radiations.

The practical work is to familiarise students with simple measurements and calculations associated with radiological protection. Fee: £40.

**Two-Phase Heat Transfer**

*5th to 9th January, 1970*
*1st to 5th June, 1970*

Should be of particular value to engineers and scientists working in the field but may also appeal to those requiring an introduction to two-phase heat transfer.

The subject is approached in a fundamental way and although its application to nuclear reactors problems has some emphasis, the material presented is useful to those requiring a knowledge of the problems inherent in two-phase heat transfer and of current solutions, theories and developments. The lectures are given by experts in their subjects and ample time is allowed for discussion.

The course in January is held at A.E.E. Winfrith and in June at Harwell.

There are visits to laboratories at Winfrith or Harwell. Fee: £40.

**Modern Physical Techniques in Materials Technology**

*12th to 16th January, 1970*
*19th to 23rd October, 1970*

Arranged in conjunction with the Institute of Physics and the Physical Society and the Metals and Metallurgy Trust.

Presents an opportunity to scientists engaged in research and development to familiarise themselves with seventeen different modern physical techniques of vital importance in materials technology. Lectures are given by specialists actively engaged in these fields.

The basic principles of each technique are outlined, together with the scope and limitations, and the course presents an overall picture of the inter-relation of the techniques and of their applications in the physical sciences. Fee: £40.

**Glassblowing**

*12th January to 6th February, 1970*
*9th February to 6th March, 1970*
*6th April to 1st May, 1970*
*27th April to 22nd May, 1970*
*1st to 26th June, 1970*
*29th June to 24th July, 1970*
*27th July to 21st August, 1970*

A practical course covering the rudiments of scientific glassblowing and other techniques used in working with glass.

There are at least two hours of instruction each day followed by practice, all under the immediate supervision of an experienced glassblower. The number on each course is small so that individual attention can be given and the level of instruction varied to suit the aptitude of the individual. Beginners are accepted but those with some experience can start immediately on more advanced work. A certificate of attendance is given and a confidential assessment of performance and aptitude is made. Fee: £120.

**Radioisotope Methods in Chemistry**

*26th January to 13th February, 1970*

Intended for chemists employed in pure or applied research who need a basic introduction to radioisotope methods coupled with specialised information in particular chemical fields.

Students will be encouraged to suggest experiments which they wish to carry out in the third week. Fee: £120.

**Advanced Radiological Protection**

*16th February to 13th March, 1970*

For the experienced health physicist to extend his understanding of the underlying philosophy and scientific bases of his profession. Attention is also given to the managerial and professional responsibilities of the health physicist. The subjects covered include many of those dealt with in the Post-Graduate Radiological Protection Course but emphasise more advanced aspects and modern developments.

The topics include more advanced lectures on radiation physics, dosimetry and modern developments in radiation detection. The practical work comprises syndicate studies in place of laboratory work, to provide participants with an opportunity to conduct joint exercises with their professional colleagues from other establishments and countries and so obtain a very wide perspective of their profession. Fee: £160.

**Seminar on Harwell's Multi-access Computing System**

*18th and 19th February, 1970*
*13th and 14th May, 1970*

The objective 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 are given the opportunity to use it. Lectures describe how it is implemented, giving particular emphasis on what is required for similar systems to be implemented on other computers. Fee: £16.

**Pressurised Equipment**

*9th to 13th March, 1970*

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

Covers the following broad aspects of the subject:

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

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

# I.R.P.A. international congress

The International Radiation Protection Association was set up at the first International Congress held in Rome in 1966; the second International Congress and trade exhibition is to be held at Brighton, 3rd to 8th May, 1970, organised by the Congress Executive Committee of the British Radiological Protection Association.

The aims and function of I.R.P.A. are to facilitate international contacts and co-operation amongst those engaged in radiation protection work, to provide for discussion of the scientific and practical aspects of the protection of man and his environment from the hazards caused by radiations, thereby facilitating the exploitation of radiation and atomic energy for the benefit of mankind. By mid-1968, I.R.P.A. had 16 affiliated health physics or radiation protection societies with approximately 6,000 members in 60 countries throughout the world. The President of I.R.P.A. is Dr. K. Z. Morgan, Oak Ridge National Laboratory, U.S.A., and the secretary is Dr. P. Bonet-Maury, Paris, France.

The Congress Executive Committee is under the Chairmanship of Dr. W. G. Marley of the U.K. Atomic Energy Authority; its Secretary-General is Mr. C. A. Adams of the Central Electricity Generating Board, (Laud House, Newgate Street, London, E.C.1) to whom applications for registration form and brochures should be made.

The theme for the Congress is "Radiation and Man "; this will cover the whole field of radiological protection, the range of topics being:

Applied or operational health physics, including monitoring of workers and workplaces;
Public health problems, waste disposal, environmental monitoring and public relations;
Medical aspects;
Radiation biology;
Radiation physics and dosimetry;
Instrumentation;
Radiochemistry;
Emergency procedures and plans;
Training and education.

Final details of the programme have not yet been fixed but it is hoped to have sessions on the following subjects:

1. Radiation effects in man—to include examples of radiation injury in man, reviews of epidemiological data and risk estimates;
2. The behaviour of radioactive materials in man—to include metabolic studies in man and proposed models of retention, translocation and excretion;
3. Personal monitoring programmes for external radiation and internal contamination—to include statements of policy on necessary scale of programmes, new techniques and new methods of interpretation, illustrated by operational experience;
4. New developments in instrumentation for personal monitoring.

It is intended to hold two symposia during the Congress; these will consist of invited papers followed by wide ranging discussions, the proposed titles being " Biological Recovery " and " Plutonium Problems ".

The Secretary of the Scientitfic Programme Committee, which has an international membership, is Mr. H. J. Dunster, U.K.A.E.A. (Authority Health & Safety Branch, A.E.R.E., Harwell, Berks.)

There will be an exhibition associated with the Congress, covering trade as well as scientific and technical aspects of radiation protection. Taking part will be research and atomic energy organisations and companies manufacturing products relevant to radiological protection. The exhibits will include new ideas and equipment in the development stage as well as established apparatus and services. Equipment for all branches of radiological protection will be represented, including detectors, nucleonic instruments, air samplers, filters and ventilation equipment, shielding transport containers, glove boxes and fume cupboards, surface and finishes for active areas, protective clothing and breathing apparatus, reactor instrumentation and handling equipment and minor items such as labels and warning signs. There will be a section devoted to books and journals. The exhibition is being organised, on behalf of the Exhibition Committee, by M. J. Druce (Export Services) Ltd., 30/40 Ludgate Hill, London, E.C.4.

# U.K.A.E.A. display at NUCLEX '69

*Mr. J. C. C. Stewart, Deputy Chairman of B.N.D.C. (formerly Member for Reactors, U.K.A.E.A.) and Dr. Myron Tribus, Assistant Secretary for Science and Technology, U.S.A. (left and second from left), at the U.K. stand at the International Nuclear Industries Trade Fair (NUCLEX), held at Basel, Switzerland, from 6th-11th October. The 1,000 square metre display, presented jointly by the U.K.A.E.A. and the British Nuclear Forum, covered the whole range of British nuclear products and services.*

**World wide services**

The unique facilities and unrivalled resources of the U.K.A.E.A.—the world's leading nuclear research and development organisation—which are available on a commercial basis to industry both within and outside the U.K. were a major feature of the U.K.A.E.A. stand.

The Authority's irradiation facilities at Harwell and Dounreay (which have already attracted £3M worth of business in three years) had a prominent position on the stand, together with a display on the Winfrith SGHWR, recently announced as an addition to the range of reactors in which test irradiations of reactor fuels can be undertaken for customers. Here, as at the other irradiation sites, comprehensive facilities exist for the post-irradiation examination of specimens, and these are available to customers whether the irradiation has taken place in U.K.A.E.A. reactors or elsewhere. Already about £¼M worth of business has been received for this post-irradiation examination service.

Other test equipment available includes full scale rigs for fuel element assembly testing under flow, temperature and pressure conditions of both gas- and water-cooled reactors. Additionally the gas-cooled rig can simulate on-power loading and unloading conditions.

Of more general application throughout a wide range of industries are facilities and experience acquired by U.K.A.E.A. with application outside the nuclear field in such areas as:

- Heat transfer and fluid dynamics
- Non-destructive testing
- Specialised methods of joining, forming and machining
- Instrumentation
- Materials technology
- Tribology
- Reliability engineering
- Project engineering
- Health and safety

Technical services, including computer facilities
Pressure vessel technology.

**Production Group display**

The plants of the U.K.A.E.A.'s Production Group are now manufacturing fuel for 33 power reactors and reprocessing fuel from 30 power reactors.

At Springfields and Windscale, the U.K.A.E.A. have the world's leading fuel element manufacturing and reprocessing plants in commercial operation, producing a quarter of a million fuel elements each year and having a reprocessing capacity of 2,500 tonnes per annum.

The Group were, therefore, a major participant in the Nuclex Exhibition.

A feature of the Group's recent successes has been its break-through into the manufacture and reprocessing of light water reactor fuel. This includes the following:

| | |
|---|---|
| Dodewaard, Holland | —BWR fuel manufacture |
| Zorita, Spain | —PWR fuel reprocessing |
| Beznau, Switzerland | —PWR fuel reprocessing |
| Garigliano, Italy | —BWR fuel reprocessing |

The Group also manufactures and reprocesses fuel for the Latina reactor (Italy) and the Tokai-mura reactor (Japan), both of which are British designs.

Recently the Group added to their facilities a new plant for the production of uranium hexafluoride (or " hex ") and is now commissioning a large-scale plutonium fuel manufacturing plant at Windscale.

**Sodium instrumentation**

The 250 MW(e) Prototype Fast Reactor at Dounreay uses 1000 tons of liquid sodium as coolant, and instruments designed to measure sodium flow, level, pressure and purity in the PFR were described on the U.K.A.E.A. stand. The instruments were:

*Saddle coil flowmeter*

This measures the electric potential difference produced across liquid sodium moving in a stationary magnetic field. The magnetic field is produced by passing a d.c. supply through two air-cored coils formed in the shape of saddles. The flowmeter can, therefore, be added to existing pipework, external to any cladding and is light enough to be supported by the pipe. It can be used on pipes with diameters greater than 0.15 metres and does not require calibration.

*Flux distortion flowmeters*

These consist essentially of a central primary winding, energised from an a.c. source, together with two similar secondary windings positioned symmetrically on each side of the primary. The secondary windings are connected differentially so that the voltages induced in them by the primary field are balanced and opposed. The difference voltage is nominally zero when the sensor is fitted into a metal pocket or immersed in static sodium, but moving sodium distorts the fields as if the primary field had been displaced in the direction of the flow. The differential voltage induced by this displaced or distorted field is linearly proportional to sodium velocity over a wide range of flow. This type of flowmeter is used in the PFR to measure sodium flow through the reactor core and from each of three primary pumps.

*Sodium level measurement at temperatures up to 700°C*

Sodium level sensors of the mutual inductance type depend on the " short-circuited turn " effect of the enveloping liquid metal. The short-circuited turn reduces the mutual inductance between the sensor windings over the covered length of the sensor. Because this is a bulk effect, the sensor can operate through the walls of a containing pocket with only moderately reduced sensitivity. For the same reason the operation of the sensor is relatively unaffected by the degree of wetting of the pocket outer surface and by residual sodium or sodium compound films thereon. These are considerable practical advantages, and this type of sensor, installed in pockets, will be used in PFR for sodium level measurement, high and low level trips and alarms, and a portable sodium dipstick.

*Electromagnetic differential pressure gauge*

This consists basically of a copper plated stainless steel pipe, placed between the poles of a magnet, and connected between high and low pressure taps. The current induced when sodium flows through the pipe is a direct measure of the applied pressure. The current crosses the liquid metal in the pipe and returns via a shunt. The potential drop across the shunt is used to measure the current.

*Automatic plugging meters*

To limit corrosion rates and minimise the possibility of duct blockages in PFR, the coolant impurity level will be maintained at below 10 ppm. Automatic plugging meters are a convenient means of monitoring the impurity levels in sodium. They maintain a partial plug of impurity in an orifice to give an accurate measurement of saturation temperature; this temperature is recorded and displayed continuously. The orifice is cooled and partially blocked with impurities so as to restrict its flow to a chosen reference value. Departure of the measured orifice is adjusted to cause either an increasing or decreasing degree of blocking, whichever is required to bring the orifice flow back to the reference value. The liquid metal temperature near the orifice is measured and displayed; at equilibrium, this temperature coincides with the saturation temperature. " Active " and " inactive " versions of an automatic plugging meter have been developed to monitor the PFR primary and secondary coolant circuits respectively.

The Authority's licensees for these instruments are the English Electric Co. Ltd., Reactor Equipment Division, Whetstone, Leicester, England, and Fairey Engineering Ltd., Cranford Lane, Heston, Hounslow, Middlesex, England.

(Leaflets describing the instruments are available from the UKAEA's Public Relations Branch, 11, Charles II Street, London, S.W.1. (Tel. No. Whitehall 6262, Ext. 320).)

**U.K. papers**

Twelve papers, covering a wide variety of topics, were presented by U.K. authors at the Technical Meetings held concurrently with the Fair. The papers are listed below.

**U.K.A.E.A.:**

*A British View on Plutonium Utilisation,* Dr. Hans Kronberger.

*The Construction, Commissioning and Operation of the S.G.H.W.R.,* H. Cartwright, R. McKeague, D. Smith.

*Techniques of Reactor and Site Hazard Assessment,* J. R. Beattie.

*Isotopic Power Batteries,* E. Wiblin and J. Gaunt.

*Radiation—an Industrial Tool,* S. Jefferson.

**U.K. industry:**

*The HTR—Choice and Style of Performance,* G. M. Insch (BNDC), J. D. Thorn (UKAEA), J. N. Hurst (Rolls-Royce Ltd.).

*PFR Design and Construction—a Progress Statement,* R. H. Campbell (TNPG).

*Industrial Experience on 300 MW(e) PFR Influences Future Designs,* M. K. Shaw (English Electric Co. Ltd.), N. G. Worley (Babcock & Wilcox Ltd.), J. D. Waters (Fairey Engineering Ltd.).

*Experience of Concrete Pressure Vessels in Relation to Reactor Safety,* R. E. D. Burrow (Taylor Woodrow Construction Ltd.), J. D. Hay (TNPG), J. R. M. Southwood and A. J. Williams (BNDC).

*Digital Computer Applications to Advanced Gas-cooled Reactor Systems,* J. E. Makin (TNPG) and J. M. Shirra (English Electric-A.E.I. Projects Ltd.).

*Advances in Current Gas-cooled Reactor Designs in the U.K.,* C. S. Lowthian (TNPG) and J. F. Tyrrell (BNDC).

**C.E.G.B.:**

*The Performance of the CEGB Nuclear Power Stations,* R. J. Weeks and D. J. Silverleaf.

**Nuclex publications**

A series of publications was available on the A.E.A. exhibition stand at Nuclex, including two brochures, *Instruments for Radiological Protection* and *Electronic Radiation Instruments,* which describe two series of instruments designed at Harwell and Aldermaston, respectively, and developed in conjunction with British industry. Full details of the instruments were given, together with names and addresses of manufacturers.

There were also 19 data sheets illustrating various aspects of A.E.A. work.

Copies are available from Public Relations Branch, Room 102, U.K.A.E.A., 11 Charles II Street, London, S.W.1.

## The A.E.A. at Melbourne

The U.K.A.E.A. had an 1,800 sq. ft. stand at the Expo Electric exhibition in Melbourne, Australia. from 5th-14th October. The A.E.A.'s stand outlined Britain's leading position in world nuclear power generation—the U.K. having produced more electricity from nuclear reactors than the rest of the world combined.

The main feature of the A.E.A.'s exhibit was a detailed account of Britain's newest reactor system—the 100 megawatt (electrical) S.G.H.W.R. power station at Winfrith. Larger versions of the S.G.H.W.R. have been designed to give outputs of up to 450 and 600 megawatts.

Recently a design team of engineers from Australia was attached to the U.K.A.E.A.'s reactor design headquarters at Risley to investigate the possible use of S.G.H.W.R.s in Australia.

There were a selection of the A.E.A.'s fuel elements on display and models of S.G.H.W.R. and fast reactor power systems. Britain is one of the world's largest manufacturers of nuclear reactor fuel which is exported to many countries all over the world.

Dr. G. R. Bainbridge, Assessments Manager in the Technical Operations Directorate of the Authority's Reactor Group, was a specially invited speaker at a conference held by the Electrical Development Association of Victoria concurrently with the exhibition. His subject was " Electrical Generation and Associated Developments in the Use of Atomic Energy." Dr. Bainbridge was also available for discussions on the Authority stand.

Part of the stand consisted of a cinema in which there was a continuous showing of Authority colour films on reactors, nuclear fuel, desalination and the industrial applications of radioisotopes.

## Compact high voltage power unit

The U.K.A.E.A. have developed a compact 600W-output high voltage power supply which uses modular Cockcroft-Walton multipliers, each providing 20 kV.

The power unit was developed at Harwell and the Authority has licensed Miles Hivolt Ltd. to manufacture the equipment.

The Cockcroft-Walton multipliers are powered from mains voltage via a 50 cycles/sec to 10,000 c/s thyristor converter. Because the frequency is high, the power transformer and capacitors in the Cockcroft-Walton multipliers are small. The output from the converter is inherently current limited so that it can feed into a short circuit without damage. Within its current rating, the d.c. stability of the output is a few parts in $10^4$.

A stabilised 60kV unit employing three 20kV modules would have a Cockcroft-Walton system and a voltage divider each 17 in. × 17 in. × 17 in., and a converter unit 10½ in. × 17 in. × 17 in. The voltage divider provides the feedback to stabilise the output of the multipliers against mains variation and load current variations.

A version of the power unit stabilised against mains variation was developed originally for the ion sources in the Tandem Van de Graaff Generator at Harwell. A fully stabilised version was then developed for the Harwell Mk.4 Variable Geometry Isotope Separator and another is being commissioned for a similar separator under construction for the University of Salford. A further unit will be incorporated in a machine to be supplied to the National Bureau of Standards in the U.S.A.

The Harwell Mk. 4 Variable Geometry Isotope Separator is manufactured by Lintott Engineering Ltd., under an Authority licence.

Further information is available from Miles Hivolt Ltd., Old Shoreham Road, Shoreham-by-Sea, Sussex, Telephone No. Shoreham-by-Sea 4511.

Photographs of the power supply are available from the Photographic Library, UKAEA, 11, Charles II Street, London, S.W.1. (Tel. Whitehall 6262, Ext. 368).

*19th September, 1969*

## Symposium at Tribology Centre

Since the National Centre of Tribology was set up by the Ministry of Technology in 1968, over 60 contracts have placed with the Centre by British industry and many hundreds of enquiries and problems dealt with.

Over 100 engineers from all branches of industry attended a two-day symposium and demonstration at the Centre, at Risley, Nr. Warrington, Lancashire, on 30th September and 1st October.

The symposium was intended to explain the principles and applications of tribology to real industrial problems and to show how large economies can be achieved by improving lubrication practice and reducing wear. Conservative estimates indicate that £500m could be saved in the U.K. each year by the proper analysis of wear and lubrication problems. It is for this purpose that the Tribology Centre was established.

The Centre provides a comprehensive information, consultancy and development service to industry to assist in solving problems in this field.

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

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

Visits to the Risley Centre were organised for demonstrations of the work carried out there. *29th September, 1969*

## New heavy ion accelerator

A.W.R.E. Aldermaston, have over a number of years built up considerable experience in the design and construction of ion sources and specialised ion accelerators.

The U.K.A.E.A. have licensed Edwards High Vacuum International Ltd. to use design information and experience available at Aldermaston in the design and development of accelerators with energies up to 150 keV for the production of heavy ions for ion implantation. The Authority also had a display on its stand at Nuclex '69 (Basle, 6th-11th October) describing a prototype heavy ion machine.

Aldermaston's experience has already shown that a heavy ion accelerator system should be as flexible in design as possible for the variety of applications. The new accelerator is, therefore, conceived with interchangeable parts to give flexibility. For instance, since there is no universal ion source capable of producing the complete range of ions, the accelerator accepts different types of source.

The accelerator uses a three element saddle field lens to focus the beam from the source without altering the energy. By using the same electrode system as an asymmetrical lens, the beam is accelerated as well as focused.

In addition to using ion implantation for doping materials, low energy ion beams can be used in the examination of surfaces. Heavy ions striking a surface produce X-rays characteristic of the elements present. Unlike those from electron excitation the spectra have no continua and with suitable filters and detectors, low atomic number materials can be analysed. Recent work at AWRE has shown that heavy ion bombardment can produce interesting effects on the growth and properties of thin films. Initial thin film growth starts from the formation of critical nuclei. Bombarding glass surfaces with suitable heavy ions can produce nuclei which give rise to preferential coating on the irradiated area when the film is deposited either by vacuum evaporation or from electroless plating solutions.

Implantation of oxygen into metal films will transform it into oxide. The electrical resistance of the thin film increases slowly at first with ion dose and then at an increasing rate until the oxidation is complete. The method can be used to produce resistive films and if the oxide is transparent it can be used to discharge static charges on windows.

Further information is available from Edwards High Vacuum International Ltd., Manor Royal, Crawley, Sussex, England. *1st October, 1969*

## Fuel irradiation in SGHWR

The U.K.A.E.A. is now able to offer to overseas customers irradiation facilities in its 100 MW(e) Steam Generating Heavy Water Moderated Reactor at Winfrith Heath in Dorset. This will provide a unique opportunity for the customer to gain operational experience on his fuel designs on a scale and under conditions typical of advanced pressure tube or pressure vessel boiling water reactors.

The Authority's extensive services which can be offered in support of the SGHWR irradiation facilities, include design and assessment of experiments and post irradiation examination. The Winfrith 9 MW full size heat transfer rig is also available for hire.

The core of the Winfrith SGHWR consists of 104 zirconium alloy pressure tubes passing through an aluminium tank (calandria) containing the heavy water moderator at low temperature and pressure. The pressure tubes, which are 5.14 in. (130.6 mm) internal diameter, contain the zircaloy clad fuel assemblies having a fuelled length of 144 in. (3.66 m). The coolant is light water at 970 p.s.i.a. (67 bar) and 273°C. at channel inlet. The average channel power is 2.9 MW, with a maximum of about 4.0 MW for a standard SGHWR fuel assembly.

Fuel designs requiring higher flow rates or pressure drops can be accommodated in four channels of standard dimensions, which are fed with coolant from an additional pump in series with the main circulators.

*2nd October, 1969*

## Thyopac-3

The thyroid gland plays an essential role in regulating the body's metabolism. As several illnesses can be attributed to over- or under-activity of the gland, it is most important for doctors to have a measure of thyroid function as an aid to diagnosis.

Tests using radioisotopes of iodine have been used for a number of years as a method of assessing thyroid function. In the T3 test, the capacity of a serum sample to bind liothyronine is measured, using liothyronine labelled with iodine-125. From this, thyroid activity can be assessed. Although the test is only an indirect measure, it has gained importance because it can be used in the out-patient clinic, and being an in-vitro procedure, it involves no radiation dose to the patient.

Several forms of T3 test are available, but the new version developed by The Radiochemical Centre and now introduced as Thyopac-3, offers several practical advantages. Control of time and temperature during the laboratory procedure is no longer critical. Washing procedures are eliminated and whereas previous tests have often entailed the use of special counting equipment, with Thyopac-3 equipment normally available in the laboratory can be used. Clinical trials in twelve major hospitals with Thyopac-3 indicate that it provides results superior in consistency and reliability to those of other T3 tests.

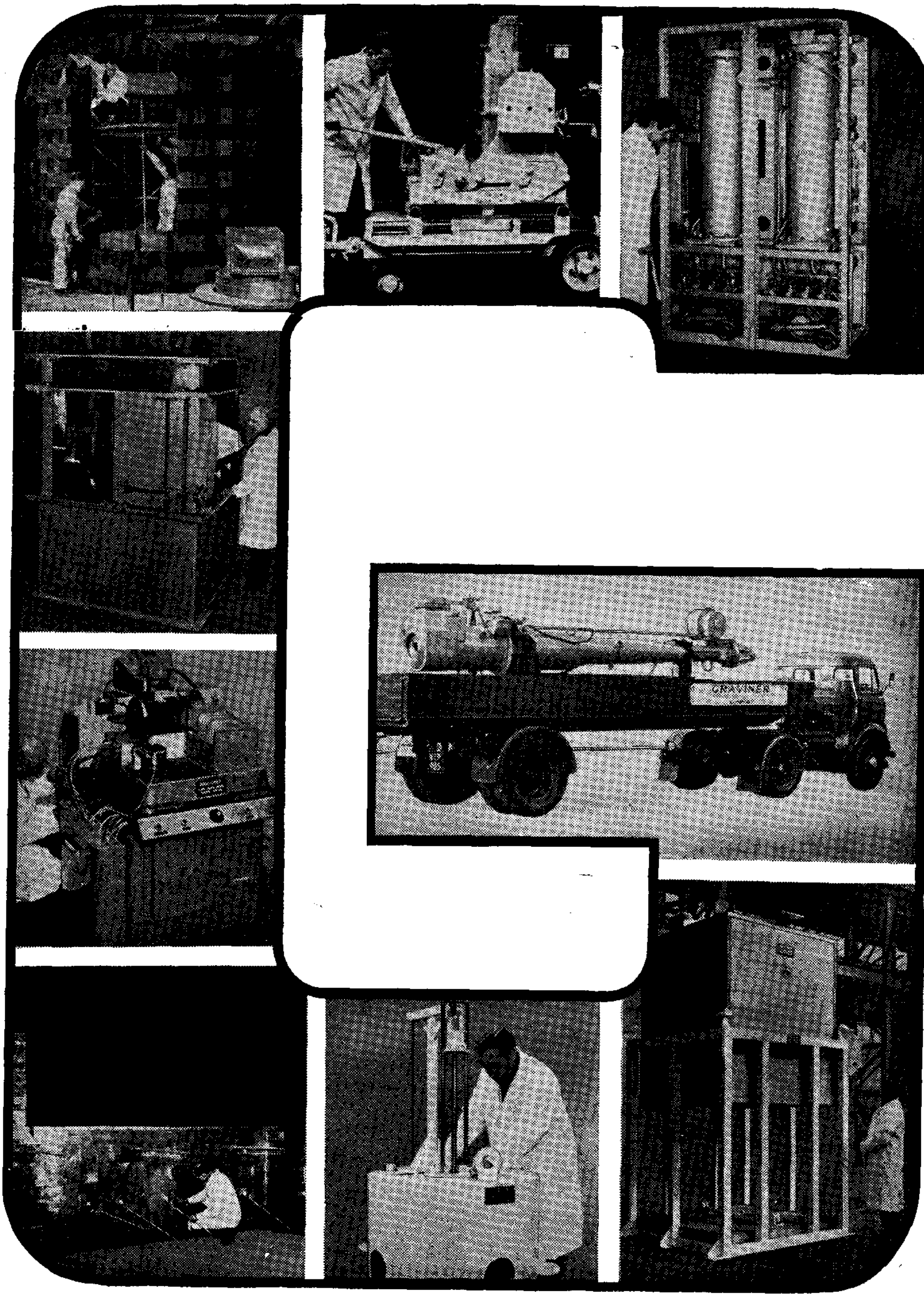
Each Thyopac-3 kit contains 12 vials, enough for 12 tests or 10 tests and 2 standards. Each vial contains (within narrow limits) the same weight of absorbent granules suspended in the same volume of buffered liothyronine—I-125 (T3 I-125). A vial of standard reference serum is also provided. The standard serum is a desiccated animal serum which upon reconstitution has a T3 value which has been accurately determined. This value is printed on each kit.

Further information is available from The Radiochemical Centre, Amersham, Buckinghamshire, England. Telephone: Little Chalfont 4444.

*2nd October, 1969*

### Inventions and designs licensed to industry

New editions of the booklet *Inventions and designs licensed to industry* are now available in English, French and German from the Public Relations Branch, U.K. A.E.A., 11 Charles II Street, London, S.W.1. This booklet lists the many inventions and designs made by the A.E.A. and the companies which have been licensed to use them by the U.K.A.E.A. Patents Licensing Department.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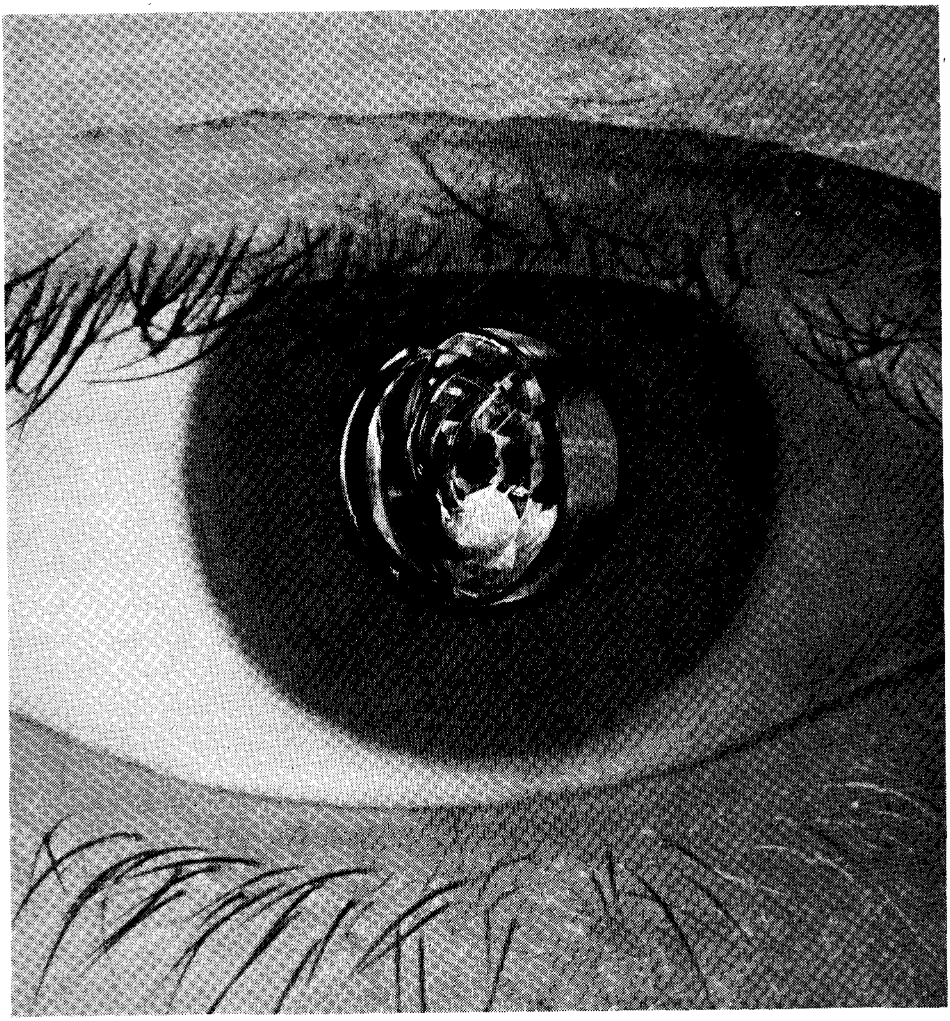

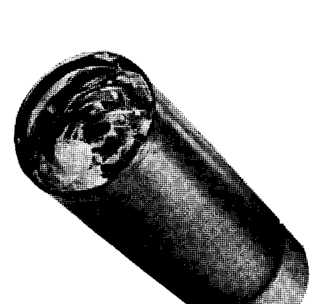

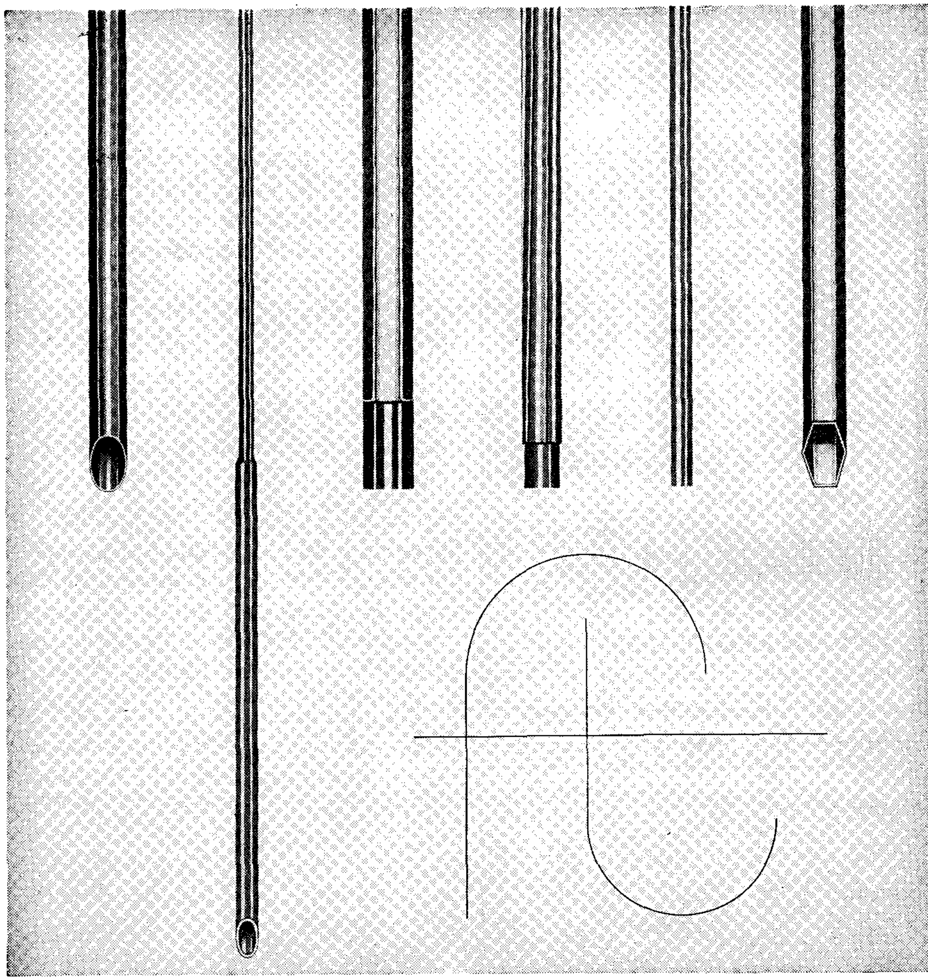





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