AN ILLUSTRATED SUMMARY OF
THE FOURTEENTH ANNUAL REPORT OF
THE UNITED KINGDOM ATOMIC ENERGY
AUTHORITY FROM 1ST APRIL 1967
TO 31ST MARCH 1968

ATOM68

NUCLEAR POWER

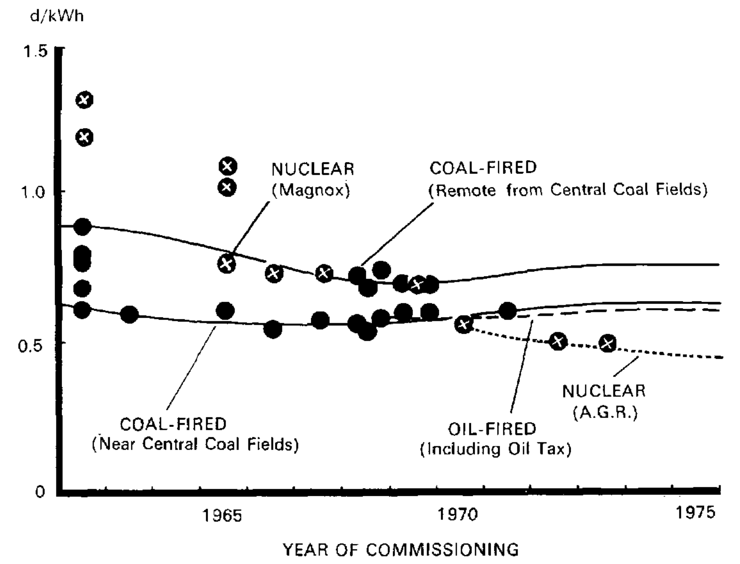


Figure 1 shows that nuclear power stations are now producing electricity at a lower cost than coal-fired plants serving the same parts of the country.

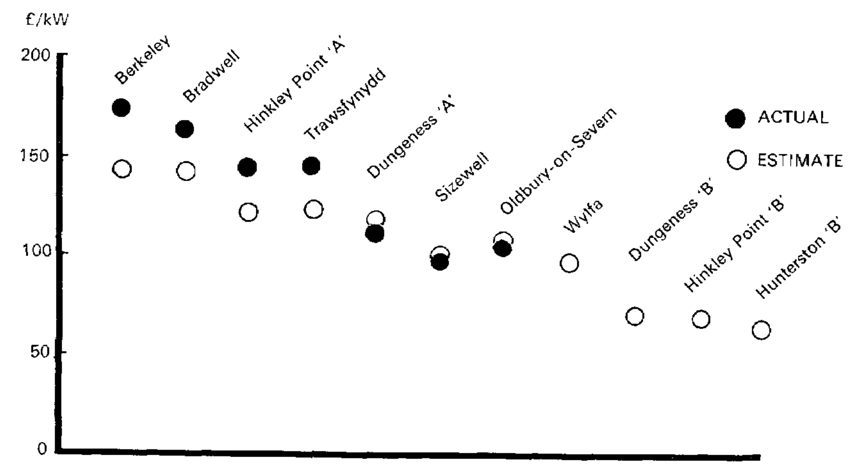


Figure 2 shows how construction costs have been reduced and how the stations are now being built at costs close to the original estimates.

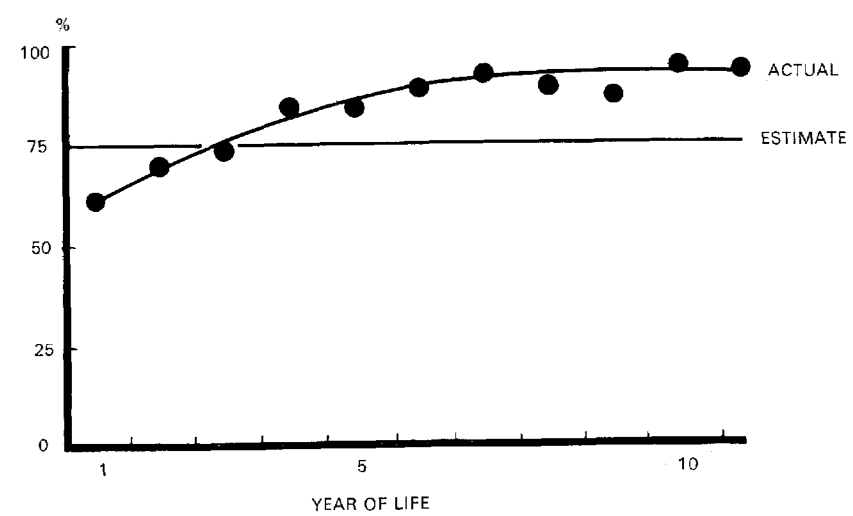


Figure 3 shows how, with over 3,000 MW in operation, confidence has been established in the reliability of nuclear power stations. Calder Hall and Chapelcross are operating, year after year, at high load factors. After the initial years of operation, the C.E.G.B. and S.S.E.B. stations are running at annual load factors better than the estimate of 75%. Monthly load factors are often spectacular. In March 1968 Berkeley and Bradwell both achieved 100%. There are very few coal-fired stations with such an impressive record of availability.

These three diagrams and their descriptions are reproduced by permission of the Central Electricity Generating Board from an article on "Nuclear Power: Achievements and Expectations" by Mr. E. J. Pipe, C.Eng., M.I.Mech. E., Group Head of the C.E.G.B.'s Development Policy Branch.

Photograph on front cover: The Prototype Fast Reactor under construction at Dounreay, May, 1968. It is scheduled to come on power in 1971.

On back cover: H.R.H. the Prince Philip at Winfrith on the occasion of the formal opening of the SGHW reactor on 23rd February, 1968.

IN BRITAIN 1968

Nuclear energy is now a firmly established fuel for electricity generation, as recognised in the Government White Paper on Fuel Policy (1967).

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

While the recent increase in the rate of ordering of nuclear stations in the U.S. has attracted much attention, the fact that the United Kingdom has more accumulated experience than any other seems to be still inadequately appreciated. Table 1 shows the installed nuclear capacity in the principal countries (excluding the Soviet bloc) at 31st March, 1968, and the cumulative nuclear electricity produced at that date.

The British electricity boards at present operate their nuclear stations as base-load stations and the record of reliability has been so good that all seven (Berkeley, Bradwell, Hinkley 'A', Trawsfynydd, Dungeness 'A', Sizewell and Hunterston 'A') were able to operate continuously over the winter months to meet the 1967/68 record demands. The C.E.G.B. stations each operated non-stop for 2837 hours between November and March and the S.S.E.B. station for 3024 hours. After the initial years of operation average yearly load factors for all the British stations exceed 75% and for lesser periods regularly reach 100%.

After receiving a wide range of evidence, and visiting a number of Authority establishments, the Select Committee on Science and Technology published their report on the nuclear industry. At the end of the year under review, the recommendations were being considered by the Minister of Technology.*

* A statement on proposals for the reorganisation of the industry was made by the Minister in the House of Commons on 17th July, 1968.

TABLE 1

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

TABLE 2

Civil Non-Nuclear Research and Development under Section 4 of the Science and Technology Act 1965 Individual Ministerial Directives	Expenditure 1967/68 £'000	Qualified Scientists and Engineers Man/Years
Desalination	713	47
Biological Centrifuge	5	1
Hydrostatic Extrusion	115	4
Single Purpose Transducers	8	1
Nondestructive Testing Centre	143	15
Ceramics Centre	232	22
Improved Utilisation of Steels	39	2
Atmospheric Pollution	44	4
Tribology	5	—
Graphite Fibres	25	3
Minor Projects	21	1
TOTAL	**1,350**	**100**
Work on Repayment		
E.S.R.O. Satellite Design Study	58	6
Advanced Radio Telescopes	19	2
High Temperature Fuel Cells	20	3
Computer Software	9	1
For Government Departments	720	62
For Industries Universities etc.	25	1
TOTAL	**851**	**75**

TABLE 3

Nuclear Civil Research and Development

	Expenditure £ million (approximate)										Qualified Scientists and Engineers	
	1963/64		1964/65		1965/66		1966/67		1967/68		31.3.67	31.3.68
	Current	Capital	Current	Capital	Current	Capital	Current	Capital	Current	Capital		
Reactor research & development programme												
(i) Major Development												
(a) Gas-Cooled Systems	10.0	1.5	9.0	1.0	8.0	0.5	7.5	0.5	7.0	—	425	400
(b) Water Moderated Systems	5.0	2.0	5.5	4.0	6.5	5.0	7.0	6.5	5.5	3.0	390	365
(c) Fast Systems	7.0	1.5	9.0	1.5	10.0	1.0	9.0	2.0	8.5	5.0	605	585
(ii) General Reactor Technology	4.0	1.0	4.0	0.5	4.5	—	4.0	0.5	4.0	0.5	315	245
Other Research												
(a) Basic Research	5.0	1.5	5.0	1.5	6.0	1.0	7.0	1.0	6.5	1.0	470	430
(b) Health and Safety Research	1.0	—	1.0	—	1.0	—	1.0	—	1.0	—	95	75
(c) Isotope Research	0.5	—	0.5	—	0.5	—	0.5	—	0.5	—	65	65
(d) Plasma Physics and Fusion Research	3.5	1.5	3.5	1.5	3.0	1.0	3.5	0.5	3.5	—	200	190
	36.0	9.0	37.5	10.0	39.5	8.5	39.5	11.0	36.5	9.5	2565	2355

NOTES

1 The staff figures include qualified staff providing supporting scientific, engineering and administrative services in establishments engaged on the Authority's civil research and development programme. In addition, supporting services for the programme are provided by the Production Group in fabricating and processing fuel for the prototype reactors, by the Engineering Group in constructing capital facilities, and by the Authority Health and Safety Branch.

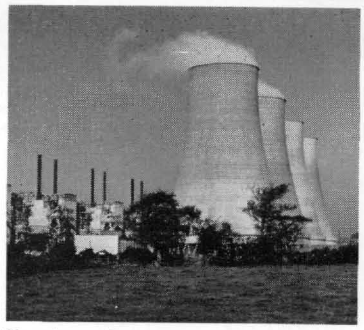
2 In addition to the total of qualified staff at 31.3.68 shown above, some 90 were employed on work on repayment for other organisations.

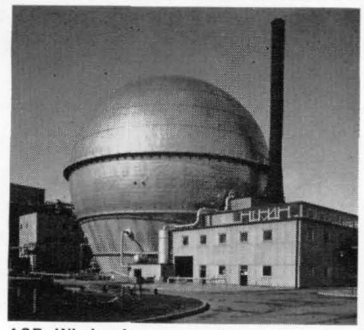
3 The numbers of qualified scientists and engineers deployed to research and development projects on 31st March, 1967, have been revised slightly since the 13th Annual Report following some changes in classification.

R&D 1968

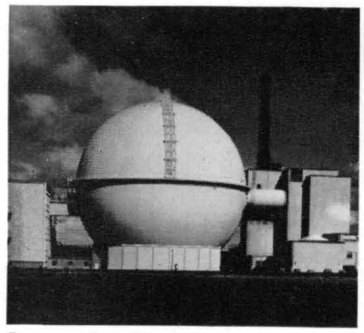
During the year the three Authority research and development committees (dealing respectively with: Reactor Research and Development; General Nuclear Research and Development; and Non-Nuclear Research and Development) became fully operational. All the Authority's research and development programmes have now been reviewed; decisions have already been taken in certain areas which will lead to redeployment of effort, while other important areas are still under consideration by the committees.

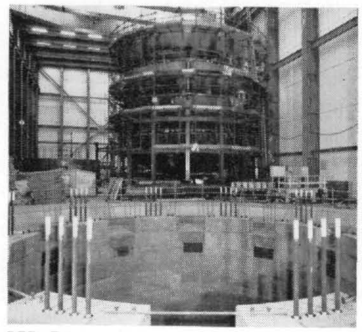
REACTOR RESEARCH AND DEVELOPMENT

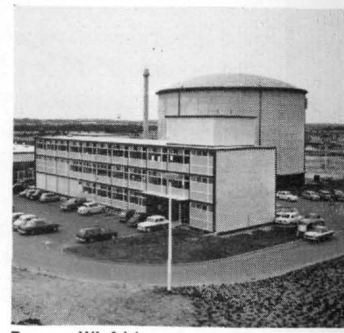

Chapelcross Reactors

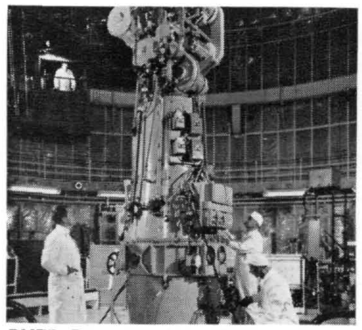

AGR, Windscale

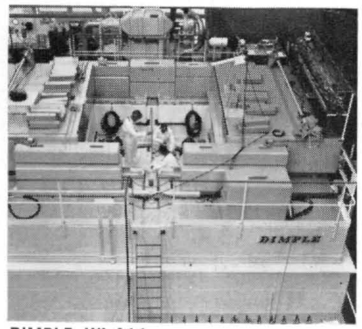

SGHWR, Winfrith

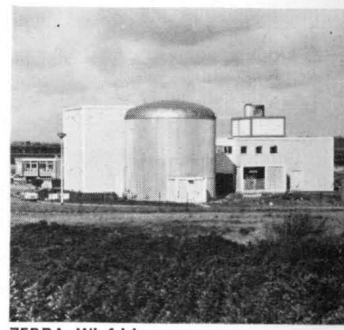

Dounreay Fast Reactor

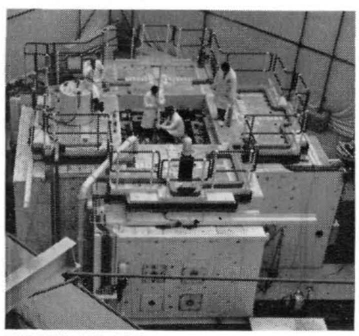

PFR, Dounreay

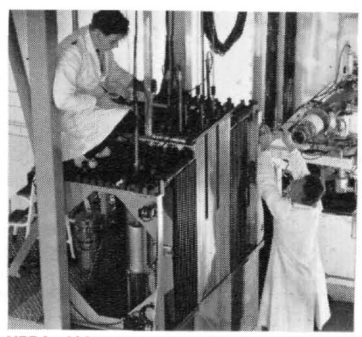

Dragon, Winfrith

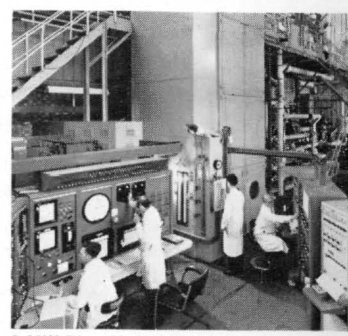

DMTR, Dounreay


DIMPLE, Winfrith

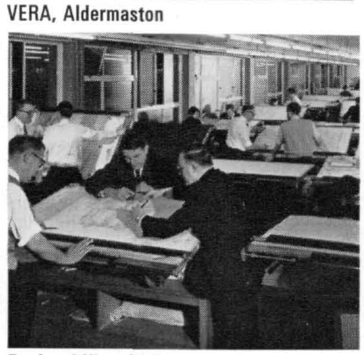

ZEBRA, Winfrith

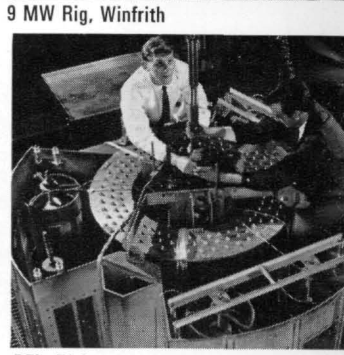

NESTOR, Winfrith

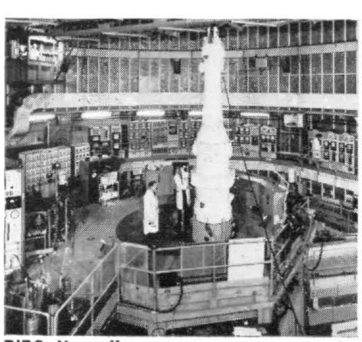

VERA, Aldermaston


9 MW Rig, Winfrith


HERO, Windscale


Design Office, Risley

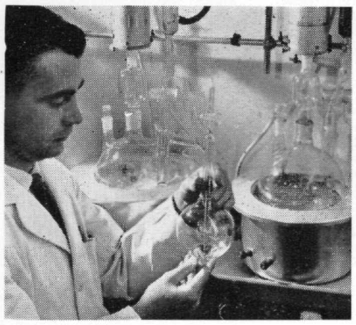

REL, Risley


DIDO, Harwell


PLUTO, Harwell


Computers

GENERAL NUCLEAR RESEARCH AND DEVELOPMENT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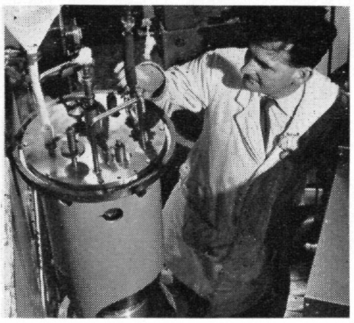
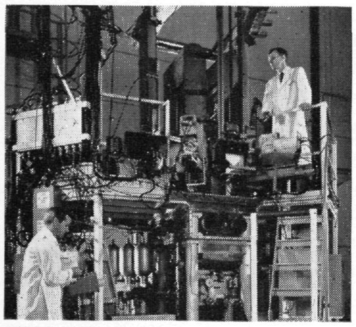
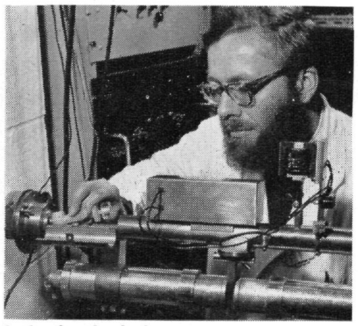
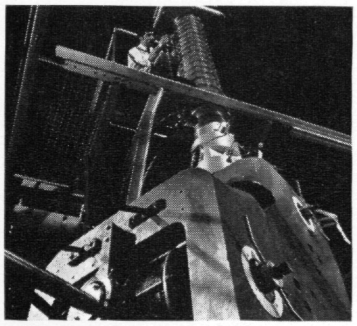
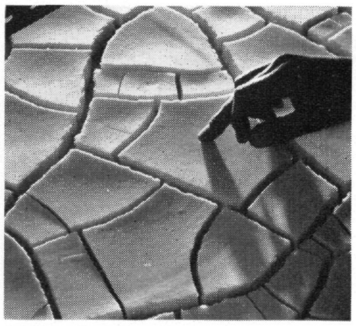
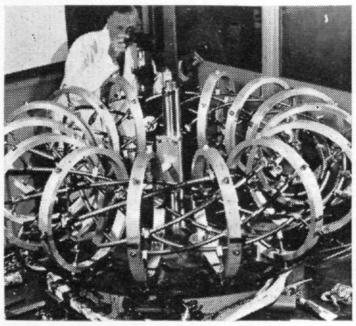

Neutron Beam Studies

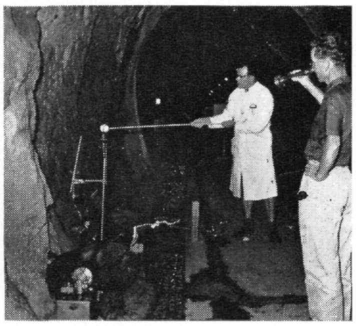

VIPER, Aldermaston


Activation Analysis


Ion Implantation

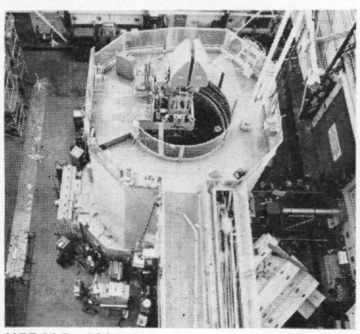

Uranium from Sea-Water

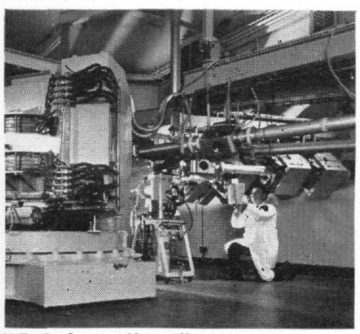

Fusion


Isotopes: Tracers

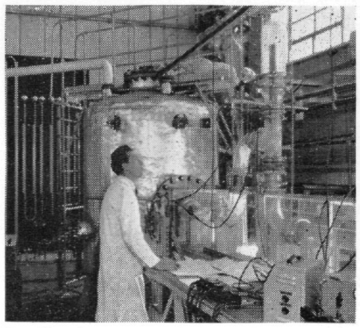

Isotopes: Irradiation

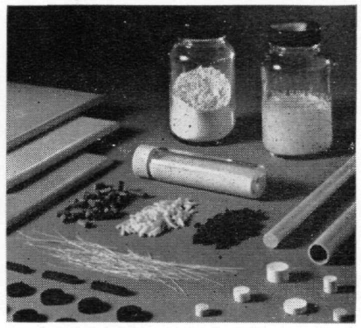

Isotope Generators

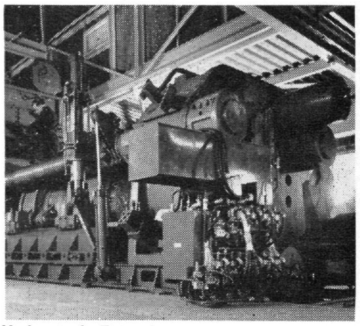

HERALD, Aldermaston

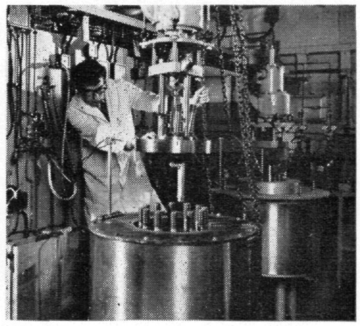

V.E. Cyclotron, Harwell

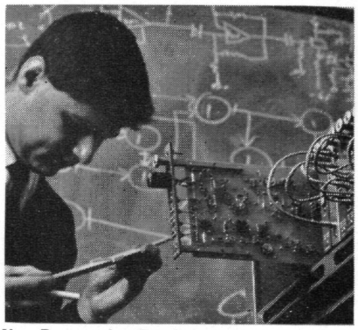
NON-NUCLEAR RESEARCH AND DEVELOPMENT


Desalination


Ceramics Centre


Hydrostatic Extrusion


Tribology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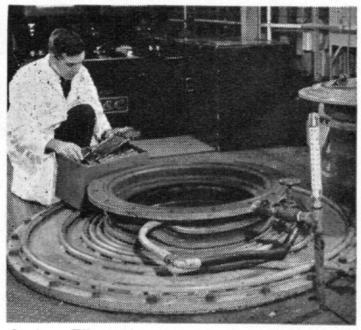
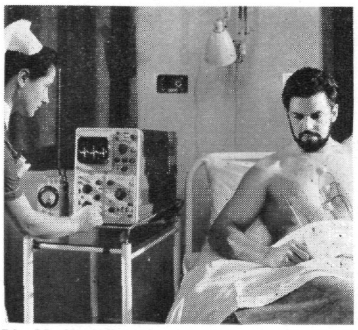

Carbon Fibres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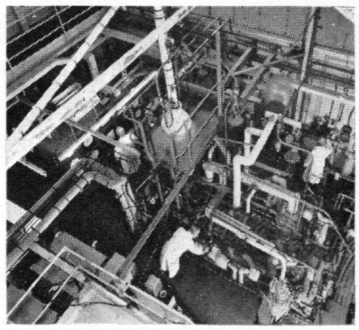
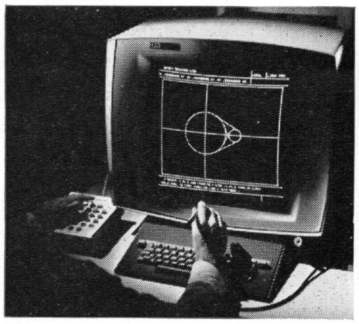
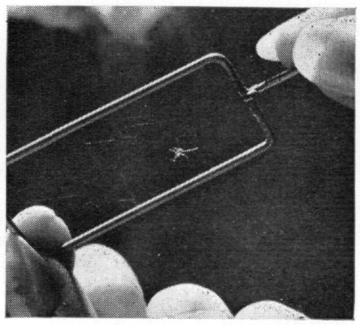

Heat Transfer and Fluid Flow


Computers for Engineering


Air Pollution

THE REACTOR PROGRAMME

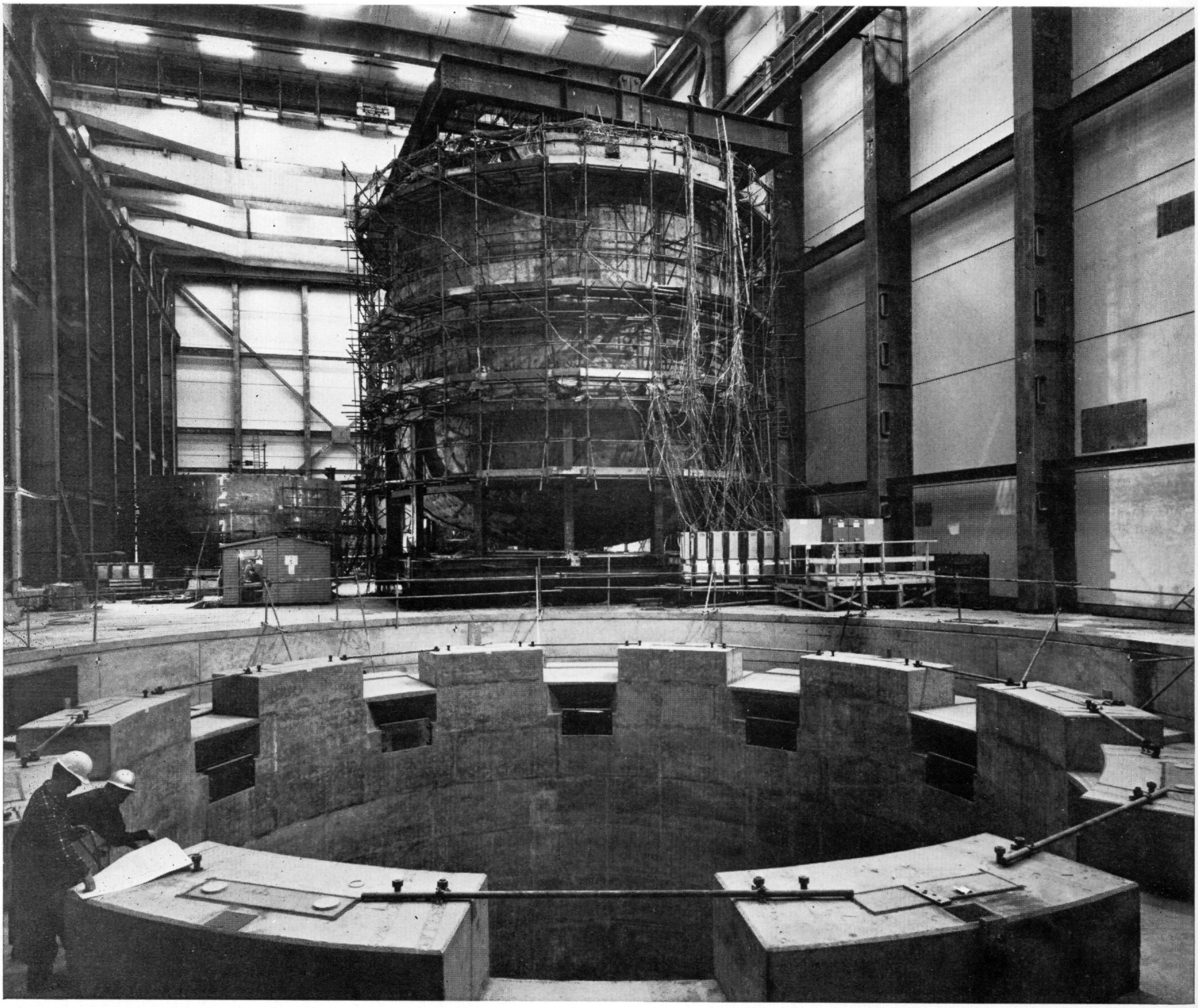
The First Nuclear Power Programme covered the construction of some 5,000 megawatts of nuclear generating stations with Mark I gas-cooled reactors, coming on power between 1956 and 1969. The Second Programme envisages a total of 8,400 megawatts to be commissioned by 1975. Work has started on stations at Dungeness, Hinkley and Hunterston totalling 3,700 megawatts and proposals for stations at Hartlepool and Heysham are being considered. The design of the stations under construction is based on the advanced gas-cooled (Mark II) reactor developed by the Authority and a primary objective of the Authority's work in the field of reactors is to ensure the success of the advanced gas-cooled reactor and assist in the exploitation of the system overseas.

An objective on a longer timescale is to develop a commercial fast reactor for adoption by the Electricity Generating Boards in the 1970's.

The reactors already operating and being built as part of the First and Second Nuclear Power Programmes will produce plutonium as well as feeding power to the national grid. The best use of plutonium is as fuel for fast reactors which themselves breed additional plutonium and very substantially reduce the requirements for uranium, thus further reducing nuclear fuel costs. The sodium-cooled fast reactor now being built by the Authority at Dounreay is scheduled to operate at full power of 250 megawatts in 1971.

The foreseeable supply of plutonium will be insufficient to enable fast reactors alone to meet the anticipated requirement for new nuclear generating stations for some years. During this period further thermal reactors fuelled with uranium will therefore be built in parallel with an increasing installation of plutonium-burning fast reactors.

Therefore a third objective is to improve the economic performance of thermal reactors. In the shorter term, improved designs of A.G.R.s and commercial designs of S.G.H.W.R.s are already available; in the longer term, designs of gas-cooled reactors using coated particle fuel, based on Dragon Project technology, are being prepared.



P.F.R. PROGRESS The photograph shows the reactor vault and reactor leak jacket of the 250 megawatt Prototype Fast Reactor at Dounreay in May, 1968. The 200-ton jacket has now been lowered into the vault and is floating on water ready for its final positioning.

GAS COOLED REACTORS

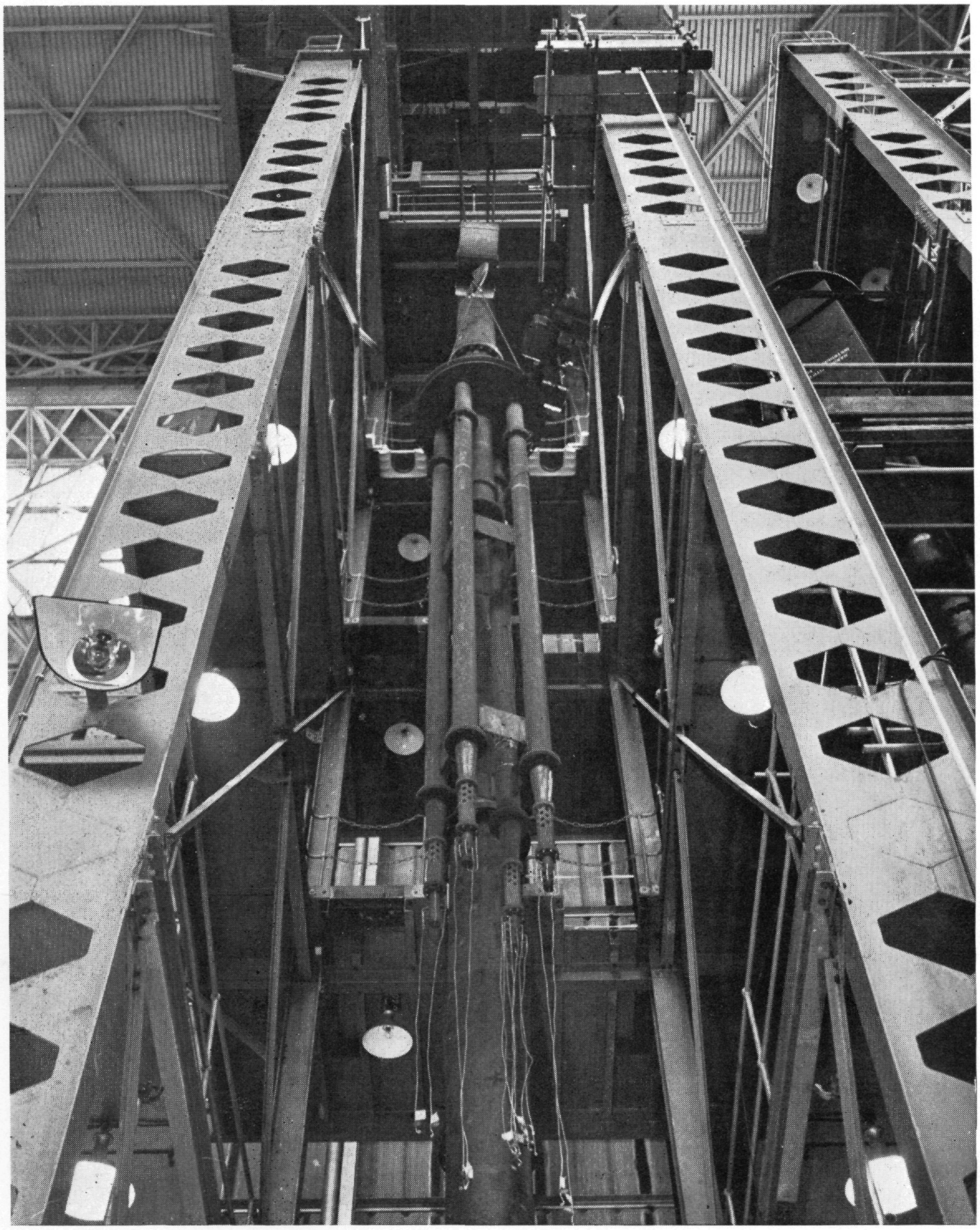
The Authority's work in support of the second nuclear power programme, which is based on the advanced gas-cooled reactor, is in two main directions: to confirm that the fuel and the graphite moderator will have satisfactory technical and economic performance for the required life, and will allow the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

Work continued on the development of more advanced versions (Mark III) of the gas-cooled reactor system with the objective of achieving a further significant reduction in generating costs. Design concepts suggested by the consortia and the Authority were studied with the electricity boards and the consortia; several possible lines of development were crystallised, and reference designs were produced so that the alternatives could be examined in depth and on a comparable basis. All designs are based on graphite-coated fuel particles of uranium dioxide or dicarbide, at a low enrichment.

In collaboration with the Commissariat à L'Energie Atomique of France, the Authority studied the application of gas turbine driven generators to carbon dioxide cooled Mk. III reactors for direct-style power generation. This application holds out the possibility of useful capital cost savings for central power stations in the longer term.

The Windscale A.G.R. continued to be used as a test facility for fuel development and has operated for over five years on experimental programmes with an average availability of over 84%. The maximum irradiation in the original fuel charge reached over 27,500 MWD (H)/t, which is greater than is required for the commercial stations. Irradiation of fuel pins designed for the commercial stations is approaching the required level.

On 6th February, 1968 the Minister of Power stated in the House of Commons that he accepted the advice of the Nuclear Safety Advisory Committee that the safety of a gas-cooled reactor in a pre-stressed concrete pressure vessel is such that it may be constructed and operated much nearer built-up areas than has so far been permitted in the U.K. In reply to a supplementary question he agreed that sites at Hartlepool and Heysham would be acceptable in terms of safety. This assessment of the safety of these reactors should improve the prospects of exploiting U.K. designs of gas-cooled reactors for sites near urban centres overseas.



R.D.L. The Reactor Development Laboratory at Windscale provides information for the design of commercial versions of the Advanced Gas-Cooled Reactor. The major facilities include the Windscale A.G.R. Above: a fuel-loading test-rig.

SGHWR

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

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

The S.G.H.W.R. fuelled with enriched uranium continues to be developed with particular attention to the attractive features of the system. These include factory fabrication of components, off-load refuelling with little loss of availability, and load following capability.

Commercial designs for reactors of 300 megawatts to over 500 megawatts have been produced and larger units are now being studied.

The Authority are continuing to develop proposals for an S.G.H.W.R. power station for the North of Scotland Hydro Electric Board. A joint study has been started with the Central Electricity Generating Board for an S.G.H.W.R. station with two 625 megawatt reactors.

The joint U.K.A.E.A./Australian Atomic Energy Commission study on a natural uranium S.G.H.W.R. (begun in 1966) was intended initially to concentrate on a 250 to 300 megawatt reactor, but the size was increased to 500 megawatts at an early stage. Ten A.A.E.C. staff were attached to the Authority in January, 1967, and a further twelve joined the study in August of that year. Six New Zealand staff joined the study at about the same time and two representatives of the New South Wales Electricity Trust early in 1968. A complete reference design is now being prepared.

Studies are being carried out in association with British industry to establish the costs of U.K. production of the heavy water required for commercial stations compared with purchase from existing producers overseas.

FAST REACTORS

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

The design of the P.F.R. is based on experience gained from the smaller Dounreay Fast Reactor (D.F.R.) which has been operated by the Authority for several years. This reactor is now used to provide information on the irradiation behaviour of fuel and materials for fast reactors and other reactor systems.

Design work started on a larger generating station using a 1300 megawatt reactor. Many features will be similar to those of the P.F.R., but experience gained in its design and construction will be incorporated in the new design to reduce costs and improve reliability. Physics experiments in the ZEBRA, DIMPLE, and LIDO reactors to predict performance were completed and further experiments in ZEBRA are being made to improve performance predictions and to enable improvements to be made in the designs of larger reactors.

The Authority are participating in an assessment of fast reactors with coolants other than sodium, sponsored by the European Nuclear Energy Agency.

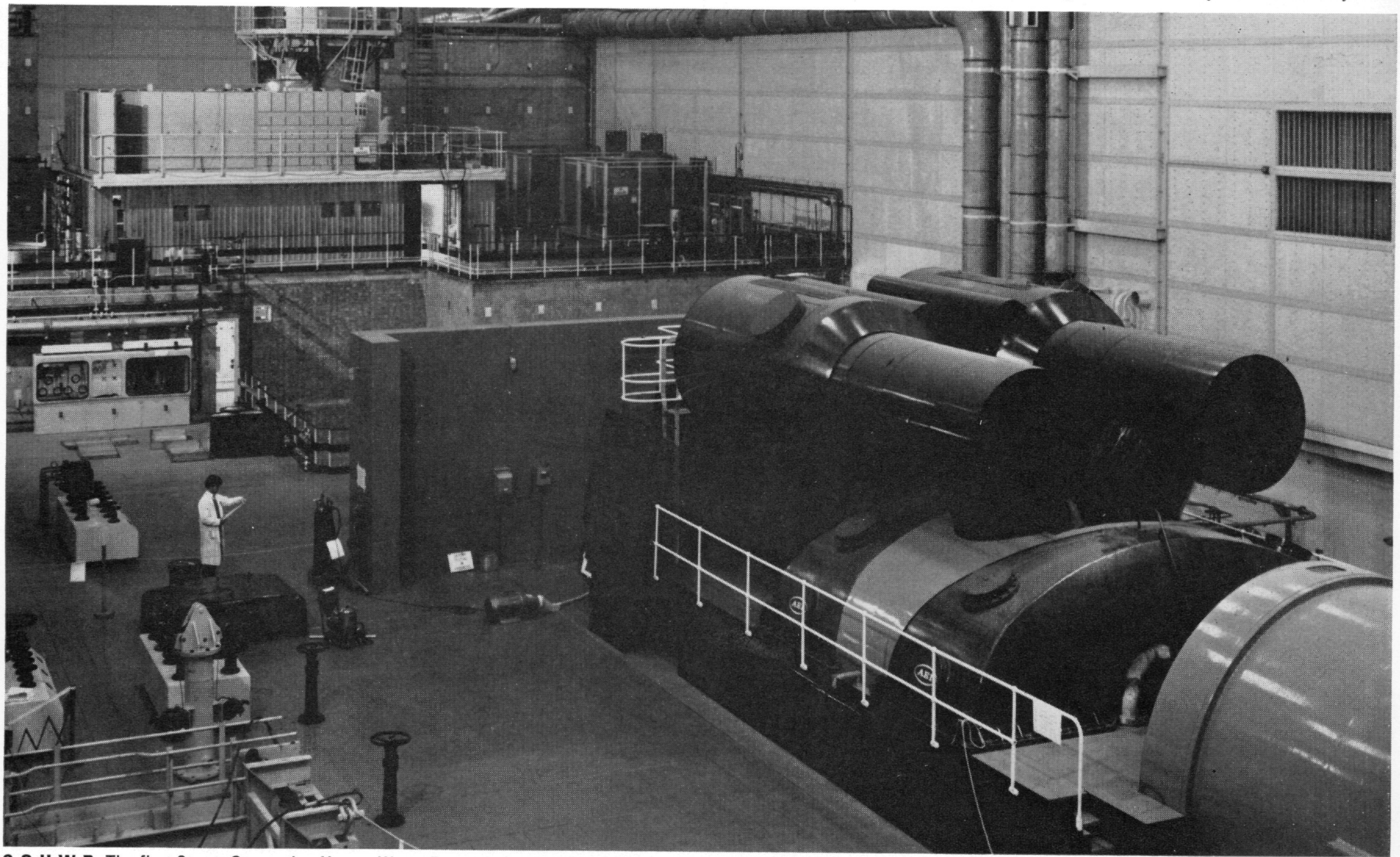
The Dounreay Fast Reactor operated satisfactorily with a full load of experiments until May, 1967, when a leak was detected of liquid metal coolant from the primary circuit into the surrounding leak jacket. Tracer techniques, followed by acoustic measurements, located the leak in a section of one of the pipes connecting a heat exchanger to the reactor vessel. At the end of March, 1968, the pipework was being repaired and power was resumed on 22nd June, 1968.

The whole operation was carried out without hazard to the general public or to the people on the Dounreay site. It has demonstrated that it is quite possible to cut into, and repair, the primary circuit of a liquid metal cooled reactor which has been operating for a number of years.

Although this shut-down interrupted the programme of irradiation which the Authority contracted to undertake on behalf of foreign research establishments, interest from overseas in the use of D.F.R. irradiation space has not relaxed. One further contract was signed during the year and numerous others are being negotiated.

SMALL REACTORS

During the year, two reports—one from the Vickers' Shipbuilding Group and the other from the British Nuclear Forum—drew attention to the possible application of nuclear power to the high speed, high utilisation requirement presented by the container ship. The Authority worked closely with



S.G.H.W.R. The first Steam Generating Heavy Water Reactor power station was built by the Authority at Winfrith and began exporting electricity to the grid at the end of 1967, thus meeting the $4\frac{1}{2}$ year programme set in 1963. The reactor was brought to its full power (100 megawatts) in January.

SEA ROUTE The stainless steel reactor jacket for the Prototype Fast Reactor was brought by sea from Dalmuir to Wick in Caithness and then transported by road to Dounreay. Weighing 80 tons, it was carried in four parts and assembled on site. The station is to come on power (250 megawatts) in 1971.

Vickers' Shipbuilding Group to re-assess the application of the burnable poison pressurised water reactor (B.P.W.R.) to a 40,000 shaft horsepower marine requirement. A complementary analysis of the operation of a nuclear container ship by a shipowner is necessary before the overall economics can be properly assessed.

Work on a land-based version of the B.P.W.R. was rounded off with the preparation of specifications and estimates for small reactors in the range 20-60 megawatts (electrical). A world wide market survey was conducted on the application of reactors in this size range. This analysis indicated only a small number of probable applications over the next ten years with a tendency towards the upper end of this size range. In view of the development and successful operation of the S.G.H.W. reactor which could be offered in sizes down to about 100 megawatts, it has therefore been decided not to pursue the B.P.W.R. specifically as a small land-based reactor development.

The operation of the BR-3 reactor at Mol in Belgium under the joint Anglo-Belgian collaborative programme continued most successfully. The reactor was operated at very high availability (about 98%) and the core, representative of fuel that would be used in a small B.P.W.R. or Vulcain reactor, achieved by the end of March, 1968 an average burn-up of about 17,000 megawatt-days per tonne with a peak of about 38,000 megawatt-days per tonne, without any fuel failures. This has greatly increased the confidence with which a fuel charge for a B.P.W.R. could be specified to last the four or five years life cycle of a marine reactor core.

SODIUM Part of the main test loop of the 6,000 gallons-per-minute sodium pump rig at the Reactor Engineering Laboratory, Risley. R.E.L.'s main concerns are engineering, physics and instrumentation.

NATIONAL ECONOMIC BENEFIT

Authority decisions on the investment of resources in major development projects are made on the basis of the expected benefits. Particular decisions need to be made by comparing the money still to be spent and the benefits which would be lost if it were not spent. (The methods used in the Authority for appraisal of development expenditure include the use of discounted cash flow techniques which take due account of the time lag between cash outlay and benefits. These are expressed in terms of present worth at a common date, using the discount rate of 8% recommended by the Treasury).

For reactor projects the benefits likely to accrue are primarily reductions in the generating costs of electricity, although there are a number of secondary benefits, both social and economic.

For appraisal of R & D programmes, the Authority's reactor development work can be considered under three heads:

- (i) the existing type of A.G.R., including short-term improvements;
- (ii) more advanced thermal systems—the S.G.H.W.R. and further development of the gas-cooled reactor;
- (iii) fast reactors.

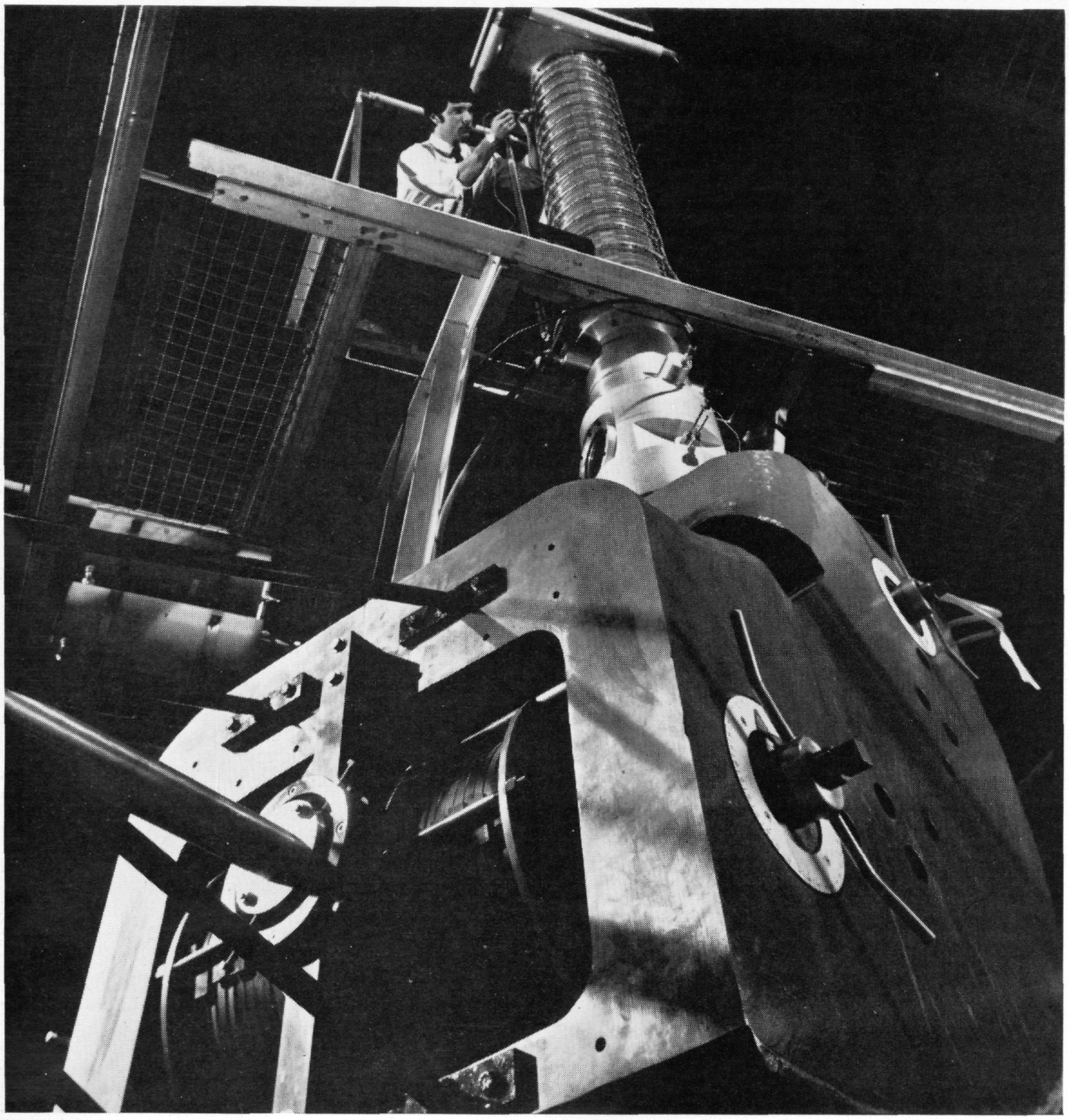
As regards the first category, the cumulative costs on the current A.G.R. are expected to reach about £110 million (of which less than £20 million is still to be spent). **This A.G.R. programme could lead to a substantial national economic benefit as compared with installing the best available fossil-fuelled alternatives.**

If one ignores the possibility of still more advanced types of gas-cooled reactor being introduced, the national economic benefit from A.G.R. could be some £600-£700 million (in present worth terms at 31st March, 1968). Adopting a more cautious set of assumptions—including fossil fuel prices of just under 3d. a therm—the benefit would still be £350-£400 million.

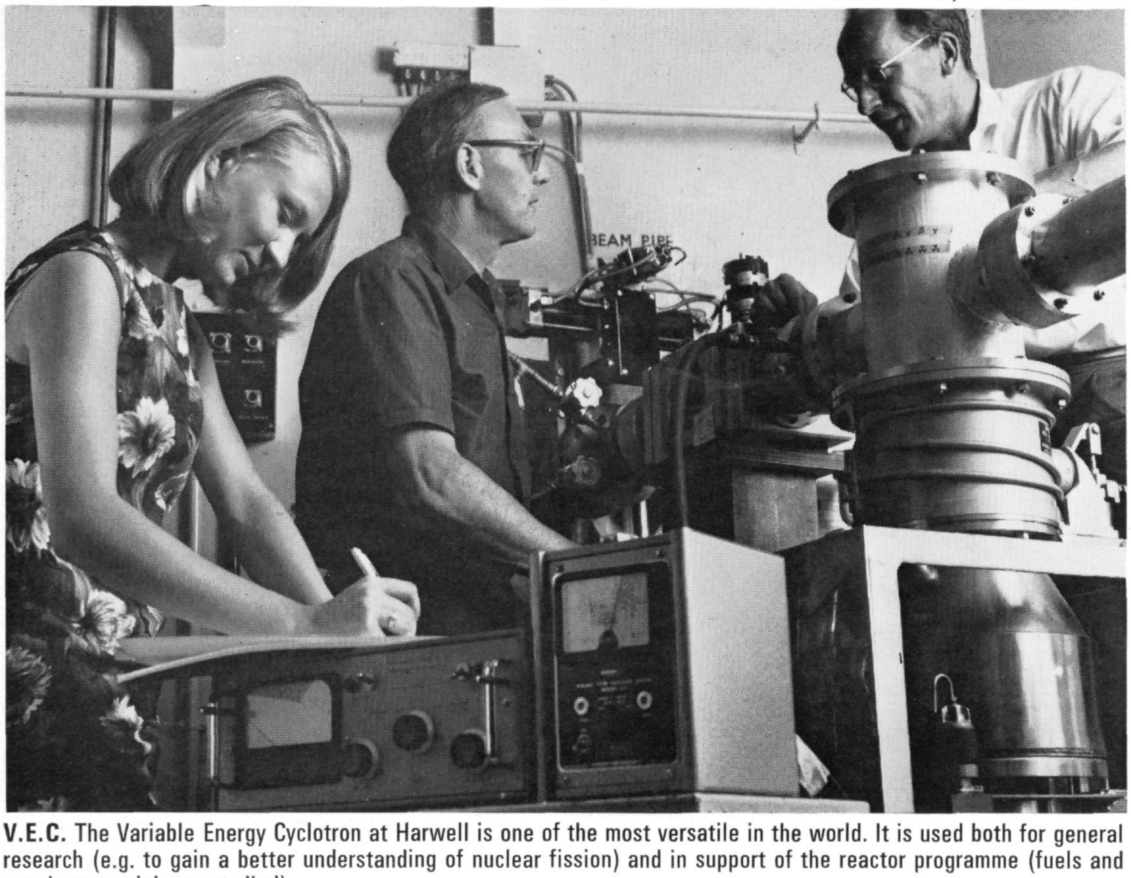
In practice, some of this benefit will come from more advanced reactors developed under heading (ii); from (ii) and (iii) together there will be an *additional* benefit estimated at around £800 million. This gives a total benefit—arising from all three programmes which could be £1,500 million (present worth) and hardly less than £1,150 million.

Development costs under (ii) to date amount to some £60 million; the current development programme for fast reactors, following the initial period of exploratory study, has cost about £75 million to date.

GENERAL NUCLEAR RESEARCH AND



Ion Implantation Part of the work of the Metallurgy and Electronics and Applied Physics Divisions at Harwell involves the development of techniques for injecting selected ions—including radioactive tracers—into solids (particularly semi-conductors). The 500 keV Cockcroft-Walton generator has been modified for heavy ion acceleration.



V.E.C. The Variable Energy Cyclotron at Harwell is one of the most versatile in the world. It is used both for general research (e.g. to gain a better understanding of nuclear fission) and in support of the reactor programme (fuels and canning materials are studied).

The Authority's programme of general nuclear research and development covers both underlying and applied nuclear research. It is the principal source from which extensions or new applications of nuclear processes may arise.

It comes under five main headings:—

Underlying nuclear research
The bulk of this work is carried out at Harwell.

Industrial applications of nuclear processes
This is mainly the work of the Wantage Laboratory.

Nuclear fusion and plasma physics research
This is carried out at the Culham Laboratory.

Detection of nuclear explosions
This is part of the Aldermaston programme.

Major equipment: uses and development
This relates to materials testing reactors, particle accelerators, computers, etc.

These categories of research are closely integrated with each other; with research in support of the reactor programme; and with the non-nuclear projects. It is in this integration that much of the effectiveness of the programmes depends. There is also active co-operation with industry, with university research departments (and other research organisations) and also with overseas agencies

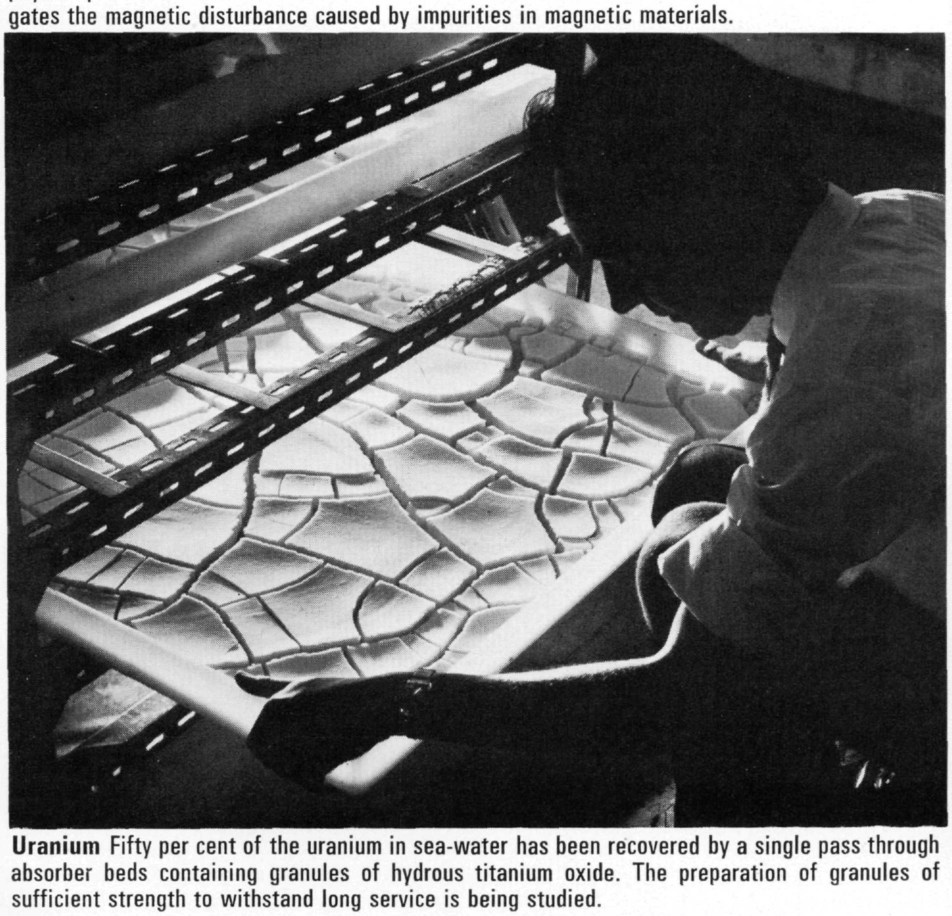
An indication of the effort devoted to the programme is given by the approximate numbers of qualified scientists and engineers engaged on such research at 31st March, 1968. These were: 395 on underlying research, 130 on applied nuclear research and a further 190 on plasma physics and fusion research.

This underlying nuclear research will be reduced over the next three years to not more than 10% of the Authority's total civil R. & D. effort and individual items will be judged against the criterion of their relevance to the applied programmes. Before projects for the second category, applied nuclear research, are approved, they will be subject to an analysis of their potential national economic benefit. The Programmes Analysis Unit and the Economics and Programming Branch are playing an important part in these analyses.

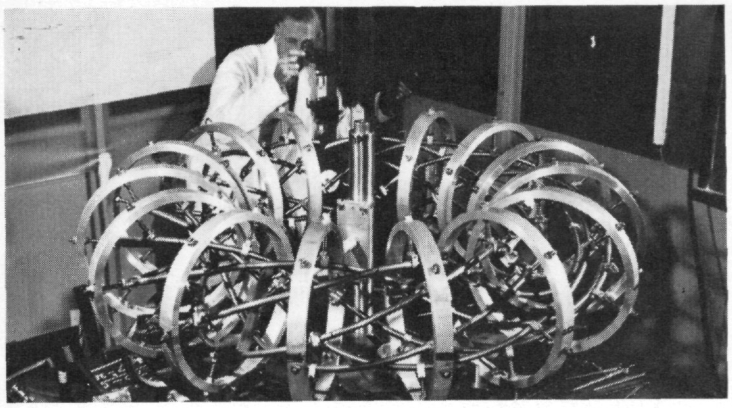
The underlying research programme is concerned mainly with the properties of materials, especially with the effect of irradiation, how these properties limit the performance of materials in reactors and with ways of extending their limits.

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

Neutron Beams Increasing use is being made of neutron beams for studying a wide range of physics problems. The instrument shown—used in association with the PLUTO reactor—investigates the magnetic disturbance caused by impurities in magnetic materials.



Uranium Fifty per cent of the uranium in sea-water has been recovered by a single pass through absorber beds containing granules of hydrous titanium oxide. The preparation of granules of sufficient strength to withstand long service is being studied.



Toroidal stellarator under construction at Culham.

FUSION POWER

A report issued by the Culham Laboratory on the technology and economics of fusion power considered the form a reactor might take if it were to be an acceptable power source, assuming that the physics problems of stability were solved.

The study revealed that costs were dominated by the expense of the magnetic field structure and that a generous allowance had to be made for the cost of using superconductors on such a large scale. This is one of the areas identified as requiring further technological study. Among other problems are those of the vacuum wall (which must stand appreciable thermal load in addition to an intense neutron dose throughout its working life), the injection of fuel to the plasma and the disposal of the reaction products and unburnt ions which have an appreciable energy when they leave the plasma.

The fusion research programme at Culham continued mainly on the problems of the magnetic confinement of high temperature plasma, with increasing attention to toroidal systems in which the plasma has to cross the closed magnetic field lines to escape. The three kinds of toroidal system under study are stellerators, multipoles and pinches, the difference between them lying in the method used to generate the magnetic field. Good progress has been made in the study of the effects of micro-instabilities on the degree of plasma confinement in toroidal systems, but it is still too early to pick out any one of the three types as being the most promising route to a fusion reactor.

Mr. R. R. Carruthers, Head of Technology Division, Culham Laboratory, read a paper on "The Technological Aspects of Fusion Power Generation" to the Institute of Electrical Engineers in December, 1967.

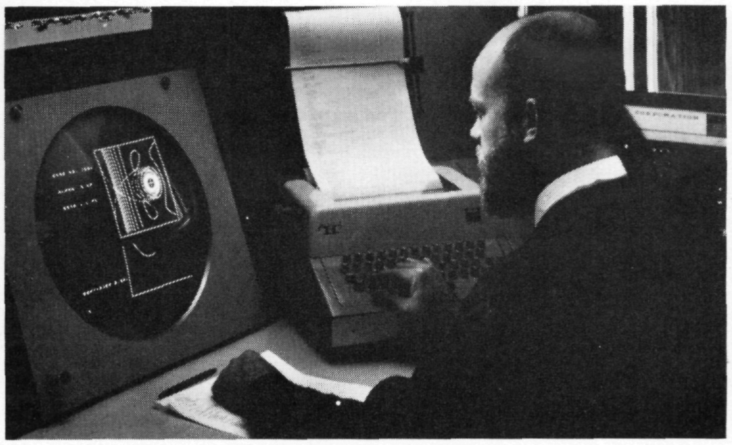
He began his lecture by saying: "Nuclear fusion is a potential source of power using a cheap, abundant fuel, and a nuclear reaction which does not lead to the continuous build-up of radioactive waste. Unfortunately this very desirable objective has proved to be somewhat hard to achieve. It is over thirty years since the experiments of Cockcroft and Walton and nearly twenty years since work was started in this country to try and harness the fusion reaction to the generation of power. In this time we have seen the fission reaction proceed from the laboratory to Fermi's first reactor to what is today becoming one of our major sources of power."

In his paper he described a costing study of a 17-metre toroid incorporated in a system which would deliver an electrical output of about 2,100 megawatts (thermal efficiency 45%). He said it was interesting to note that this power station required daily fuel intake of only 2 kilogrammes.

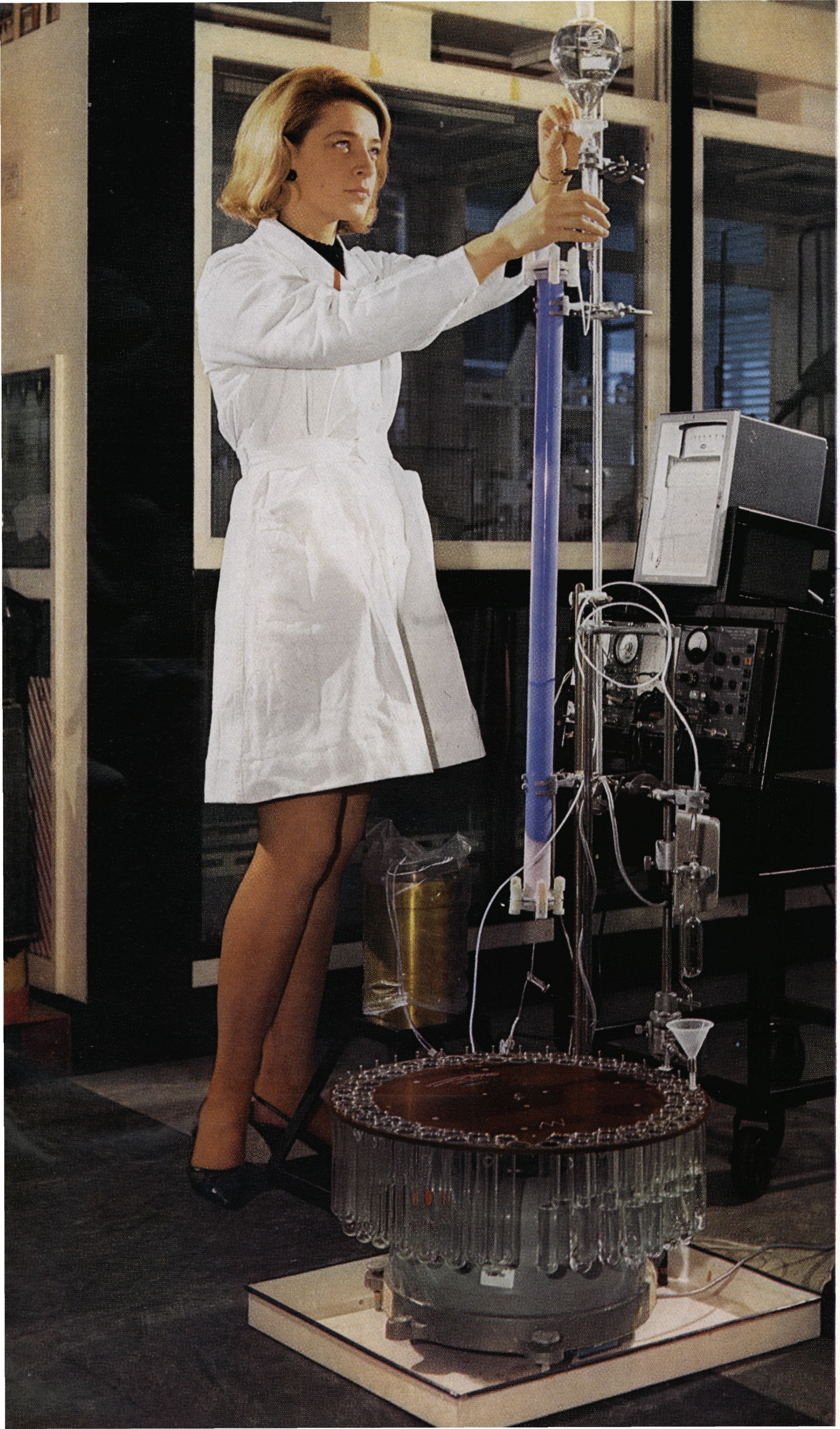
The study arrived at figures of £69.5—£74 per kilowatt for capital cost, a fuel cost of 0.004d. per kilowatt/hour and a generating cost of 0.231—0.251d. per kilowatt-hour. The latter figure compared with the estimate of 0.264d. for a 2 x 1,000 megawatt fast breeder fission reactor.

He added: "These figures are very encouraging and meet our first objective which was to show that a fusion reactor could be envisaged at a cost not too far removed from competitive power sources. We must note that the cost advantage stems largely from the negligible fuel cost and small percentage changes in capital charges can easily change the picture."

He ended by saying: "Before this goal can be achieved, not only must we await further progress in the study of plasma containment but there is a wide range of technological problems to be faced and answered."



Design of magnetic field configurations by computer.



ISOTOPES

Sales of radioisotopes from the Radiochemical Centre, Amersham, increased by 17% to £2.85 million (with 58% exported). Over the last five years the average rate of growth in sales value has been 14% and exports have averaged 55%.

The growth of sales was spread over many products and territories. It was particularly good among the new pharmaceuticals for use in medical diagnosis. Business with the United States advanced overall by 50% in the year.

(In June, 1968, it was announced that the Centre had formed a joint company with G. D. Searle & Co. (Inc.) of the U.S.A.—to be known as The Amersham/Searle Corporation —for marketing operations in North, Central and South America.)

The number of consignments sent out by the Centre was 76,000 compared with 68,000 last year. More than half a million despatches of isotopes have now been made since the beginning of the British service in 1948.

←Separation of Carbon-14 labelled compounds by column chromatography at the Radiochemical Centre, Amersham.

ISOTOPES

The development of the isotope-heated thermoelectric generator, RIPPLE, has continued at Harwell in collaboration with the licensee, Submarine Cables Ltd. Another two generators are now in regular service with marine light authorities in Denmark and Sweden and a generator powering a radio landing beacon has been installed in the Outer Hebrides (see right).

RIPPLE 1 and 2, first put into operation in 1965, had operated continuously for 26,000 hours (up to 31st March, 1968), with complete reliability and completely untended.

A survey of Africa and Australasia made in collaboration with Submarine Cables, Ltd., revealed a substantial number of applications which, together with those already found in Europe (principally Scandinavia), provide a good potential for these generators.

RIPPLE generator being installed in the Outer Hebrides for use with an airfield marker beacon. It is the first of its type in the world.→

ISOTOPES

Many of the industrial applications that have arisen so far from the nuclear programme involve the use of radioactive isotopes either as sources of radiation or heat, or as tracers.

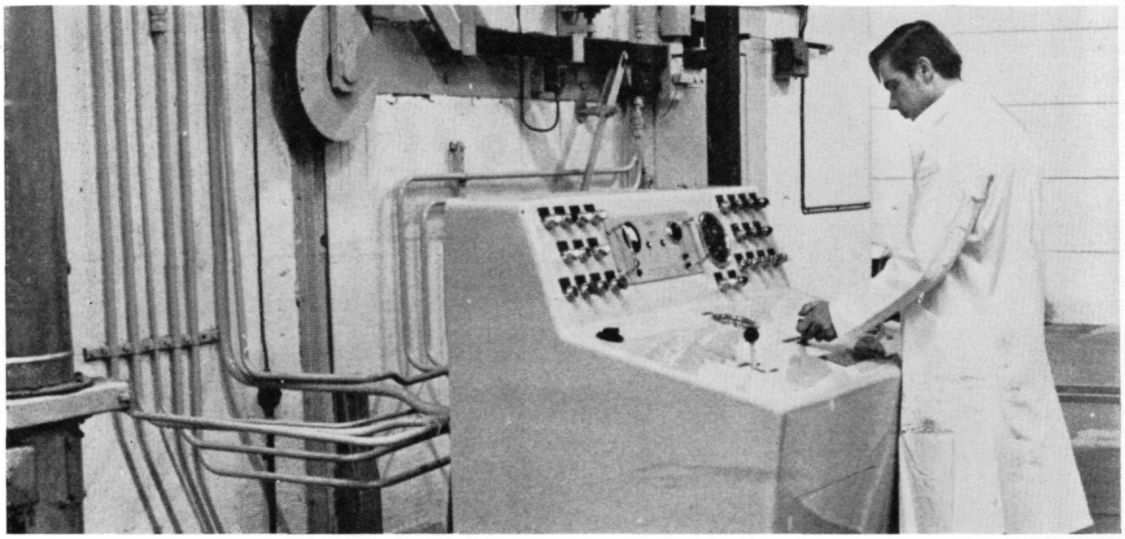
The Wantage Research Laboratory has continued to maintain advisory services, supported by a field experimental service, to stimulate the exploitation of radioisotope and radiation techniques.

The Activation Analysis Service, introduced in 1965, was further automated and extended to meet the high demand for this service from industry.

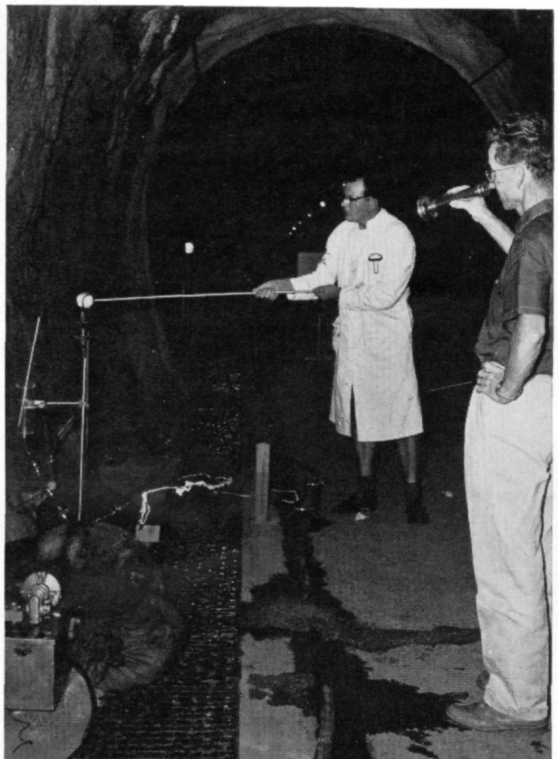
The sterilisation of medical equipment continued to be the main use of the Wantage Package Irradiation Plant; a direct service for hospitals included weekly collection and delivery in the London area.

Four more commercial gamma-irradiation plants were built by Authority licensees and are now in operation overseas. In Holland H. S. Marsh Ltd., built a pilot-scale food irradiator and they also built plants in Italy and Sweden for sterilising medical equipment. The large Swedish plant will be used also for food irradiation. A grain disinfestation plant in Turkey, built by Nuclear Chemical Plant Ltd., is demonstrating the economics of this process.

Prospecting X-ray fluorescence spectroscopy is used by the Institute of Geological Sciences for mineral prospecting. This portable analyser will assay selected elements *in situ* in a few seconds without chemical treatment.



Irradiation Control console of the irradiation plant for the sterilization of medical equipment, built by H. S. Marsh Ltd., at Skärhamn, Sweden. (Photo: Courtesy Radona Irradiations A.B.)



Water Flow Measurements—using radioactive tracers—at a hydro-electric power station in Batang Padang, Malaya. Precision to better than ±0.5% is achieved.

BRITISH DESIGNED GAMMA STERILIZATION PLANTS

Location	Built and Designed by	Date of Operation	Principal Purpose	Maximum Design Loading of Cobalt-60 (curies)
Wantage Package Irradiation Plant	Rubery Owen	1960 August	Sterilization of medical supplies and pharmaceuticals, packaging materials and special service for hospitals.	500,000
Gamma Sterilization Pty. Ltd, Dandenong, Victoria, Australia.	Gamma Sterilization Pty. to U.K.A.E.A. design.	1960 September	Sterilization of goat hair for carpets. Medical products.	2,000,000
Johnson's Ethical Plastics Ltd. Slough.	H. S. Marsh Ltd.	1962 November	Sterilization of disposable syringes and needles.	500,000
Ethicon Ltd. Edinburgh.	Nuclear Chemical Plant Ltd.	1963 January	Sterilization of surgical sutures	250,000
Gillette Industries Ltd. Reading	H. S. Marsh Ltd.	1964 May	Sterilization of surgical scalpels and disposable syringes.	750,000
Swann-Morton (Manufacturers) Ltd. Sheffield.	Vickers Ltd.	1966 February	Sterilization of disposable scalpel blades.	75,000
Ethicon G.m.b.H., Hamburg, Germany.	H. S. Marsh Ltd.	1966	Sterilization of medical products.	750,000
SPV. Wageningen, Holland.	H. S. Marsh Ltd.	1967 August	Sterilization of fruits and vegetables.	250,000
Grain Irradiation Plant, Iskenderun, Turkey.	Nuclear Chemical Plant Ltd.	1967 February	Grain disinfestation.	360,000
Helinos A.B. Skärhamn, Sweden.	H. S. Marsh Ltd.	1968 January	Sterilization of medical products.	1,000,000
I.C.O. Bologna, Italy.	H. S. Marsh Ltd.	1967 November	Sterilization of disposable syringes.	500,000

NON-NUCLEAR RESEARCH AND DEVELOPMENT

The non-nuclear research and development activities of the Authority continued to grow in 1967/68. The Minister of Technology required the Authority (in accordance with Section 4 of the Science and Technology Act, 1965) to undertake research into five additional matters:—

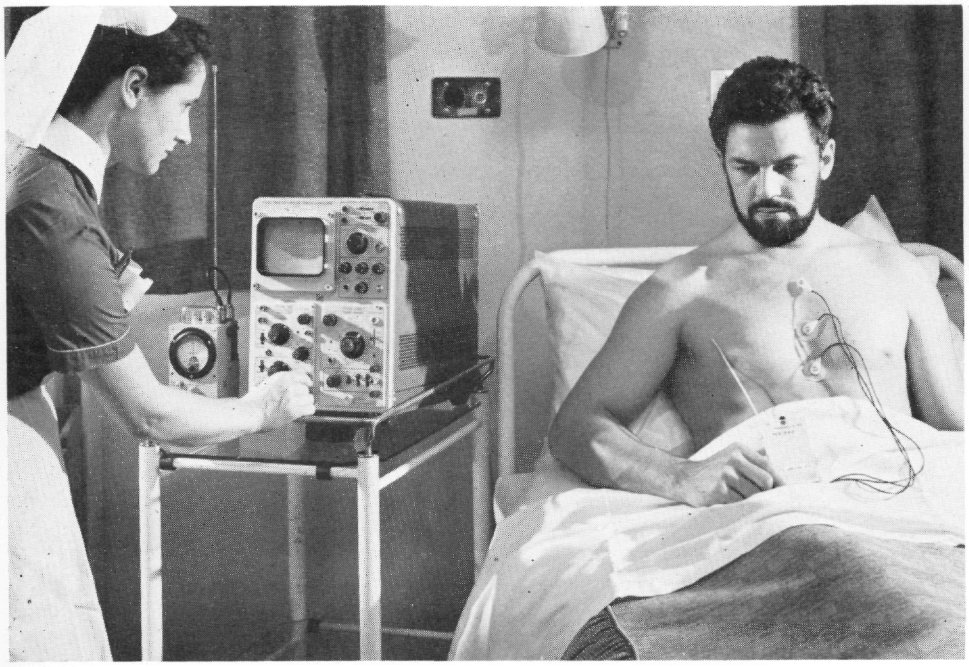
- Atmospheric pollution
- Heat transfer and fluid flow
- Computer software
- Graphite fibres

The Minister also approved extensions to the existing programmes of research into desalination and fuel cells.

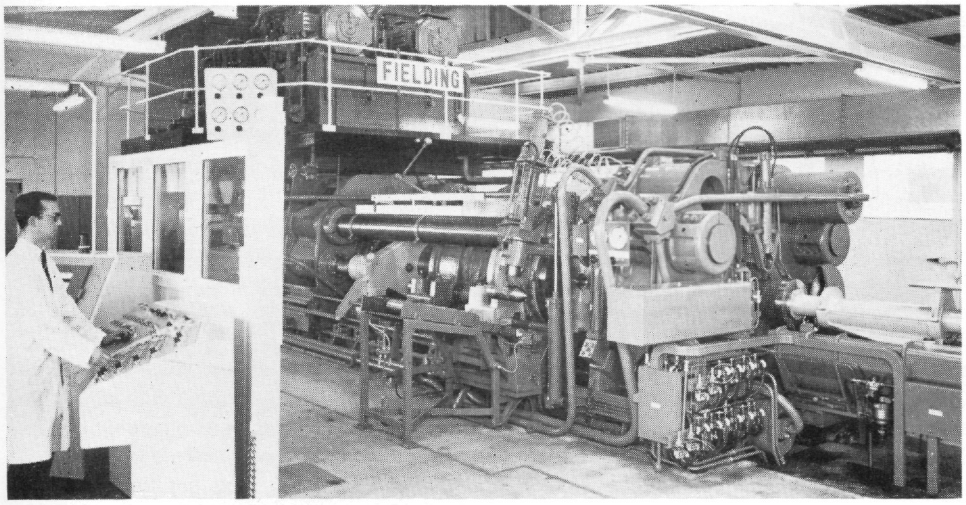
At the end of the year, four further proposals (high temperature corrosion; high temperature chemical technology; quality control; water renovation by reverse osmosis) were under consideration (the last three of these have since been approved). The volume of non-nuclear research commissioned at Aldermaston by Government departments also increased substantially.

Each major project is carefully analysed against national benefit criteria. Studies in this field by the Programmes Analysis Unit have included desalination, carbon fibres and high temperature corrosion. The prospective benefits from the successful conclusion of a project may be by way of lower costs, export promotion, import saving etc., the nature of the project determining how Authority expenditure is recouped. In some cases, work is carried out under direct contract to external customers, and at their expense; in others, work is primarily directed to general national benefit (e.g. the reduction of atmospheric pollution), and no revenue to the Authority is sought.

Between these extremes, most projects involve research and development in collaboration with industry under commercial agreements providing for the payment of royalties to the Authority on sales of the developed product or process. The Authority also now operate several research-based advisory and testing centres which charge for services rendered to customers or clients. The work of these centres, and most of the collaborative projects with industry, is planned and kept under review by advisory committees on which the Authority's partners or clients are fully represented. In all cases close co-operation is maintained with Research Associations and other establishments working in the same fields. At the national level, the Authority's close liaison with industry is reinforced by their membership of the Research Committee of the Confederation of British Industries.

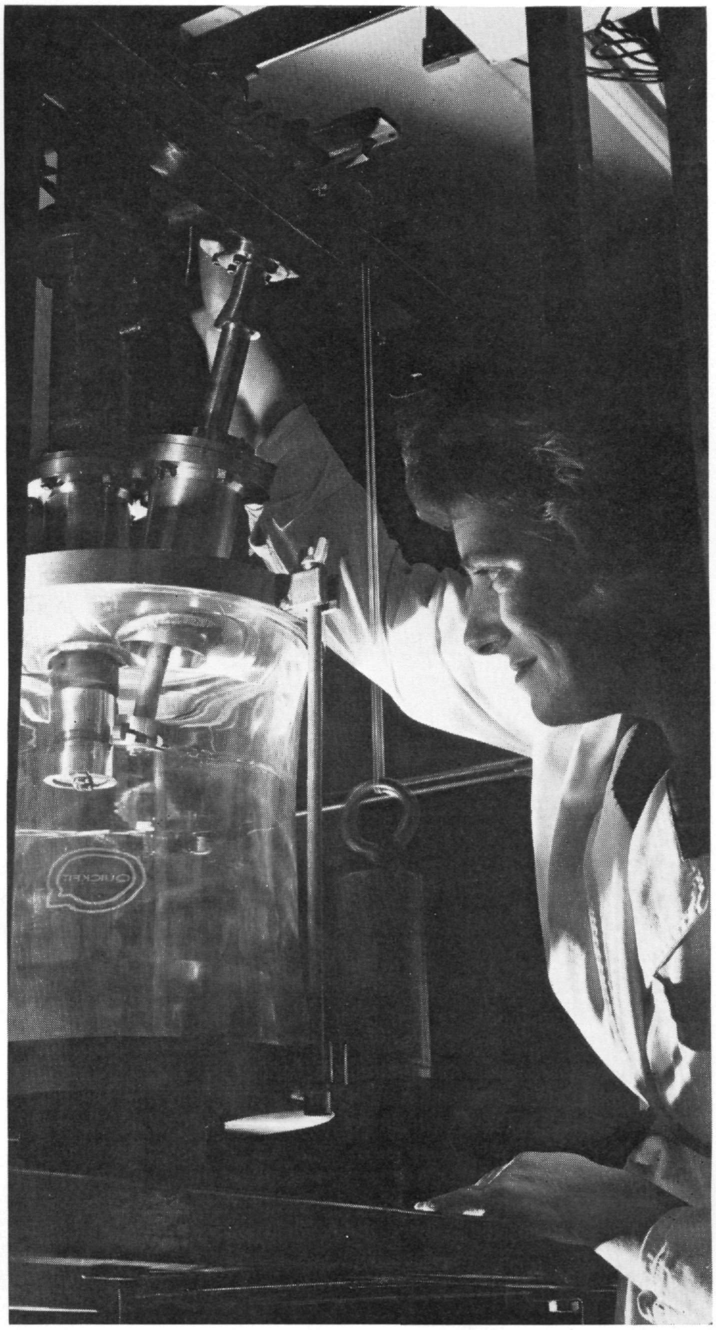


BIO-MEDICAL TECHNOLOGY The Aldermaston programme in support of bio-medical technology has been expanded considerably at the request of the Ministry of Health. The photograph shows equipment which is being developed to provide radioed information about the functioning of a patient's heart before, during and after surgery. The patient has electrodes fixed to his chest by adhesive and wires from these electrodes are connected to the small radio transmitter at his waist. Signals from the transmitter are picked up by the receiver on the left and are shown as an electro-cardiogram on the oscilloscope screen.



HYDROSTATIC EXTRUSION The 1,600-ton extrusion machine built by Messrs. Fielding and Platt to the Authority's specification at the Reactor Fuel Element Laboratories at Springfields was commissioned.

A considerable quantity of aluminium and copper billets has been extruded with an accuracy and finish of the products as good as that achieved in earlier, small-scale experiments with lower extrusion pressures. The Springfields invention of "augmentation" (i.e. mechanically assisting the billet) enables billets to be extruded at a lower pressure for a given extrusion ratio and ensures controlled flow of the material. Industrial organisations continue to show a lively interest in the project and work has been carried out for a number of metal-working firms.



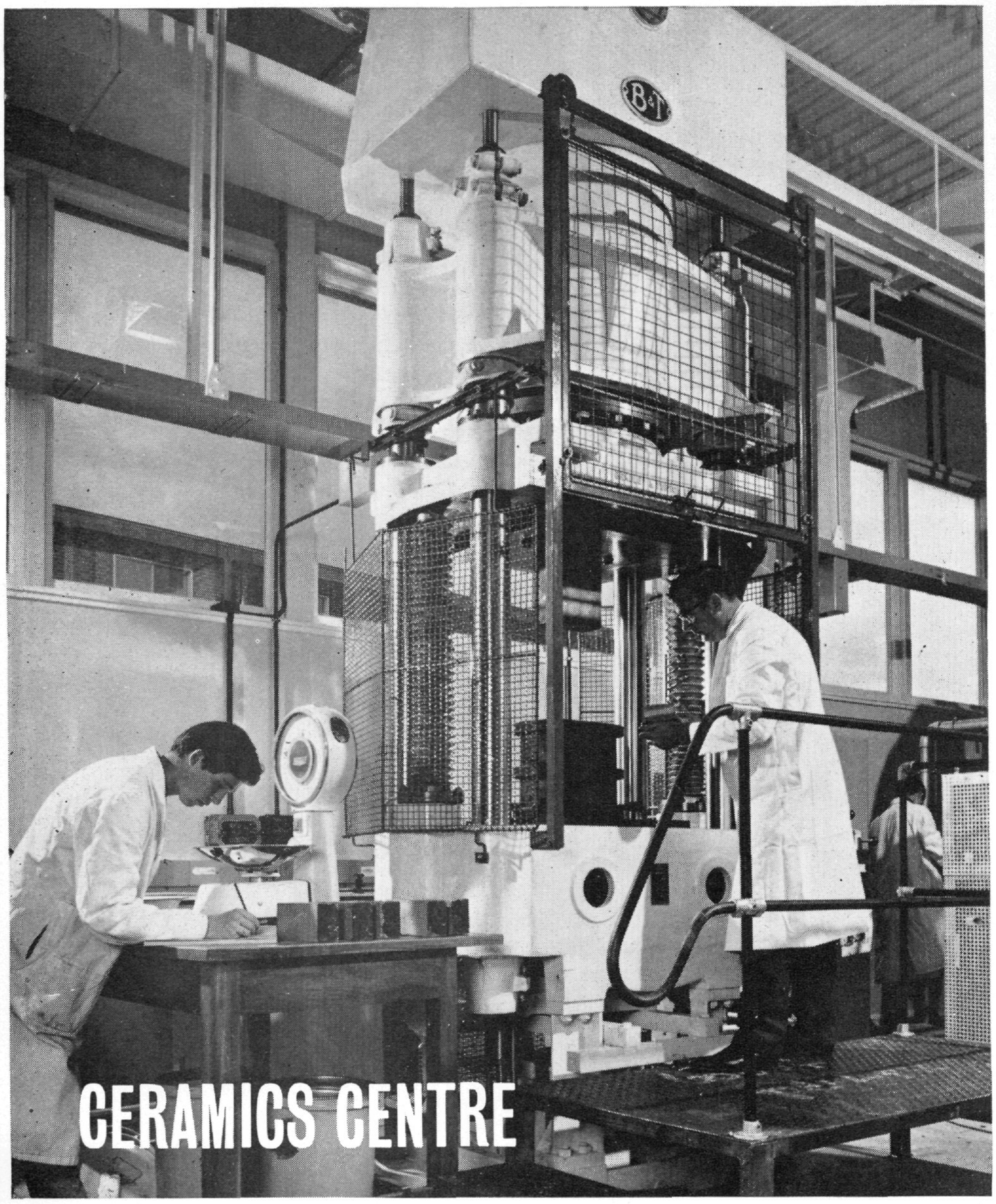
TRIBOLOGY A major National Centre of Tribology (the science of lubrication and wear) was set up at the Reactor Engineering Laboratory, Risley, in January, 1968; smaller centres have been established at Swansea and Leeds Universities. The objective is to help industry solve tribological problems by providing a consultation service and by undertaking experimental R. & D. programmes to deal with specific problems. The Risley Centre will also co-operate with universities in providing facilities for post-graduate training in the subject.

Most of the enquiries from industry involved bearing or rubbing problems in environments—such as high temperature—where conventional lubricants cannot be used.

HARWELL a new beginning

Addressing a press conference at Harwell in July, the Director—Dr. Walter Marshall—said: "The big change we are making is to increase rapidly the amount of work on applied projects for industry. In one sense this is not entirely new, because we have always undertaken applied work of this kind, but in past years these activities have always been secondary to our main role which has been to assist the nuclear power programme. But by this time next year applied research in close association with British industry will be the largest activity in Harwell's programme.....

"Harwell is changing rapidly. We have made a beginning on a new orientation of our work. We are continuing with work on the reactor power programme and on underlying research but we are building up new programmes also. We are seeking new relations with industry; we are experimenting with new kinds of commercial agreements. We are getting a good response from industry and we are very encouraged. It is too early to say whether or not we shall succeed but I personally feel sure that we shall and I think you will find today that all the Harwell staff have considerable confidence in the future."



CERAMICS CENTRE

The Harwell Ceramics Centre undertakes a widely-based programme of ceramics research geared to the needs of industry. Picture shows a 350-ton hydraulic press.

The Ceramics Centre at Harwell aims at undertaking a wide range of ceramics research geared to the needs of British industry. The research programme was planned in conjunction with industry and the research associations, with special regard to the form of collaboration most appropriate to the particular industry concerned. By the end of the year under review, about half the professional staff were on work in direct collaboration with industry and the rest on longer-term work, much of which should lead to new collaborative programmes or licensing agreements.

The Centre also provides information and advice. Some 500 general enquiries were received from industry, about 60 of which were stimulated by the Regional Offices of the Ministry of Technology (in about 40 cases the problems were solved by putting firms in touch with each other). Nearly half the enquiries related to ceramic applications requiring further technological development and some (e.g. the development of ceramic heat-exchangers) are being evaluated as possible future projects.

An agreement was reached with General Refractories Ltd., and Pickford Holland & Co. Ltd., for a research programme to develop (jointly) improved and cheaper oxide refractories—with a longer service life—for iron and steelmaking. The agreement provides for joint ownership of rights in the results and in royalties from licensing or from sales of new products. Each firm plans to mount a comparable effort of their own during 1968. New products are being tested at all the laboratories concerned. A similar agreement was reached with Thomas Marshall and Co. (Loxley) Ltd., to develop improved carbon refractories for blast furnaces.

Trial samples of carbides and oxides produced by the sol-gel process were supplied to over 30 firms to establish the technical and commercial value of such orders. Promising applications under study include as catalysts, absorbers, paint constituents and ferrites. The Authority licensed W. & C. Spicer Ltd. to manufacture zirconia-based powders on the scale of several tons a year using a sol-gel process developed at Harwell to the pilot-plant scale.

A two-year contract was received from Smiths Industries Ltd. for work on the thermal and mechanical properties of industrial ceramics which is closely integrated with their own development programme on advanced ceramics.

HEAT TRANSFER AND FLUID FLOW

The experience gained in the measurement and study of heat transfer and fluid flow and its application to the design of nuclear plant has demonstrated the important influence that attention to these factors can have in designing and operating plant to achieve optimum economic performance. An industrial survey was carried out to assess how far an extension of the Authority's own programme on heat transfer and fluid flow would assist in the design and operation of such plant as boilers, condensers, air-coolers and other heat exchange plant, gas/liquid contactors, stills and chemical reactors. Discussions with firms in the chemical, process and power industries identified a number of design problems where the Authority could give valuable assistance.

A design information service and a consultancy and testing service, based at Harwell, are now being offered to industrial firms. Firms making use of the former service receive six confidential design reports each year on agreed subjects for a subscription of £1,000 per annum. The consultancy and testing service makes the staff and facilities of the Authority in this field available to industry for sponsored work for which an appropriate charge will be made. A supporting programme of more general research ensures the continuing usefulness of the service to industry. Initially, much of the effort is being devoted to two-phase (e.g. gas/liquid) flow problems.

CARBON FIBRES

The Royal Aircraft Establishment, Farnborough, evolved a process for making very strong, stiff carbon fibres on the laboratory scale and requested Harwell to provide experimental fibres on the hundredweight scale to government laboratories and industrial firms who are developing their use for reinforcing plastics. In the engineering industries interest in these new lightweight materials is growing, and Harwell had earlier found several uses in the nuclear field. Know-how was communicated by Harwell and R.A.E. to Rolls Royce Ltd., who are developing carbon fibre reinforced plastics for use in advanced gas turbines, as well as to Morganite Research and Development Ltd. and Courtaulds Ltd. The National Research Development Corporation is responsible for these commercial developments and a joint development and exploitation programme was established between the Corporation, the Authority and R.A.E.

Harwell has shown that metals such as aluminium and copper can be reinforced with carbon fibres, that by incorporating them into boro-silicate glass the fracture characteristics can be modified, thus turning the glass into a tough material, and also has shown how to ensure good adhesion between such fibres and synthetic resins when producing reinforced plastics.

Carbon fibres produced in the U.K. have aroused widespread interest overseas and a major part of the joint programme involves research and development work to establish the data for building and operating large-scale production plants as economically as possible. Non-destructive testing techniques are also being developed for application to resin-bonded carbon fibre structures.

Atmospheric pollution

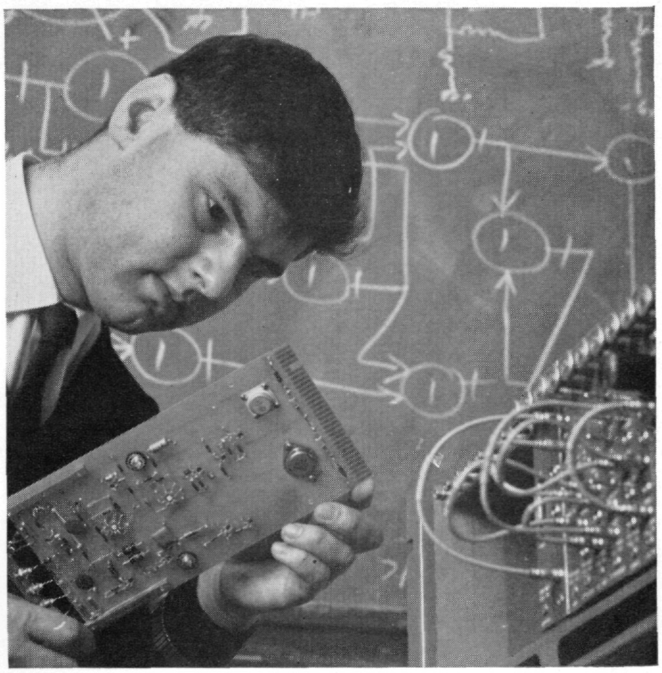
It is estimated that atmospheric pollution costs Britain about £350 million a year, including the direct costs of cleaning and damage to buildings and other indirect costs.

Many of the problems encountered in protecting workers and the general public against the hazards of radiation and radioactive materials are problems of the environment analogous to those in other fields such as public health, agriculture and meteorology.

The Minister of Technology approved (in July, 1967) a research programme at Harwell on atmospheric pollution which included studies of the physical and chemical interactions of pollutant gases and aerosols. This programme is being carried out in collaboration with the Warren Spring Laboratory.

The main concern so far has been the problem of industrial mists. With the help of Imperial Chemical Industries, Ltd., the Constantine College of Technology, the Teesside Airport Authority and local health authorities, aerosol samples were collected at five sampling stations in the Teesside area and analysed for a wide range of electrolytes which could be responsible for stabilising the mist droplets. A high concentration of ammonium sulphate was found both in gross samples of mist and in individual droplets; it was also observed in the anti-cyclonic summer haze in the non-industrial area surrounding Harwell. A laboratory study was started into the uptake of sulphur dioxide and ammonia in growing droplets of water and on the relationship between visibility loss and the size distribution of droplets in fog.

One technique used by Harwell scientists in this project is to collect airborne particles and droplets on spiders' filaments for subsequent examination. Some of the fibres produced by spiders are very thin—less than 1/10,000th of a millimetre across and invisible in a normal microscope. These cause the minimum change to the passing airflow or to the shape of the deposited droplets. The "web" is produced by placing a spider on a metal frame which is rotated as the spider lowers itself by a fine safety fibre.



The main objective of the Harwell Centre is to carry out and encourage applied R. & D. to improve and extend non-destructive techniques in British industry. In the photograph a range of advanced modules is being prepared for use in ultrasonic inspection.

NON-DESTRUCTIVE TESTING CENTRE

The Non-Destructive Testing Centre has made rapid progress towards achieving its triple objective:

- solving specific materials inspection problems for industry;
- initiating industry-orientated research projects with wider and longer-term aims;
- providing a clearing-house for information and advice.

About 100 technical problems were put to the Centre by industry and in most cases the solution recommended made use of existing equipment or services. Twenty quotations for technical programmes of sponsored work were prepared and eight sponsored projects were completed or are in progress for the firms concerned (on a confidential basis).

Industry-orientated development work includes the study of new or improved inspection methods and the way in which ultrasonic energy interacts with materials. Typical examples of possible new methods under study are the use of microwaves; ultrasonic micrometry and profile monitoring; ultrasonic signal correlation; and the plotting of electrode potentials. Improvements are being sought in magnetic inspection methods; high-speed radiography; high definition radiography; and ultrasonic transducer characterisation.

The information service dealt with 300 enquiries and initiated a monthly "current awareness" bulletin, NDT/INFO, which is published by Iliffe Science and Technology Publications, Ltd.

MATERIALS

The Materials Technology Bureau was set up to pass on knowledge and share experience with industry over the whole field of advanced materials which the Authority have produced by both conventional and non-conventional techniques. This covers manufacture and testing not only of metals and ceramics but also of rubber, plastics, adhesives, surface coatings, composites and foams, all of which have to give performances beyond those for normal industrial products.

The Bureau is being increasingly used by industry; last year it dealt with over 200 enquiries from 60 separate firms. These enquiries revealed a strong need for more literature, reports and new-product testing. The demands on the Bureau to undertake experimental investigations, on repayment, grew steadily.

Desalination

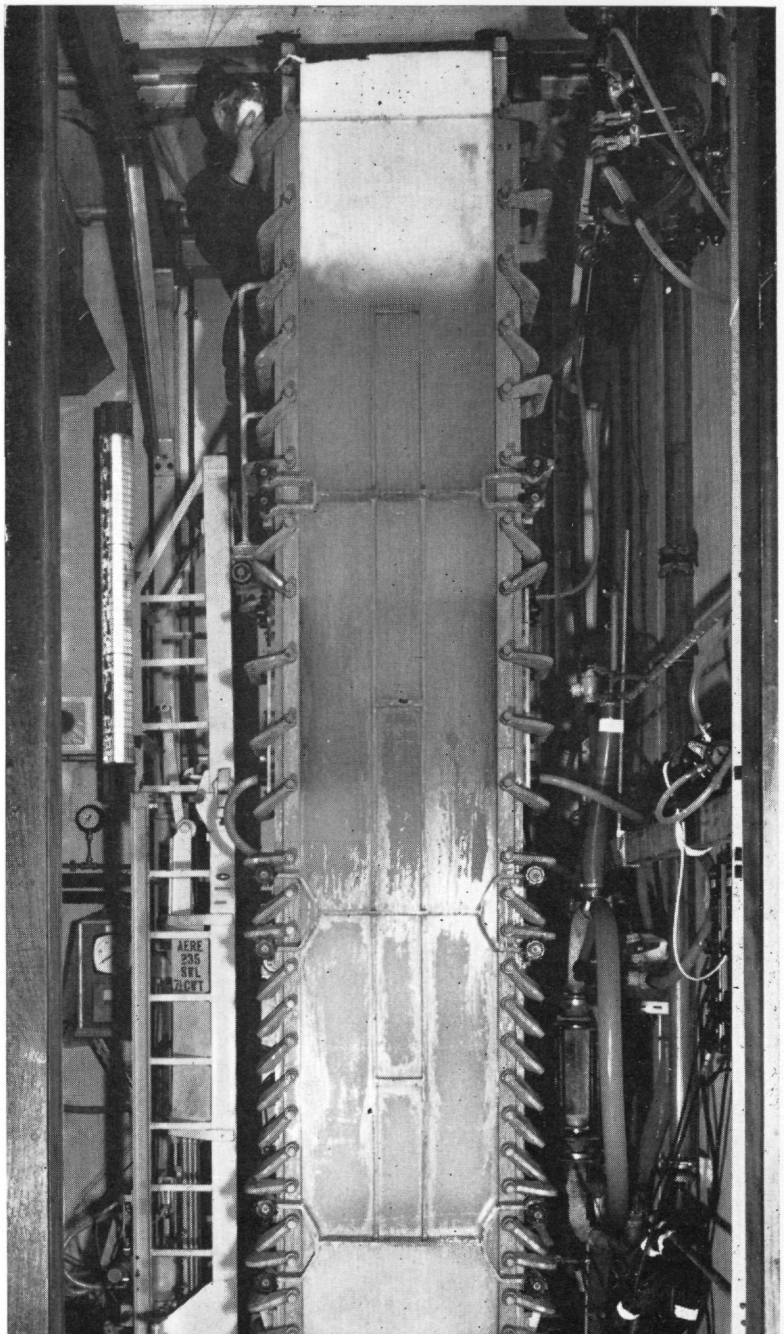
The Authority programme of desalination has concentrated on the further development of the *multi-stage flash distillation* process (M.S.F.) in collaboration with Weir Westgarth Limited and on exploring alternative methods of producing fresh water from brackish and sea water. The original three-year research and development programme was due to end early in 1968, but in December the Minister of Technology, after an appraisal by the Programmes Analysis Unit, approved an extension to 1971 at a cost of £4 million.

Detailed design improvements in M.S.F. plant resulting from the collaborative programme with Weir Westgarth Limited are now being incorporated in commercial designs with marked success in overseas markets. Weir Westgarth's seawater test facility at Troon was opened and the operation there of large test rigs confirmed many of the improvements in flashing and heat transfer arising from earlier work at Harwell and Winfrith.

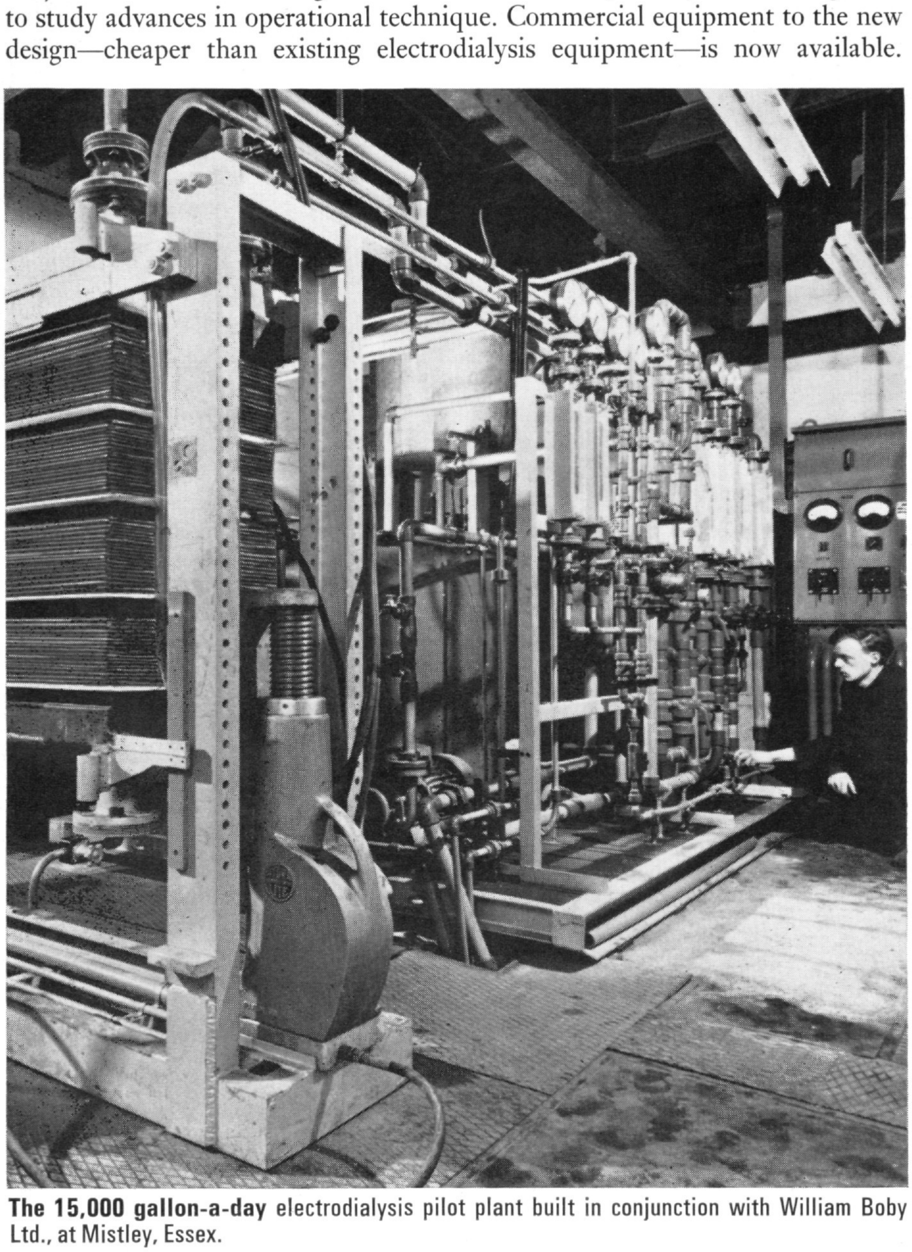
Large experimental equipment was built to further the development of the *freezing* process using butane as a secondary refrigerant. Experiments are being performed at Harwell on the 700 gallon-a-day scale and Simon Carves Limited will use the results when designing larger scale experiments.

The Authority continued to support work on the *reverse osmosis* process, both in university departments and industrial laboratories. A joint programme was formulated with Portals Holdings Limited, aimed at the manufacture of small-scale prototype equipment. (A.E.A. are collaborating with the Water Pollution Research Laboratory in applying the principle of reverse osmosis to the purification of water polluted by industrial and sewage effluents).

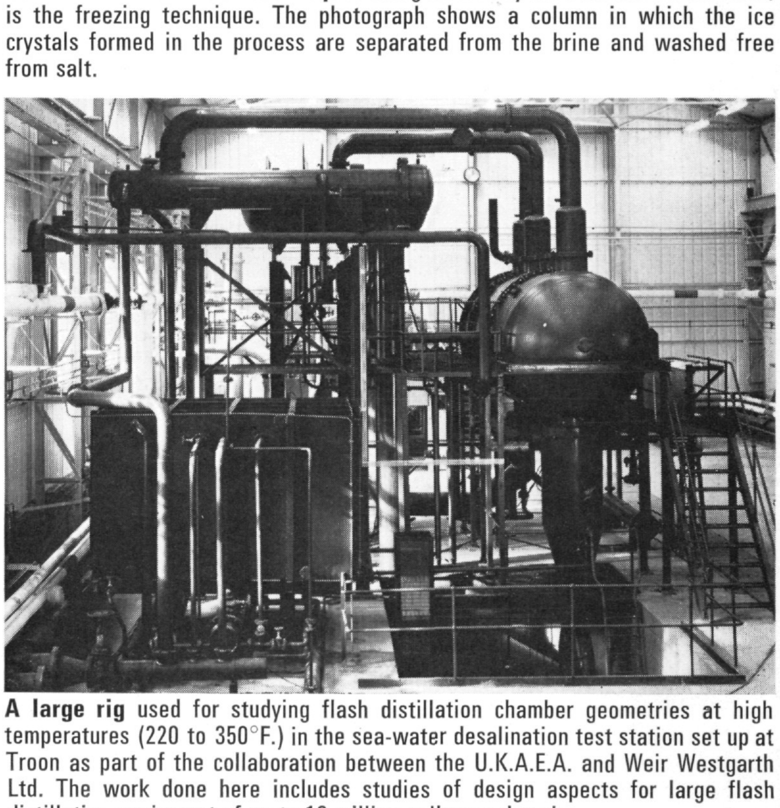
The 50,000 gallon-a-day *electrodialysis* pilot plant built to the improved design developed by William Boby Ltd., continued to operate satisfactorily in conjunction with Tendering Hundreds Water Board, Essex, and is being used to study advances in operational technique. Commercial equipment to the new design—cheaper than existing electrodialysis equipment—is now available.



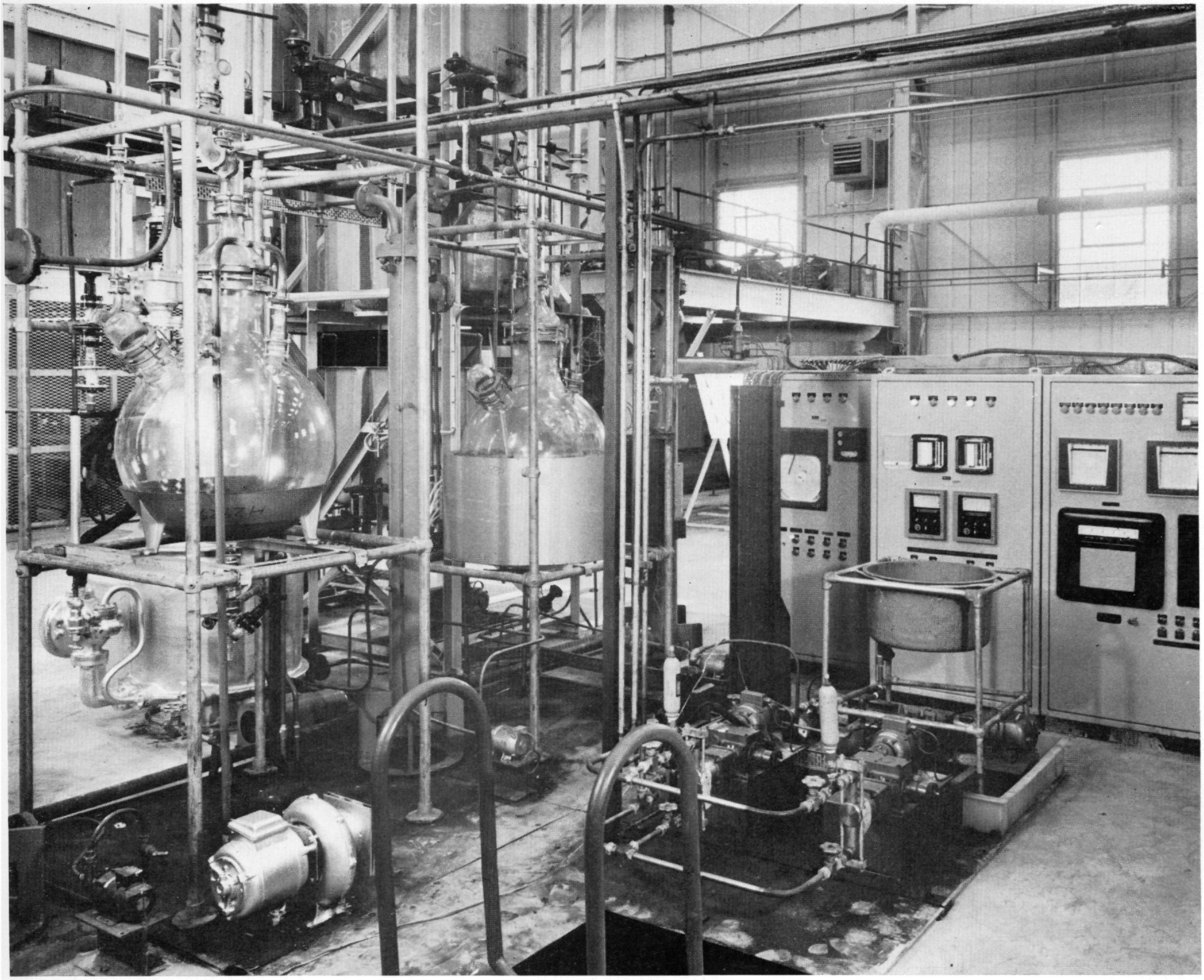
One of the desalination techniques being studied by the U.K.A.E.A. at Harwell, is the freezing technique. The photograph shows a column in which the ice crystals formed in the process are separated from the brine and washed free from salt.



The 15,000 gallon-a-day electrodialysis pilot plant built in conjunction with William Boby Ltd., at Mistley, Essex.



A large rig used for studying flash distillation chamber geometries at high temperatures (220 to 350°F.) in the sea-water desalination test station set up at Troon as part of the collaboration between the U.K.A.E.A. and Weir Westgarth Ltd. The work done here includes studies of design aspects for large flash distillation equipment of up to 10 million gallons-a-day size.



A large rig at Troon, Scotland, for studying corrosion of construction materials used for sea-water flash distillation plants.

DESALINATION PLANT

Dealing with water of 500-35,000 p.p.m. saline content.

Plants completed or contracts concluded since May, 1967 by the Authority's industrial collaborators

Place	Gallons per day	Contract (or Completion) Date	Firm
FLASH DISTILLATION			
Qatar	2 x 1 million	May 1967 completed August 1968	WEIR WESTGARTH LTD.
Australia-Hammersley Iran	2 x 200,000	June 1967 *completed*	WEIR WESTGARTH LTD.
Malta Electricity Board	3 x 1.2 million	November 1967	WEIR WESTGARTH LTD.
Jersey	1.5 million	July 1968	WEIR WESTGARTH LTD.
Abu Dhabi	2 x 2 million	August 1968	WEIR WESTGARTH LTD.
ELECTRODIALYSIS			
*Vieste, Italy	240,000	March 1968	WILLIAM BOBY LTD.
*Bid Boland, Iran	175,000	May 1968	WILLIAM BOBY LTD.

**Brackish water.*

"Mr. Andrew C. Smith, chairman of Weir Westgarth, said that from a national point of view the company's three years' collaboration with the U.K.A.E.A. was now starting to pay off in world markets and that it had assured the U.K. a place among the top international suppliers of such plant."

"The Financial Times", 8th August, 1968

INTERNATIONAL OCCASIONS

Extensive support was given by the Authority to the British Nuclear Export Executive (B.N.X.) in their promotion of advanced gas-cooled reactors overseas as well as to the British nuclear industry in the same field.

Following discussions between B.N.X. and a Norwegian study group, an agreement was signed between the Authority and the Norwegian Institute for Atomic Energy. (The group is studying both the boiling water reactor and the A.G.R. for power stations constructed and operated under Norwegian conditions. Among the members of the study group is the State Electricity Authority). The Authority commenced co-operating under this agreement in the study of the A.G.R. system for construction in both cave and open sites in Norway.

Technical support continued to be given to Brown Boveri et Cie AG, Mannheim, in exploitation of the A.G.R. in West Germany under the co-operation agreement signed last year with Atomic Power Construction Ltd. and Brown Boveri.

Discussions have been held with both U.K. and Japanese industry on the possibility of licensing the advanced gas-cooled reactor for sale in Japan.

The successful completion and commissioning of the S.G.H.W.R. power station at Winfrith now means that with the A.G.R. the United Kingdom has two thermal reactor systems available to meet the wide range of requirements of potential customers. Discussions were held with fourteen potential users who showed an interest in the S.G.H.W.R. system.

An agreement was signed between the Authority and the Power Reactor and Nuclear Fuel Development Corporation of Japan for the purchase by the Corporation of scientific information concerned with the performance and physics of the steam generating heavy water reactor and associated experimental facilities. It will be used by the Corporation in support of their work on the development of an advanced thermal reactor in Japan.

The research reactor for Switzerland built by Fairey Engineering Ltd. with support from the Authority was formally handed over and is operating satisfactorily.

The Authority continued to give strong support to the activities of the International Atomic Energy Agency. In all, the Authority were represented at some 38 symposia and expert panel meetings of the Agency during the year on subjects which included heavy water power reactors, physics and related safety problems of fast reactors and fuel burn-up predictions in thermal reactors.

Progress in the development and operation of the European Nuclear Energy Agency reactor experiment, "Dragon", continued satisfactorily. Arrangements were made with the other signatories to this joint project by which it is kept in being until 31st December, 1968*.

The E.N.E.A. "Top Level Group" was re-activated to consider scope for co-operation in heavy water reactors and gas-cooled and steam-cooled fast reactors.

Mr. D. E. H. Peirson, Secretary of the Authority, led the U.K. team at a meeting of the U.K./Euratom Joint Working Group (which reports to the Ministerial Continuing Committee for Co-operation in Brussels in January, 1968.)

Among the countries with whom collaboration continued were Australia, Austria, Brazil, Canada, the Federal Republic of Germany, Finland, France, Greece, Italy, Japan, New Zealand, Norway, Pakistan, Portugal, Roumania, South Africa, Spain, Sweden, the U.S.A. and the U.S.S.R.

* In July, 1968, the Council of Ministers of the European Community approved a proposal on the redistribution of costs of the "Dragon" Project which will enable it to continue until 31st March, 1970. Britain's share of costs was increased from 40.8 per cent. to 46.8 per cent.; Euratom's reduced from 46 per cent. to 40 per cent. Austria, Switzerland, Denmark, Norway and Sweden share the other 13.2.

Over 80 experts from the atomic energy and electricity industries of 26 overseas countries attended the formal opening by H.R.H. the Prince Philip of the Steam Generating Heavy Water Reactor at Winfrith on 23rd February, 1968. The photographs below were taken during their visit to the S.G.H.W.R. exhibition, which remains in situ at Winfrith as an aid to the sales promotion of this system.

Left to right: Mr. J. Lorne Gray, President of Atomic Energy of Canada, Ltd.; Mr. R. V. Moore, Managing Director, Reactor Group, U.K.A.E.A.; Sir Stanley Brown, Chairman of the Central Electricity Generating Board; and Mr. F. G. Johnson, U.K.A.E.A.

Above:
Dr. Karl Wirtz (left), Chairman of the Scientific Council, Karlsruhe, Federal Republic of Germany, with Dr. C. G. Campbell, U.K.A.E.A.

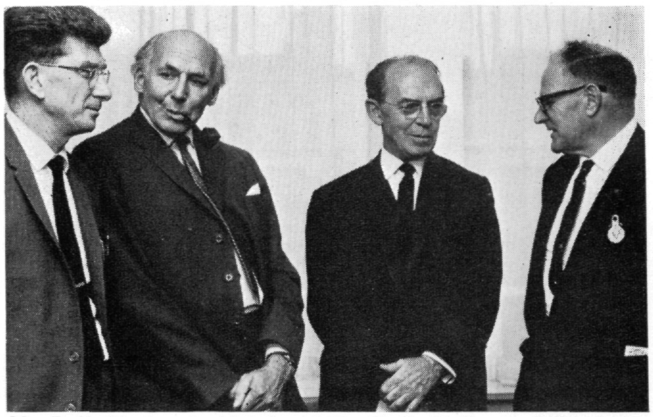
Right:
Mr. A. A. Farmer, U.K.A.E.A., describes features of an S.G.H.W.R. model to Mr. H. Murata, Director, Power Reactor and Nuclear Fuel Development Corporation, Japan.

Commissioner W. E. Johnson, of the U.S. Atomic Energy Commission (centre) visited the P.F.R. site at Dounreay in April, 1968. Mr. J. C. C. Stewart, U.K.A.E.A. Member for Reactors, is on the left.

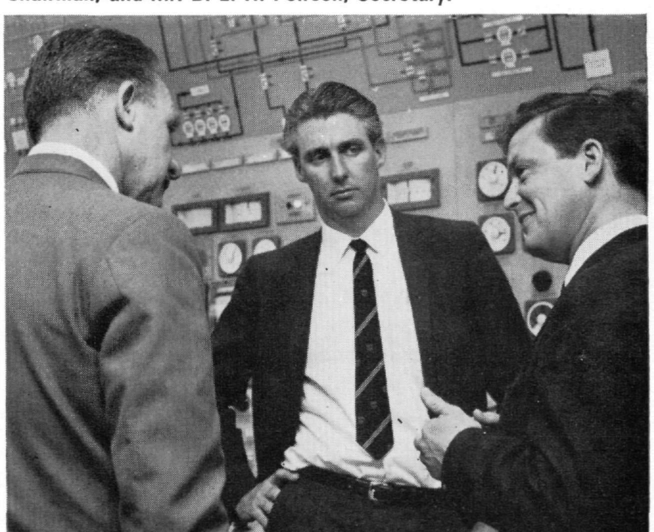
In February, 1968, Dr. J. M. Hill, Chairman of the Authority, and Mr. H. Murata, of the Power Reactor Development Corporation, Japan, signed an agreement for the purchase by the Corporation of scientific information on S.G.H.W.R.

The Rt. Hon. Anthony Wedgwood Benn, Minister of Technology, received the Danish Prime Minister on the Authority stand at a British engineering exhibition in Copenhagen, in June, 1968.

Nuclear power was the theme of an Authority exhibit at a trade fair in Wellington (August, 1967). Sir Bernard Fergusson, Governor-General of New Zealand, is seen with Dr. Michael Davis, U.K.A.E.A.



Mr. E. B. Mackenzie (right) and Mr. G. R. McKenzie (left) of the New Zealand Electricity Department, visited the Authority in August, 1968. They are seen with Sir Charles Cunningham, Deputy Chairman, and Mr. D. E. H. Peirson, Secretary.



A team of Australian power officials visited Winfrith during a tour of nuclear installations in the U.K. Back to camera is Mr. F. H. Carr, of the Australian A.E.C.

Fuel

A.G.R. A uranium oxide fuel pellet for the Advanced Gas-Cooled Reactor. Each pellet will produce as much electricity as one ton of coal.

The work-load of the Production Group's factories increased during the year under review, mainly as a result of continuing preparations for the full-scale manufacture of oxide fuel to be used in commercial advanced gas-cooled reactors.

In November, 1967, a section of the Capenhurst gaseous diffusion plant which had been shut down since 1962 was successfully re-commissioned. This was the first stage in the expansion of the capacity to produce uranium at low enrichment for oxide fuel. Modification of the larger process units continued and the first will become operational in the autumn of 1968. The capacity of the completed project will meet the needs of the first three commercial A.G.R. stations: Dungeness 'B', Hinkley 'B' and Hunterston 'B'.

Further increases in separative work capacity will be needed during the 1970's to meet the needs of subsequent stations. The prototype of a larger separation unit is being manufactured and will be tested this year.

Development of the use of centrifuges for possible use in isotope separation continued.

The main production effort at the Springfields factory continued to be devoted to the manufacture of magnox fuel elements. No initial fuel charges for reactors were required, but replacement fuel was supplied for all the 22 reactors of this type operating in the United Kingdom as well as for the reactors at Tokai Mura in Japan and Latina in Italy. Production in 1967/68 was 8 per cent above that in 1966/67.

The three new uranium oxide fuel plants will be commissioned this autumn and will become fully operational by the end of the year.

The prototype uranium hexafluoride manufacturing plant continued to be used both to increase the efficiency of the process and to produce the feed material for the Capenhurst diffusion plant. Early difficulties have been overcome and improvements in the process have increased the output by more than 50 per cent over that of the original design. The results of this work were embodied in the design of a large hexafluoride plant which was constructed by the Works' personnel and completed in February, 1968.

The quantity of irradiated magnox fuel reprocessed at Windscale during the year was 8 per cent. greater than in 1966/67. This was achieved with a further decrease in operational manpower.

The value of export sales in the year was £4.7 million. Many of the major contracts extend over a number of years and in these cases this total figure includes only the value of the business completed in 1967/68.

Business was done with the following countries:—Australia, Belgium, Canada, Denmark, France, W. Germany, Holland, Italy, Japan, Norway, Rumania, Sweden and U.S.A.

The more important items were:—

(a) supply to Japan of replacement magnox fuel for the Tokai Mura reactor;

(b) supply to Italy of replacement magnox fuel for the Latina reactor;

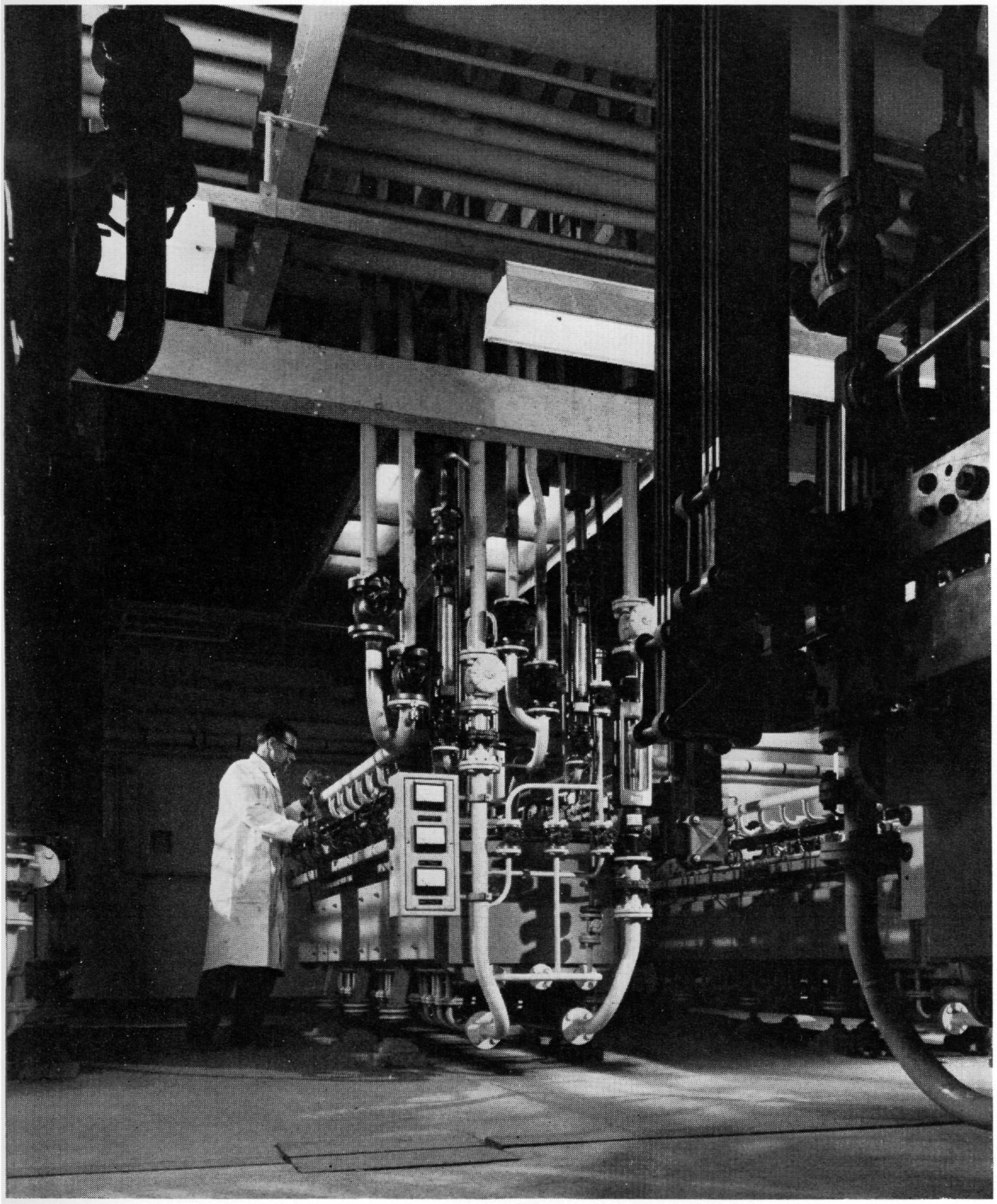
(c) reprocessing of irradiated magnox fuel from the Latina reactor;

(d) supply to Italy of experimental plutonium fuel for the Garigliano reactor;

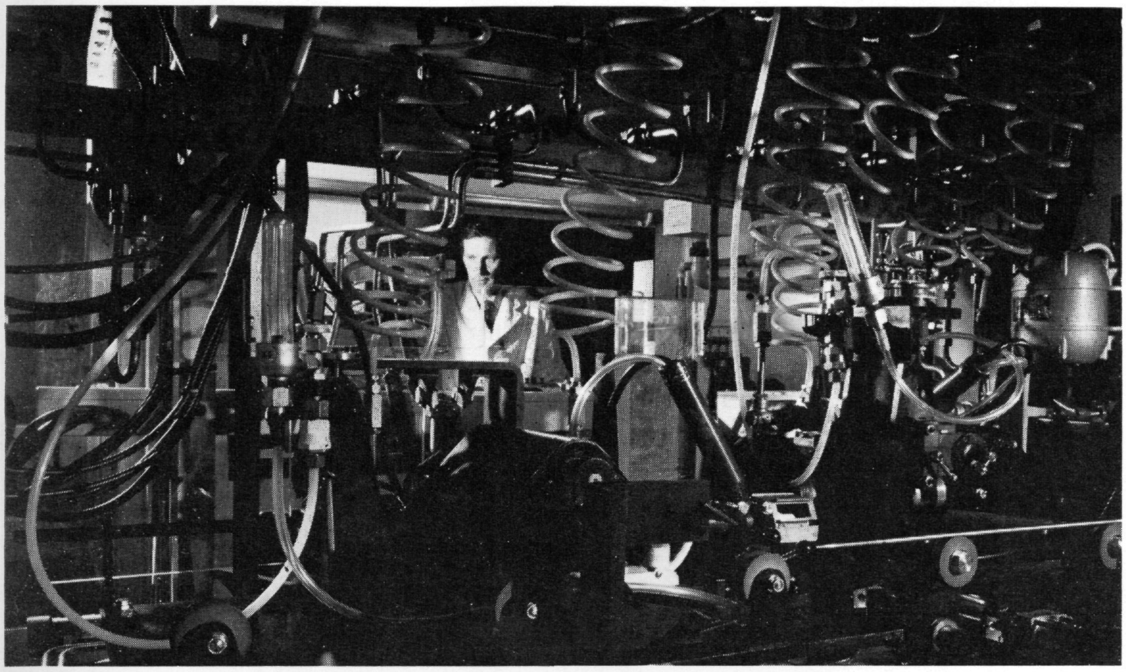
(e) supply to Belgium of plutonium oxide;

(f) supply to Sweden of enriched uranium oxide powder for the Marviken reactor.

A joint company in Italy, Combustibili Nucleari, has been formed with Societa Minerali Radioattivi Energia Nucleare. The joint company in Germany, Nukleardienst, has proved of assistance in the preparation of nuclear fuel services offers for advanced gas-cooled reactors.

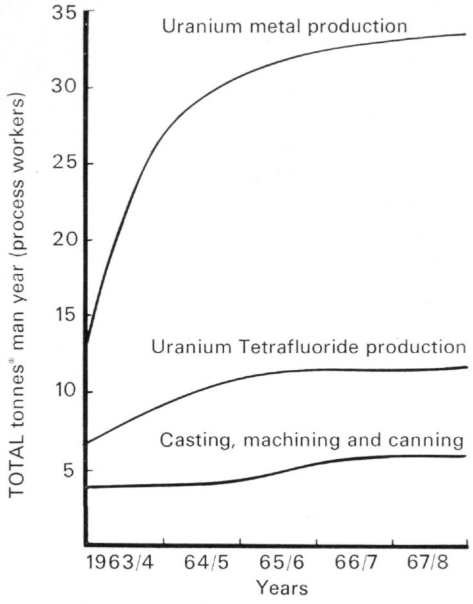


"Hex" The new uranium hexafluoride plant has been installed at Springfields to meet the additional productive capacity required for the 8,400 megawatts of Advanced Gas-Cooled Reactors to be commissioned by 1975 and to meet export demands.



Aldermaston A small-scale plant has been set up at Aldermaston for development studies on the manufacturing processes of fuel for the Prototype Fast Reactor. It will also make experimental fuel sub-assemblies for the P.F.R.

Fig. 1 Productivity at Springfields
Output per man year (process workers)



*1 tonne = 1000 kilograms

Fig. 2 Productivity at Windscale
Output per man year (process workers)

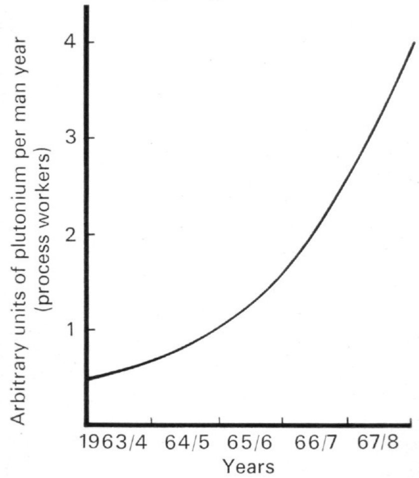
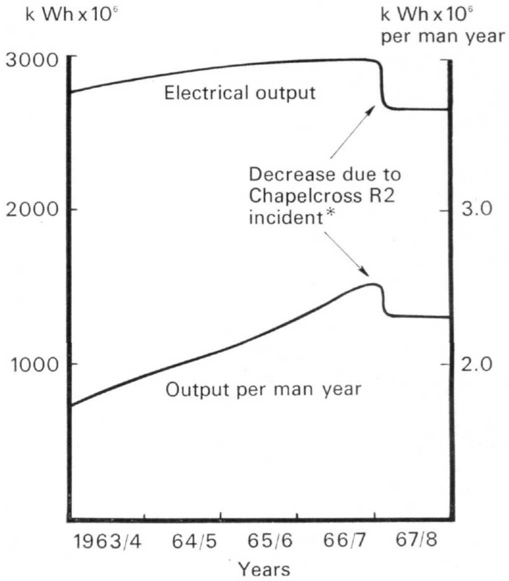


Fig. 3 Output and productivity at Calder and Chapelcross
Electrical output / Output per man year



Experimental fuel in one channel of Chapelcross reactor No. 2 melted on 11th May, 1967. This was the first major set-back in eleven years' successful operation of the Calder-type reactors. It was announced in July, 1968, that the channel had been cleared but that further remedial action would be necessary before the reactor could go back on power.

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