Atom'66

An illustrated summary of the twelfth annual report of the United Kingdom Atomic Energy Authority from 1st April 1965 to 31st March 1966

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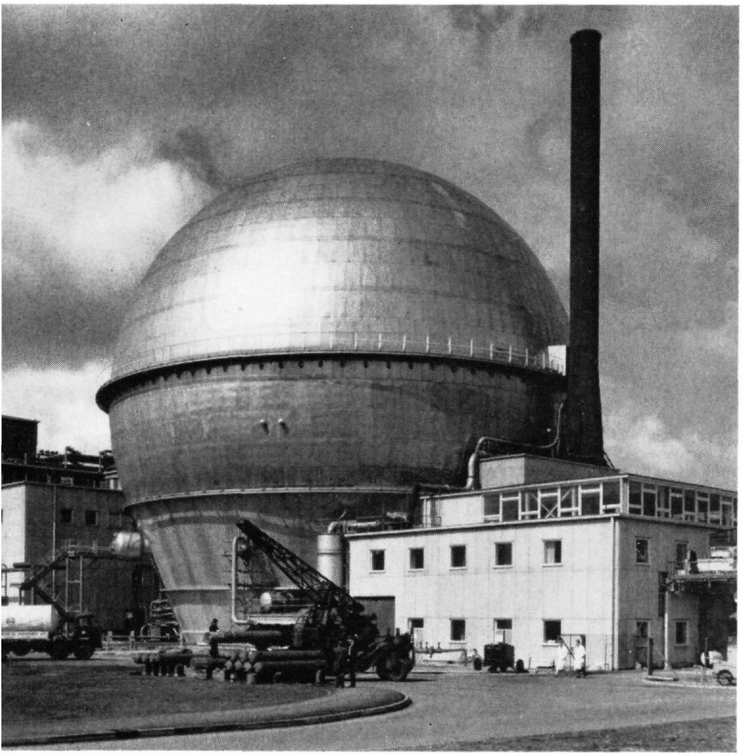
THE UNITED KINGDOM ATOMIC ENERGY AUTHORITY

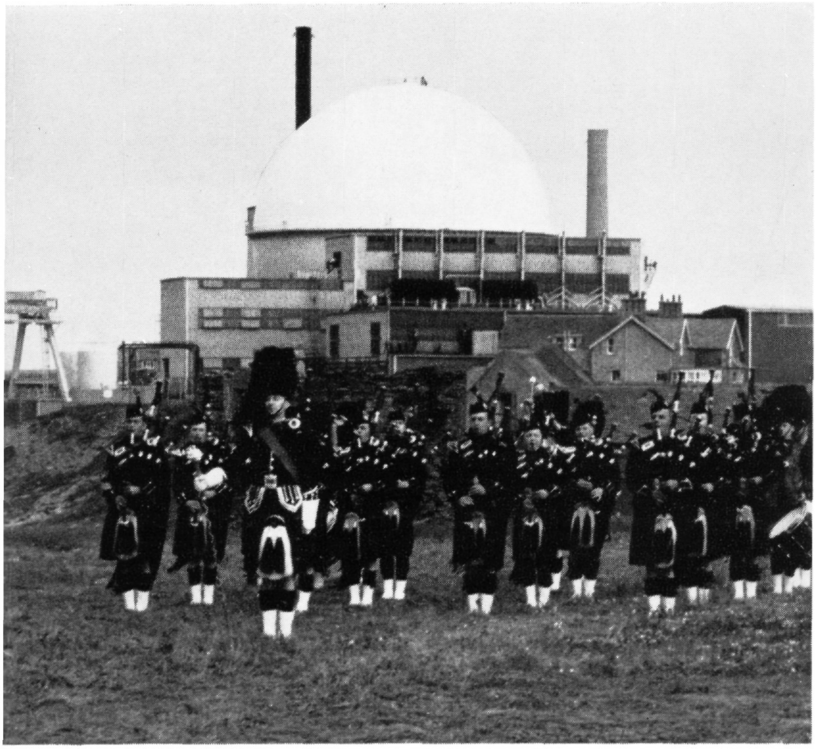


The Advanced Gas-Cooled Reactor at Windscale. Britain's 1970-75 nuclear power programme will be based on this reactor system.

H.R.H. Princess Alexandra visited a nuclear power exhibit organised by the Authority and the British Nuclear Forum in Tokyo in September, 1965.

The year ended 31st March, 1966, was a year of decisions of great importance in the nuclear energy field. These decisions concerned the Advanced Gas-Cooled Reactor (A.G.R.), the size of the nuclear power programme, the marine propulsion programme, the reactivation of Capenhurst, and the construction and siting of the Prototype Fast Reactor. These decisions will direct the course of the Atomic Energy Authority's activities for a number of years to come.

Review of the year: 1st April, 1965 to 31st March, 1966



The building (by 1970) of a 250 Megawatt Prototype Fast Reactor at Dounreay was approved in February, 1966. The picture was taken during the site-opening ceremony.

To provide enriched uranium for the second nuclear power programme the Capenhurst plant is to be modernised.

On 25th May, 1965, the Minister of Power announced in the House of Commons that he had accepted a recommendation from the Central Electricity Generating Board (C.E.G.B.) that an Advanced Gas-Cooled Reactor system should be adopted at Dungeness "B", this reactor having shown clear economic and technical advantages over the alternative systems and having a good potential for further development. This statement was amplified at the end of July, 1965, by the issue by C.E.G.B. of a detailed appraisal of the technical and economic aspects of Dungeness "B". This showed that the generating cost from Dungeness "B" at 75 per cent. load factor and 20-year life per unit sent out, would compare favourably with generating costs from the best boiling water reactor (B.W.R.) bid and from comparable stations burning coal or oil at British market prices. **It also forecast that over a five-year period (the longest period for which C.E.G.B. were prepared to forecast) the cost advantage of the A.G.R. was likely to increase rather than diminish. The reduction in total generating cost which might be achieved within this period was estimated to be about 20 per cent.**

The White Paper on Fuel Policy presented to Parliament in October, 1965, announced the decision of Her Majesty's Government that for planning purposes it should be assumed that on average over the six years 1970–75 about one nuclear power station a year would be commissioned, starting in 1970 with Dungeness "B" and possibly including a second Scottish station. The programme would be based on the A.G.R., but the government did not exclude the possibility of another reactor type making a contribution. It was estimated that on these assumptions, and with further developments in nuclear technology and expected increases in the size of stations, a total of 8,000 Megawatts (electrical) might be in commission under the second nuclear power programme by 1975.

On 9th December, 1965, the Minister of Technology announced in the House of Commons the government's decision that **the Authority's Capenhurst plant should be modernised and reactivated to supply enriched uranium for the manufacture of fuel for the second nuclear power programme.** The minister explained that although the Capenhurst product would initially be more expensive than enriched uranium from the United States, the Authority had designed modifications to the Capenhurst plant that would greatly improve efficiency of production and had forecast that the gap between U.S. and Capenhurst prices should narrow progressively during the 1970's.

On 9th February, 1966, the Minister of Technology announced a major decision in the progress towards commercial fast reactors. He told the House of Commons that the government had approved **the construction of a 250 Megawatts (electrical) Prototype Fast Reactor** and had decided that it should be built at Dounreay. The fuel production plant would be at Windscale.

On the marine side the President of the Board of Trade stated on 29th July, 1965, that the government had decided that the prospects of building a nuclear ship that would be economic to operate were as yet too remote to justify the large government expenditure necessary to build a prototype. The Authority would, however, continue to explore methods of improving the economics of the present types of small reactors and to examine new ways of bringing an economic nuclear merchant ship nearer.

These decisions mark out the main components of the Authority's programme for several years to come; in addition they make it necessary for the Authority to attempt to forecast what should be the shape and size of their resources thereafter. The principal target of the Authority's research and development effort has been economically competitive nuclear power. Now that this is within foreseeable distance of being achieved, it is natural that the research and development effort should be reduced. Major reviews have been carried out within the Authority of both the research and the reactor development programmes in order to determine what resources will be necessary in from five to ten years' time. At the end of the year 1965/66 these reviews were under consideration by Members.

The Authority's programme of research and development of nuclear warheads for the services continued as authorised by the government. Collaboration with the U.S. was actively maintained and on 10th September, 1965, an underground test of a British nuclear device was successfully carried out by a joint U.S./U.K. team at the Atomic Energy Commission's Nevada test site.

In December, 1965, the Authority published a report on "The Detection and Recognition of Underground Explosions", which reviewed work carried out by the Weapons Group since 1958.

Nuclear power stations in the United Kingdom, including Calder Hall and Chapelcross, continued to perform satisfactorily and by the end of the year had supplied a total of more than 50,000 million units of electricity to the grid. Of the stations in the first C.E.G.B. programme, the second reactor at Hinkley Point, the two reactors at Dungeness "A", and the two reactors at Sizewell were commissioned during the year.

DEPLOYMENT OF RESOURCES: NUCLEAR CIVIL RESEARCH AND DEVELOPMENT

	Expenditure: £ million (approximate)				Qualified Scientists and Engineers	
	1964/65		1965/66		31.3.65	31.3.66
	Current	Capital	Current	Capital		
1 REACTOR RESEARCH AND DEVELOPMENT PROGRAMME						
Gas-Cooled Systems	9	1	8	.5	500	425
Water-Moderated Systems	5.5	4	6.5	5	480	410
Fast Systems	9	1.5	10	1	575	670
General Reactor Technology	4	.5	4.5	—	365	375
2 OTHER RESEARCH						
Basic Research	5	1.5	6	1	360	420
Health and Safety Research	1	—	1	—	120	95
Isotope Research	.5	—	.5	—	80	60
Plasma Physics and Fusion Research	3.5	1.5	3	1	200	190
	37.5	10	39.5	8.5	2,680	2,645

The signing of a contract for the supply by the Authority of a further 7,000 fuel elements for the Latina power station in Italy.

The average full power output for the year from the Windscale A.G.R. was 105 MW(heat), giving an electrical output of 35 MW(electrical) gross. Excluding reductions in power for experimental purposes, **a planned availability of 84 per cent. has been maintained since the reactor went on power over three years ago.** In the Dounreay Fast Reactor two long irradiation programmes were completed, during the second of which a new high output figure of 64 MW(heat) was achieved. Construction of the Steam Generating Heavy Water Reactor at Winfrith continued to keep to schedule.

The Authority's sales during the year totalled £35·7 million, showing a trading surplus of £2·1 million.

In 1965/66, expenditure from Parliamentary Grants on the Authority's programme of nuclear civil research and development was £48 million of which £39·5 million was current expenditure and £8·5 million was on capital facilities. The number of graduate and professional engineers and scientists employed on the programme in 1966 was 2,725 of whom 80 were doing work on repayment for other organisations.

On 13th May, 1965, the Radiochemical Centre, Amersham, celebrated its 25th anniversary with an Open Day, at which the principal guest was Sir John Cockcroft.

The diversification programme made possible by Section 4 of the Science and Technology Act, 1965, got under way during the year, with the issue by the Minister of Technology of a number of directions to the Authority. So far, just over £1 million has been budgeted for 1966/67.

The principal overseas projection of the Authority's activities during the year was the nuclear energy stand at the British Trade Fair in Tokyo in September, 1965. This coincided with the 9th General Conference of the International Atomic Energy Agency which was held in Tokyo, being the first General Conference of the Agency to be held outside Vienna. Sir William Penney gave a review of nuclear power development in the U.K. at a special meeting arranged by the Japanese Atomic Industrial Forum.

Among the many overseas visitors during the year were Professor A. M. Petrosyants, Chairman of the Union of Soviet Socialist Republics' State Committee for the Utilisation of Atomic Energy, who with four of his colleagues spent two weeks in July and August visiting Authority establishments and nuclear power stations.

One of the principal overseas orders secured by the Authority during the year was a contract for the supply of over 7,000 fuel elements for the 200 MW(electrical) Latina nuclear power station in Italy. This batch of fuel will consist of 80 tons of natural uranium and will yield an output of approximately 2,000 million kilowatt-hours.

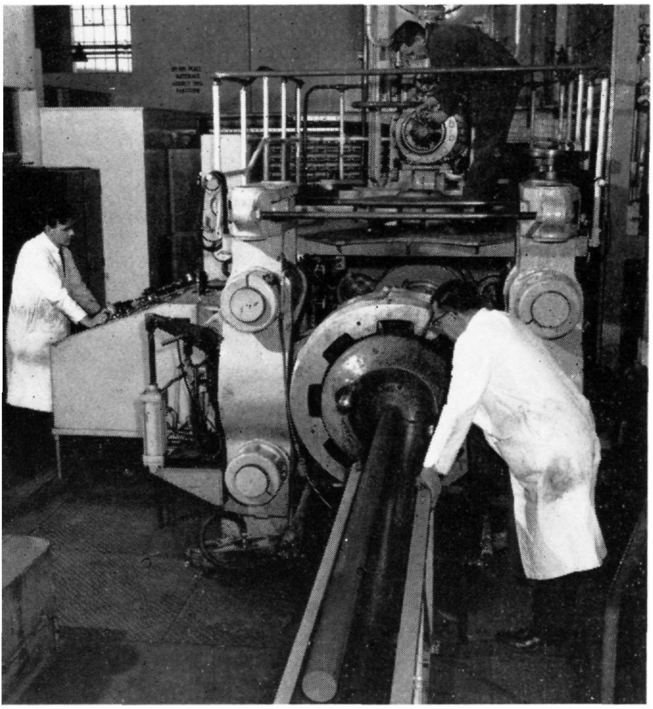
Two Finnish utilities, Imatra and Ekona, invited bids for nuclear power stations in the 300/350 MW(electrical) region. The three U.K. consortia decided not to submit bids. The Authority considered that the Steam Generating Heavy Water Reactor (S.G.H.W.) was an appropriate system to offer for the conditions applicable in Finland and accordingly submitted bids to both utilities. At the year's end the utilities were in process of deciding on their shortlists.*

During the year the Authority and the three Consortia held a number of top level discussions concerning power reactor export promotion, with the general objective of sharpening the impact abroad of British reactor systems and avoiding unnecessary competition overseas between the Consortia. At the year's end these discussions were still continuing.†

* Imatra announced their short list in May, 1966; the Authority were not included.

† The formation of the British Nuclear Export Executive was announced on 10th June, 1966. The members are the Authority; Atomic Power Constructions Ltd.; Nuclear Design and Construction Ltd.; and The Nuclear Power Group Ltd. The offices of the Executive ("B.N.X.") are at Dorland House, 14/16 Regent St., London, S.W.1.

Nuclear power: the future



An extrusion press at Harwell for the production of graphite fuel tubes for the "Dragon" reactor.

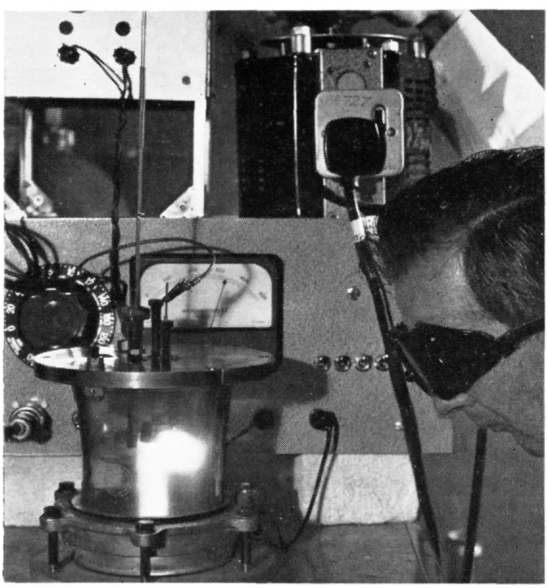
A review has been carried out of the Authority's future programme for the development of commercial power reactors.

The main objectives of the review were:—

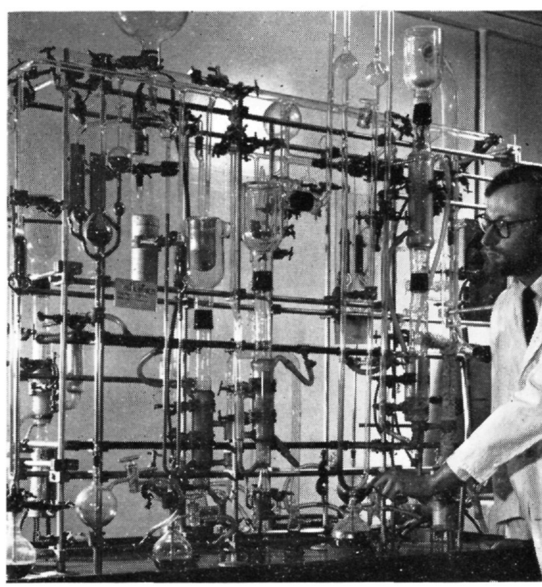
to assess the role of nuclear power in the United Kingdom electricity generating system beyond 1975, and in the export market;
to make recommendations on the reactor research and development programme required to support this role.

The review has confirmed that the main emphasis in the reactor development programme should be given to:—

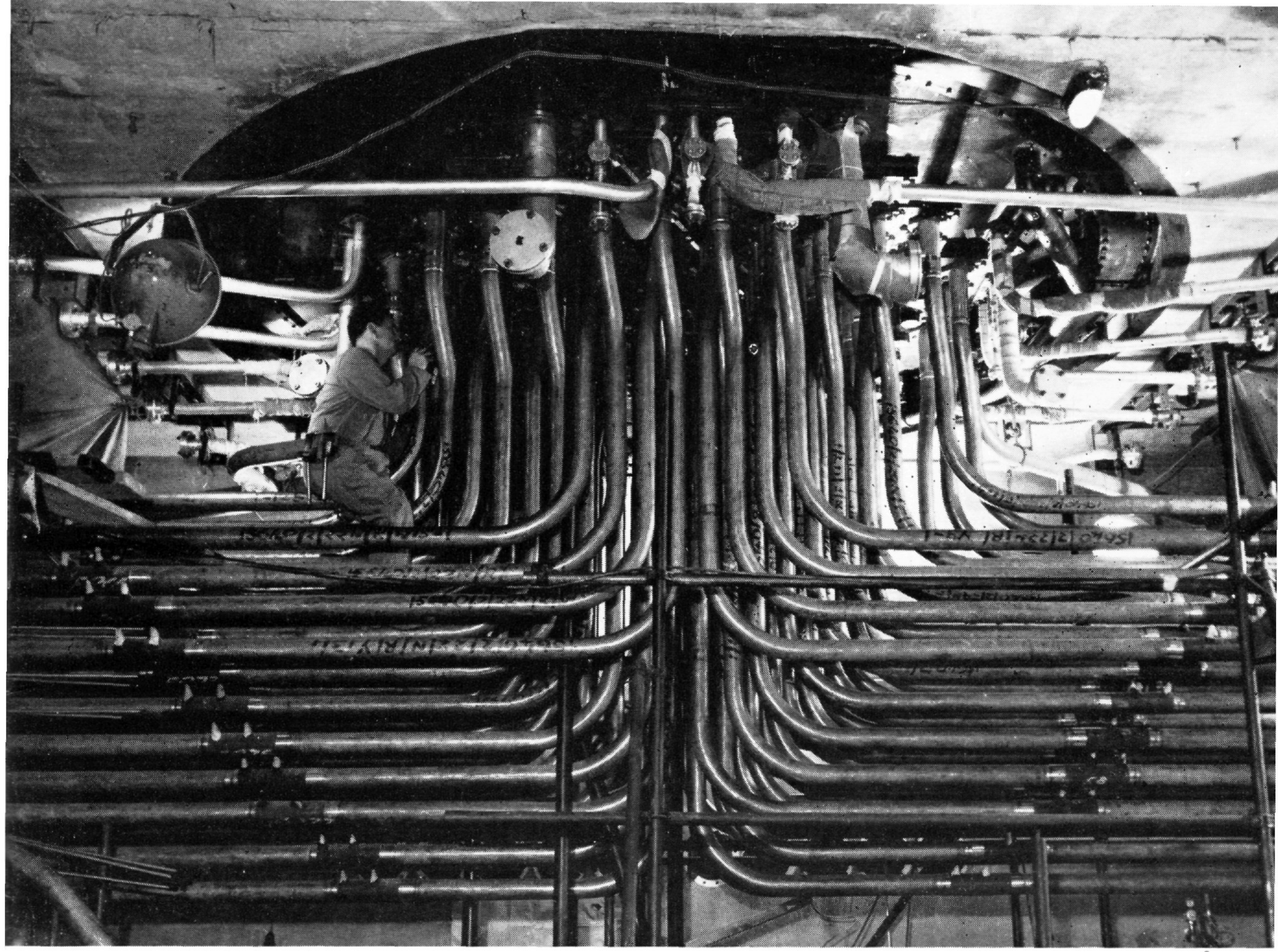
the early development of Sodium-Cooled Fast Breeder Reactors;
the full exploitation of the Advanced Gas-Cooled Reactor;
completion of the Steam Generating Heavy Water Prototype Reactor and the preparation



Plasma arc welding of miniature thermocouples at the Reactor Engineering Laboratory, Risley.



Studies of improved graphites for A.G.R. are carried out at the Reactor Materials Laboratory, Culcheth.



A view of the Steam-Generating Heavy Water Reactor at Winfrith showing feeder banks to boiling channels. This reactor is expected to be on full power by the autumn of 1967.

of commercial designs initially for the export market.

The review has shown that a very considerable reduction in the total annual cost of generating electricity would result from adopting a large nuclear power programme in the U.K. from 1975 onwards.

ADVANCED GAS-COOLED REACTORS

The second nuclear power programme (1970–75) will be based on the use of Advanced Gas-Cooled Reactors and the Authority's development work is directed towards their exploitation in this country and overseas. The development programme is fully orientated in support of the Dungeness "B" station and those to follow. Longer range work is also being instituted so that the full performance potential of the A.G.R. system can be realised.

The Windscale A.G.R. has continued to play a primary part in this work as an experimental facility. Excluding reductions in power for experimental purposes, a plant availability of 84 per cent. has been maintained since the reactor went on power over three years ago. The average full power output for the year ending 31st March, 1966, was 105 Megawatts (heat), giving an electrical output of 35 Megawatts (electrical) gross.

The replacement of the original Windscale A.G.R. fuel charge by fuel similar to that proposed for commercial A.G.R. power stations has continued. By the end of the year one quarter of the fuel channels were operating with fuel pins of the size proposed for Dungeness "B". The highest irradiation reached by a fuel pin during the year was approximately 17,000 MWd(H)/t and 10,000 MWd(H)/t in pins of the design proposed for Dungeness "B". The average burn-up from fuel in Dungeness "B" will be 18,000 MWd(H)/t.

The irradiation of deliberately damaged fuel in the Windscale A.G.R. has continued. A commercial type of fuel pin, with a small hole in the can, has been in the reactor since December, 1964, and an original type pin with a slit 1 in. long since August, 1964. They have confirmed that fuel pins with defective cans can remain in the reactor for long periods without affecting operational performance.

A further 2,000 irradiated fuel pins have been examined, and the general condition of the pins and stringer components was excellent. Almost half of these pins came from experimental stringers covering a wide range of operating conditions and designs. Other experiments due for discharge have been allowed to remain in the reactor because of the excellent results derived from earlier experiments.

The operating pressure of the Windscale A.G.R. is below that proposed for the commercial stations, but modifications are being made to experimental loops in the reactor to permit operations at 400 p.s.i. To simulate pin behaviour under high pressure, pins have been irradiated with cans in which the wall thickness has been reduced to give stress conditions similar to those predicted for commercial A.G.R.s.

Other aspects of the commercial A.G.R. core component design will be tested in a large facility under construction at Windscale. In this it will be possible to test components under simulated re-fuelling conditions and it will be used in collaboration with the Consortia. An existing facility at Springfields, previously used for work on magnox fuel elements, has been modified to make similar studies under normal commercial A.G.R. gas-flow conditions.

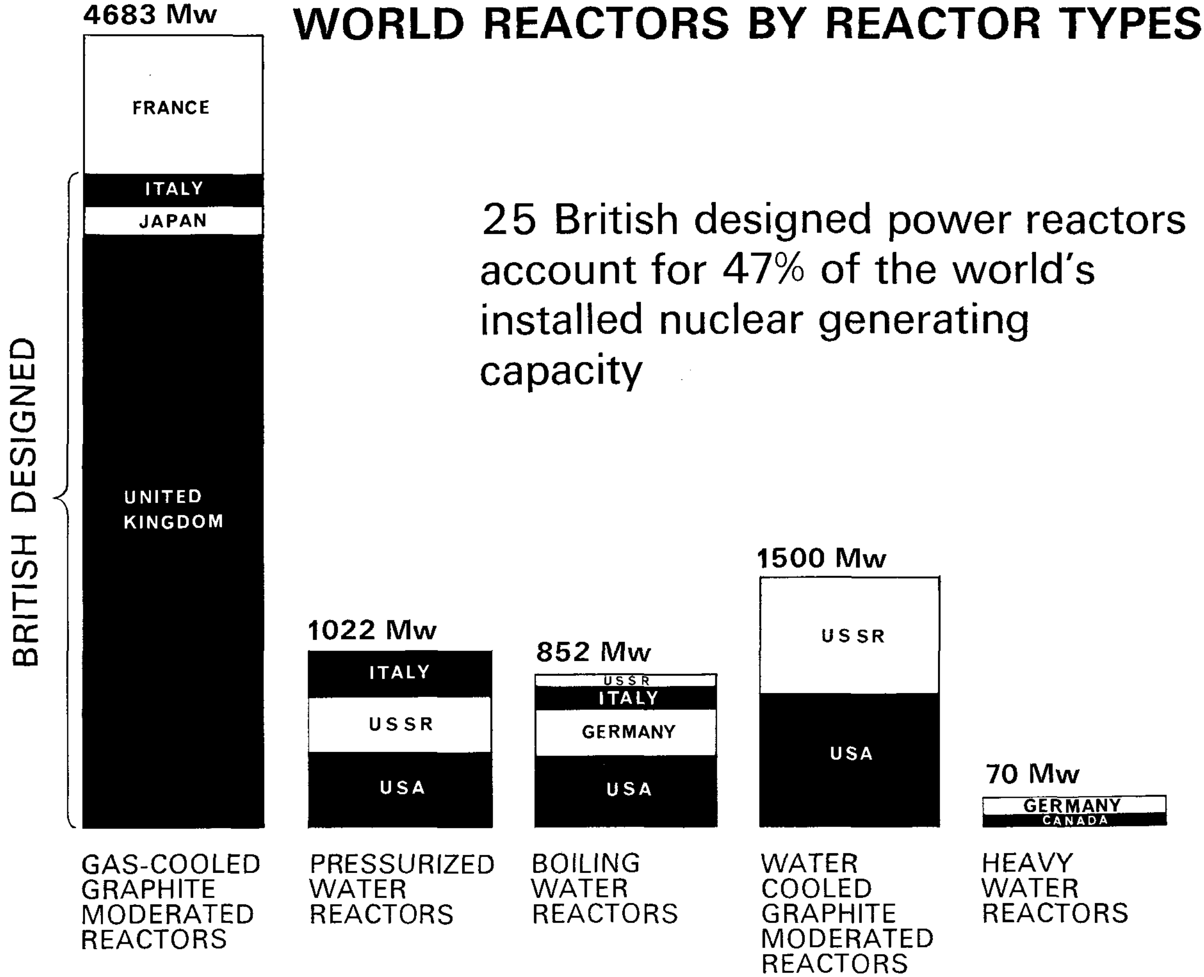
The performance of the Windscale A.G.R. refuelling machine has been excellent. Almost 400 on-power fuelling operations have been carried out since July, 1963. Little mechanical trouble has arisen and a high machine availability (90 per cent.) has been maintained.

The development of dispersed fuels for advanced designs of the A.G.R. has continued. These dispense with the need for a fuel can and are based on a dispersion of small spheres of coated uranium carbide in a matrix of silicon carbide.

Work at Culcheth and Harwell has shown that (i) changes in the dimensions of graphite blocks

Construction work in progress on the Steam-Generating Heavy Water Reactor at Winfrith (March, 1966)

WORLD REACTORS BY REACTOR TYPES



under irradiation are acceptable at higher neutron doses than are found in a commercial A.G.R.; and (ii) the corrosion of graphite by the coolant under irradiation is tolerable when the carbon dioxide contains minor additives.

The accelerated tests of graphite in the Dounreay fast reactor and materials testing reactors have been extended to greater than the life-time dose expected in the Dungeness "B" reactor and cover the temperature range 270–560°C. The dimensional changes found in the improved graphites have permitted the core designers to produce suitable designs.

The coolant in the Windscale A.G.R. has been running for over two years with the addition of a small quantity of methane to inhibit graphite corrosion. Daily measurements using the carbon-14 technique continued to indicate a corrosion rate that is significantly lower than that tolerable for Dungeness "B".

S.G.H.W.R.

All key dates have been met so far in the construction programme of the Steam Generating Heavy Water Moderated Reactor at the Atomic Energy Establishment, Winfrith.

Building and civil construction are complete, with the exception of the administration building. All the core components have been successfully installed, and the primary steam circuit is in an advanced stage of erection.

It has been demonstrated that this design of reactor, which enables the reactor civil construction to be completed before the erection of the shop-fabricated core components, reduces the overall site construction time.

Plans for commissioning the prototype are being prepared and it is expected that **full power will be achieved in the autumn of 1967.** The use of experimental loop facilities to investigate different designs of fuel is being planned to ensure full exploitation of the system. Four boiling channels in the reactor are to be adapted so that tests can be made on a design of fuel for an S.G.H.W.R. fuelled by natural uranium.

Studies of the use of natural uranium oxide fuel, as compared with enriched fuel, in the S.G.H.W.R. have shown some cost penalty at present, though the system could still be attractive **to possible overseas customers who do not have their own supplies of enriched material.** Higher density fuels, such as uranium metal, are being investigated and irradiation experiments have been started in the Dounreay Fast Reactor.

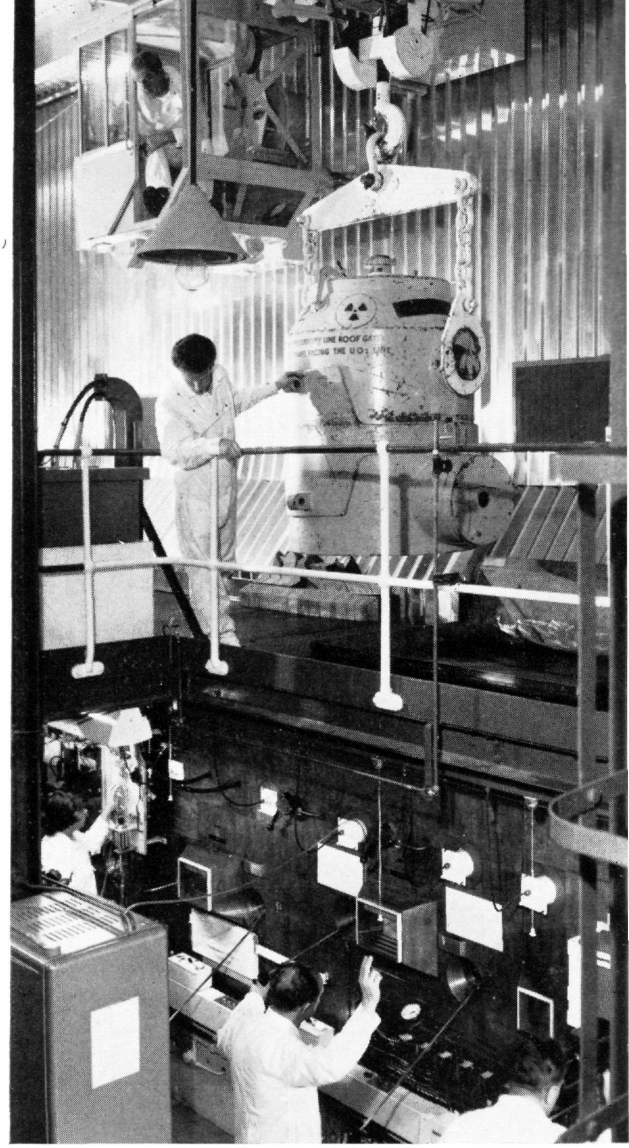
HIGH TEMPERATURE GAS-COOLED REACTORS

Progressive increases in power output have been achieved by the Dragon reactor experiment (sited at Winfrith) of the Organisation for Economic Co-operation and Development. A heat output of 10 Megawatts was reached in November, and maintained until mid-January for plant tests and accelerated irradiation experiments on special, up-rated fuel elements. During this run the behaviour of the plant, equipment and fuel was entirely satisfactory and the reactor has operated with higher coolant outlet temperatures than any other designed for continuous running. The successful commissioning and initial operation of the reactor experiment have confirmed the basic features of helium-cooled reactor technology incorporated in the reactor. The next stage in the reactor's programme will be to raise its output to the design level of 20 Megawatts (heat).*

Recent investigations in the PLUTO loop of the irradiation behaviour of coated particle fuels on behalf of the Dragon project have emphasized their potential as high burn-up fuels.

FAST REACTORS

The Dounreay Fast Reactor completed its eighth run lasting 81 days on 9th April, 1965, during which it produced 4,790 Megawatt-days of energy. The reactor was then shut down for reloading fuel, for the removal and replacement of the first experimental sub-assembly, which had reached its design target burn-up of 5 per cent. (heavy atoms), and for the replacement of 25 other experimental rigs. At the beginning of the ninth run there were three sub-assemblies and 84 experimental rigs in the reactor. This run lasted for 86 days and terminated on 13th August, 1965, after producing 4,930 Megawatt-days. During this run the reactor operated at a new high output figure of 64 MW(heat) and 15 MW (electrical), and continued to be very stable and easy to control.



At Windscale ceramic fuels are examined to find out the effects of irradiation. The picture shows a flask of A.G.R. fuel-pins being lowered into the shielded examination line.

* The reactor reached its full thermal power of 20 MW on 24th April, 1966.

The use of the D.F.R. as an irradiation test facility is diversifying and at the end of the year 90 experimental rigs and three sub-assemblies were being irradiated. Most of the available space (70 per cent.) is being used in support of the fast reactor programme and the remainder for experiments on materials for A.G.R.s and the S.G.H.W.R.

Preparations for the construction of the 600 Megawatts (heat), 250 Megawatts (electrical) Prototype Fast-breeder Reactor (P.F.R.) at Dounreay were well under way at the end of the year under review.* Building layouts, and civil and structural drawings were being finalised and preliminary discussions had been held with industry for the supply of major plant equipment.

The final specification of the fuel for the P.F.R. will not be fixed for some time. Nevertheless, a substantial effort has been deployed in specifying processes and equipment for manufacturing P.F.R. fuel and fuel elements, and all manufacturing processes are well advanced. There is now ample information, based on pilot plant experience at Aldermaston, to proceed with the design of the plant at Windscale for manufacturing P.F.R. fuel assemblies.

As a part of the overall decision on the Prototype Fast Reactor approval has been given for the fuel plant. Construction, which will cost £2·5 million, will start in 1966 so that production can begin in the Spring of 1969.

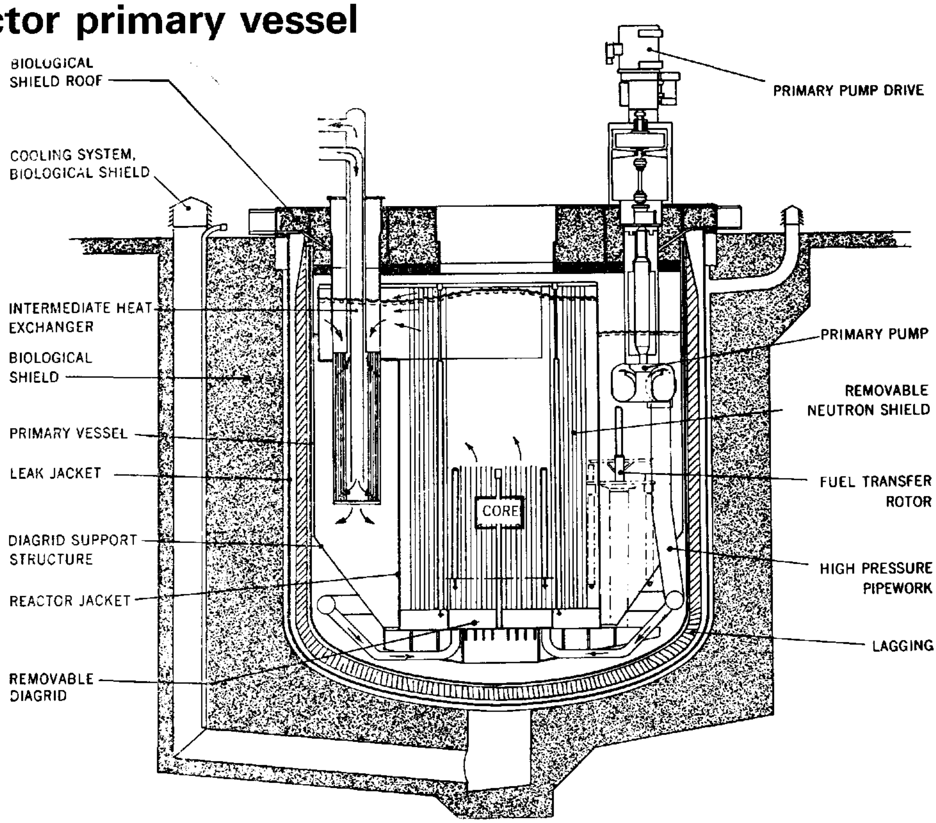
The design study of a 2×1,000 Megawatts (electrical) fast reactor power station endorsed in general the conceptual design of P.F.R. as representing the most likely features of the first commercial fast reactors.

A capital cost estimate for this study indicates a cost similar to that of the best thermal reactor available at the same time, but with potential for further reductions, which (together with low fuel costs) predict **an electrical generation cost of about 0·3d. per unit.**

Consideration is being given to fast reactors

* Preliminary work on site started in mid-April, 1966. Deep rock excavation and foundation work began in July. The project will be completed by 1970.

Reactor primary vessel



A cutaway diagram of the reactor primary vessel of the Prototype Fast Reactor now being built at Dounreay.

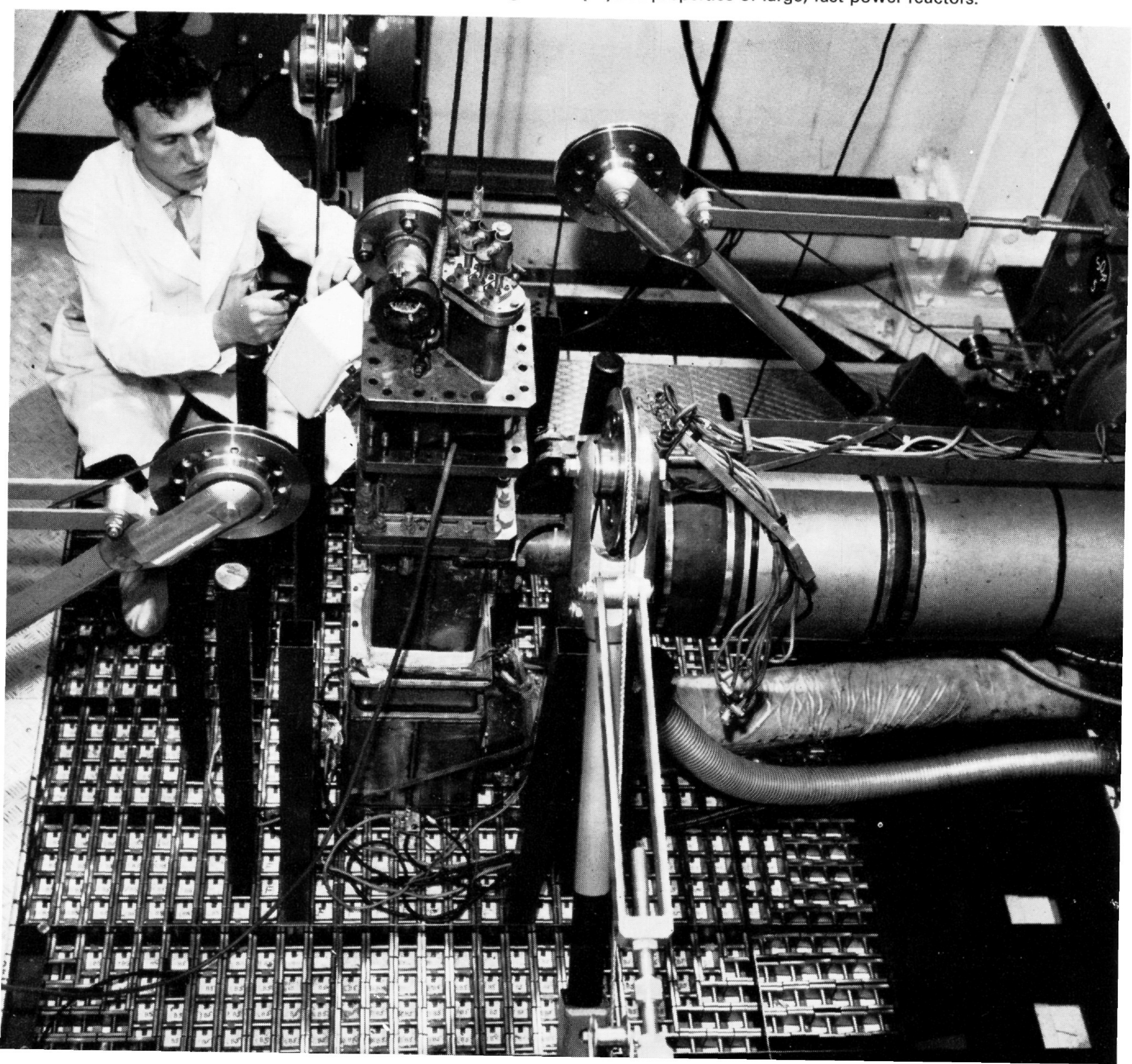
using coolants other than sodium for long term development. An assessment study of one of these alternatives – a steam-cooled fast reactor – has been started to define the parameters. There are capital cost savings in using a direct cycle plant, provided that acceptable solutions to the safety problems are worked out.

SMALL REACTORS

Since the Government's decision not to continue with the development of a prototype reactor for merchant ship propulsion, the Authority have reviewed their work on small reactors in order to investigate methods of improving the economics of the present types, to examine alternative marine applications with improved prospects for nuclear propulsion and the use of small reactors for industrial purposes. Market surveys are being made to establish the commercial potential for small reactors in the 20-60 Megawatt range.

An agreement has been made between the Authority and Fairey Engineering Ltd., to exploit the market for small research reactors.

The ZEBRA reactor at Winfrith is used to investigate the physics properties of large, fast power reactors.



With the Authority acting as licensors and consultants the company has already secured an order from Switzerland.

GENERAL

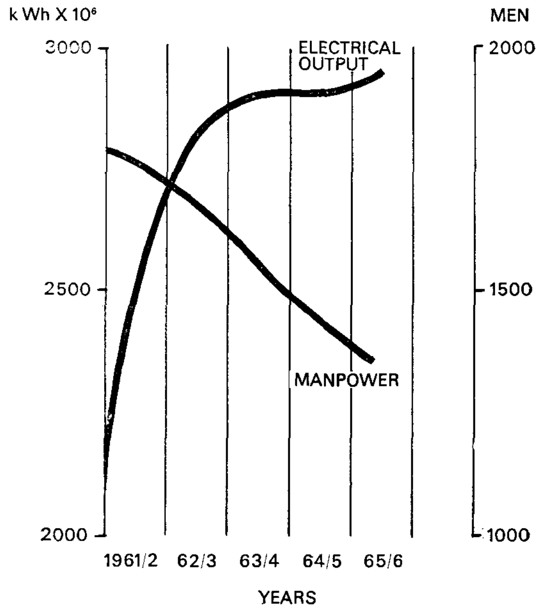
Apart from work relating to specific reactor systems, a large part of the reactor research programme, especially at Harwell and Winfrith, is concerned with more general research on reactor systems to gain a better understanding of properties and behaviour; this may be applicable to more than one type of reactor.

For example, the existing theoretical knowledge of two-phase heat transfer and fluid flow is inadequate for designing complex fuel bundles of the type used in the S.G.H.W.R. and similar reactors. One approach is to test full scale designs; another is to use model fluids such as refrigerants in the Freon range to simulate high pressure water. Extensive measurements have been made of the burn-out phenomenon in Freon with single tubes and with clusters of tubes; comparison with equivalent results for high pressure and high temperature water has shown close agreement.

Another example is that in gas-cooled reactor designs using steel pressure vessels, neutron flux levels for start-up and control are measured by means of neutron detectors located outside the pressure vessel at atmospheric pressure and near to room temperature; whereas with concrete pressure vessel reactors the neutron detectors must operate inside the pressure vessel at full reactor pressure and temperature. A development programme undertaken in collaboration with the Consortia and the Central Electricity Generating Board has led to advances in instrument technology for concrete pressure vessel gas-cooled reactors which are also applicable to fast reactors.

The major existing sources of fast and thermal neutrons for studying radiation damage are the Authority's material testing reactors and they have been progressively modified to keep pace with the rising demand from users for more experiments and higher fluxes and heat ratings. The operating powers of both PLUTO and the Dounreay Materials Testing Reactor have been raised from 15 Megawatts to 20–25 Megawatts giving substantial increases in neutron damage fluxes. The improvements were largely accomplished by using new fuel elements, consisting of concentric rings of fuel, which have larger heat transfer areas.

Manpower utilisation: Calder and Chapelcross



The Calder and Chapelcross reactors are now operated primarily as electricity producers and effectiveness of operation is measured by manpower utilisation and total station output with special emphasis on output during the winter months when it is of greatest value to the national supply system. The design of these power stations, each involving four reactors and eight turbines for 160 Megawatt (electrical) capacity, limits the manpower economies which can be achieved, but rationalisation has made possible a steady improvement.

The data for the last five years are shown in the diagram above, which also shows the change in units sent out annually. During 1965 one reactor at Calder Hall was re-fuelled with elements having a herringbone heat transfer surface resulting in some increase in output. This change will in due course be made to the remaining reactors at the two sites. Annual average load-factor was further improved to 93 per cent and, of greater importance, **the load factor achieved during the winter months was 100 per cent.**

The reactors, particularly those at Chapelcross, continue to be used for irradiation trials of many types of fuel element for British, French and Japanese reactors. In such trials fuel elements typical of those loaded in C.E.G.B. stations have already achieved channel average irradiations **which exceed by 50 per cent the original design objective of 3,000 Megawatt-days per tonne.**

WORLD FUEL SERVICE

Progress in extending the fuel cycle services of the Authority to overseas customers has been achieved by inaugurating the first large scale international movements of irradiated fuel on a regular basis. The Authority's charter ship, *Stream Fisher*, is plying between Anzio and Barrow with irradiated fuel from the Latina reactor (near Rome) in accordance with the reprocessing contract signed with Ente Nazionale per l'Energia Elettrica.

A further significant achievement in this connection was the organisation by the Authority of the movement of irradiated materials testing reactor fuel from Marseilles to Leith for reprocessing at Dounreay. This fuel, which was originally supplied to France by the United States Atomic Energy Commission was irradiated in the "Pégase" reactor at Cadarache.

The unique experience gained by these movements and the equipping of the "Stream Fisher" for the carriage of irradiated fuel place the Authority in a favourable position to extend reprocessing services to other customers in any part of the world.

Among other notable orders received during the year were the following:

The supply to Italy of a further 80 tonnes of replacement fuel for Latina. This fuel was delivered between September and December, 1965.

A contract with the Commissariat à l'Energie Atomique (France) for the reprocessing at Dounreay of irradiated fuel from the "Pégase" reactor at Cadarache. The contract involves a total of 120 kg. of uranium (300 fuel elements) at a nominal enrichment of 90 per cent., held on lease from the U.S.A.E.C. 72 kg. have been received at Dounreay in the year under review.

An order from the C.E.A. for the supply of approximately 15 tonnes of nickel plated, depleted uranium strips for use in the "Masurca" zero energy fast neutron facility.

An order from the Swiss Federal Institute for Reactor Research for the supply of 300–400 kg. of 5 per cent. enriched uranium dioxide, foil wrapped pellets for the Physical Constants Test Reactor being built at Würenlingen.

Sundry overseas sales of depleted uranium for various uses totalling over £120,000.

An order from the Junta de Energía Nuclear (Spain) for the fabrication by the Authority of 300 Materials Testing Reactor fuel plates for the JEN–1 reactor. This order, which was secured despite widespread international competition will

Fuel element plates for materials testing reactors in Britain, Australia, Denmark and Germany are manufactured at Dounreay.

involve the processing at Dounreay of uranium-235 held on lease by Spain from the U.S.A.E.C.

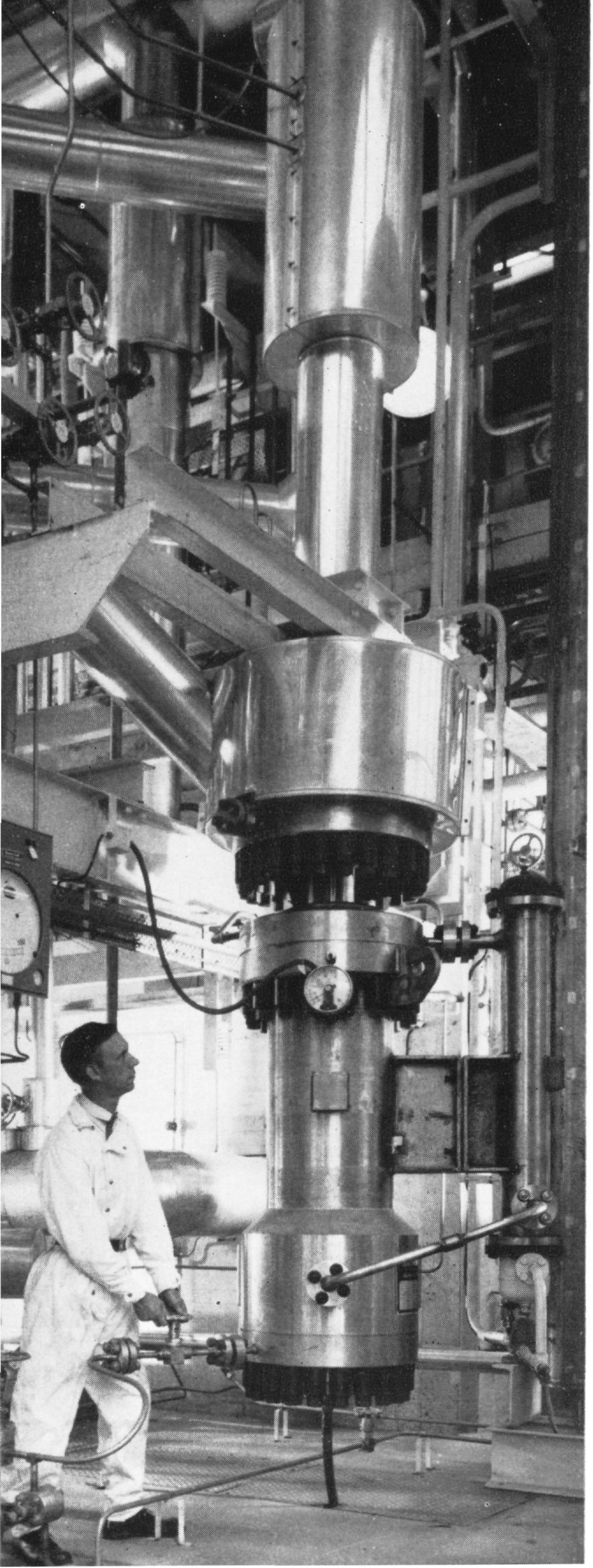
Substantial contracts were concluded during the year for the reprocessing of Materials Testing Reactor fuel from Denmark and France, and operations have started on each. In both cases the original uranium-235 of the fuel was provided by the United States Atomic Energy Commission, and recovered material is returnable in a form which meets the Commission's specification.

CAPENHURST

Because of the new decisions taken in the nuclear energy field, it has become possible to forecast with greater certainty the roles of the various production factories and the requirements for development, investment and manpower.

It has become clear that new and larger diffusion plant units will be required at Capenhurst at an earlier date than had previously seemed probable.

In December the government authorised in principle modifications to existing equipment at the Capenhurst plant at a total cost of £14·4 million. Specific authorisation was given for expenditure of £8 million for the first phase of modifications and work started immediately for completion by 1969. In addition to providing the output to meet the initial requirements of the enriched fuel programme, the



modifications will substantially increase efficiency.

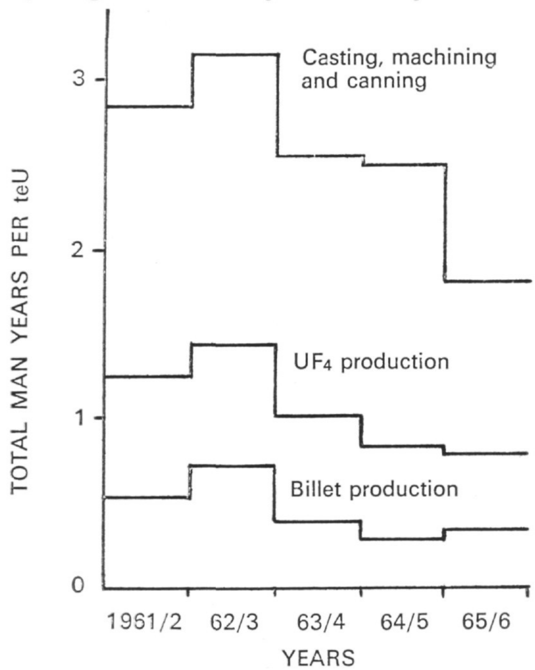
A programme of development and testing, together with the clarification of future domestic needs and export possibilities, has made it possible to plan the further expansion on which the efficiency and economy of the plant will increasingly depend.

PRODUCTIVITY

Further progress has been made in the improvement of productivity. In particular, incentive bonus schemes have now been applied on a significant scale in the Springfields and Windscale factories with financial advantage both to the Production Group's customers and to its employees.

During the year, magnox fuel was manufactured at below budgeted cost and all deliveries met the customers' programmes. The most significant improvement in the use of manpower was in the casting, machining and canning areas and resulted in considerable part from the application of incentive schemes based on work measurement to the canning lines. Throughout the factory 230 men are now employed on incentive schemes and work studies are in progress with a view to further extension.

Springfields manpower requirements



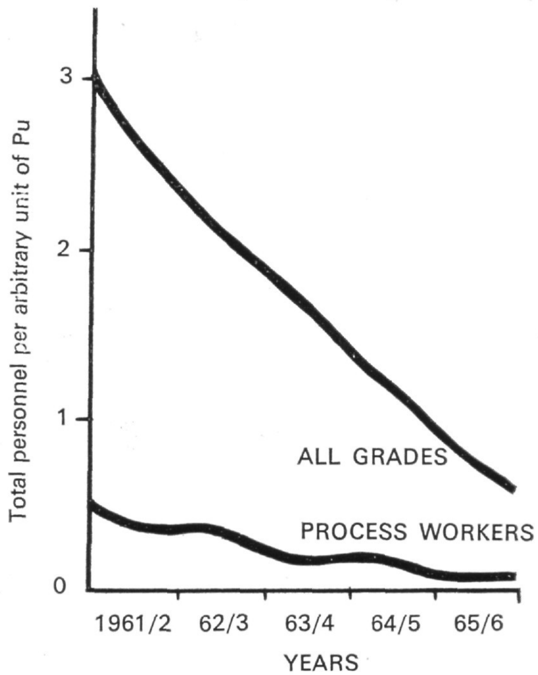
An S.G.H.W. loop endurance test rig at the Reactor Fuel Element Laboratories, Springfields.

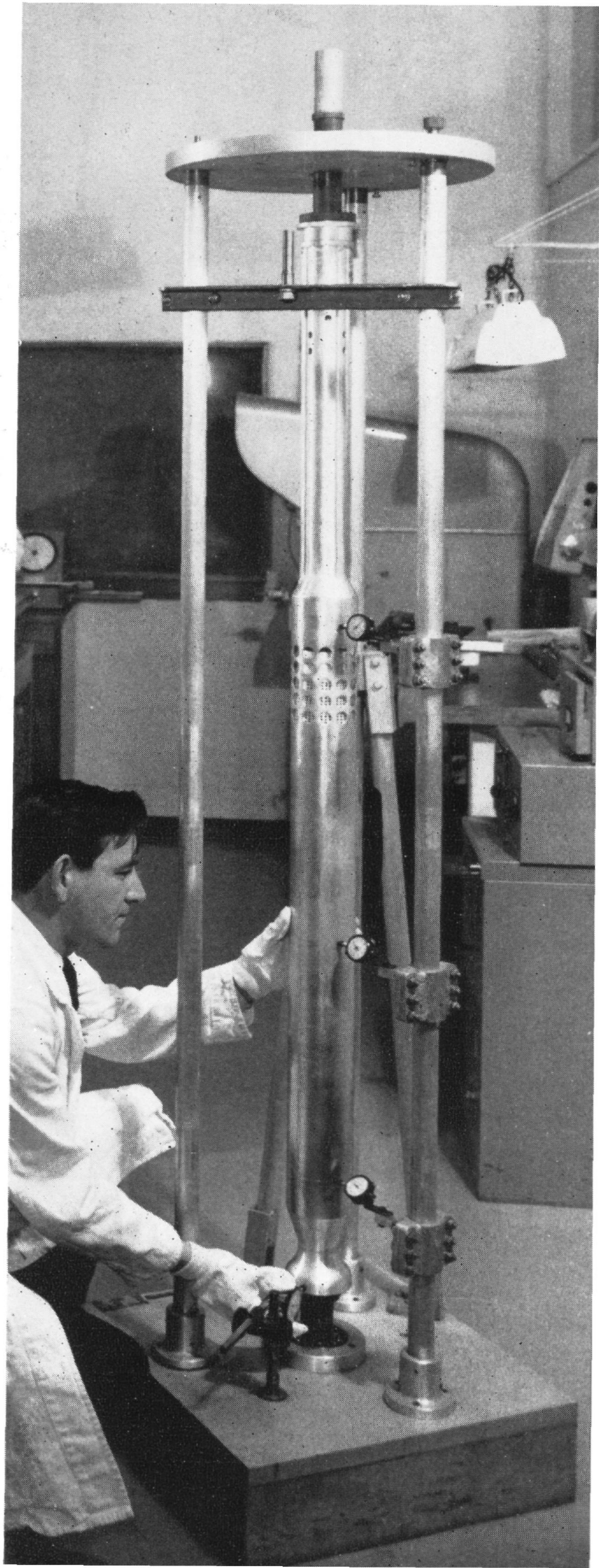
Despite the increasing variety of types of element required as more stations need replacement fuel, it has been possible to reduce the total number of production lines thus providing space which will be devoted in future to oxide fuel production. The development of the main production plant for oxide fuel to meet the needs of the next phase of the nuclear power programme is now almost complete. It is expected that the resulting semi-automatic production line will have manufacturing costs which will be fully competitive in the international market for oxide fuel.

Improvements in manpower utilisation on the Windscale site continued. A part of the increase in productivity is attributable to the increased quantity of fuel being reprocessed; the rest results from reduction in manning requirements. Over 400 of the site staff are now employed under incentive bonus schemes and the number is being extended.

The new chemical reprocessing plant has operated successfully, reprocessing fuel of a wide range of burn-up reaching 3,000 Megawatt-days per tonne. Steady improvement in the throughput of the plant has been achieved, and operating economies have been made in the light of experience.

Windscale manpower requirements





Inspection of Materials Testing Reactor fuels at Dounreay. A wide range of enrichments can be supplied.

Expertise for Industry

High-speed photographic techniques which will arrest a bullet in flight can be used equally to study the motion of machines. The "E.12" series of cameras developed at A.W.R.E., Aldermaston, can record a sequence of images at 60 million frames per second.

The application of their expertise in the non-nuclear field and the exploitation of its commercial possibilities are not new to the Authority.

Prior to the Science and Technology Act, 1965, it derived from and was incidental to the Authority's nuclear development programme. Under Section 4 of the Act, the functions of the Authority are extended to include the undertaking of scientific research (including development work) in such matters **not connected with atomic energy** as may, after consultation with the Authority, be required by the Minister of Technology.

Thus the Authority's considerable technical resources, special techniques and expertise can now be diversified into the United Kingdom's industrial technological development and productivity on a far wider front than was possible before the new Act came into force. The Authority already have a number of projects for which formal requirements have been issued by the Minister. These include: desalination, hydrostatic extrusion, development of a biological liquid centrifuge, single-purpose transducers, space technology and a number of minor projects in a variety of fields including medical engineering, automation and industrial processing, sintering of refractory metals and X-ray equipment.

Suggestions have originated from within the Authority and a considerable number from outside. Steps are being taken to promote the flow of ideas from outside and to identify particular problems of industries and firms on which the Authority may be able to assist and which can respond, in the short term, to a technological stimulus.

The main criteria to be satisfied in the consideration of projects are: (i) the nature of the development must lie within the general scope of the Authority's know-how, and resources; (ii) the development must be of potential benefit to the national economy with a clear prospect of technological application in the foreseeable future.

It is desirable that there should also be an industrial partner in prospect willing and able to take advantage of the development and also to make a significant contribution; alternatively a firm or firms willing to enter into an undertaking, on commercial terms, to exploit the product of development when proven.

DESALINATION

In April, 1965, the Authority were required by the Minister to assume responsibility for research and development into methods of desalination. An initial three-year programme with a budget of £1·3 million was authorised.

The Authority are responsible for the Desalination Research and Development Committee, which acts as a forum for the exchange of views on desalination; enables British industry, government departments and universities to present proposals for investigation or development; acquaints the Water Resources Board with the progress of development in desalination methods; is kept informed of the Board's requirements.

In accordance with the overall objective of **assisting British industry to maintain its share of an expanding export market in the face of increasing overseas competition,** the programme has two main aims:

(a) to exploit the development potential of the currently favoured process of multi-stage flash distillation;

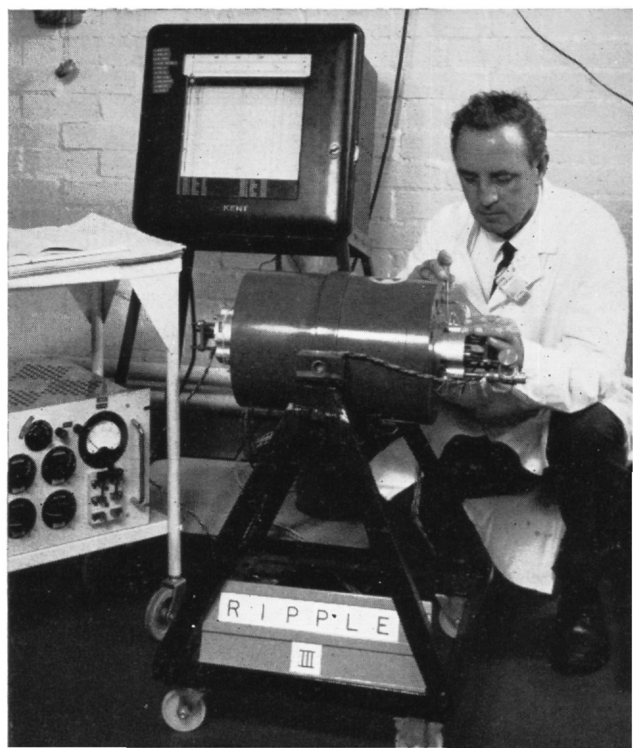
(b) to identify and develop alternative processes which may ultimately supersede multi-stage flash distillation.

Designed to exploit the development potential of multi-stage flash distillation, a research and development collaboration agreement has been negotiated between *Weir Westgarth Limited* and the Authority. A programme of work between Weir Westgarth and the Authority is jointly controlled and co-ordinated. Weir Westgarth's contribution is presently being undertaken by G. & J. Weir at Glasgow but will be transferred to a new sea water test facility at Troon later this year. The Authority's contribution is divided between the Reactor, Research and Engineering Groups. For example, theoretical and experimental investigations of the basic nature of the behaviour of boiling liquids under flashing conditions have been undertaken at A.E.E., Winfrith, where the expertise derived from two-phase flow and heat transfer problems of the Steam Generating Heavy Water Reactor can be directly applied to flashing-flow investigations.

In the field of brackish water conversion, electrodialysis competes favourably with processes based on distillation. This process is being commercially exploited by *W. Boby Limited,* with whom the Authority are collaborating in a small development programme designed to improve performance of electrodialysis plant designed and manufactured by the company.

In the search for alternative processes to flash distillation for desalination of sea water the Authority are at present concentrating on reverse-osmosis and freezing. At the Atomic Energy Research Establishment, Harwell, the reverse-osmosis work, at present directed towards an understanding of the physical chemistry of the mechanism, has made significant progress. Work on the freezing process is still in the feasibility stage: the next phase is to carry out a design study to give an indication of capital costs.

Several overseas countries with both power and water deficiencies have shown interest in studies of dual purpose nuclear power/desalting plants. Engineering Group have carried out a number of such studies providing power and water costs from either an A.G.R. or an S.G.H.W.R. project, coupled with desalination plants.



Harwell have developed Britain's first isotope-powered generator (RIPPLE). A RIPPLE marine navigation light is expected to come into service at Dungeness during 1966

HYDROSTATIC EXTRUSION

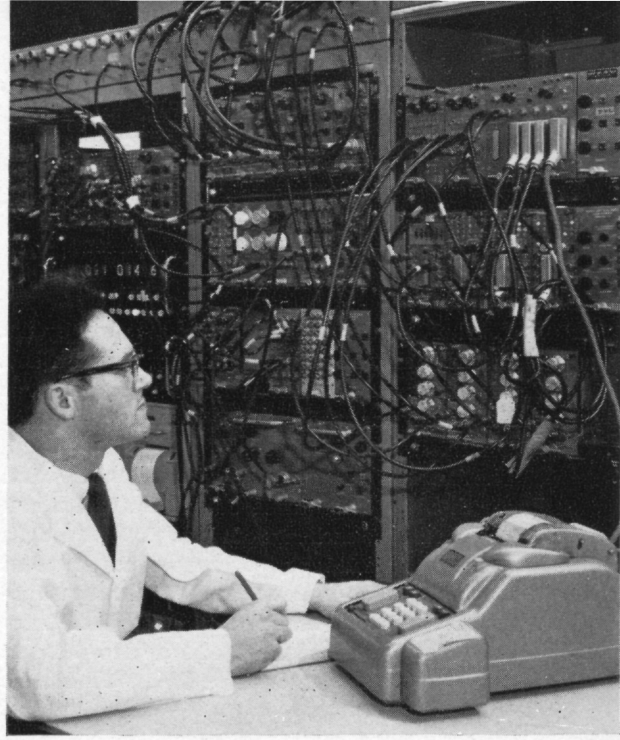
At the Reactor Fuel Element Laboratories at Springfields the Authority have for some time past been investigating the use of hydrostatic extrusion in the nuclear field. These investigations have resulted in a small hydrostatic extrusion machine of advanced design being produced in conjunction with *Fielding and Platt Limited,* who subsequently took a licence from the Authority and have already sold a number of machines of this design.

A three-year programme of further development work, to be carried out in collaboration with Fielding and Platt Ltd., has been approved and is aimed at production of a 1,600-ton power hydrostatic extrusion press. Its design includes features and principles which have been tested experimentally on a smaller scale, including augmented extrusion. This is a new and important variation of the basic principle of hydrostatic extrusion which combines some of the advantages of both hydrostatic and conventional techniques and which will, it is envisaged, allow **a major reduction in the cost of capital equipment in the extrusion of wire bar from billet.**

TRANSDUCERS

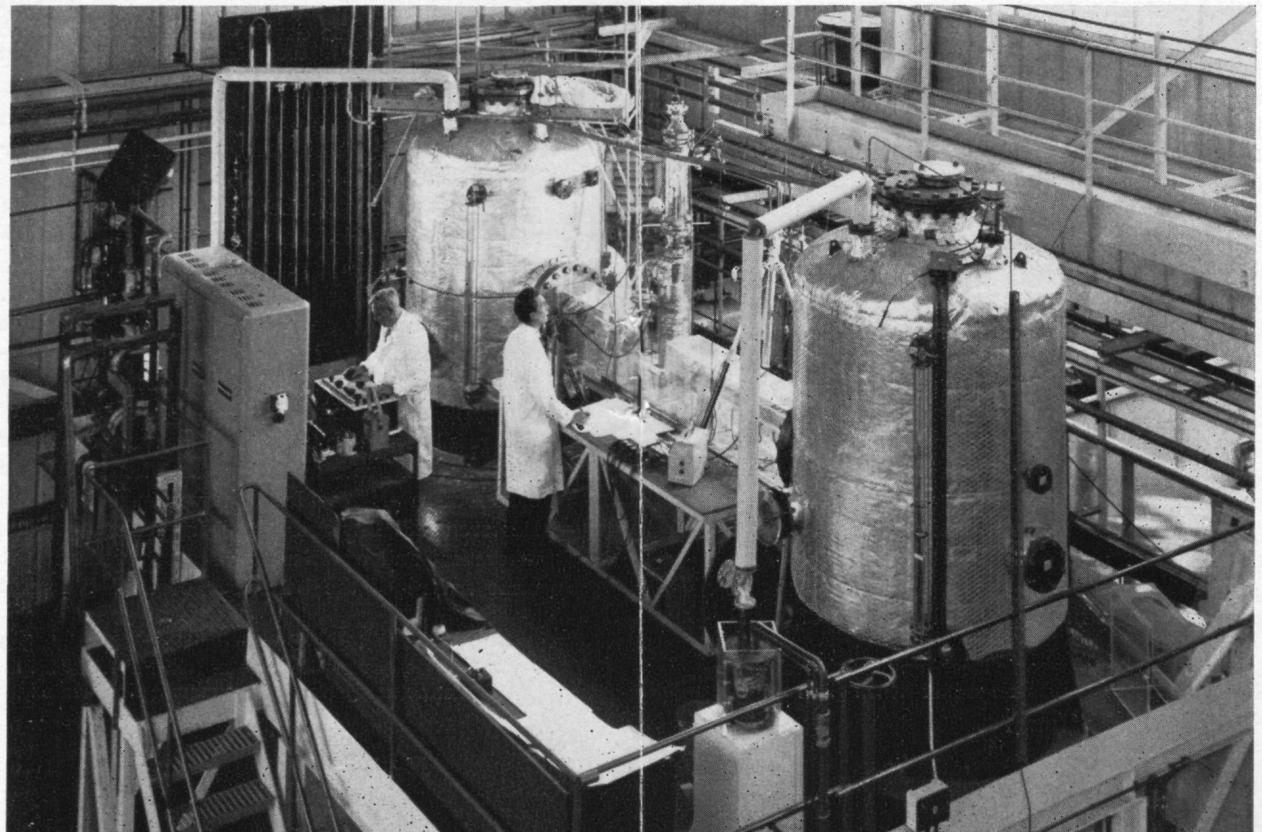
Studies of the economics of instrumentation systems for Authority projects (particularly those where data processing or computer control is involved) have indicated that significant cost reductions could be achieved if simpler, and hence cheaper, transducers were available for the conversion of such variables as pressure, flow, etc., into electrical signals. It was felt that equipment of this type could also benefit industry at large.

It is reasonable to expect there would be more application in industrial plants of computer-based data reduction and control systems if the cost were comparable with that of conventional systems. To this end the Minister has required the Authority to proceed with the development and testing of a range of single-purpose transducers. Application of these transducers is not, however, limited to advanced systems and in this development **particular attention is being paid to the needs of smaller industries, in line with the policy of promoting low cost automation.** The project is being carried through in collaboration with *George Kent Limited* and the *National Research Development Corporation* and is already well advanced.



Originally developed for nuclear research, the "Harwell 2000" series of transistorised electronic units has also found wide use in industry.

A.W.R.E., Aldermaston, in collaboration with the Ministry of Health, have developed the mechanism for an artificial hand powered from an electric motor.



Desalination. The "Seaspray" test rig at Winfrith for studying flashing steam/water mixtures in multi-stage flash distillation plants.

SATELLITE PAYLOAD

For their first major project the European Space Research Organisation (ESRO) have proposed studies in the new field of ultra-violet and X-ray astronomy using a Large Astronomical Satellite (L.A.S.). The Authority undertook a contract to make a design study for a complete scientific payload. This design study has been carried out as a co-operative venture by a team led from the *Culham Laboratory,* incorporating staff of *A.W.R.E., Aldermaston,* the *Space Department of the Royal Aircraft Establishment, Farnborough,* and the *Physics Department of University College, London.* Two other European groups also completed design studies. The several proposals were under consideration by ESRO at the end of the year.*

The L.A.S. project provides for a highly stabilised observation platform to be maintained in orbit for a year at a height of some 650 kilometres. The underlying aim is to provide for a wide range of astronomical investigations, which could involve up to 30 European scientists in making full use of the observational data.

SPACE TECHNOLOGY

In addition to work for ESRO, the Authority have for some time been working in the field of space technology under contract to government departments and the universities. The computer processing of the data from the Ariel II Anglo-American satellite, launched in 1964, is being done at A.W.R.E., Aldermaston, for the Space Research Management Unit and a development contract has also been undertaken to produce a special tape recorder for use in the Ariel III satellite, scheduled to be launched early in 1967.

Under a contract from the Ministry of Aviation, A.W.R.E. is operating as the co-ordinating Research and Development authority for the PETREL Space Research Rocket Project. The aim of the project is to provide a cheap vehicle of simple design capable of taking a variety of scientific payloads of up to 30 lbs. weight to a height of some 135 kilometres. Other participants are *Bristol Aerojet Limited* and the *Rocket Propulsion Establishment, Westcott.* A.W.R.E. is also designing the telemetry of the rocket. The first development firings of the rocket will take place early in 1967 at the Hebrides range.

* In July, 1966, E.S.R.O. decided to adopt the British design study and to place a contract with the U.K.A.E.A. for a scientific payload.

BIOLOGICAL CENTIFRUGE

At the request of the *Medical Research Council*, experimental work on the use of very high speed centrifuges for separation from liquids has been undertaken. This project is aimed at developing equipment for use in the study of viruses and other particles of similar size and of medical interest.

PORTABLE FLASH X-RAY EQUIPMENT

Basic principles have been established for the design of a small X-ray generator for radiography for industrial and medical purposes and approval has been given to make and test a production prototype suitable for licensing for commercial manufacture. It will incorporate a field emission X-ray tube and a spiral voltage generator giving a short pulse of a fraction of a microsecond. This development is being undertaken by A.W.R.E.

BERYLLIA

As part of the nuclear programme the Authority have carried out investigations into the methods of preparation and properties of beryllia. Apart from nuclear uses, beryllia has applications in the electronics industry in microwave vacuum devices because of its high thermal conductivity, mechanical strength and high electrical resistance at high frequencies, and because these properties do not change over a wide temperature range. The Authority have developed a method of manufacturing beryllia which will enable an improved high strength material of greater density to be produced consistently. Initial industrial trials of sample material have been encouraging and larger scale trials are now in hand.

COMPUTERS IN ENGINEERING

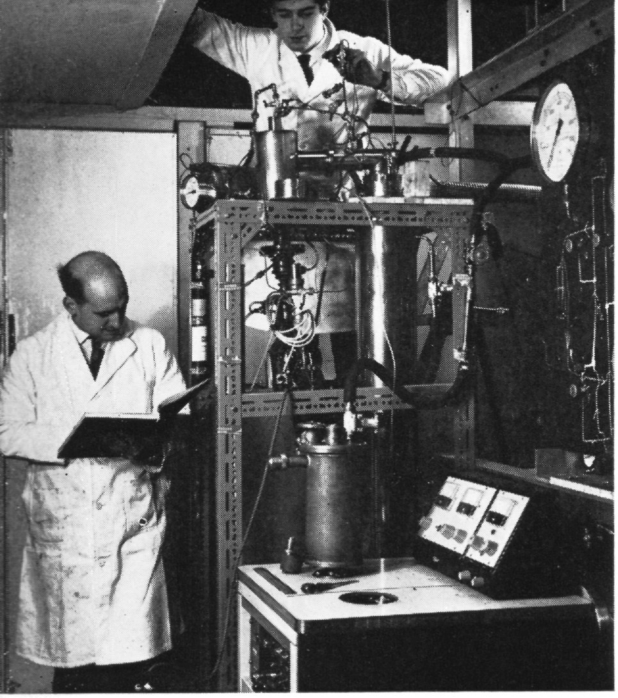
The Ministry of Technology is sponsoring a project at A.W.R.E., Aldermaston, to assist industry to apply modern computer aids to engineering design planning and production, including the use of numerically controlled machine-tools. The project will make use of the existing extensive computer facilities at A.W.R.E. and special peripheral facilities such as a high-speed plotter for the automatic production of drawings on micro-film or sensitised paper. Facilities will be provided for instruction in the use of computer aids to engineering and assistance will be given to industrial firms in developing their own programmes.

ALDERMASTON

To use the surplus capacity released by some reduction in the nuclear weapons programme, an inter-departmental committee was set up to consider what non-atomic civil or defence work could be undertaken for other government departments by the Authority's Weapons Group. As a result, during the last three years a substantial amount of work has been undertaken at A.W.R.E. In the current year it has occupied some 50 man-years of professional staff.

Medical Engineering: Collaboration during the year with representatives of the Ministry of Health and allied research organisations, with the object of exploiting the skills which exist within the Authority to aid work on medical engineering, has resulted in the development at A.W.R.E. of the mechanism for an **artificial hand.** Early models demonstrating the principle of operation were developed at St. Thomas's and West Hendon Hospitals, but the work undertaken at A.W.R.E. was to miniaturise the control circuits and to adapt an existing artificial hand to be powered from an electric motor. In practice, the miniaturisation of the electronic unit entailed a complete redesign, although the general principles of operation remained the same. The hand is made of metal

A new method of ultrasonic machining developed at Harwell greatly improves the rate at which glass and ceramics can be cut.



Testing the refrigerator, employing entirely new principles, conceived at A.E.R.E., Harwell.

encased in a moulded plastic glove, and contains a small d.c. motor which can move the first two fingers together towards the thumb. The project has involved the manufacture of 12 pre-production models for clinical trials by the Ministry of Health.

Forensic Work: Studies on behalf of the *Home Office* have continued at A.W.R.E. and plans have been announced for the conversion of an existing building to house a Home Office Forensic Science Research Laboratory and a second laboratory to provide a service for police forces in the Home Counties. Present laboratory work at A.W.R.E. includes a survey of the elemental composition of **hairs** from a representative sample of the population of England and Wales. It has been shown that, although the composition of hairs from one person varies, sufficiently large differences exist between individuals for the method to provide useful forensic evidence in many cases. The extension of this technique to **glass splinters** is now being investigated. The chemical composition of **finger prints** is also being studied with a view to improving methods of developing latent prints. Research is also being carried out into possible automatic methods of finger-print analysis and classification.

EXPLOITATION

The Authority have continued their policy of assessing the commercial possibilities of all inventions made by Authority staff (both those which become the subject of patent applications, and those which do not) and of drawing the attention of British and foreign firms to those inventions which are thought to be of commercial interest.

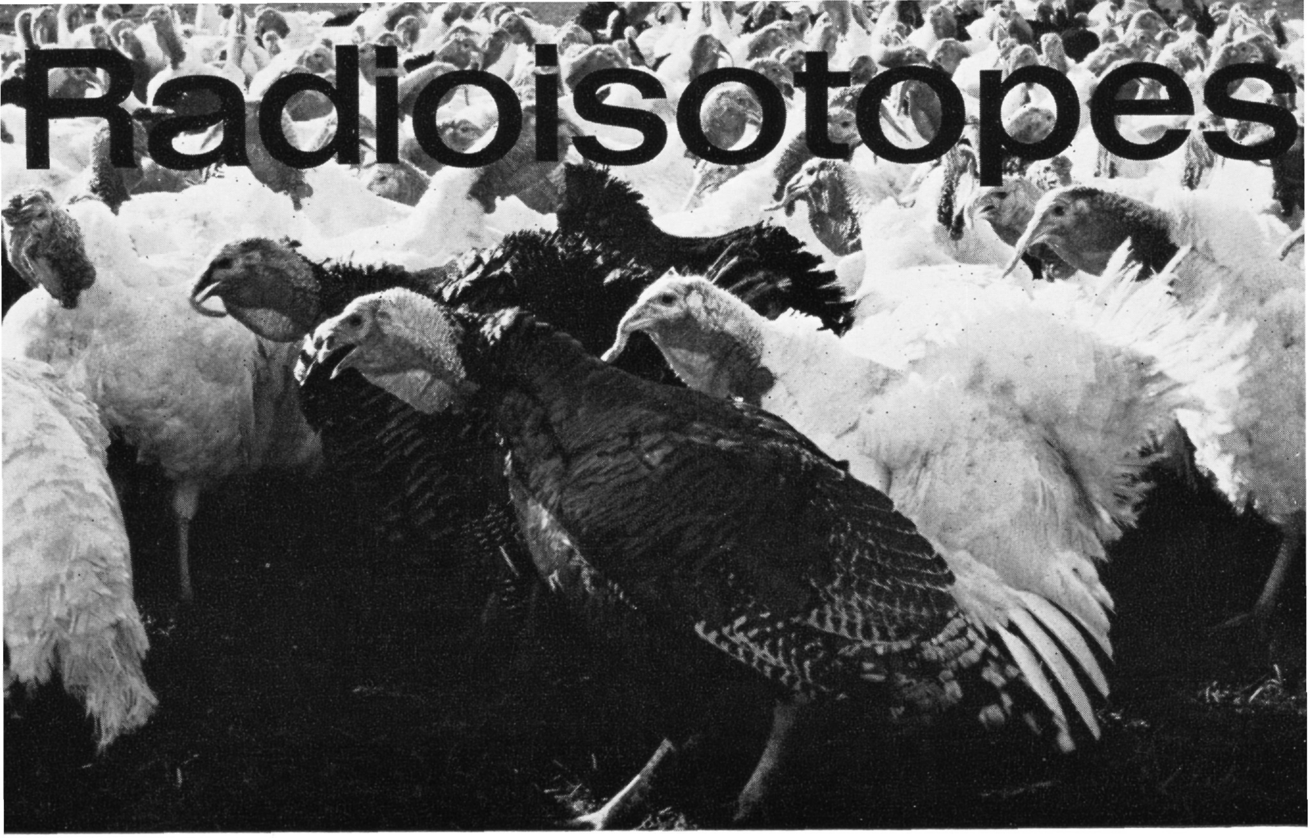
Terms for over 50 agreements have been negotiated during the year with firms (largely in the U.K.) which, under the agreements, are authorised to make use of Authority owned patents and information. Examples are:

Direct Conversion of Heat to Electricity: At A.E.R.E. development of the RIPPLE type thermoelectric generator with a radioisotope (strontium-90) heat source has been continued. Two generators RIPPLE 1 and 2 have been built to demonstrate their use as the power source for a **marine navigation light.** Both devices have so far completed successfully over one year of continuous operation. A third generator (RIPPLE 3) has been developed and is undergoing tests. Its power output is 400 milliwatts (electrical) as compared with the 30 milliwatts (electrical) outputs of RIPPLE 1 and 2.

Agreement has been reached between the *Trinity House Corporation*, the *Central Electricity Generating Board* and the Authority for in-service evaluation at Dungeness nuclear power station of a marine navigation light powered by a 1 Watt (electrical) RIPPLE type generator which is at present being developed at A.E.R.E. The new light will replace an existing one powered by gas and it is expected to come into service during 1966. Similar evaluation programmes are being discussed with other European navigation authorities interested in the use of isotopic power sources and two more 1 Watt (electrical) generators are expected to be placed in service during 1966 for evaluation under actual operating conditions.

The Harwell Refrigerator: A refrigerator employing new principles has been developed which will continuously maintain temperatures much lower than those previously obtainable under steady conditions. The system, based on the heat of solution of the two isotopes of helium, was first conceived at A.E.R.E. The refrigerator employs **the first entirely new refrigeration cycle to be conceived and successfully demonstrated in the last 25 years** and is a major advance in the technology of low temperatures. It works in a temperature range within one tenth of a degree of absolute zero. The equipment has been developed under contract and is available commercially.

Radioisotopes



The Authority have continued to develop the supply of radioactive materials as a business enterprise, and in support of the many medical, industrial and scientific interests that depend upon them. Sales of products from the Radiochemical Centre at Amersham increased by 12½ per cent. in 1965/66 to £2,164,000 with 55 per cent. exported.

Sales were well spread over the principal product groups, and growth of demand for radioactive pharmaceuticals for use in medical diagnosis and in research was particularly encouraging. Sales of cobalt-60 for industrial irradiation plants were maintained at a high level, with 487,000 curies delivered to six locations, including one on the continent of Europe.

The complementary activities of investigating new uses of radioisotopes and large sources of gamma radiation were continued at the Wantage Research Laboratory, and the laboratory's experimental and advisory service for industry attracted about 300 new enquiries of substance during the year.

PRIMARY ISOTOPE PRODUCTION

Nuclear reactors are still the most important source of radioisotopes, but the prototype and commercial power reactors built in recent years have contributed little additional productive capacity, as in general the designs of present day power reactors are not suited to isotope production. This has emphasised the need for making more effective use of the heavy water reactors at Harwell and the power reactors at Chapelcross and Calder Hall, which are the mainstay of isotope production in the United Kingdom. By taking advantage of the higher operating power of PLUTO and of a new rig designed specifically for the purpose, the quality of iridium-192 for industrial radiography has been improved by about 40 per cent. In the same reactor the production of iodine-131 and phosphorus-32 has been transferred to a new rig which permits target materials directly immersed in the heavy water in the core of the reactor to be unloaded while the reactor is at full power. This, together with new chemical processing plants recently completed at Amersham, has substantially improved the reliability of supply and the quality of these important isotopes. These and other processes are interchangeable between PLUTO and DIDO, so improving the dependability of the supply still further.

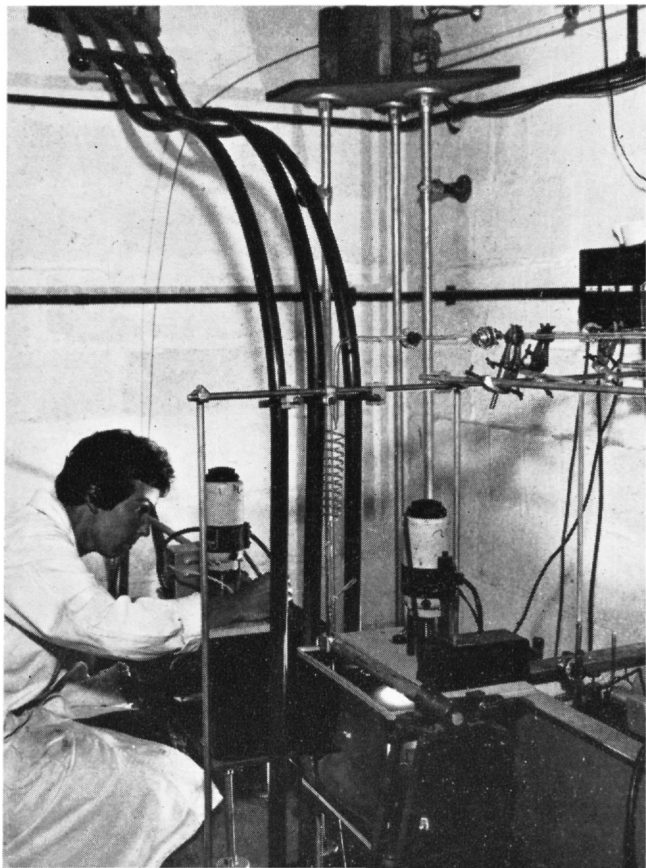
The installation of the cyclotron for isotope production at Amersham has been completed and good progress has been made with the design and installation of the target system. Pre-production trials are now in hand, and routine manufacture of some of the more important isotopes (sodium-22, cadmium-109, cobalt-57, etc.) will begin shortly.

NEW PRODUCTS

Neptunium-237, which is the starting point for making plutonium-238 (used as a power source for **satellite instrumentation)** occurs in the waste

Left above: The ventilation of poultry houses has been among the subjects studied with the aid of radioisotopes by the Wantage Research Laboratory.

Left below: A consignment of cobalt-60 from the Radiochemical Centre, Amersham, being shipped to Germany. It will be used in a plant for sterilising medical equipment.



Right: An experimental assembly at Wantage for the study of detergents. The aim is to avoid pollution of rivers and lakes.

streams from the reprocessing of irradiated fuel at Windscale. Following a successful extraction of this material on a pilot scale, neptunium-237 has been offered for sale through the Radiochemical Centre. (The response has been sufficiently encouraging to justify the planning of a full-scale plant which is to be ready by 1968).

A further 80 items were added to the Centre's extensive list of labelled compounds. Reflecting the continuing interest in **molecular biology,** about 20 of these were components of the nucleic acids, such as the bases, the nucleosides and nucleotides, labelled with carbon-14, tritium, or phosphorus-32.

The range and quality of radioactive substances for **medical use** are being extended progressively in step with the demand, which is increasing particularly fast for diagnostic purposes. The list of "radiopharmaceuticals" supplied by the Radiochemical Centre now includes more than 80 items.

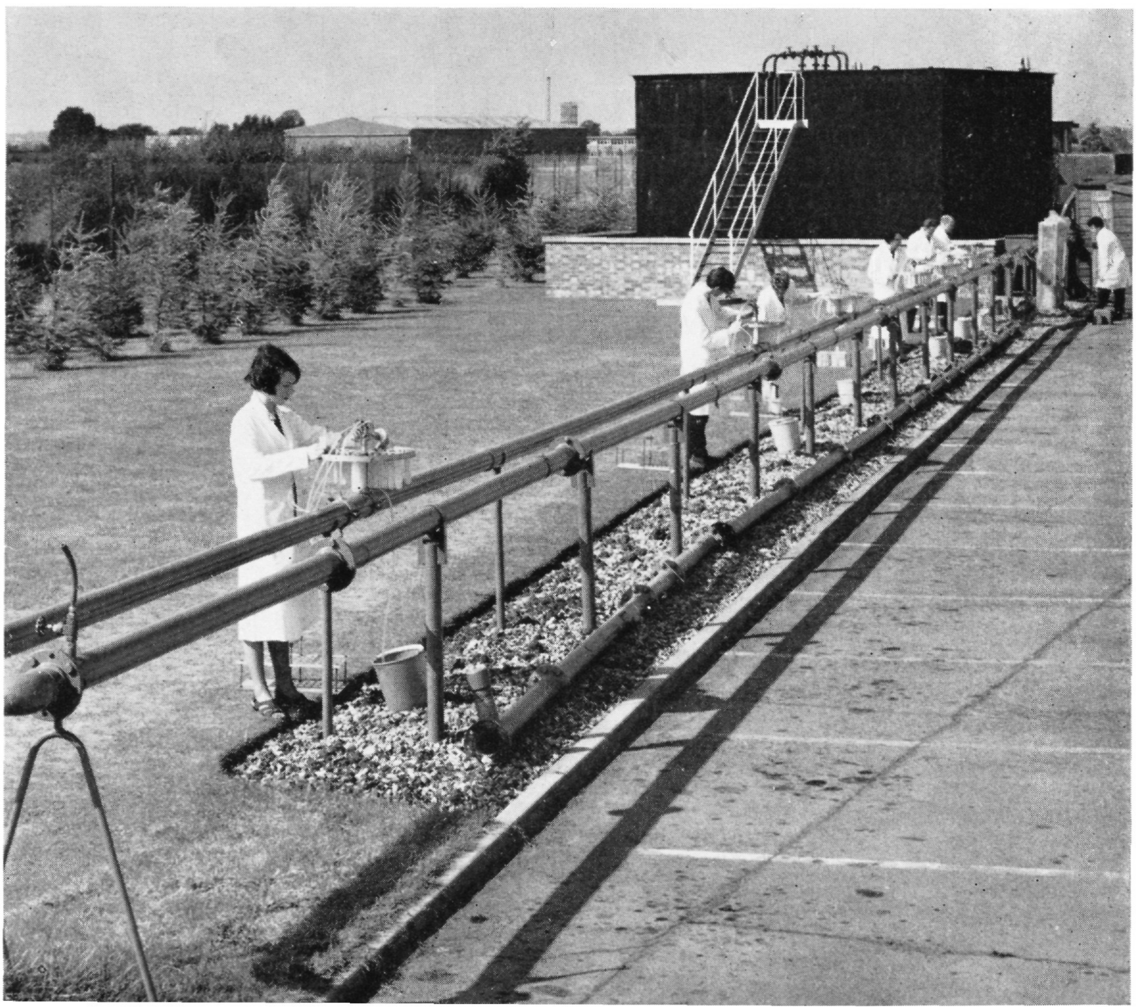
RESEARCH FOR INDUSTRY

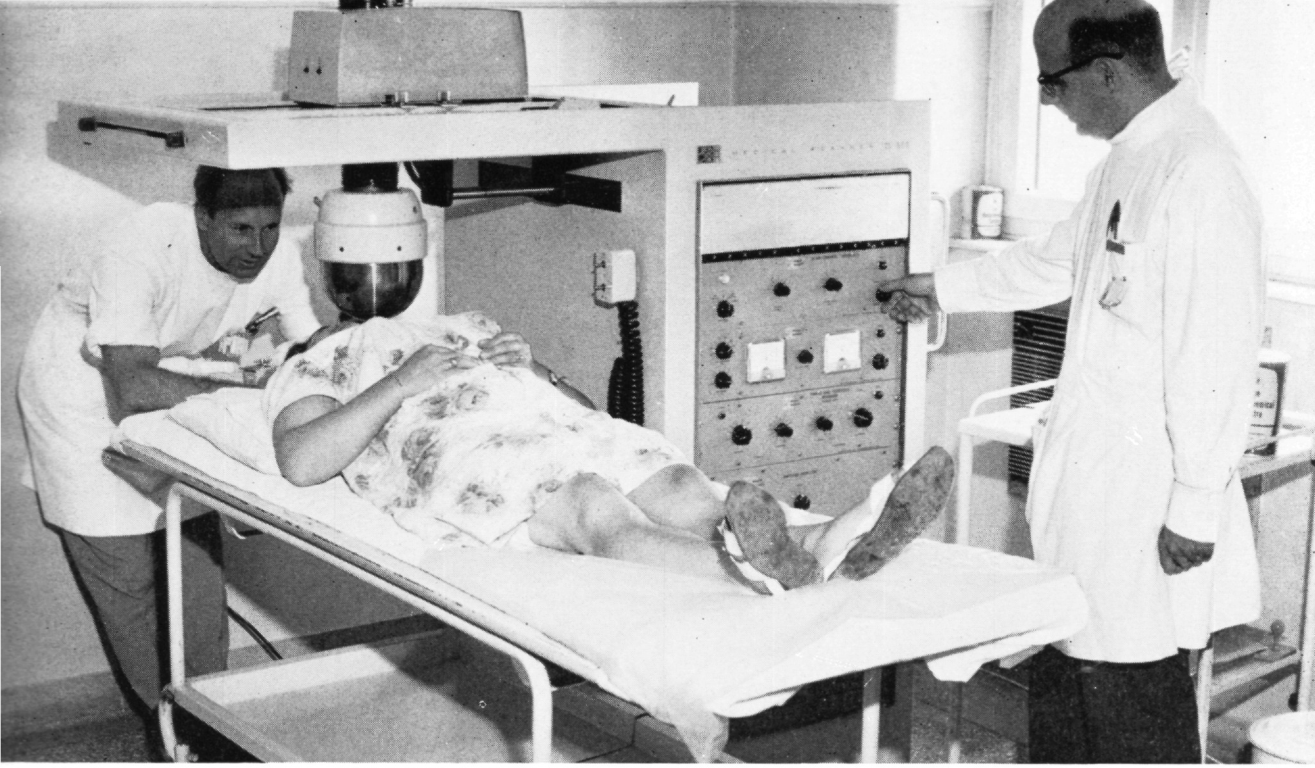
At the Wantage Research Laboratory, isotope techniques continue to be evolved and applied over a wide front to industrial process control, plant evaluation and analysis and to the mining and processing of raw materials such as coal and mineral ores.

The package irradiation plant is being used to full capacity, mainly for sterilising medical supplies. The Army is still the largest user, but over 40 industrial firms also participate.

In addition to the three commercial plants already operating in this country, the Authority's licensees have completed a plant in *Sheffield* for sterilising surgical scalpels and another in *Hamburg* for sutures. Other plants which are planned or under construction include a large experimental plant for food processing in *Holland* and one for the disinfestation of grain in *Turkey*.

An experimental pipe-line at Wantage for studying the flow-rates of liquids.





Iodine-131 from Amersham being used at the Alexandra Hospital in Athens to "map" a patient's thyroid gland.

The staff at Wantage have assisted with the design studies for these new plants, and the cobalt-60, is being provided by the Radiochemical Centre. The aggregate value of materials processed in industrial gamma sterilisation plants of British design **exceeds £20 million a year.**

Although radioactivation analysis is well known as a reliable and sensitive technique, it has not been much exploited by industry, partly due to lack of facilities or experience. To explore the demand, a full service of activation analysis has been made available to industry, using the Harwell reactors and the 14 MeV neutron generator at Wantage; during the first year, over 3,000 samples were analysed.

Determinations of total nitrogen, phosphorus and potassium in typical fertilisers in less than five minutes have demonstrated the potential of the neutron generator for rapid, instrumental, on-line analysis on factory premises. Oxygen has been measured to a few parts per million in steel and aluminium and at higher concentrations in Zircaloy containing boron.

Two commercial versions of portable X-ray fluorescent equipment are available and about 70 instruments are in use. The industrial version is mainly used for measuring plating thickness and for identification of steels and alloys through their minor constituents at levels above 100 parts per million. The geological version is used for mineral assay in the field of tin, copper, molybdenum, lead and zinc in ores and at the working faces of tin mines.

SILT MOVEMENT

Following the preliminary study in 1961 of silt movement in the Firth of Forth, the movement of spoil from the Oxcars dumping ground was investigated quantitatively using ground glass containing scandium-46 as tracer and the vertical distribution of the tracer in the mud returning to Rosyth dockyard was also measured. The results showed that the situation of this spoil ground was unsatisfactory.

A critical examination of hydrographic and tracer distribution data suggested an alternative spoil ground and a preliminary investigation using lanthanum-140 as a tracer showed very little upstream movement. Pending a longer term study, this new dumping area is already being used for spoil deposition **with the prospect of reducing dredging costs in the estuary.**

LONG TERM RESEARCH

The main object of the Authority's long-term research programmes is to provide a scientific basis for solving the technological problems of atomic energy, anticipating future problems, and looking ahead to new methods or applications. Much of the more basic research is done in close co-operation with university departments; in other fields there is collaboration with industry and international agencies.

Some of the Authority's research may lead to applications outside the atomic energy industry.

SUPERCONDUCTING MATERIALS

Among many aspects of materials research the Authority have a direct interest in superconducting materials. At low temperatures they have negligible electrical resistance which makes possible the production of very high magnetic fields. This is of importance in developing plasma containment systems for fusion research, in one method of converting heat directly to electricity and in the development of particle accelerators.

Superconducting materials are mainly alloys of the refractory metal niobium and it has been found that their superconducting properties vary according to the metallurgical processes to which they have been subjected and must be considered dependent on the structure of the alloy. This dependence of magnetic properties on structure is being studied for various promising materials including a range of niobium-tin alloys.

FIBRE-REINFORCED MATERIALS

Advanced reactor systems must operate at high temperatures to give better steam conditions and improved efficiency. At high temperatures ceramics must be used but are inherently brittle and soft. Techniques have now been developed for producing ceramics of high density, with few pores to act as incipient cracks, and having very fine grain structure which is conducive to strength.

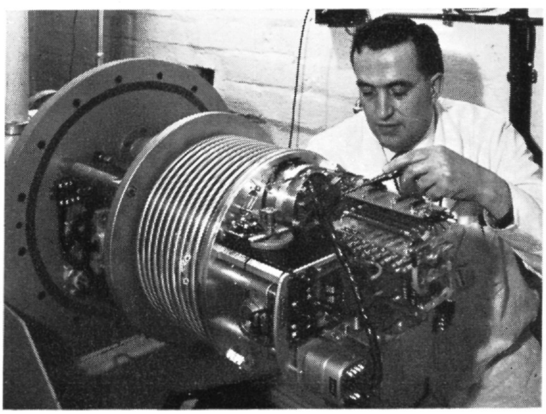
The natural strength of many fibrous materials suggests that their toughness might be further improved by embedding fibres in a ceramic matrix. Specimens of high quality polycrystalline magnesia containing fibres of alumina or zirconia are now being made.

Metals of increased strength, particularly under conditions of high temperature, can also be produced by incorporating strong fibres in metallic matrices. Aldermaston has studied the production of alumina whiskers and their bonding to the matrix, with a considerable measure of success.

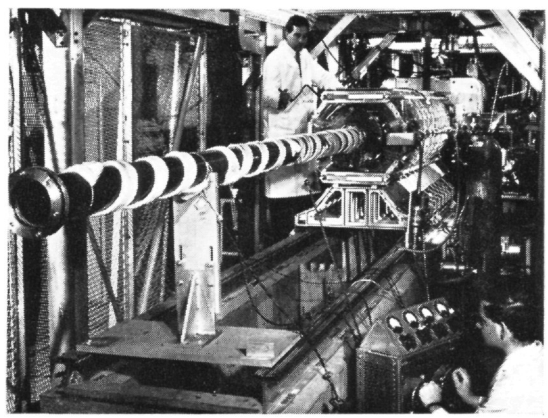
Studies of bonding have shown that oxygen impurities as low as 40 parts per million can seriously weaken the bond between tungsten whiskers with considerable success.

STUDIES OF VITAMIN B12

The diffraction pattern produced by passing X-rays through materials composed of regularly ordered atoms has long provided information on interatomic spacing. Wave properties are also associated with neutrons which may also be used for providing information on the spacing of atoms. Neutron diffraction provides information on the



The high voltage terminal of Harwell's 400 keV Van de Graaff accelerator used for studying radiation damage in solids.



The Magnetic Trap Stability Experiment is one of the assemblies used for nuclear fusion and plasma research at Culham.

Telemetry data receiving aerial used at Aldermaston in conjunction with university research on cosmic radiation.

spacing of hydrogen atoms which cannot be obtained by X-ray methods although it is necessary to use strong neutron beams such as are available only from nuclear reactors.

The intense neutron flux available from Harwell's research reactor PLUTO has been used for neutron diffraction studies in the biological field carried out in collaboration with the University of Oxford. In a four month continuous run, during which data was recorded automatically, the position of atoms within the vitamin B12 molecule were measured. The molecule consists of 181 atoms, which is four times as many as any molecule previously investigated by means of neutrons. Nearly half of the atoms are hydrogen.

ELECTRO-MAGNETIC SEPARATION OF ISOTOPES

Stable (non-radioactive) isotopes are required in milligram quantities with a high degree of purity for use as targets for studies in solid state physics and particle bombardment in nuclear physics research. Separation of isotopes is carried out electro-magnetically at Harwell and during the past four years over 2,500 isotopic targets and samples have been prepared for use by scientists in the Authority, in British universities and overseas.

Until recently it was very difficult to obtain separation of certain isotopes such as iron-57 and tin-120 at enrichments greater than 85 per cent. Improved methods of operation have now been devised and enrichment to over 99 per cent. is now regularly achieved.

ACTIVATION ANALYSIS

The Authority's own need for accurate and sensitive chemical analysis, as well as the availability of powerful radiation sources, has led to the further development of methods of activation analysis. In addition to improvements on old methods a new non-destructive technique has been evolved. This is based on the detection of gamma radiation emitted during irradiation rather than the conventional measurements after completion of irradiation. Light elements in, for example, steel and alloys when bombarded by charged particles will emit gamma radiation with wavelength characteristic of the material present and intensity proportional to the quantities present. The method is of particular value in providing information on the surface composition of thick samples.

INFORMATION STORAGE

Potassium iodide becomes coloured when subjected to ultra violet light and this suggests that single crystals might be used for the micro-storage of information. Preliminary experiments at Harwell have shown that the resolution is limited only by the wavelength of the light used in colouring the crystal and in reading out the information. It has been found possible to record a page of writing on six square millimeter of crystal. The principle is more likely to be of value as a computer store however, in view of the limited period for which an image is retained.

COMPUTER AND DATA PROCESSING

Small computers are being used to an increasing extent to monitor, arrange and display data from an experiment. This enables scientists to control the progress of their experiments more efficiently and to make better use of expensive facilities such as a reactor or accelerator. The computer may itself control the experiment and offer unattended over-night and week-end operation with automatic collection of data. The usefulness of such a system can be extended if they are connected to a powerful central computer. Computer complexes of this sort are being studied.

The powerful Stretch computer at Aldermaston has been supplemented by an Atlas 2. These and ancillary facilities constitute the most powerful and

High-speed computers are one of the tools used by scientists in the Mathematical Physics Division at Aldermaston.

Adjustments being made to one of the sub-master switches used to fire the 996 capacitors which supply Culham with one Megajoule of energy for a large thetatron experiment.

comprehensive computing installation in the country. It is used by Harwell, Winfrith and Culham as well as by workers at Aldermaston itself.

Aldermaston staff have compiled a system which enables computer tasks to be transferred from one machine to another in spite of differences in machine language.

COSMIC RAYS

Cosmic rays may have energies much greater than those imparted to charged particles by accelerators. This together with the variety and complexity of the phenomena associated with them provide continuing interest to the nuclear physicist. A group from Harwell using one of the radio telescopes at Jodrell Bank have, for the first time, detected radio pulses associated with cosmic ray showers. A new field of astrophysical investigation has thus been opened up.

FUSION AND PLASMA PHYSICS

The Authority's nuclear fusion and associated plasma physics research has continued at Culham Laboratory at the same level as in the previous year. The programme has included studies on systems for plasma containment supported by basic and technological research, including advanced computing development. In September, 1965, the International Atomic Energy Agency held a world conference on the subject at Culham Laboratory, reviewing the significant developments since the Salzburg meeting in 1961.

The conference showed the more consistent pictures emerging from different experimental groups, the much closer agreement between experiment and theory and generally a clearer grasp of the problems which still prevent the stable containment of hot plasma in a magnetic field. In particular the conditions for hydromagnetic stability have been demonstrated by theory and experiment.

DETECTION OF UNDERGROUND EXPLOSIONS

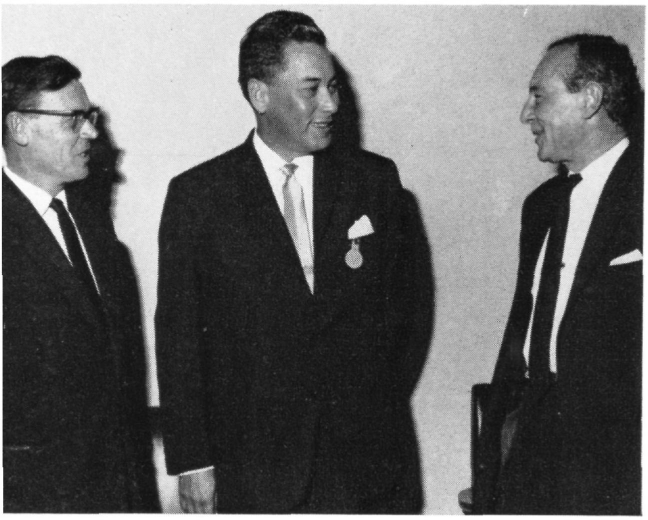
A special illustrated report on the history and achievements of the Authority's seismological project since its inception in 1958 was published by the Authority in December, 1965.

The Authority continued to operate the experimental array at Eskdalemuir and in conjunction with the Dominion Observatory, Ottawa, the similar array at Yellowknife. Experiments were initiated at both arrays which confirm that, on quiet sites, arrays of the Yellowknife type could be be developed to identify with a high degree of probability earthquakes with average seismic magnitude of m4 (magnitude m4 is equivalent to between 1 kiloton of explosive in hard rock to about 10 kilotons in alluvium).

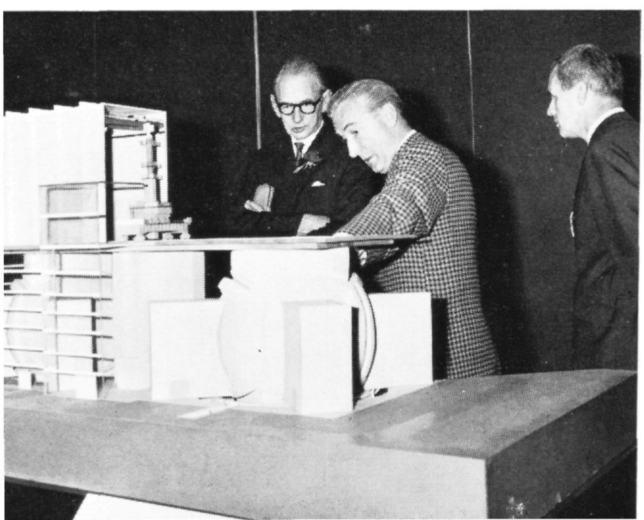
The plans for two new experimental arrays matured during the year and suitable sites, geologically similar to Yellowknife, were found at Gauribidanur, about 50 miles north of Bangalore, India, and at Tennant Creek, which is about 300 miles north of Alice Springs, Australia. The array installations were completed in December, 1965. They are being operated by the Indian Atomic Energy Establishment and by the Australian National University respectively.

The resulting data are of considerable value to geophysicists and are of world wide interest in the study of the physics and natural resources of the earth.

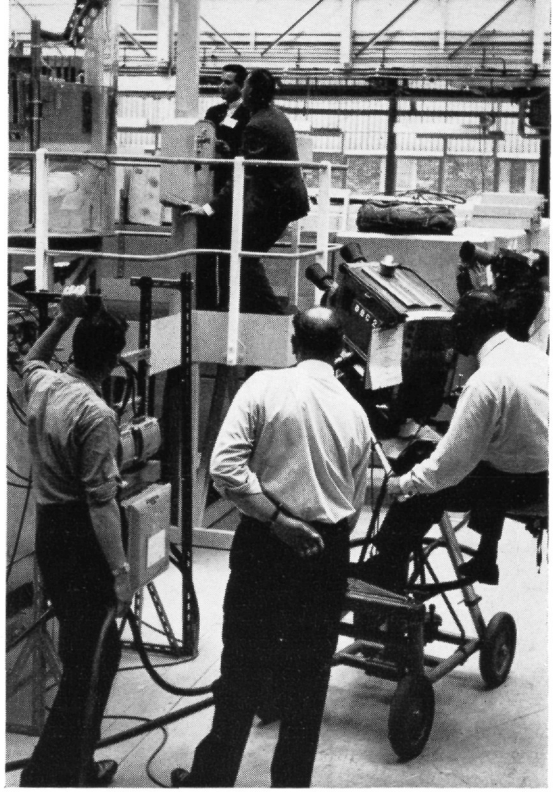
A team of Japanese scientists led by the President of the Japan Atomic Energy Research Institute visited the Authority in October, 1965.



Señor Ing. J. H. Teran, Mexican Minister of Hydraulic Resources (centre), discussed desalination methods with Authority experts in October, 1965.



The Rt. Hon. Douglas Jay, President of the Board of Trade (left) inspects a model of an A.G.R. at the British Week in Milan (October, 1965).



A BBC camera team at Winfrith shooting a sequence which was incorporated in an American television programme on "Nuclear Power in Britain".

INTERNATIONAL AFFAIRS

Sir William Penney continued as United Kingdom representative on the Scientific Advisory Committee to the Secretary General of the United Nations.

Authority representatives took part in the negotiations which led to the Agency adopting safeguards procedures for nuclear power reactors **to ensure that they are used for peaceful purposes only.** In June, 1965, Her Majesty's Government announced their intention voluntarily to place the nuclear power station at Bradwell under safeguards and Authority representatives have been

Three hundred delegates from 25 countries attended an I.A.E.A. conference on fusion research at the Culham Laboratory in September, 1965.

closely associated with the specific negotiations to implement this offer.*

The Authority have contributed to other aspects of the Agency's work through Sir William Penney's membership of its Scientific Advisory Committee and through participation by their staff in the work of eleven advisory panels and study groups.

The Authority acted as hosts to the Agency's International Conference on Plasma Physics and Controlled Nuclear Fusion Research which was held at the Culham Laboratory in September, 1965, and were represented at nine other scientific meetings sponsored by the Agency. Eleven Agency Fellows have been attached to Authority's establishments or attended courses at their schools during the year under review.

The United Kingdom delegation to the Ninth General Conference of the Agency held in Tokyo in September, 1965, was led by Sir William Penney.

As a member of the European Nuclear Energy Agency of O.E.C.D. the Authority have continued to participate in the Dragon Project (see "Nuclear Power") and the Halden Project (Norway); they have also supported the Nuclear Data Compilation Centre at Saclay, France, and the Computer Programme Library at Ispra, Italy, with expert advice and the provision of basic material.

Long-term prospects for nuclear energy in the European Community and the United Kingdom were discussed at the sixth meeting of the U.K./Euratom Continuing Committee for Co-operation in Brussels on 8th July, 1965.

Having joined the British Nuclear Forum as an associate member in October, 1964, the Authority are directly associated with the B.N.F. contribution to the European organisation Foratom. A strong Authority contingent joined the B.N.F. delegation to the second Foratom Congress in Frankfurt in September, 1965, when the present position of nuclear power in Europe was examined.

Mr. J. C. C. Stewart (Member for Reactors) led an Authority team to Athens in March, when the Greek authorities sought advice on their plans for a nuclear power programme.

The Swiss Association for Atomic Energy arranged a meeting in December at which Authority engineers spoke on technical aspects of A.G.R. A team from N.O.K., the Swiss electricity generating organisation, visited Winfrith in August, 1965.

* This agreement entered into operation on 1st September, 1966.

A Parliamentary delegation from the United Arab Republic touring the Engineering Laboratory at Winfrith.

Monsieur M. A. Pierson, Belgian Minister of Economic Affairs, and Professor J. Errera, head of the Belgian C.E.A., with Sir William Penney (right) during a visit to London in December, 1965.

In November Sir Alan Hitchman (Deputy Chairman) visited Australia for discussions about the Australian Atomic Energy Commission's programme and co-operation to forward its implementation. Sir Alan also had talks in New Zealand about plans for the introduction of nuclear power and assistance which might be provided from the United Kingdom.

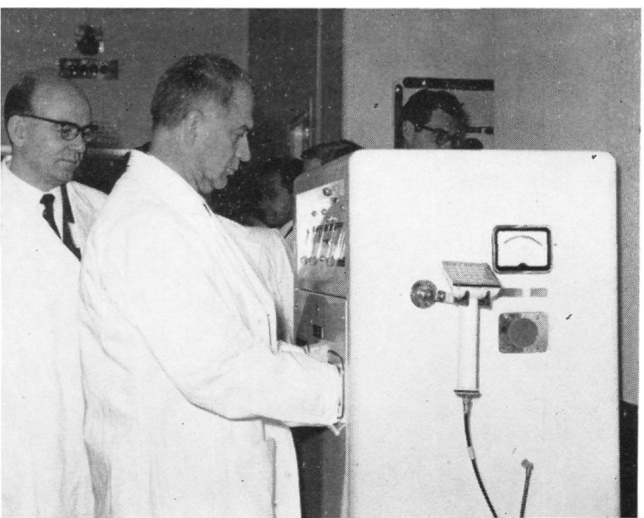
Dr. H. Kronberger (Scientist-in-Chief, Reactor Group) was one of the five British delegates to the international symposium on desalination held by the U.S. Government in Washington in October, 1965. United Kingdom papers described the **experience gained by British industry in installing some three-quarters of the world's existing desalination plant.**

The Israel Water Resources Authority have consulted the Authority about their desalination development programme. Major General Zur of the Israel Authority visited Winfrith to see the Steam-Generating Heavy-Water Reactor project as a system offering favourable characteristics for association with a desalination plant.

Dr. Nabor Carillo, a Mexican Atomic Energy Commissioner, visited London in April, 1965, when he outlined his Commission's provisional plans for a nuclear reactor associated with a desalination plant. In the following October talks on Mexico's desalination plans and possible assistance from the United Kingdom were held with Ing. J. H. Teran, Minister for Hydraulic Resources.

The Authority continued to participate actively in international co-operation in the field of health and safety. They provided a representative on the United Nations Scientific Committee on the Effects of Atomic Radiation and their staff contributed to the work of the International Commission on Radiological Protection. Substantial support was given to the activities of the International Atomic Energy Agency in conferences, panel meetings and information exchanges.

The Authority also provide the United Kingdom representatives on the European Nuclear Energy Agency's Health and Safety Committee and the newly formed Committee on Reactor Safety Technology Meetings took place with Euratom staff during the year. Health and Safety matters featured in bilateral exchanges with a number of countries, particularly U.S.A., France and Australia.



Members of a delegation from the Czechoslovak Atomic Energy Commission at Harwell.

BOARD MEMBERSHIP as from 1st November, 1966

Chairman

Sir William Penney, K.B.E., F.R.S.

Deputy Chairman

Sir Charles Cunningham, K.C.B., K.B.E., C.V.O.

Full-time Members

Air Chief Marshal Sir Denis Barnett, G.C.B., C.B.E., D.F.C.
(Member for Weapons Research and Development)
Dr. J. M. Hill
(Member for Production)
Mr. J. C. C. Stewart, C.B.E.
(Member for Reactors)
Dr. J. B. Adams, C.M.G., F.R.S.
(Member for Research)

Part-time Members

Mr. E. S. Booth
Sir John Cockcroft, O.M., K.C.B., C.B.E., F.R.S.
Mr. J. C. Duckworth
Lord Geddes of Epsom, C.B.E.
Sir Frank Kearton, O.B.E., F.R.S.
Mr. S. J. Pears, F.C.A.

Secretary

Mr. D. E. H. Peirson, C.B.E.

Sir Frank Kearton was reappointed as a Part-time Member for five years from 17th April, 1965.

Air Chief Marshal Sir Denis Barnett was appointed Member for Weapons Research and Development for a period of five years from 1st May, 1965.

Mr. E. S. Booth, Member for Engineering of the C.E.G.B., was appointed as a Part-time Member of the Authority for three years from 1st October, 1965. At the same time Mr. J. C. C. Stewart, Member for Reactors of the Authority, was appointed as a Part-time Member of the C.E.G.B. for a similar period.

Professor A. H. Cottrell resigned from Part-time Membership of the Authority on taking up an appointment as Deputy Chief Scientific Adviser in the Ministry of Defence on 1st July, 1965. Mr. R. M. Geddes' term of office as a Part-time Member expired on 20th November, 1965.

It was announced in November, 1965, that Dr. F. A. Vick had been appointed Vice-Chancellor of Queens University, Belfast, from 1st October, 1966, and would be resigning his appointment as Member for Research in the Authority.

It was announced in February, 1966, that Sir Alan Hitchman's appointment as a Member of the Authority would be extended from 1st April, 1966, for a further period to 31st October, 1966, and that Sir Alan would continue to be Deputy Chairman of the Authority for this period. It was also announced that Sir Charles Cunningham (Permanent Under-Secretary of State at the Home Office) would be appointed to full-time Membership of the Authority from 1st July, 1966, for a period of five years, and that he would become Deputy Chairman when Sir Alan Hitchman left the Authority.

It was announced in August, 1966, that Dr. J. B. Adams was appointed a full-time Member of the Authority for a period of five years from 1st October, 1966, to succeed Dr. Vick (see above).

INFORMATION SERVICES

Scientific and Technical Information Service for Industry
The Librarians at A.E.R.E., Harwell, Didcot, Berks, and Reactor Group, Risley, Warrington, Lancs.

Monthly "List of Publications Available to the Public"
The Librarian, Harwell.

Weekly Information Bulletins and Library Book Lists
The Librarians at Harwell and Risley.

Information Centre and Photographic Library
11 Charles II Street, London, S.W.1 (WHItehall 6262).

Unclassified reports, bibliographies and translations

Science Museum Library, London.

National Lending Library for Science and Technology, Boston Spa and the Central Public Libraries in Acton, Birmingham, Bristol, Kingston-upon-Hull, Liverpool, Manchester, Newcastle-upon-Tyne, Nottingham, Sheffield, and official atomic energy organisations overseas.

Reports for sale can be purchased from H.M. Stationery Office or through any bookseller.

"Atom" Monthly Bulletin, Booklets, and Films
Public Relations Branch, 11 Charles II Street, London, S.W.1.

THE AUTHORITY'S REACTORS as at 31st March, 1966

NOTE: ZEUS was dismantled in 1957, ZEPHYR and HAZEL in 1958, and NEPTUNE in 1959. NERO and DIMPLE were dismantled at Harwell and re-erected at Winfrith in 1960 and 1961 respectively. NERO was dismantled in 1963, and rebuilt as JUNO.

RESEARCH AND EXPERIMENTAL REACTORS

	NAME	LOCATION	DATE OF START-UP	PEAK NEUTRON FLUX THERMAL n/cm² sec.	MAXIMUM HEAT OUTPUT	MODERATOR	COOLANT	FUEL	PURPOSE
1	GLEEP	Harwell	1947	10^9	4·5 kW	Graphite	Air	Natural uranium	Routine testing of the quality of graphite and uranium; research with oscillator; biological irradiations.
2	BEPO	Harwell	1948	about 2×10^{12}	6 MW	Graphite	Air	Natural uranium	Studies of nuclear reactor materials; isotope production; neutron physics; radiation chemistry.
3	LIDO	Harwell	1956	about 2×10^{12}	200 kW	Light water	Light Water	Enriched uranium-aluminium alloy	Thermal reactor studies including shielding and neutron spectra measurements.
4	DIDO	Harwell	1956	about 2×10^{14}	15 MW	Heavy water	Heavy water	Highly enriched uranium-aluminium alloy	Studies of nuclear reactor materials; isotope production; neutron and solid state physics; radiation chemistry.
5	PLUTO	Harwell	1957	about $2{\cdot}5 \times 10^{14}$	20 MW	Heavy water	Heavy water	Highly enriched uranium-aluminium alloy	Studies of nuclear reactor materials; isotope production; neutron and solid state physics; radiation chemistry.
6	D.M.T.R.	Dounreay	1958	2×10^{14}	22·5 MW	Heavy water	Heavy water	Highly enriched uranium-aluminium alloy	Studies on nuclear reactor materials.
7	HORACE	Aldermaston	1958	about 10^8	10 W	Light water	Light water	Uranium-235	To obtain basic nuclear information for HERALD.
8	FAST REACTOR (D.F.R.)	Dounreay	1959	2.55×10^{15} (Fast)	61 MW, 14 MW(E)	None	Sodium-potassium alloy	Enriched uranium	Fast neutron irradiation testing of advanced fuels, structural materials, etc.; development of fast reactor technology.
9	ZENITH	Winfrith	1959	2×10^8	100 W	Graphite	Nitrogen used as heating gas	Enriched uranium; plutonium	Reactor physics investigations for advanced graphite-moderated reactors.
10	HERALD	Aldermaston	1960	5×10^{13}	5 MW	Light water	Light water	Highly enriched uranium-aluminium alloy	Studies in neutron physics, radio-chemistry and nuclear reactor materials, including work with universities.
11	VERA	Aldermaston	1961	—	100 W	None	None	Highly enriched uranium or plutonium	Experimental studies of fast reactor systems.
12	NESTOR	Winfrith	1961	10^{11}	10 kW	Light water and graphite	Light water	Highly enriched uranium-aluminium alloy	Source of neutrons for sub-critical assemblies giving thermal fluxes of 10^8 in the assemblies.
13	DIMPLE	Winfrith	1962	3×10^8	Less than 100 W	Light water, heavy water, organic liquid or mixtures	None	Uranium or plutonium	Testing a wide range of lattices at uniform temperatures up to about 80°C.
14	HERO	Windscale	1962	3×10^9	A few 100W	Graphite	Carbon dioxide used as heating gas	Enriched uranium oxide	Reactor physics studies for the advanced gas-cooled reactor system.
15	DAPHNE	Harwell	1962	about 10^9	100 W	Heavy water	Heavy water	Highly enriched uranium-aluminium alloy	To simulate DIDO or PLUTO; to provide basic physics information in support of these reactors.
16	ZEBRA	Winfrith	1962	—	100 W	None	None	Uranium-235 plutonium	A flexible system intended primarily to investigate the physics of large, fast reactors.
17	HECTOR	Winfrith	1963	3×10^8	100 W	Graphite	Carbon dioxide used as heating gas	Permanent fuel: highly enriched uranium-aluminium alloy; central core variable	*Oscillator reactor: reactivity measurements on materials and fuel elements.*
18	JUNO (formerly NERO)	Winfrith	1964	3×10^8	Less than 100 W	Heavy water, light water or mixtures	None	Uranium or plutonium	Testing a wide range of liquid moderated lattices.

POWER REACTORS

	NAME	LOCATION	DATE OF START-UP	STEAM CONDITIONS AT T.S.V.	POWER PER REACTOR	MODERATOR	COOLANT	FUEL	PURPOSE
19–22	Calder (2 stations "A" and "B" —4 reactors)	Calderbridge	Station "A" 1956 Station "B" 1958	H.P. 324°C 15.7 kg/cm² abs L.P. 182°C 3.8 kg/cm² abs	240 MW(H) 45 MW(E) except No. 2 herringbone reactor— 260 MW(H) 49.5 MW(E)	Graphite 1,140 tonnes per reactor	CO_2 outlet temperature 345°C	Natural uranium in magnox cans 127 tonnes U. 115 tonnes U for herringbone canned fuel	Power and plutonium production; experimental work in aid of the U.K. power programme. Output quoted includes 9 MW(E) equivalent of steam supplied to Windscale site services.
23–26	Chapelcross (4 reactors)	Annan	1958 (1st reactor) 1959 (reactors 2, 3 and 4)	H.P. 324°C 15.7 kg/cm² abs. L.P. 182°C 4.2 kg/cm² abs	240 MW(H) (1 reactor) 245 MW(H) (3 reactors) 47 MW(E) (All)	Graphite 1,140 tonnes per reactor	CO_2 outlet temperature 345°C	Natural uranium in magnox cans 127 tonnes U per reactor	Power and plutonium production; experimental work in aid of the U.K. power programme.
27	A.G.R.	Windscale	1962	454°C 46.7 kg/cm² abs.	105 MW(H) 35 MW(E)	Graphite 210 tonnes	CO_2 outlet temperature 500–575°C	Uranium oxide (2.5% enriched) 13,200 kg UO_2 290 kg U_{235}	To study the advanced gas-cooled power reactor system and to test fuel elements for commercial A.G.R.'s.
28	S.G.H.W.R.	Winfrith	1967	298°C 62.5 kg/cm² abs.	294 MW(H) 100 MW(E)	Heavy water (some moderation) (in light water) coolant	Light water. Outlet temperature 283°C 504°C in superheat channels	Boiling channels enriched uranium oxide clad in zircaloy–2 21,100 kg U Superheat channels enriched uranium oxide clad in stainless steel 950 kg U	To obtain experience of the reliability, safe operation and economics of this type of reactor.
29	Prototype Fast Reactor (P.F.R.)	Dounreay	1971	513°–566°C 163 kg/cm² abs.	600 MW(H) 250 MW(E)	None	Liquid Sodium. Outlet temperature 560°–600°C	Plutonium oxide/ uranium oxide 902 kg PuO_2 3098 kg UO_2 in core	To obtain the information necessary for the design of high power, commercial fast reactors.

AUTHORITY ESTABLISHMENTS

Aldermaston: The Atomic Weapons Research Establishment
Headquarters of the Weapons Group. Development of nuclear warheads, together with supporting research. Nuclear research and certain development work in aid of the Authority's civil nuclear energy programme.

Amersham: Radiochemical Centre
Production and marketing of radioisotopes.

Blacknest: near Aldermaston
Centre for seismological research.

Bracknell Factory, Berkshire
Provides additional workshop capacity for the Atomic Energy Research Establishment, Harwell, especially for the machining of graphite and the small scale production of electronic equipment.

Capenhurst Works, Cheshire
Development work on uranium enrichment processes and operation of the gaseous diffusion plant for the supply of enriched uranium.

Chapelcross Works, Dumfriesshire
Operation of production reactors, including the supply of electricity to the national grid and plutonium production; experimental fuel irradiation and radiological research.

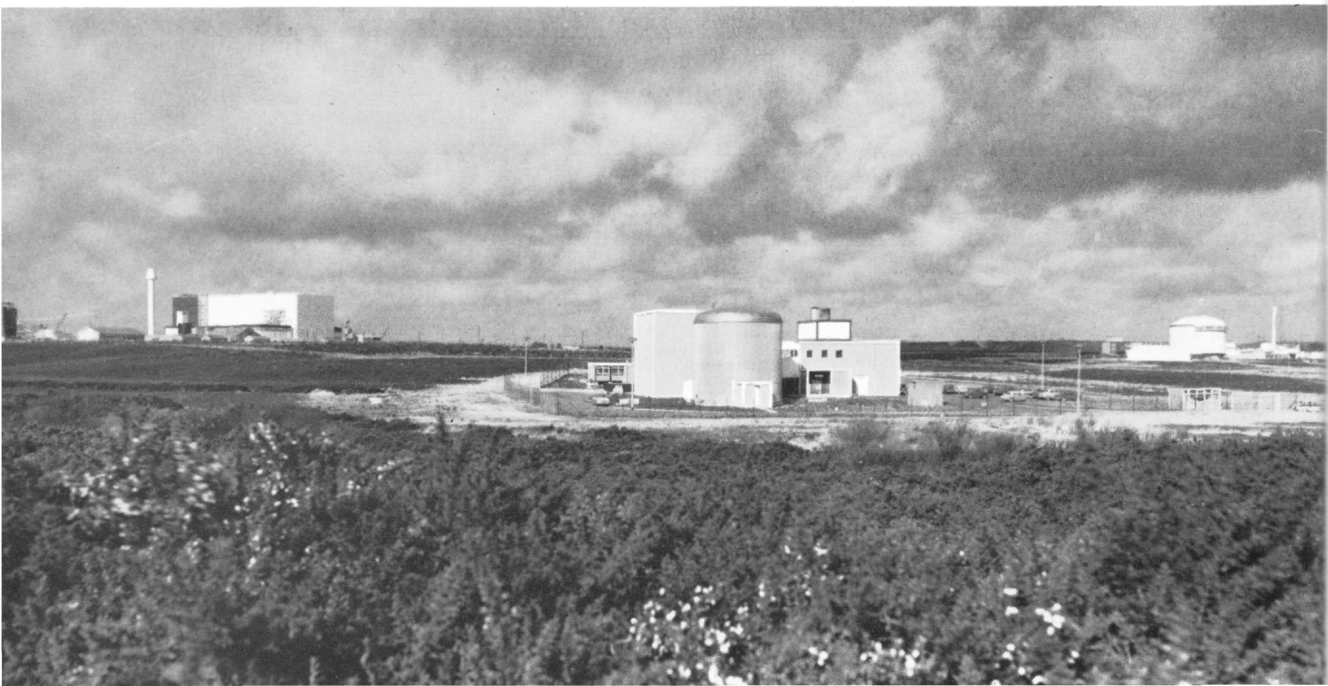
Chatham
Part of the Analytical Sciences Division, Atomic Energy Research Establishment, Harwell.

Culcheth, Warrington: Reactor Materials Laboratory
Investigation of physical and chemical properties of reactor and fuel element materials.

Culham Laboratory, Abingdon, Berkshire
The Authority's centre for plasma physics and nuclear fusion research.

Dounreay Experimental Reactor Establishment, Caithness
Site of the Dounreay Fast Reactor and the Prototype Fast Reactor. Fast reactor development including the fabrication, irradiation and reprocessing of fast reactor fuel. Provides a comprehensive irradiation service using the Dounreay materials testing reactor, and reprocesses M.T.R. fuels for United Kingdom and overseas operators. Also provides site services for the Navy Board submarine reactor project.

This view of the Atomic Energy Establishment at Winfrith in Dorset shows (left to right): the Steam-Generating Heavy Water Reactor; the ZEBRA reactor; and the "Dragon" High Temperature Gas-Cooled Reactor. (March, 1966).



Foulness, Essex
Laboratory experiments and field trials in aid of weapons development. Studies of materials and structures under stress loading for civil defence, military and reactor safety purposes.

Harwell: Atomic Energy Research Establishment
Largest establishment of the Research Group. Research mainly on materials, their properties (including nuclear properties) and the effects upon them of radiation. The work includes many branches of physics, chemistry and metallurgy, and also electronics, health physics engineering and chemical engineering. Has three materials testing reactors, three low energy reactors, several particle accelerators, and specialised laboratories for experiments with radioactive materials at all levels of activity up to kilocuries.

London Office
Headquarters of the Authority. Co-ordination with the groups of policy decisions and of the Authority's relations with government departments and other organisations in the U.K. and overseas. In addition, certain of the Authority's financial, commercial and administrative services are centred on the London Office.

Orfordness, Suffolk
Development and application of environmental testing in the weapons field.

Risley, Warrington, Lancs.
Headquarters of the Engineering, Production and Reactor Groups, providing the following main services:

REACTOR GROUP
Reactor design; technical and economic assessment studies; commercial operations and relations with industry; consultancy. The Reactor Engineering Laboratory is engaged on the engineering development of reactor components and irradiation test equipment.

PRODUCTION GROUP
Co-ordination of the production activities of the Authority's works, and commercial operations.

ENGINEERING GROUP
Chemical plant and fuel element production plant design and building and civil engineering design and construction work on major capital schemes for all Authority groups. The group also includes specialist sections such as electrical engineering, plant instrumentation, estimating, engineering standards and progress and inspection of plant and equipment supplied by manufacturers.

Springfields Works and Laboratory: Salwick, Preston
Uranium ore treatment and fuel element design and fabrication. The Reactor Fuel Element Laboratory works on the development of fuels and fuel elements for thermal reactors.

Thurso, Caithness: Superannuation Office
This office is responsible for the day to day administration of the Authority's superannuation schemes.

Wantage Research Laboratory, Berkshire
Houses the Isotope Research Division of the A.E.R.E., Harwell. Devises and develops new methods employing radioactive materials, especially for industrial applications. Site of the package irradiation plant for experimental irradiation.

Windscale and Calder Works and Laboratory: Sellafield, Cumberland
Operation of production reactors, including the supply of electricity to the national grid, plutonium production, and a training service for reactor operators. Also the operation of chemical plants for the separation of plutonium, uranium, and fission products from irradiated fuels. The Reactor Development Laboratory is engaged on the development programme for the advanced gas-cooled reactor and on A.G.R. physics, using HERO. Other work done by the laboratory covers irradiation testing, including A.G.R. fuel elements, post-irradiation examination and heat transfer studies.

Winfrith, Dorset: Atomic Energy Establishment
Reactor physics including nuclear data evaluation and reactor shielding, heat transfer and fluid dynamics, reactor control, nucleonic instrumentation, the assessment of reactor core performance including reactor kinetics, reactor operation and the use of reactors for experimental development. Studies of new reactor concepts and new applications for nuclear reactors. Site of the S.G.H.W.R., of the O.E.C.D. Dragon Project and of the Dragon Reactor, for which the establishment provides support services and the operations team.

Woolwich (Royal Arsenal)
Part of the Analytical Sciences Division, Atomic Energy Research Establishment, Harwell.

Front cover:
The Authority's charter ship, "Stream Fisher", which plies between Anzio and Barrow with irradiated fuel from the Latina reactor.

Back cover:
Radiochemical Centre, Amersham. Separation of impurities from vitamin B_{12} using ion-exchange cellulose columns.

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