ATOM 1954/1964

10TH ANNIVERSARY ISSUE

and illustrated summary of the tenth annual report of the United Kingdom Atomic Energy Authority from April 1st 1963 to March 31st 1964

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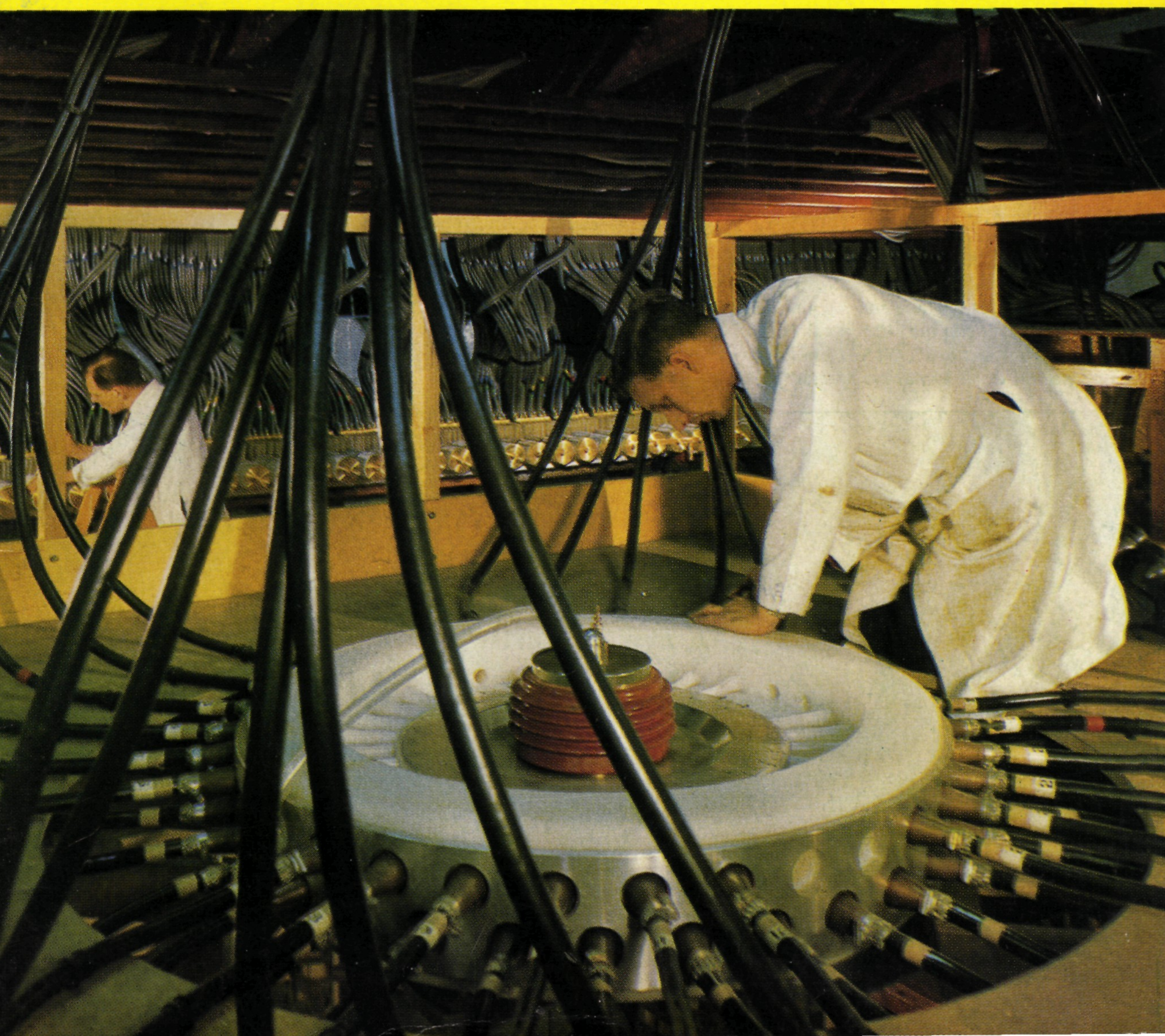
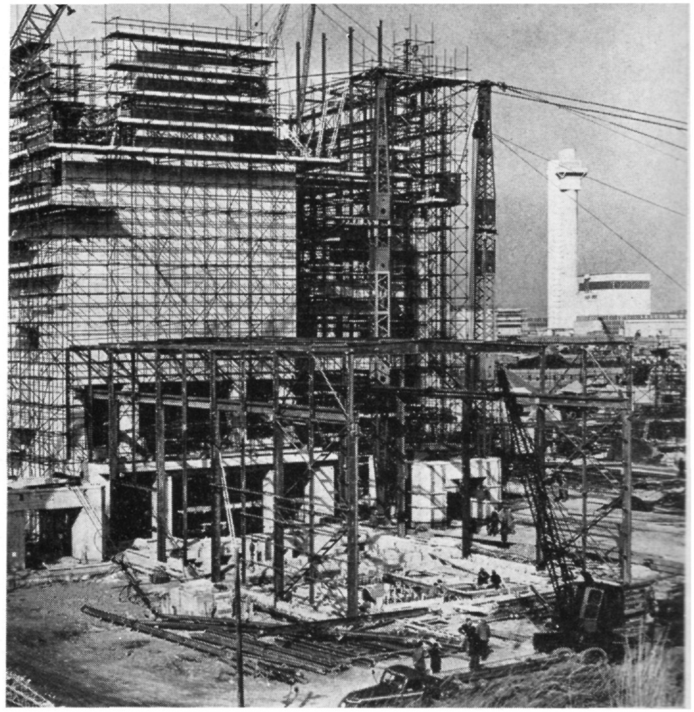
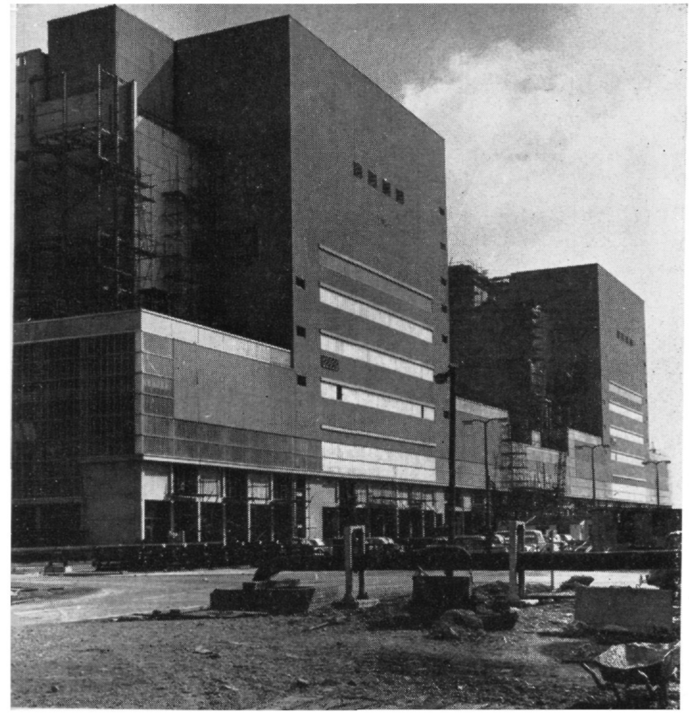


THE AUTHORITY: 1954-1964

1954 When the Authority was formed in 1954, Britain's first nuclear power station at Calder Hall (right) was still being built and no one yet knew for certain whether a nuclear reactor could in fact produce electricity reliably on an industrial scale. During the winter months of 1963–64 Calder Hall and its "twin" at Chapelcross worked at 99% of full capacity as electricity producers.





1964 Britain has the largest nuclear power programme in the world. Power stations like this (at Dungeness) are being built by British industry for the Generating Boards. The first phase of the programme will produce 5,000 Megawatts by 1969 and the Government have adopted a further 5,000 Megawatts as a planning figure for 1970–1975.

Four of the Members of the Authority at its foundation in 1954 are shown in the photograph below (taken at a press conference). Reading from the left are Sir Christopher Hinton (Member for Engineering and Production); Sir John Cockcroft (Member for Scientific Research); and Sir Edwin Plowden (first Chairman). On the extreme right is Mr. D. E. H. Peirson, who has been Secretary of the Authority since its inception, and sitting next to him is Sir Donald Perrott (Member for Finance and Administration). Not included in the photograph is the fifth "founder Member", Sir William Penney, present Chairman of the Authority.

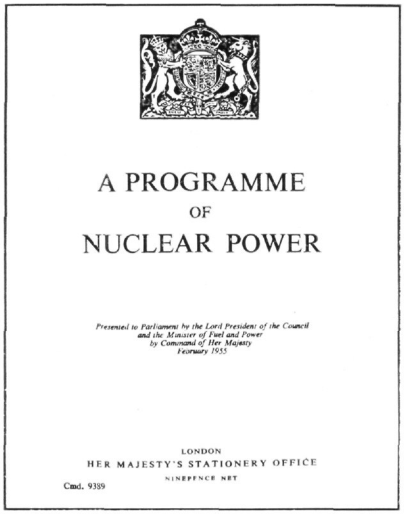
THE UNITED KINGDOM ATOMIC ENERGY AUTHORITY came into being on 19th July, 1954, and took over the then existing establishments (formerly under the Ministry of Supply) in the following month.

The reasons for the creation of the Authority were defined by the Government as follows:—

"As the industrial uses of atomic energy become relatively more prominent, the case for a form of control of the project which is more akin to the structure of a big industrial organisation than to that of a Government department becomes increasingly strong; and it will, in the Government's view, become stronger with the increase in the need for closer contact and co-operation with industry, including the nationalised industries, and the widening application of atomic techniques.

"It is considerations such as these which have led the Government to conclude that the most rapid and economical development in this field will be secured by transferring responsibility from the Ministry of Supply to a non-departmental organisation with the necessary executive power, within the framework of an approved policy and under a financial ceiling, to settle day-to-day problems. They believe that the necessary flexibility and speed of decision can best be obtained from the Board of an organisation run on industrial lines, and with no responsibility outside the field of atomic energy. They have noted that all other countries working in this field have adopted some special form of organisation, outside the normal framework of an ordinary Government department."

1955

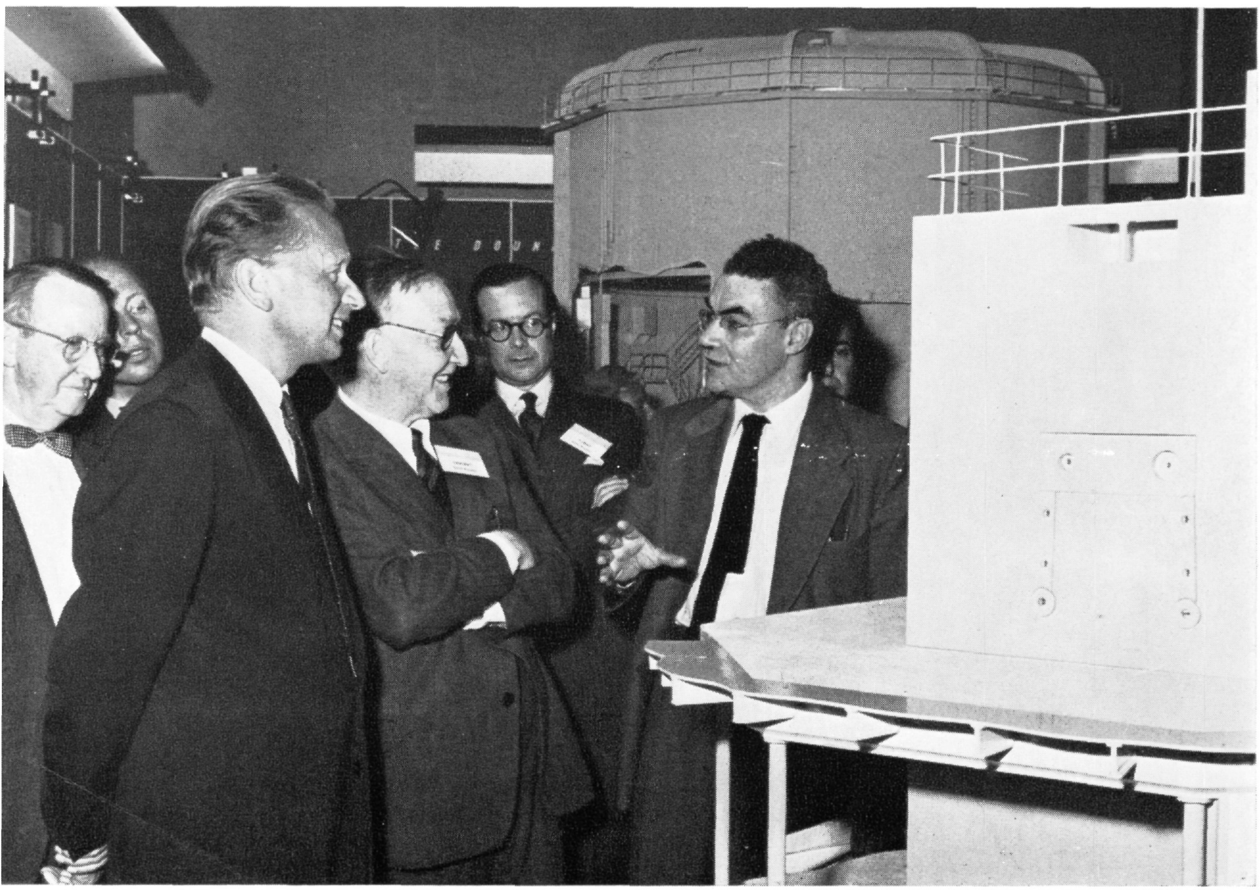

A PROGRAMME
OF
NUCLEAR POWER

Presented to Parliament by the Lord President of the Council and the Minister of Fuel and Power by Command of Her Majesty February 1955

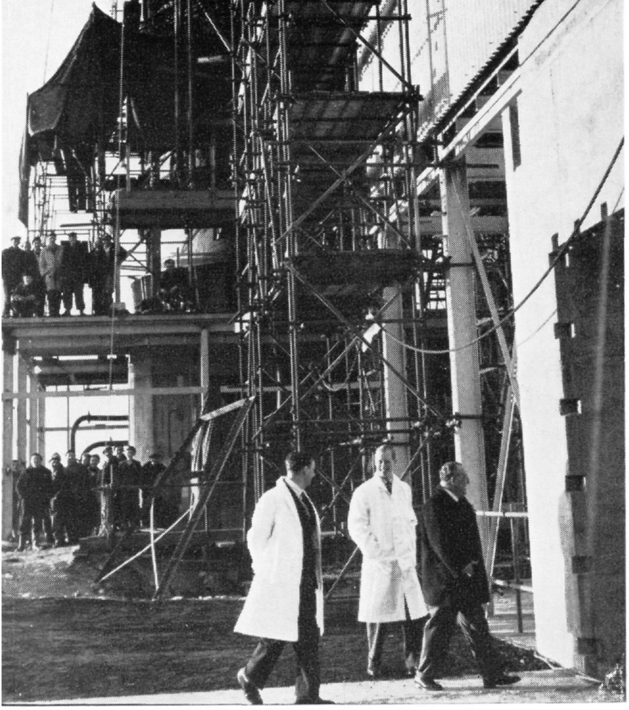
LONDON
HER MAJESTY'S STATIONERY OFFICE
NINEPENCE NET

Cmd. 9389

In February, 1955, Her Majesty's Government announced a 10-year "Programme of Nuclear Power". Under the plan improved versions of Calder Hall were to be built by British industry for the Generating Boards so as to produce $1\frac{1}{2}$–2 thousand Megawatts of nuclear power by 1965. (In 1957 the target was increased to 5–6,000 Megawatts by 1965; in 1960 it was amended to produce 5,000 Megawatts by 1968.)

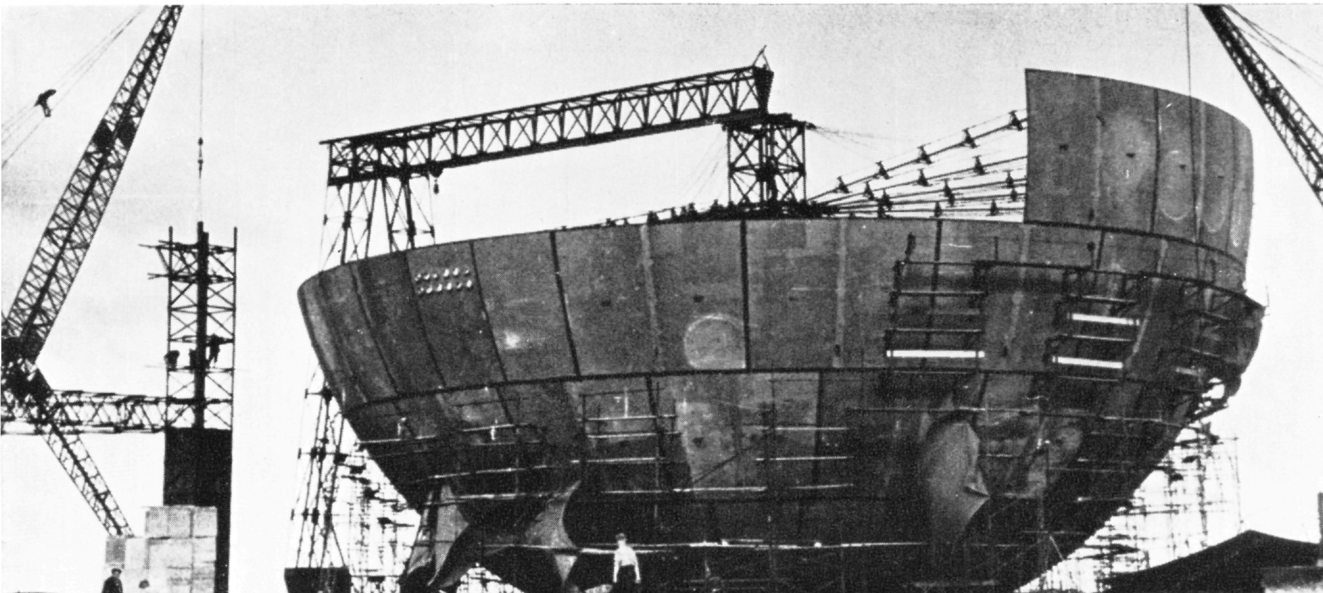


In August, 1955, the United Nations held (at Geneva) the First International Conference on the Peaceful Uses of Atomic Energy. Sir John Cockcroft, leader of the United Kingdom delegation (seen in this photograph with the late Dag Hammarskjold) said: "The Conference has been more successful than we had dared to hope from such a large gathering. It has brought together East and West after a long period of separation in the physical sciences. It has been a meeting ground for friends from all parts of the world. It has enabled us to discuss how best we can help other countries and has done a great deal to re-establish the normal pattern of communication in the scientific world."



In November, 1955, H.R.H. the Duke of Edinburgh visited Calder Hall (to be opened by Her Majesty the Queen in the following year).

In December, 1955, H.R.H. Princess Margaret visited the Radiochemical Centre at Amersham.



The protecting sphere of the Dounreay fast-breeder reactor looked like this at the end of 1955. The "bowl" is 70 feet high and 140 feet across.

1956

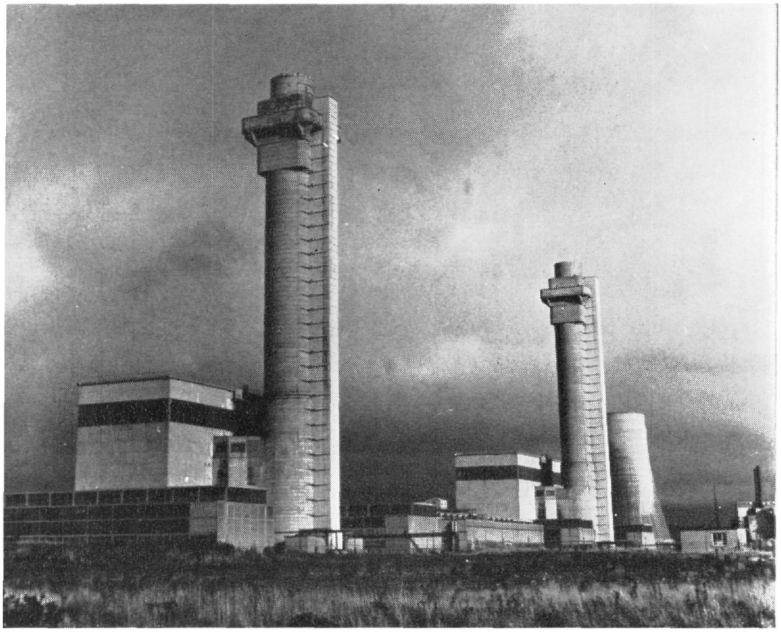
On 17th October, 1956, Her Majesty the Queen performed the opening ceremony of Britain's first nuclear power station at Calder Hall. "To-day we are present at the making of history," said Her Majesty. "Atomic scientists, by a series of brilliant discoveries, have brought us to the threshold of a new age . . . It may well prove to have been among the greatest of our contributions to human welfare that we led the way in demonstrating the peaceful uses of this new source of power."

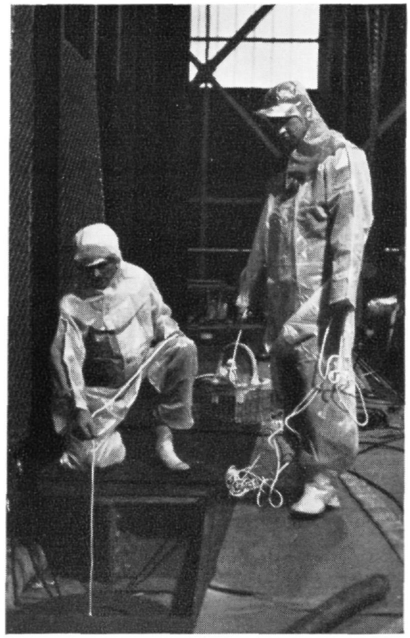
Sir Cyril Hinshelwood, President of the Royal Society, formally opened Harwell's DIDO reactor in November, 1956.

Among many foreign visitors to Harwell in 1956 was Mr. Nikita Krushchev, First Secretary of the Communist Party of the Soviet Union.

1957

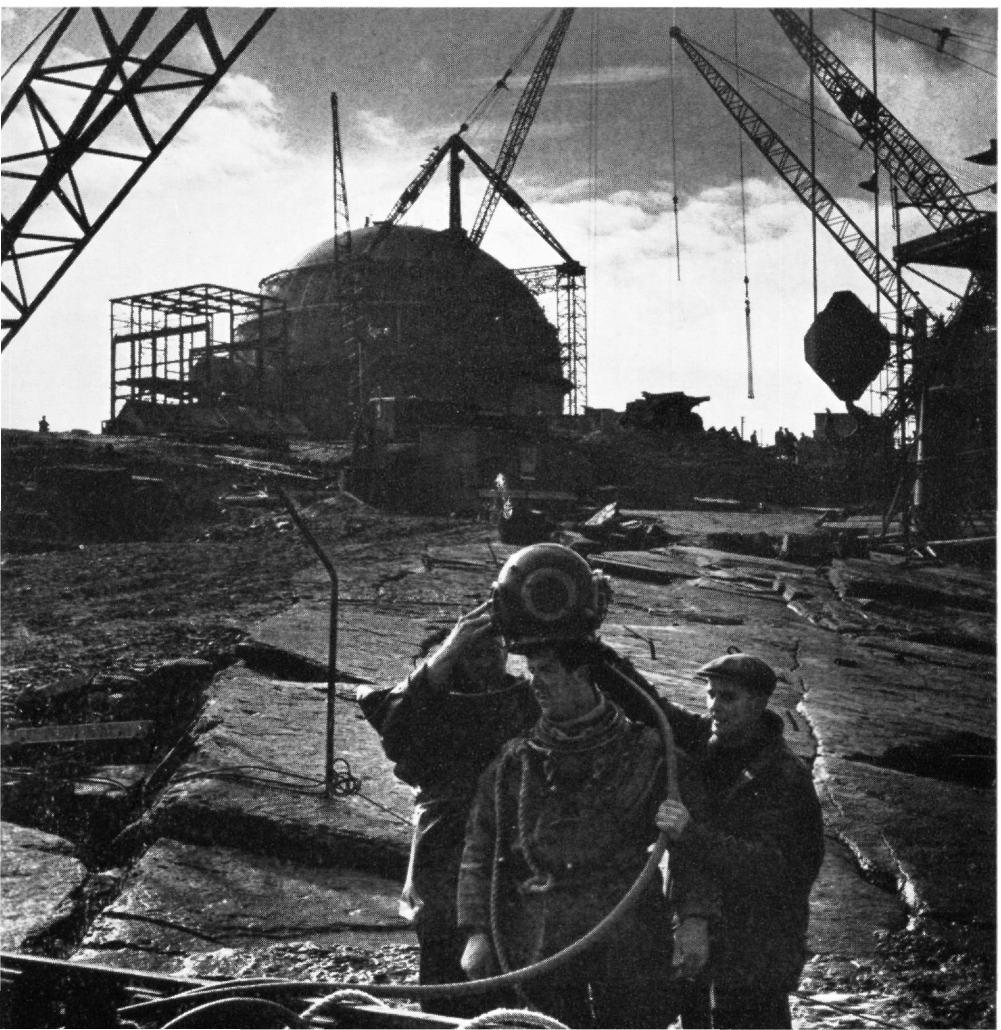
A fire occurred in Windscale No. 1 Reactor in October, 1957. An escape of radioactivity led to restriction on the sale of milk over an area of 200 square miles, but the Medical Research Council reported that it was "in the highest degree unlikely that any harm was done to the health of anybody, whether a worker in the Windscale plant or a member of the general public, as a result of the accident." Pictures show: the Windscale reactors; scientists investigating inside No. 1 Reactor building after the accident; (below) Sir Edwin Plowden, Sir William Penney and Sir John Cockcroft at a press conference on the circumstances of the accident.





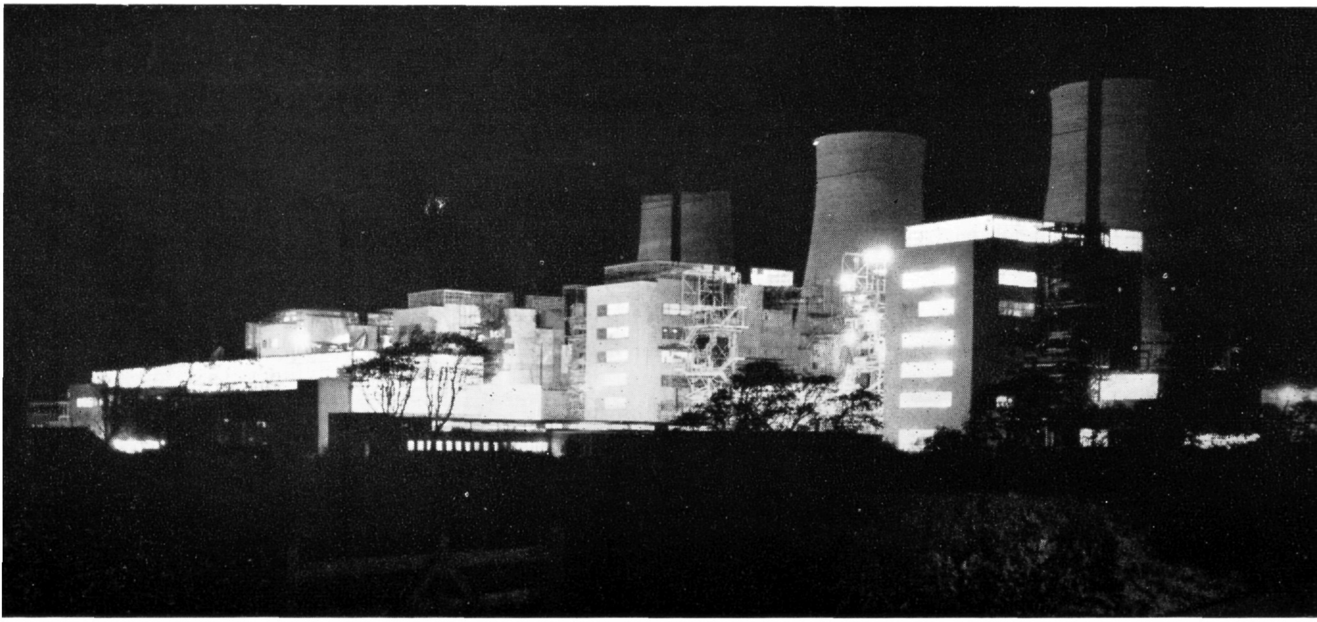
Her Majesty the Queen and His Royal Highness Prince Philip visited Harwell in March, 1957. It was in this year that Harwell's second materials testing reactor (PLUTO) began operation.

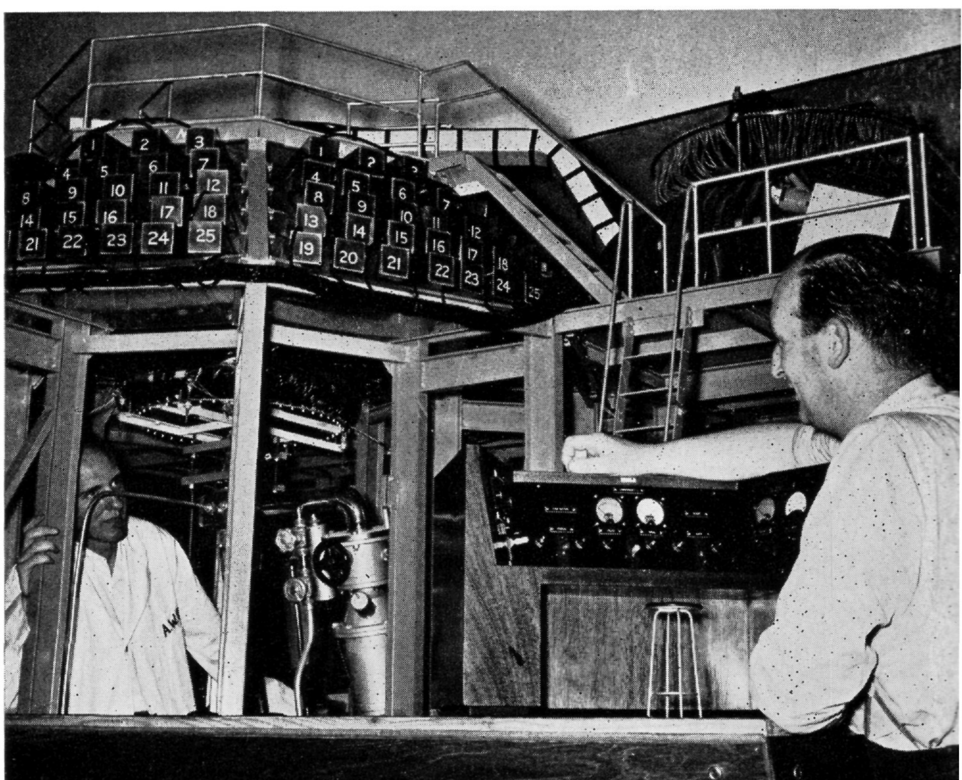
The fast breeder reactor at Dounreay had reached this stage in March, 1957. The diver in the foreground is about to undertake drilling operations in the rock of the sea-bed.



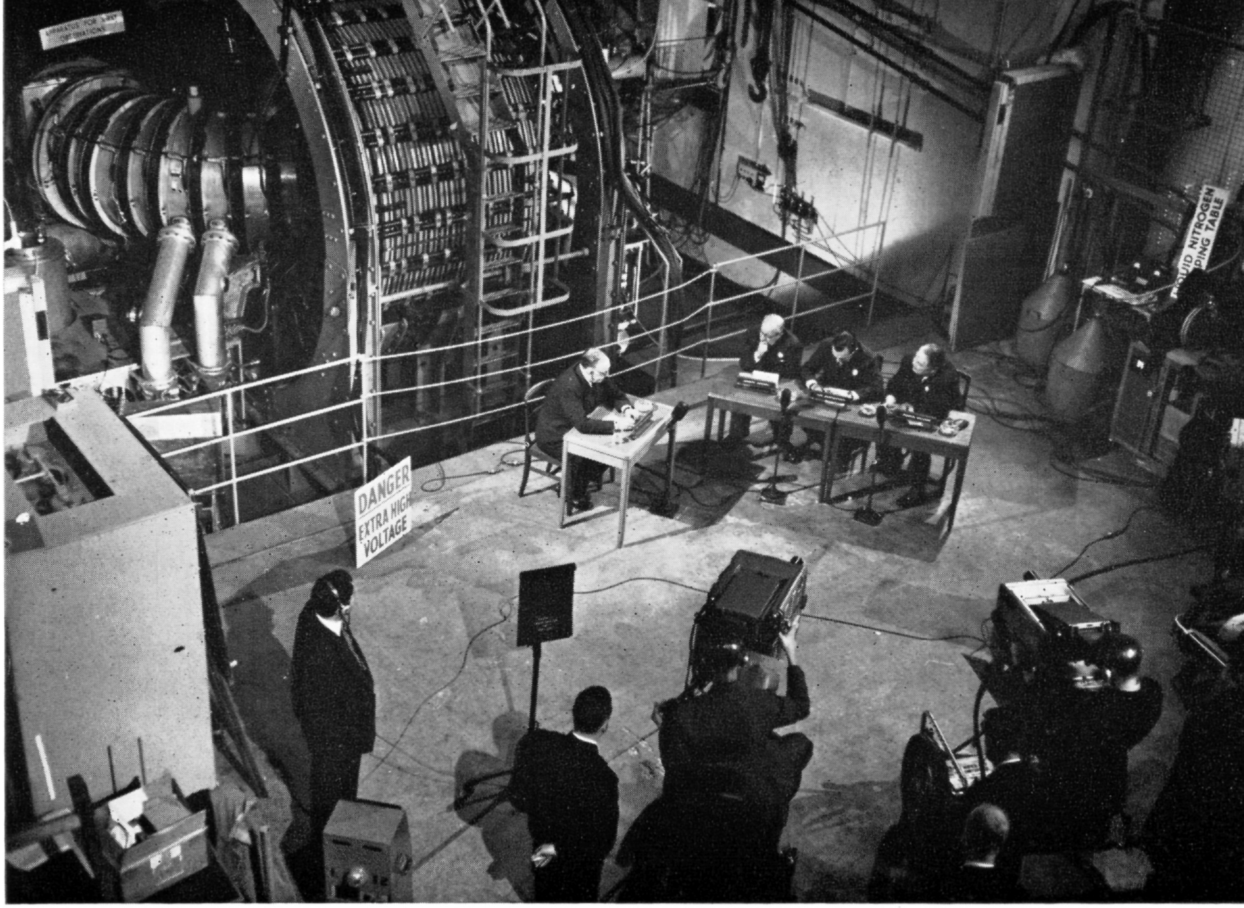
1958

The first reactor of the Authority's second nuclear power station at Chapelcross in Scotland was commissioned in 1958.

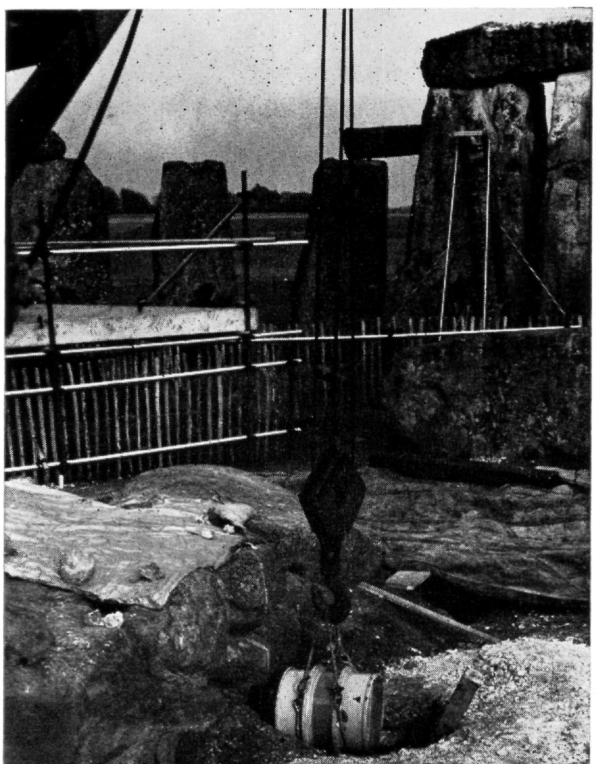




The second United Nations Conference on the Peaceful Uses of Atomic Energy was held at Geneva in 1958. This fifth-scale model of Aldermaston's fusion apparatus, "Maggie", was shown to delegates.



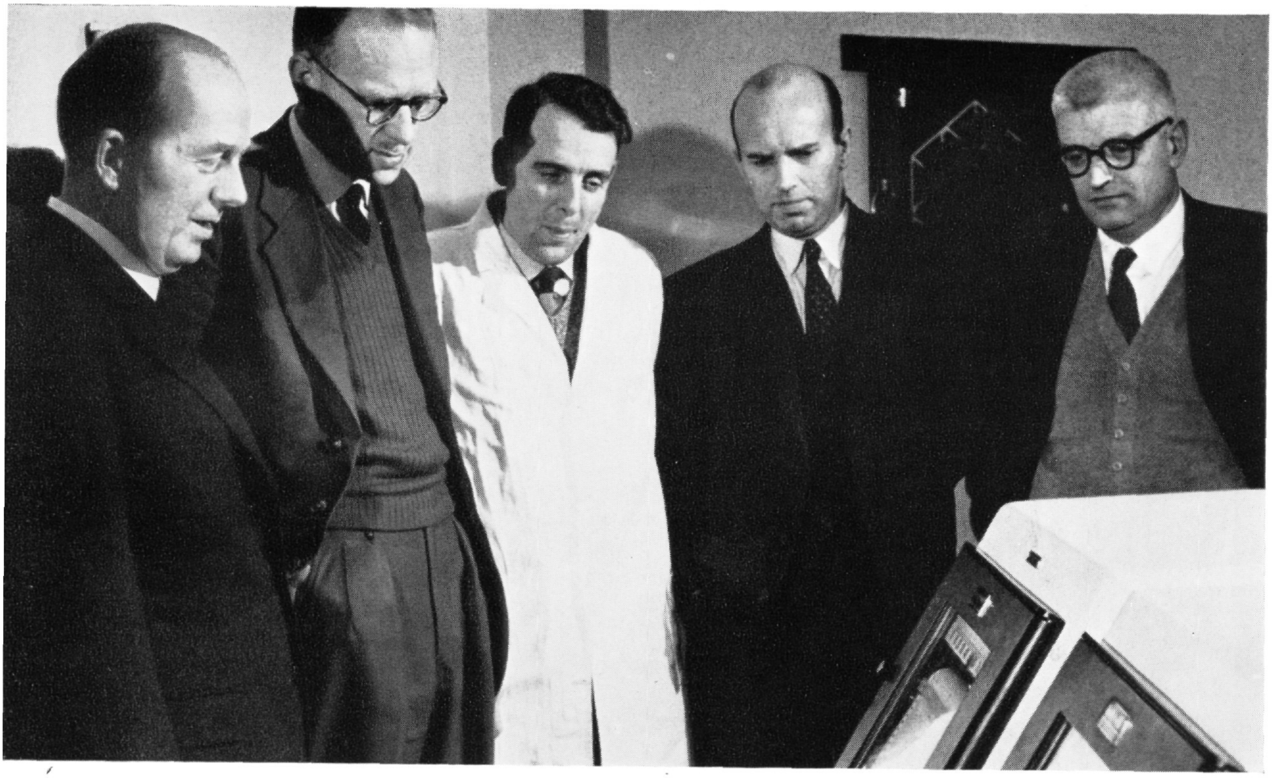
A press visit was held at Harwell in January, 1958, to make public details of the Authority's research into controlled thermonuclear reactions. In the photograph, Sir John Cockcroft is shown giving a television interview in front of ZETA.



In April, 1958, Harwell's Isotope Division used a Sodium-24 source to radiograph a crack in one of the stones at Stonehenge. The Ministry of Works wished to lift the stone, which had fallen down some centuries before, and asked Harwell to find out the extent and depth of the crack.

1959

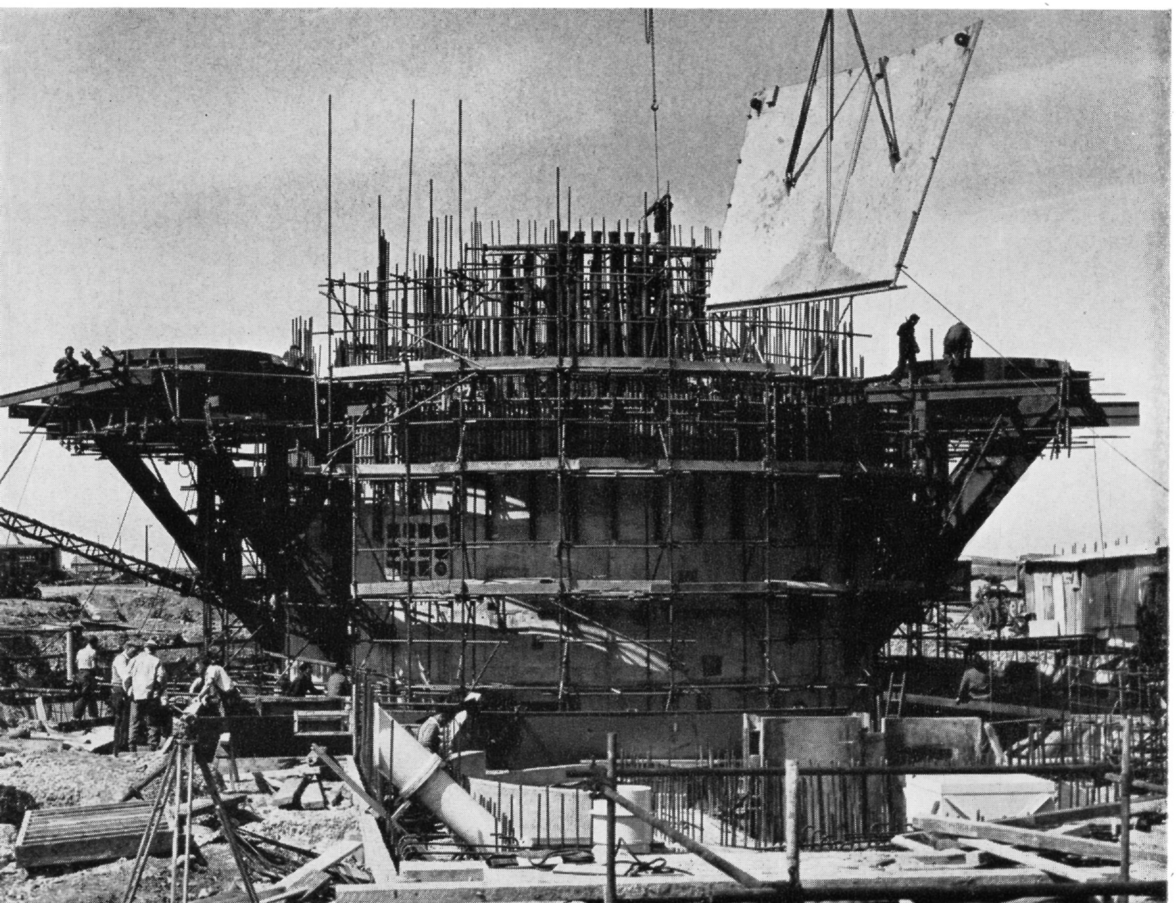
The fast reactor at Dounreay began operating for the first time on 14th November, 1959. Sir William Cook (Member for Engineering and Production) is seen on the left of this group in the reactor control-room.



New fuel element production lines at the Springfields factory were designed to meet the requirements of the nuclear power programme, with a potential output of 300,000 fuel elements per annum.

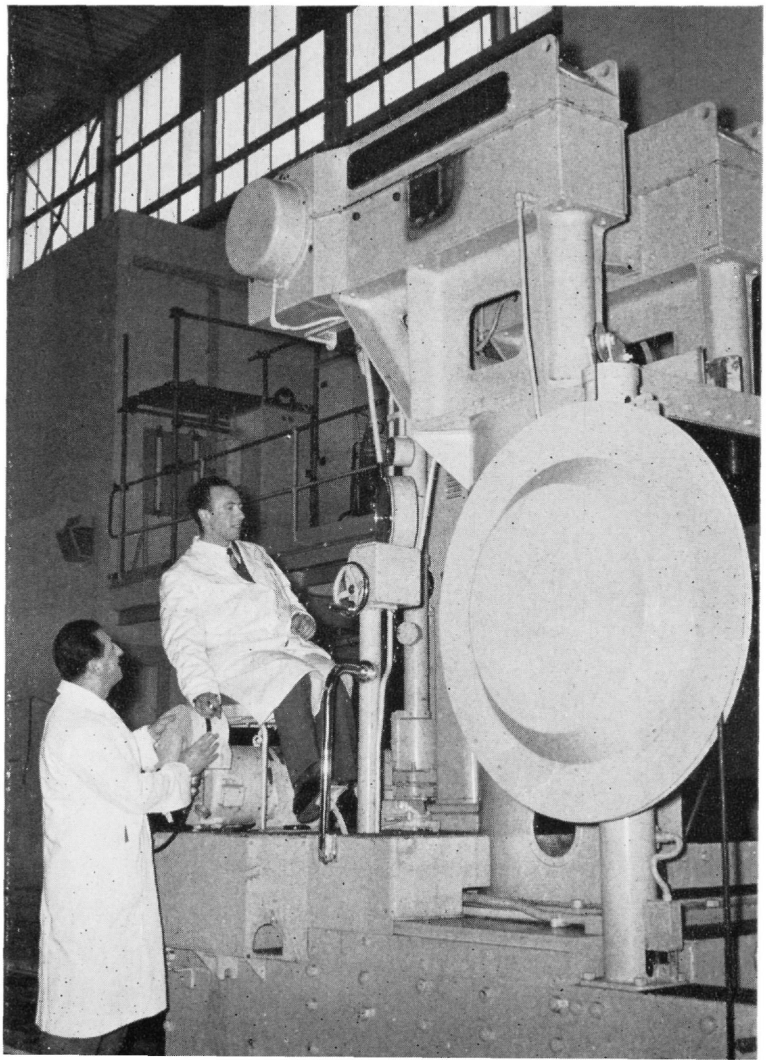
An experimental programme with Aldermaston's tandem electrostatic accelerator began in April, 1959. Harwell began work with a similar machine later in the year.

Construction work in progress on the Advanced Gas-Cooled Reactor at Windscale in June, 1959.



1960

In March, 1960, Sir Roger Makins, Chairman of the Authority, and Mr. Daigoro Yasukawa, President of the Japan Atomic Power Company, signed heads of contract for the supply of fuel elements to the nuclear power station at Tokai Mura.

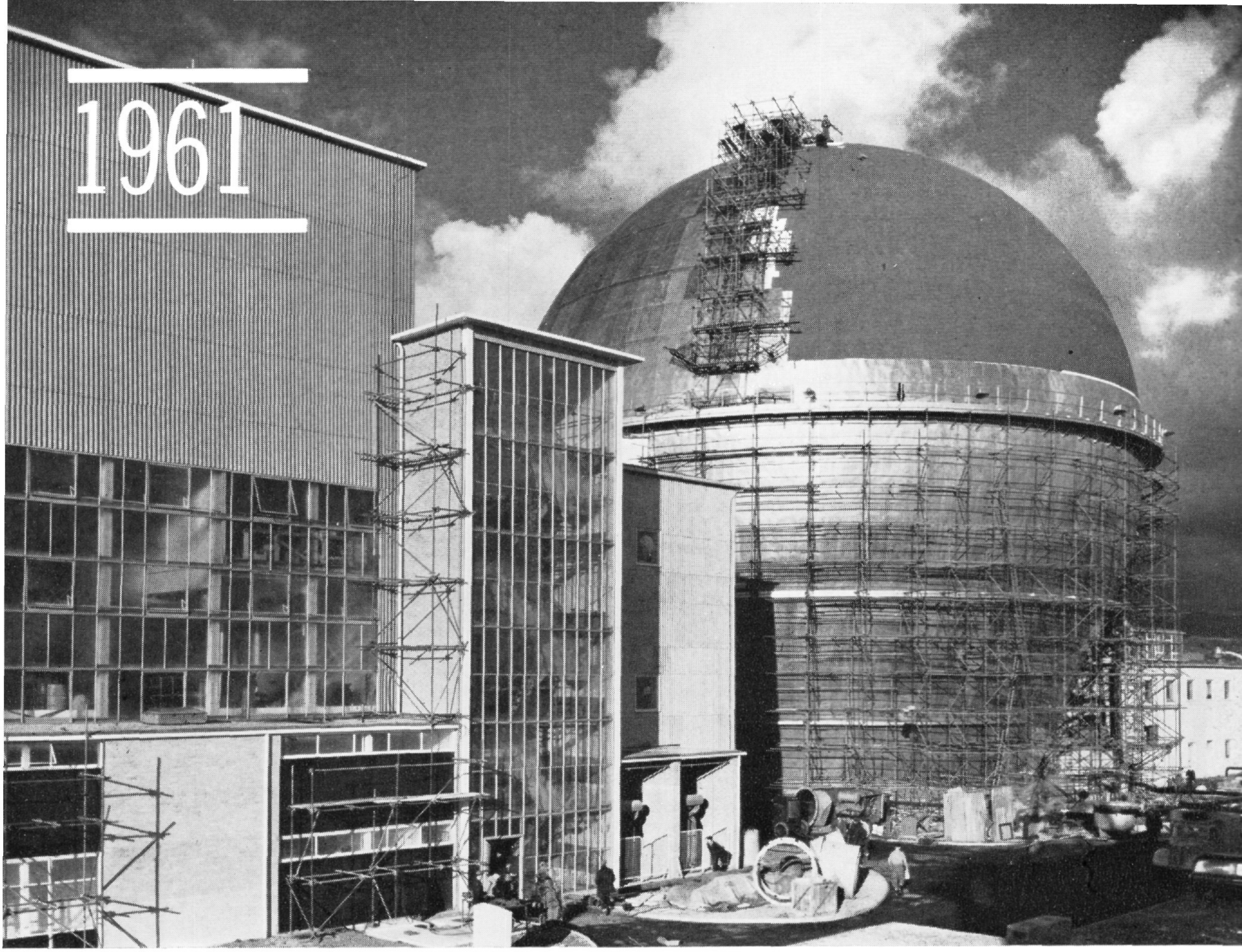


During 1960 Italian engineering staff who would hold key posts at the British designed Latina power-plant in Italy were given an intensive training course at Calder Hall.

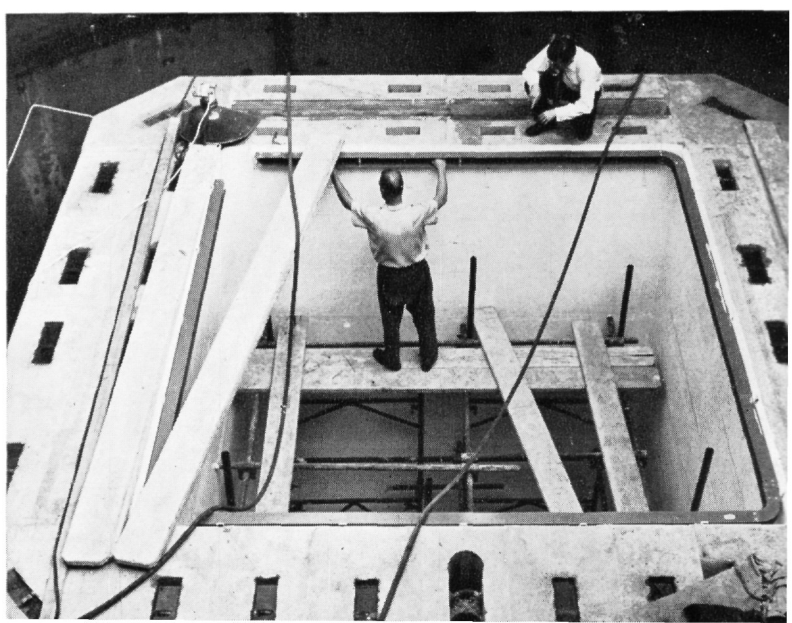
A ceremony took place at Winfrith in April, 1960, to mark the start of construction of the European Nuclear Energy Agency reactor "Dragon". Dr. Sigvard Eklund, of Sweden (Chairman of the "Dragon" Board of Management) placed in the concrete foundation slab a steel cylinder containing plans of the reactor, a copy of the Project agreement and coins from the signatory countries. Dr. Eklund is on the left, with Mr. D. W. Fry, Director of A.E.E., Winfrith (centre) and Mr. C. A. Rennie, Chief Executive of the Project (right).

The Minister for Science, Lord Hailsham, opened the new isotope research laboratories at Wantage in May, 1960. He is seen with Dr. B. O. Fasehun, of Nigeria, in the Isotope School.

1961



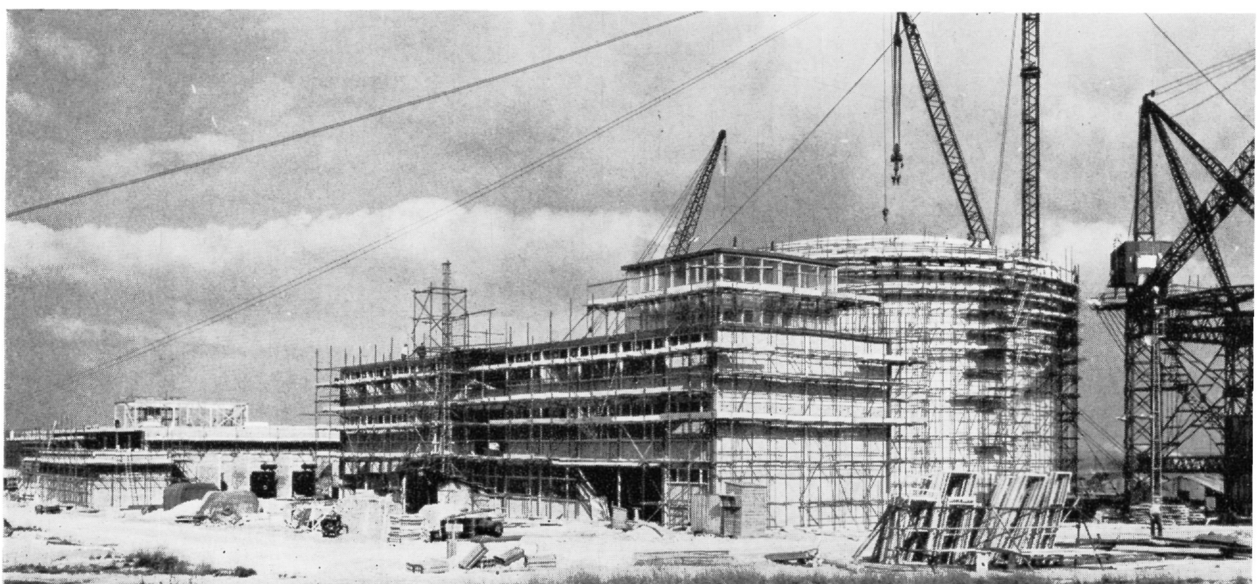
The Advanced Gas-Cooled Reactor at Windscale nearing completion, November, 1961.



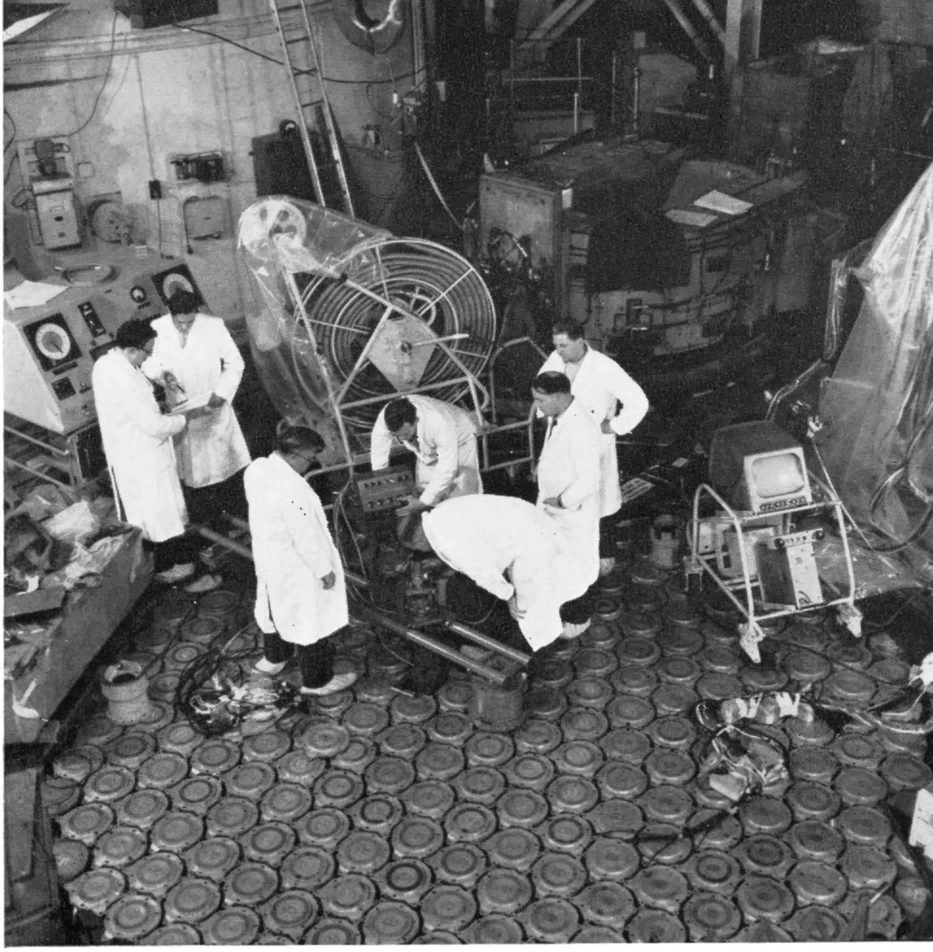
Work in progress on the ZEBRA reactor (zero-energy breeder reactor assembly) at Winfrith, designed to investigate the physics of large, fast, power reactors. October, 1961.

Culham, the Authority's new centre for plasma physics and fusion research, under construction in November, 1961.

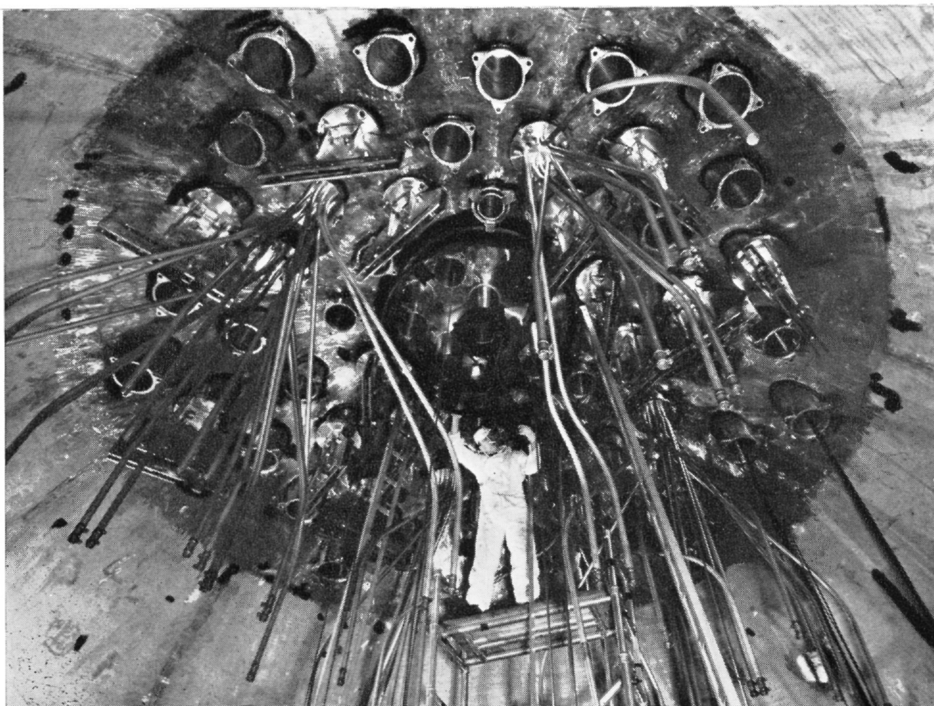
General view of the Dragon reactor site, Winfrith, in October, 1961.



1962

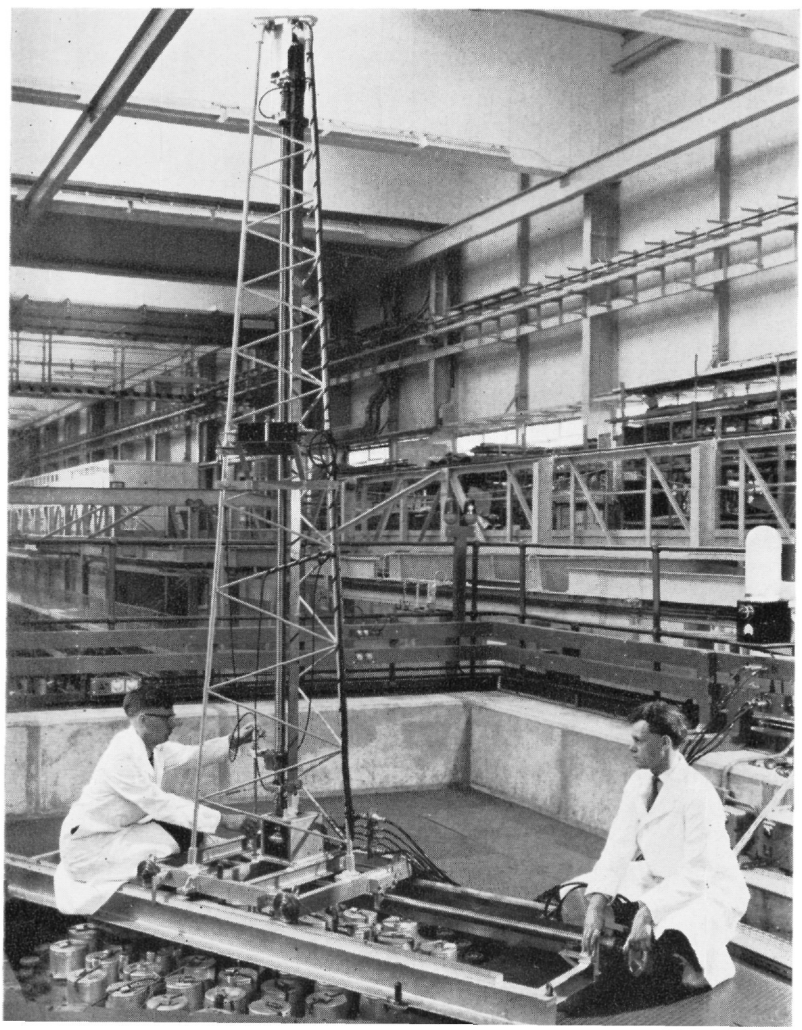


Work on the re-fuelling floor of the Advanced Gas-Cooled Reactor in May, 1962. The reactor operated for the first time in August of that year.



HERO, an experimental reactor at Windscale designed to complement the work of A.G.R. went into operation in February, 1962.

DAPHNE, a Harwell experimental reactor designed to obtain information needed for DIDO and PLUTO, started up in February, 1962.



The S.G.H.W. 1 assembly at Winfrith, used to study the design problems of a Steam-Generating Heavy-Water Reactor.

THE AUTHORITY: 1963-1964

Sir William Penney succeeded Sir Roger Makins as Chairman of the Authority in February, 1964. *Other Members of the Authority at* 1*st April,* 1964 *were:— Deputy Chairman: Sir Alan Hitchman. Full-time Members: Sir William Cook* (Member for Reactors); Air Chief Marshal Sir Claude B. R. Pelly (Member for Weapons Research and Development); Mr. J. C. C. Stewart† (Member for Production); and Dr. F. A. Vick (Member for Research). Part-time Members: Sir John Cockcroft, Professor A. H. Cottrell, Lord Geddes of Epsom, Mr. R. M. Geddes, Mr. C. F. Kearton, Sir Leonard Owen and Mr. S. J. Pears. Secretary: Mr. D. E. H. Peirson.*

* Mr. J. C. C. Stewart succeeds Sir William Cook as Member for Reactors on 1st August, when Sir William takes up an appointment at the Ministry of Defence.

† Sir Leonard Owen's appointment expired on 30th June, 1964.

At the end of the financial year 1963–1964, Government decisions were awaited on two questions of great importance to the Authority's civil research and development activities. These were the future nuclear power programme, and the question of nuclear marine propulsion.

The Authority continued to meet the demands made upon them for fissile material and also for fuel elements for reactors both in the United Kingdom and overseas. Deliveries of fuel elements reached a record high level.

The contract to supply the Latina power station in Italy was fulfilled during the year, and a contract was signed for the supply of fuel elements for the Tokai Mura nuclear power station in Japan.

The Calder Hall and Chapelcross reactors continued to operate with a high degree of efficiency, 99 per cent of full capacity as electricity producers being achieved in the winter months.

Satisfactory progress was maintained during the year with the main reactors forming the basis of the Authority's reactor development programme. The Windscale Advanced Gas-cooled Reactor operated at heat outputs up to 15 per cent above the design figure with a corresponding net electrical output of 30 MW (Electrical). During the year over 172 million kWh were supplied to the national grid.

The Dounreay fast reactor first operated at the full design output of 60 MW (Heat) during July, 1963. It continued to operate at about this power level throughout the remainder of the year, except for the necessary shutdowns for refuelling. The net electrical output of the reactor was maintained at about 12.5 MW (Electrical) and during the year over 23 million kWh were supplied to the national grid.

Construction of the 100 MW (Electrical) prototype Steam Generating Heavy-Water-moderated Reactor continued at Winfrith. It is due to be finished in 1967.

The Authority carried out much work during the year for the Working Group on Marine Reactor Research. Research work was continued on VULCAIN and on I.B.R. designs and appraisals

The Power Programme

The White Paper—"The Second Nuclear Power Programme" (Cmd. 2335) was issued on 15th April, 1964. It stated that for planning purposes a programme of 5,000 MW of nuclear generating capacity had been adopted for commissioning in England and Wales during the six years 1970–75. The C.E.G.B. would issue an enquiry for tenders for an A.G.R. station. They would also be ready to consider tenders from British industry for water-moderated reactor systems of proved design. They would ensure that these tenders were judged on a comparable basis. The Government would review with the supply industry and the Atomic Energy Authority, the results of this enquiry in order to decide the type or types of reactor to be built.

Marine Propulsion

The report of the Working Group on Marine Reactor Research (appointed by the Minister for Science and the Minister of Transport), published on 14th May, stated: "In our view the practical choices are to embark now on a programme for developing a pressurised water reactor to one of the designs on which the Authority is now working or, after tidying up work already in hand, to tackle more promising ideas should they emerge . . . We think it would be preferable, if a programme is put in hand, to construct a ship rather than a shore-based facility."

were made of five other designs, three of which were American.

The Authority's staff, industrial and non-industrial, was reduced by about 5 per cent in the year, because of the cessation of production of uranium-235 for military purposes at Capenhurst and also because of the completion of the greater part of the Authority's capital works programme. Great care was devoted to ensuring that this reduction was accomplished with the minimum of hardship to individual employees.

Expenditure in 1963/64 on the Authority's programme of civil research and development was £45 million of which £36 million was current expenditure and £9 million was on capital facilities. The number of graduate or professional engineers or scientists employed on the programme at 31st March was 2,830 of whom 180 were doing work for other bodies on repayment. The table below shows the deployment of resources in terms of current expenditure and qualified staff on the various parts of the programme.

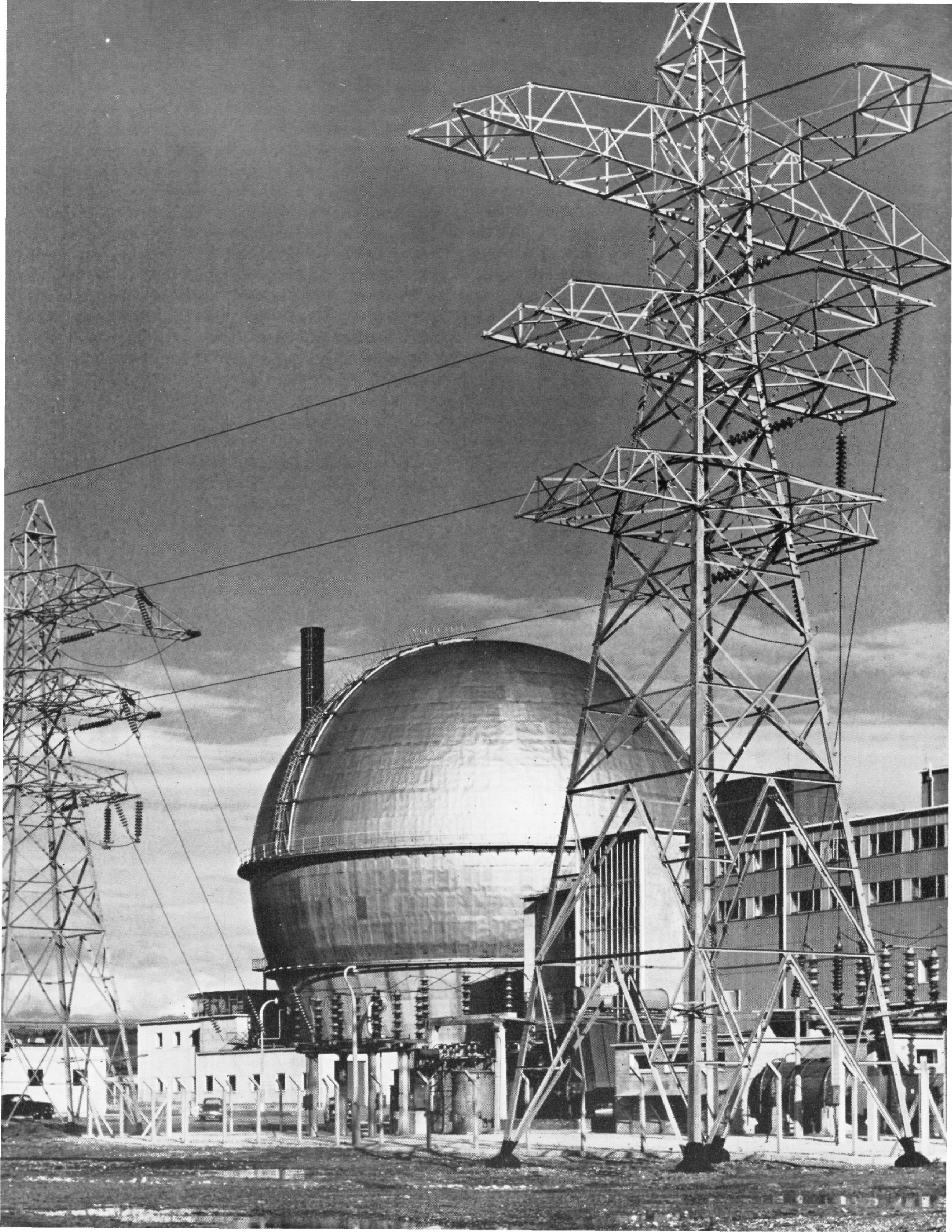
	£m. Current Expenditure		*Qualified Scientists and Engineers*	
	1962/63	1963/64	31.3.63	31.3.64
Reactor Development Programme Systems, Reactor Systems Research	26	26	1880	1900
General Research	5	6	470	470
Plasma Physics and Fusion Research	3	3	190	200
Isotopes Research	1	1	85	80

The Authority's net estimates for 1964/65 are £34,810,000 including £9,648,000 for the National Institute for Research in Nuclear Science. These are £25,395,000 less than the final grant for 1963/64 of £60,205,000, including £8,998,000 for N.I.R.N.S. The reduction was mainly due to special receipts from the defence departments.

The total income from the Authority's trading and other commercial activities in the year under review amounted to £52.5 million, made up as follows:—

	£ million
Sales of reactor fuel, fuel services, etc.	39.5
Sales of electricity	7.9
Sales of radioisotopes	1.6
Sales of reactor grade graphite	2.7
Royalties and other income from licensing agreements, etc.	0.8
Total	52.5

During the year, United Kingdom participation in the Halden reactor research programme of the European Nuclear Energy Agency (E.N.E.A.) was renewed. In October the Authority concluded an agreement with Atomic Energy of Canada Limited to extend and regulate their collaboration on research and development concerned with heavy-water-moderated, water-cooled reactors and their fuel.



REACTORS: 1964

The Authority's reactor development programme was originally based on the experience gained in operating reactors for the production of plutonium for defence purposes. From these air-cooled graphite-moderated reactors, the Authority evolved a nuclear power system based on the magnox reactor, which has now proceeded through all the stages of research, development and design to large-scale manufacture in industry.

Another step forward in the development of gas-cooled, graphite-moderated reactors was the Advanced Gas-Cooled Reactor, which is being considered for installation in the second nuclear power programme.

Further advances in gas-cooled systems are now being explored. The reactor development programme has been extended to cover the Steam-Generating Heavy-Water reactor concept.

The S.G.H.W. has the advantage of lower enrichment than the A.G.R. and the potentiality of producing superheat steam. With successful development the S.G.H.W. should have low capital costs comparable with the current designs of water reactors with substantially lower fuel costs. The Authority are now deploying as much effort on the development of a range of water reactor systems (including reactors for marine propulsion) as on gas-cooled reactor systems.

From the early days it was realised that the graphite and water-moderated thermal reactor systems utilised only a very small amount of the energy inherent in nuclear fuel and that a fast-breeder reactor system offered the chance of a far higher extraction of energy from uranium than is possible with thermal reactors.

The fast reactor system also offered the best means of burning the plutonium that is made in the thermal reactor cycle and which will accumulate in large quantities in the 1970's from the magnox reactors of the first nuclear power programme.

Much exploratory work was therefore carried out on the fast reactor concept and this was crystallised in the design, construction and operation of the experimental fast reactor at Dounreay.

The first stage of fast reactor development has been successfully completed by the full power operation and satisfactory behaviour of the Dounreay reactor. In the last year much progress has been made on the irradiation in this reactor of the ceramic fast reactor fuels that are likely to form the basis for the economic operation of large fast reactors.

Proposals are now being formulated for the next step in fast reactor development, viz. the building of a prototype fast reactor to demonstrate that satisfactory and economic operation of large fast reactor power stations is feasible. It is hoped to obtain Government approval next year for the building of this prototype.

The Authority reactor development programme is reviewed regularly by a committee under the Chairman of the Authority.

The deployment of effort at 31st March, 1964, between reactor projects is illustrated below in percentages of qualified scientists and engineers in the Reactor, Research and Weapons Groups engaged on these projects:—

System	*Percentages*
Advanced Gas-Cooled Reactor	19
Steam-Generating Heavy-Water Reactor	17
Fast Reactor	38
Civil Marine	14
High-Temperature Gas-Cooled Reactor (staff seconded to or supporting the O.E.C.D. high-temperature reactor, "Dragon")	12

A.G.R.

The Windscale Advanced Gas-Cooled Reactor has operated reliably and well; a peak output of 115 Megawatts (Heat) has been achieved and a steady load of 105 Megawatts (Heat) has been maintained. Modification to the turbine has been planned to allow an increase in net electrical capacity to about 36 Megawatts (Electrical).

Over the year the full power load factor (defined as the ratio of electricity generated to amount which would have been generated if the reactor had run continuously at full power) was 74 per cent. Part of the time when the reactor was not operating was accounted for by the three weeks' annual maintenance and inspection carried out last October; part was due to plant faults and unscheduled maintenance; the balance was due mainly to shutdowns required for experimental purposes such as

The Advanced Gas-Cooled Reactor at Windscale has the highest coolant outlet temperature of any power reactor at present operating.

Post-irradiation examination of A.G.R. fuel elements is carried out in these "caves" adjacent to the reactor.

the changing of fuel elements and graphite specimens. Excluding shutdowns for experimental purposes the operational availability of the reactor was 87 per cent. Thus the performance of the Windscale A.G.R. during its first year of power operation bears favourable comparison with any other nuclear reactor built solely as a nuclear power station or otherwise.

Encouraging progress has been made in protecting the graphite moderator from corrosion by the carbon-dioxide coolant under irradiation. Experimental irradiations have continued in materials test reactors and results have shown that the addition of methane inhibits the rate of corrosion as measured in pure carbon dioxide by a factor of between 10 and 40.

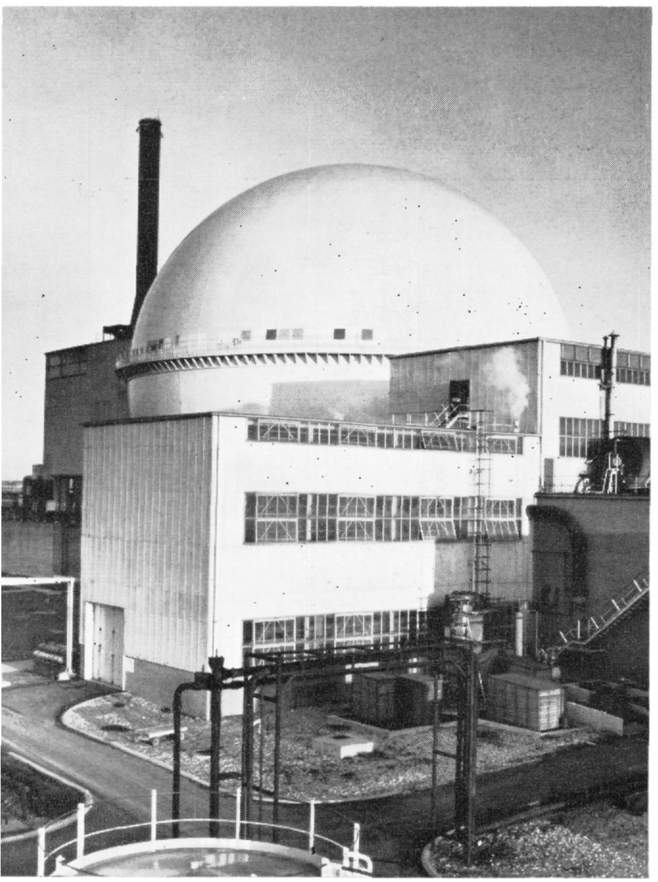
As a result of tests a coolant mixture has been chosen for a long power run in the Windscale A.G.R. The mixture is expected to ensure a full life for the graphite structure of a large A.G.R. with an ample factor of safety.

Work has continued on the production of graphite with improved properties as specified in the Central Electricity Generating Board's enquiry for the first A.G.R. station for the 1969/76 nuclear power programme. Much can be done to improve the resistance to corrosion. These graphites also have greater mechanical strength and exhibit smaller dimensional changes under irradiation. Improved graphites have been manufactured by industry and larger orders are being placed to check that the improvements can be obtained in full-scale manufacture.

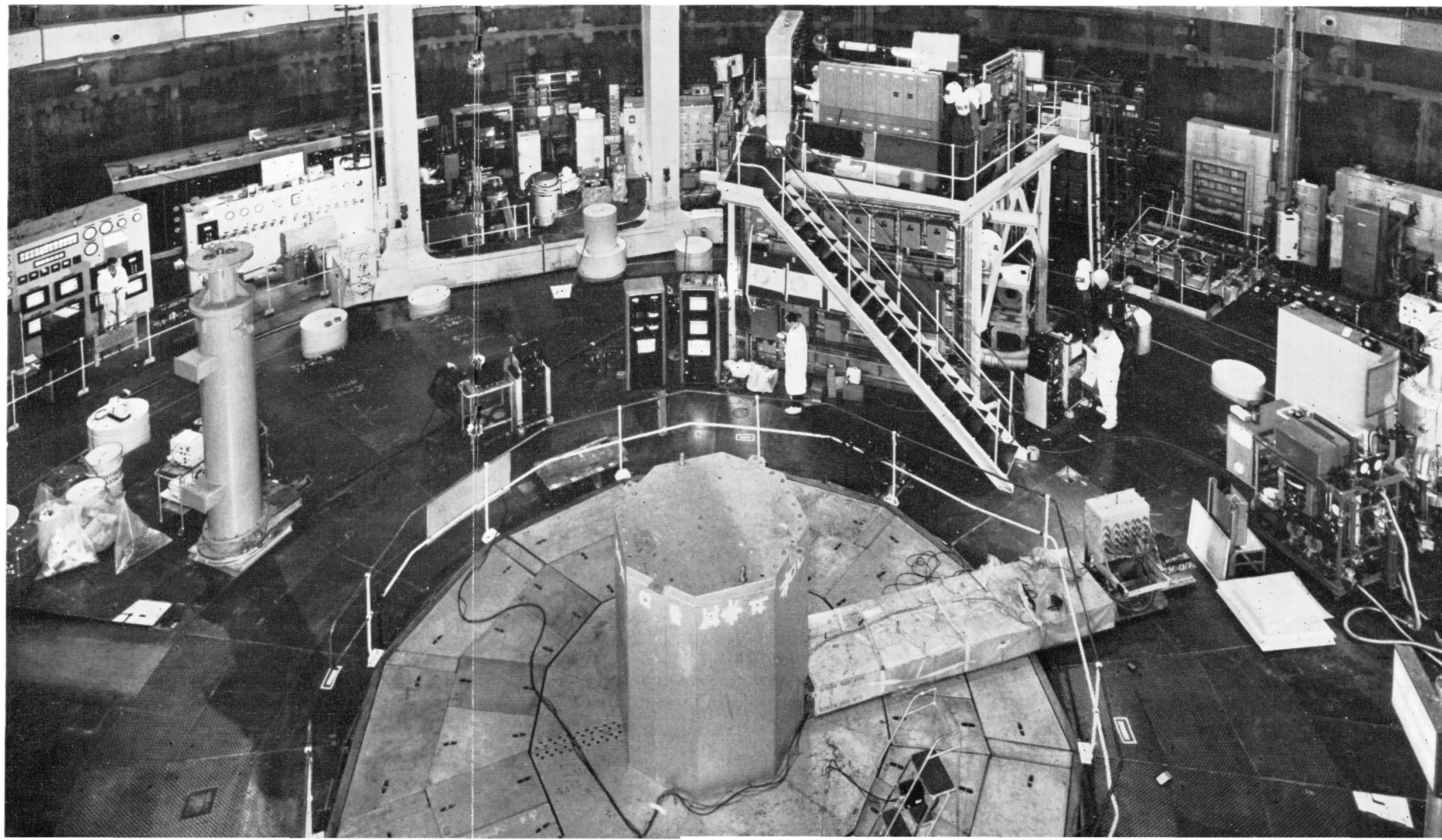
The behaviour of the fuel elements in the Windscale A.G.R. during the year has been excellent. The average burn-up of the whole fuel charge has exceeded 3,000 Megawatt-days (heat) per tonne with a peak burn-up of 6,400 Megawatt-days. No failure of the 33,000 fuel elements that have been loaded into the reactor has been detected.

In addition to 165 channels containing fuel elements of the original design there are now 20 channels containing experimental fuel elements under irradiation. The features under test include thinner cans, larger can diameter, longer elements and higher can surface and fuel temperatures.

Longer term development of ceramic fuels dispensing with a metal can has continued. Specimens are being irradiated in the Dounreay materials test reactor and are running with surface temperatures of about 1,000°C.



The Dounreay Fast Reactor. Proposals are being formulated for the building of a larger Prototype Fast Reactor.



Inside the reactor sphere of the Dounreay Fast Reactor. Modifications of the core have improved the reactor as a fuel-irradiation test facility.

Detailed studies of A.G.R. designs for civil power stations have been carried out during the year to assist the work of the Nuclear Power Committee. Nothing has emerged from the economic assessment to change the Authority view of the prospects of the A.G.R. system. With overheads spread over a programme of about 6,000 MW(E) at 75 per cent load factor, with a reactor life of 20 years, and an interest rate of 7½ per cent and a return on capital of 1½ per cent, the generating cost of the later reactors should be below 0.40d. per unit allowing for improvements expected in fuel costs. If the same plant were amortised over 25 years and operated at 85 per cent load factor, the generating cost would be about 0.35d. per unit.

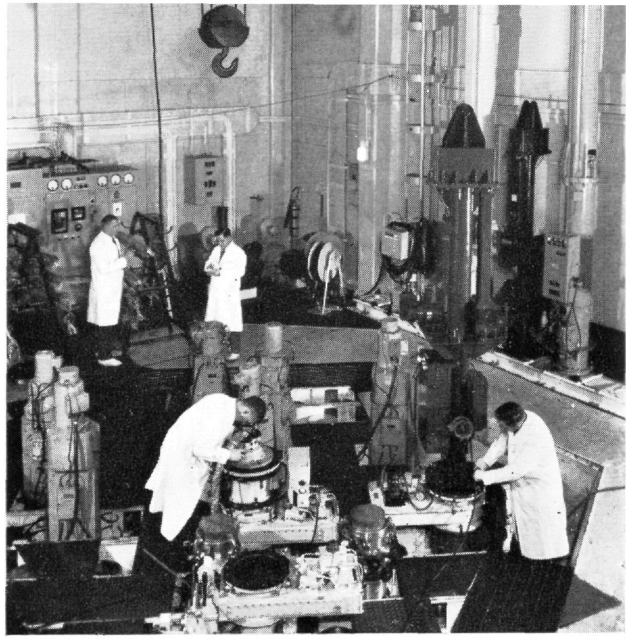
H.T.G.C.

The Authority continue to support the Organisation for Economic Co-operation and Development Dragon project sited at the Atomic Energy Establishment, Winfrith.

The construction of the reactor experiment is now virtually completed, and fuel loading should begin in the first half of 1964. The reactor is expected to go critical about mid-1964 and to operate at full power early in 1965.

The assessment studies on a power producing reactor which are part of the extended Dragon agreement are assuming increasing importance, and a design study commissioned from the AGIP/INDATOM consortium has now been received by the project.

Testing of fission product retaining coated fuel particles for use in high-temperature reactors has continued on behalf of the Dragon project. These are small spherical particles of uranium carbide, less than 1 mm in diameter, covered either with a single layer of pyrolitic carbon or with a triple coating: pyrolitic carbon/silicon carbide/pyrolitic carbon. The ability of these particles to retain fission products has been measured both out-of-pile and in-pile. The in-pile tests have been carried out in a loop in the PLUTO reactor which simulates the condition in an operating high temperature reactor. Post-irradiation examination of coated particles has shown that they can withstand high burn-ups at temperatures up to 1,600°C with a low failure rate. The results have given confidence to the development of fuels which can be operated with negligible release of fission products to the coolant gas stream.



Experiments are conducted in the Windscale reactor, HERO, to obtain data for designing larger versions of A.G.R.

S.G.H.W.

The Steam-Generating Heavy-Water Reactor is a boiling water reactor of pressure-tube construction with facilities for the development of superheat.

Some changes in design have been made to improve the flexibility of the plant as an experimental unit. The experimental facilities now planned for the prototype will enable features of single "fuel pencil" designs to be tested under various conditions and will also make it possible to test advanced superheat fuel "clusters" without risk of contamination to the turbine.

To simplify design, the control system will use liquid instead of solid shut-off rods.

The construction of the prototype at Winfrith began in May, 1963, and is proceeding satisfactorily. The primary containment, the fuel element storage pond and the foundation works for the turbine hall and the annexes are now well advanced. Contracts have been placed for all the main plant items including the primary coolant circuit, calandria, shield tanks, refuelling machine and the turbo-alternator.

The results of an experimental programme which has investigated a range of S.G.H.W. reactor core arrangements in the zero energy reactor DIMPLE and in two sub-critical assemblies have been used to develop general methods of calculating the neutron physics performance of water moderated systems.

Predictions of the fuel burn-up in a S.G.H.W.R. have been checked against data published on U.S. reactors and a fair measure of agreement obtained. Methods of manufacture and testing of satisfactory seamless zirconium alloy tube for the reactor pressure tubes have been developed in association with U.K. manufacturers. In addition to work on zircaloy-2, a stronger alloy, zirconium-niobium, has been developed and preliminary tests show that tube strengths may be increased by about 70 per cent.

The design of the S.G.H.W. reactor fuel element assembly for the boiling zone has been specified as a full core length 13 ft. long 37-rod cluster of fuel pins clad in zirconium alloy; two detailed designs are under study. A preliminary design of the superheat fuel element assembly has been evaluated; this consists of a 13 ft. long, 23-rod assembly with pins clad in the 20 per cent chromium, 25 per cent nickel, niobium-stabilised stainless steel as used in the Windscale A.G.R. The endorsement of design features is continuing in irradiation tests in the Canadian NRX reactor.

Plutonium Utilisation

Considerable quantities of plutonium will be produced by the magnox power reactors in the 1970's and investigations have continued on the use of this fissile material in place of uranium-235 for enriching thermal reactors.

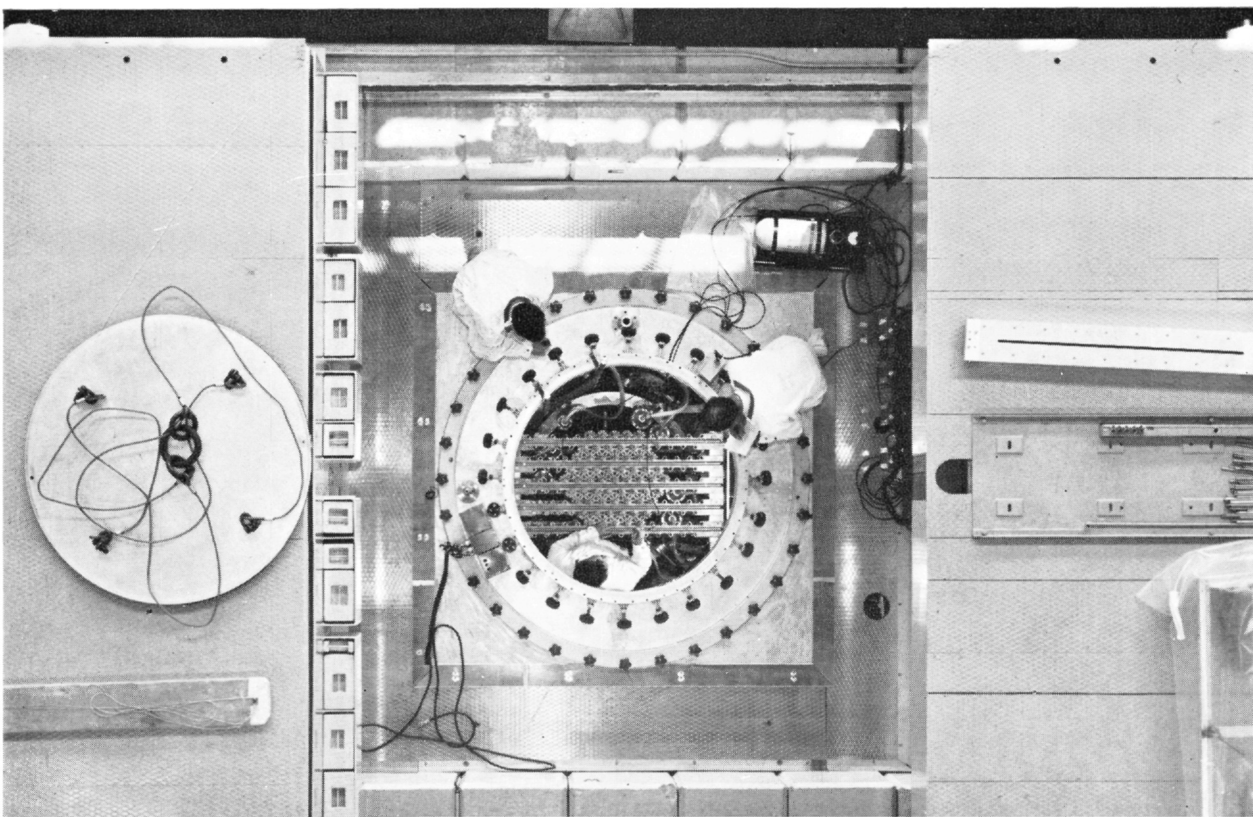
For the manufacture of small quantities of plutonium-bearing fuels needed in the reactor-physics experiments, a plutonium fuels laboratory has been commissioned at Winfrith. Plutonium-bearing fuels of a wide variety of compositions can be made. Initially experimental oxide fuels have been made for SCORPIO and HERO and for Windscale A.G.R. and by the end of the year the output was adequate to meet the target of 5 tonnes a year of oxide fuel.

To check that the irradiation behaviour of plutonium-enriched fuel elements is satisfactory, plutonium-enriched fuel elements were being made at the end of the year for irradiation in two channels of the Windscale A.G.R.

Fast Reactor

The outstanding achievement during the year has been to get the Dounreay Fast Reactor operating at full power and to continue at full power for the maximum possible amount of time in order to build up irradiation experience of fast reactor fuels. Modifications to the core have been made to improve the reactor as a fuel irradiation test facility.

Bird's-eye view of the water-moderated experimental reactor, JUNO, at Winfrith.



Work in progress (March. 1964) on the Steam-Generating Heavy-Water Reactor at Winfrith.

Full design power of 60 Megawatts (Heat), 14 Megawatts (Electrical) was first achieved in July, 1963, on the completion of loading the reactor with a modified fuel element. The reactor was operated at about this power throughout the year except for the shut-downs necessary for refuelling and loading experimental fuels. The first extended power run on the new fuel cycle with a complete fresh core began in mid-January. Except for an early shut-down for a few days to remove the first experimental pin assembly the reactor operated continuously until the end of March, when the standard metal fuel reached the present limit of burn-up of 1.3 per cent. The integrated reactor power for the year was 7,042 Megawatt-days (Heat) and the total electricity production was 33,600,000 Kilowatt-hours.

Operation of the D.F.R. at power has provided the first experimental examination of the kinetics of a high-power fast reactor. Control of the reactor has been easy and much information has been obtained on radiation and activity, effectiveness of shielding, handling of components contaminated by active liquid metal sodium/potassium alloy and fuel handling.

Factors governing the size of a Prototype Fast Reactor have been considered and discussed with the Consortia of British industry and the Central Electricity Generating Board. The prototype must be of sufficient size to prove the fuel element and fuel cycle appropriate to a large power reactor, to confirm the physics data for dilute fast reactors, to establish the safety of the system and to demonstrate its reliable operation.

Major design points of the P.F.R. which will influence the design of later and larger commercial fast reactors have been studied. Work on boilers has confirmed that a design in which the water/steam is separated from the sodium by a single wall is feasible. Various reactor and plant layouts have been considered in the light of cost, simplicity, operational convenience and safety. Work is proceeding to narrow down the issues affecting the major design points.

Design engineers of the industrial Consortia in conjunction with the Authority are engaged in a design study of a 1,000 Megawatts (Electrical) power producing fast reactor.

Good progress has been made at the Atomic Weapons Research Establishment, Aldermaston, in the development of manufacturing processes for fast reactor fuel.

Marine Reactors

Design and research work on marine reactors during the year has been concentrated on two reactor types, VULCAIN and the Integral Boiling Reactor, following the recommendations of the Working Group on Marine Reactor Research and its working parties. In addition to a re-assessment of the prospects of VULCAIN and I.B.R., the Authority have also put forward a "burnable poison" water reactor and contributed to the appraisal by the Technical Advisory Panel of four other systems: a steam-cooled, light-water design proposed by Mitchell Engineering, Ltd. (U.K.); the Consolidated Nuclear Steam Generator, Babcock & Wilcox (U.S.); the UNIMOD, Combustion Engineering (U.S.); and the air-cooled 630A design, G.E.C. (U.S.).

The report of the Working Group on Marine Reactor Research has now been published. Although a more difficult target has been set for nuclear propulsion to become competitive in a wide field, further work confirms the promise that the integral principle should lead to capital cost reductions because of its simpler and more compact design. There is as yet no Government decision on whether a marine reactor should be built.

The joint development work on VULCAIN by the Authority and a consortium of Belgian firms (Syndicat Vulcain) has gone well. In the U.K. the work has concentrated on fuel development and experimental physics associated with core design.

In Belgium, the zero energy facility VENUS has been completed according to programme. VENUS is being used initially to check the performance of the BR-3/VULCAIN core using fuel elements of the correct shape, dimensions and fuel enrichment. The fissile material for VENUS has been supplied by the Authority and fabrication into fuel pins shared equally between the two countries. Preparations are well advanced for the modification of the Belgian BR-3 reactor when it is made available to the project in August. After conversion, it will be possible to test a VULCAIN type core under conditions which will simulate the power changes expected in ship operation.

Engineering development in support of VULCAIN carried out in the U.K. has included fluid flow, the development of the main circulating pump, and endurance tests of fuel assemblies and shut-off rods. Specimens of fuel pins, assembly components and complete fuel assemblies are being made for experimental testing under conditions which simulate the forces that might arise from ship movement or accident conditions.

Work continued on the I.B.R. system but the design of the core structure revealed difficulties which led to work being suspended at the end of 1963 pending consideration of the overall marine programme. The work on "burnable poison" cores has been continued, however, in view of its general application to water reactors.

The "burnable poison" technique shows promise as an alternative to the mixed moderator control technique adopted in the VULCAIN design for regulating the burn-up of the fuel. Using the engineering principles and fuel development experience gained on the VULCAIN programme, a reference design of a Burnable Poison Pressurised Water Reactor was evolved and presented by the Authority to the Technical Advisory Panel.

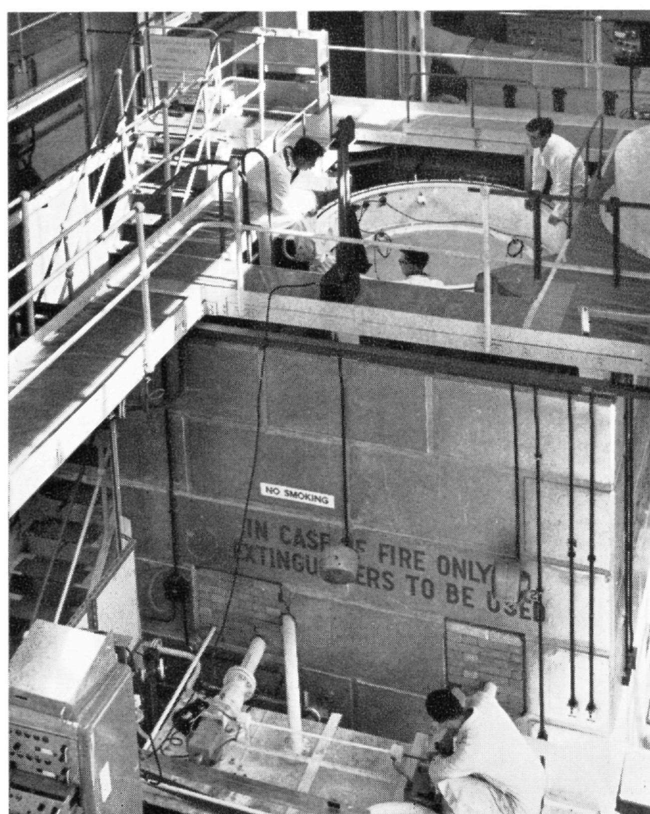
Calder Hall

A further increase in annual output of electricity from the Calder Hall and Chapelcross reactors was recorded during the year. The output of 2,800 million units was equal to almost 93 per cent of the theoretical capacity with continuous full operation throughout the year.

In the winter months of November to February (inclusive), output at over 99 per cent of full capacity was achieved. Development work has led to further improvement in operating techniques and a good exchange of information in this area exists between the various operators of magnox reactors.

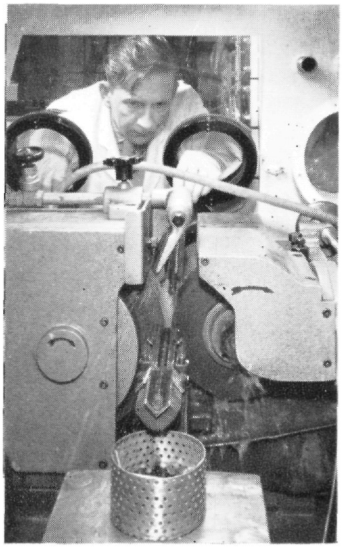
In addition to their primary role as electricity producers, the reactors have an important place in the Authority's research and testing programme, particularly for the evolution of new designs of fuel element.

Experimental elements form about 7 per cent of the total fuel in current use in the eight reactors at Calder and Chapelcross. Hollow rod fuel elements for the Tokai Mura and French EDF.2 reactors, and a novel form of flat plate type element, are all being tested in the Chapelcross reactors.

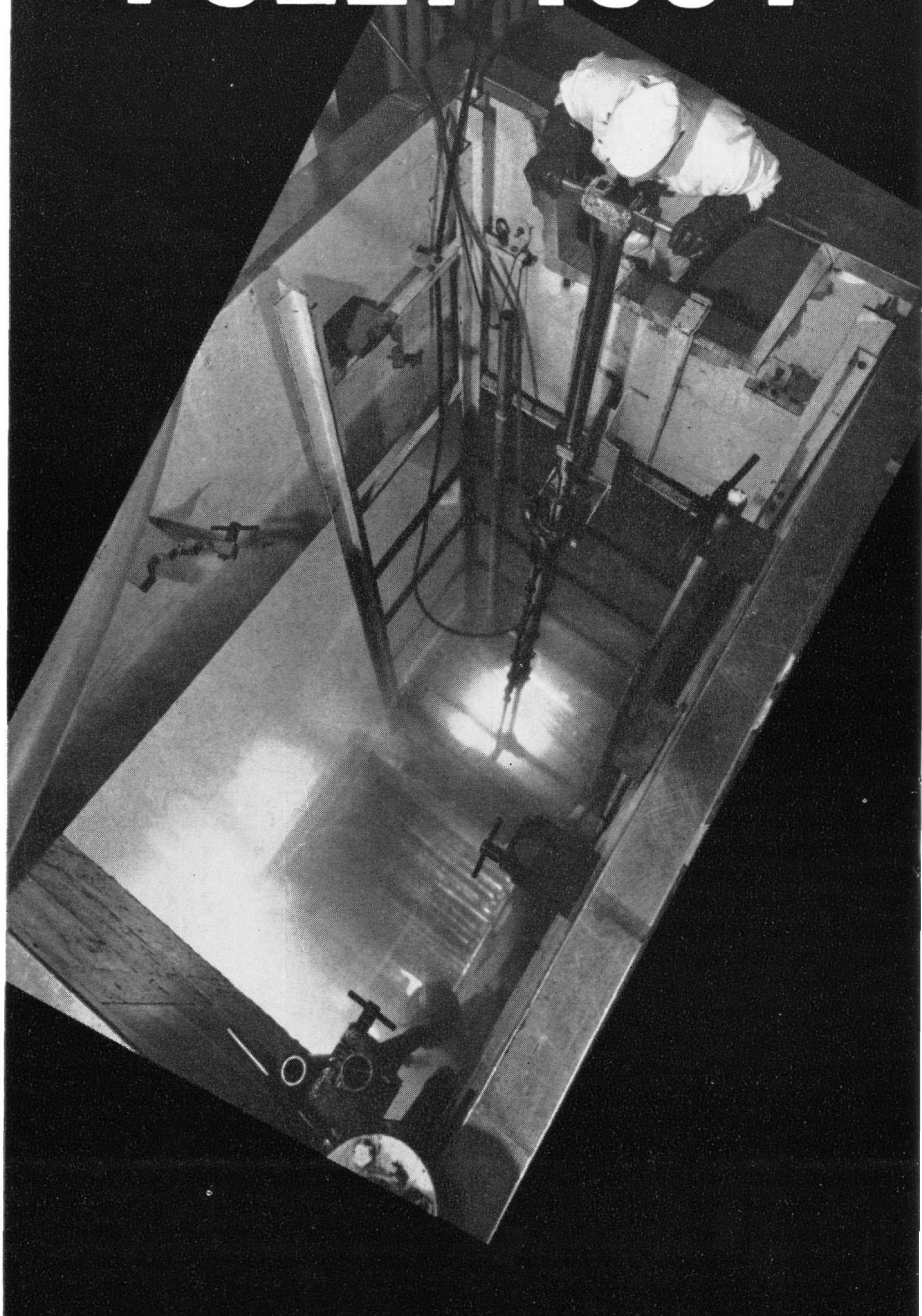


HELEN II, at Winfrith has been used to study the behaviour of plutonium-enriched thermal reactor systems.

FUEL: 1964



Plutonium fuel manufacture at Windscale. This machine, in a protective glove box, is used for grinding plutonium pellets.



Irradiated fuel elements being decanned under water at Windscale prior to reprocessing.

Irradiated fuel from the Bradwell power station in its transport container en route to Windscale for re-processing.

The year 1963–64 saw the anticipated peak in production—at the Springfields plant of the Production Group—of fuel for magnox (Calder Hall type) reactors.

Some 250,000 fuel elements were produced, involving completion of six initial charges for the reactors at Trawsfynydd and Hunterston and for the first reactors at Hinkley Point and Dungeness; commencement of manufacture for Tokai Mura (Japan); and the supply of replacement elements for Bradwell, Berkeley and Latina (Italy).

The production for Tokai Mura is the first occasion on which a hollow fuel rod has been manufactured by the Authority on a substantial scale; this necessitated the introduction of new drilling and machining techniques.

A contract was signed with the Japan Atomic Power Company in July, 1963, for the supply of magnox hollow fuel elements for a period of ten years for the nuclear power station at Tokai Mura. The contract has a total value of over £10 million, and delivery of the initial fuel charge is scheduled to be completed in August, 1964.

Delivery of the contractual quantity of 400 tonnes of fuel to the Latina nuclear power station was completed during the year. Preliminary discussions have taken place with E.N.E.L. (the Italian Electricity Authority) with a view to securing contracts for the reprocessing of the irradiated fuel arising from Latina.

The initial fuel charge for the Windscale Advanced Gas-cooled Reactor which was manufactured at Springfields, consists of enriched uranium oxide pellets clad in stainless steel cans. This fuel performed satisfactorily during the first year's operation.

Production of small quantities of oxide elements has continued and experimental fuel has been supplied for use in the Windscale A.G.R.

In the expectation that substantial supplies of enriched uranium will eventually be required to meet the demands of the civil power programme, development work to improve the production process is continuing at Capenhurst. In particular, substantial progress has been achieved in the development of a high efficiency stage unit which will be required to enable the plant to produce at competitive prices.

Development work on the gas centrifuge as an alternative to gaseous diffusion has continued satisfactorily. Close liaison has been maintained with similar work in America.

At the Dounreay fabrication plant, in addition to supplying the M.T.R. (Materials Testing Reactor) fuel requirements for the Authority's research reactors, fuel has been manufactured for supply to the research reactors at Lucas Heights (Australia),

Irradiated fuel elements from the Australian reactor, HIFAR, were returned for re-processing at Dounreay in June, 1963.

Risø (Denmark) and Jülich (Germany), and for a number of research reactors operated by U.K. universities. In all a total of about 5,000 MTR type fuel plates was manufactured in the plant.

Experience during 1963–64 of the new plutonium finishing plant at Windscale has been very satisfactory. Annual maintenance costs were only about one-quarter of those for the old plant, and the costs of labour, supervision and support services have been reduced to half the former level.

Construction of the new chemical reprocessing plant (also at Windscale) was completed during the year. It is planned to bring the plant into full active operation in the summer of 1964. It is designed to treat the highly irradiated fuel from Calder and Chapelcross and from the reactors of the Central Electricity Generating Board and the South of Scotland Electricity Board and, in addition, to handle any overseas business which may be obtained.

The MTR chemical re-processing plant at Dounreay processed 70 kilograms of irradiated uranium during the year, including a further three consignments from Denmark and the first shipment of irradiated fuel returned from the Australian reactor HIFAR (of the same type as the Harwell reactor, DIDO). The latter fuel was carried in the Danish antarctic research vessel *Nella Dan*, off-loaded at Liverpool and transported by road to Dounreay. The success of these operations has enabled the Authority to seek further business of this kind.

The final stages of design, development and evaluation of a new type of fuel element incorporating a herringbone design of heat transfer surface were satisfactorily concluded during the year. Such a fuel element has now been specified by the C.E.G.B. for reactor No. 2 at Sizewell nuclear power station. Further improvements to the design, including the elimination of the mechanical stabilising device, are being examined in connection with the development of a fuel element design for Wylfa Head nuclear power station.

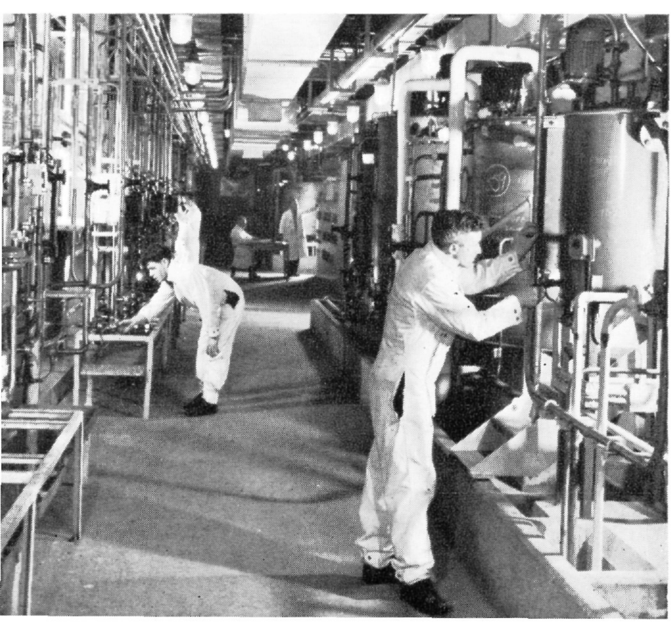
Fuel elements closely resembling the fuel elements used in the Generating Boards' nuclear power stations have now reached irradiation levels in the Authority's reactors approaching or exceeding the 3,000 Megawatt-days per tonne channel-average expected in the civil reactors. The most important are:—

Type of element	*Channel average irradiation MWd(H)/t*
Berkeley prototype fuel element	4,600
Bradwell prototype fuel element	3,100
Bradwell production fuel element	2,680

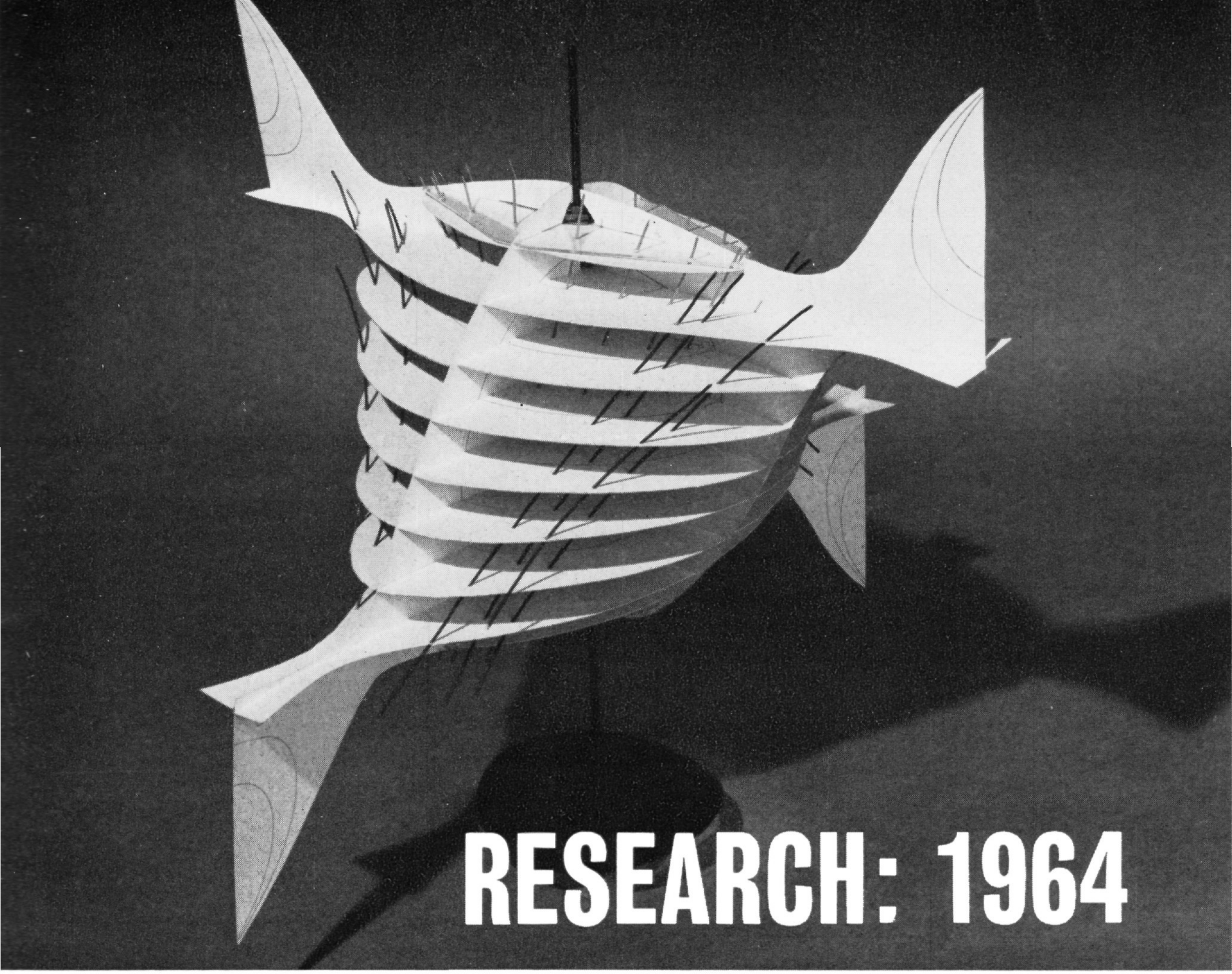
The proceeds of sales of fuel elements in recent years have been as follows:—

£'000

Year	*Reactor Fuel* *Power*	*Research*	*Other Materials*	*Total*
1960–61	10,224	645	206	11,075
1961–62	9,377	246	202	9,825
1962–63	22,210	295	308	22,813
1963–64(1)	36,861	166	2,459	39,486



Construction has been completed at Windscale of a new chemical re-processing plant.



RESEARCH: 1964

A 3-D model from Culham of a "magnetic well" for the containment of plasma. The wires represent lines of magnetic force.

Besides the development of specific reactor types, the Authority have many programmes of research applicable to reactor systems in general. This work covers such topics as nuclear measurements, radiation effects on materials, new materials for fuels, cans, and moderators, and safety matters. Although most of the work is done in the Research and Reactor Groups, Weapons Group also makes valuable contributions.

The Authority's programmes of general research are devised to provide the scientific knowledge needed for the development of atomic energy, both to solve the technological problems that arise in the present programme and to anticipate future problems and look ahead to new methods and applications. Specialised, and often very expensive, equipment such as research reactors or particle accelerators is needed for much of this work which consequently has to be done in the Authority's laboratories though it is basic research. Wherever possible there is close collaboration with universities and other establishments both at home and abroad.

The collaboration with universities takes several forms. Scientists from universities and similar institutions both at home and overseas can work at Harwell and Aldermaston, and thus have access to the establishments' unique facilities. At the end of March 1964 there were about 20 scientists attached to Harwell for periods exceeding one year, and over 70 paying shorter visits. Another form of collaboration is the placing of research contracts with universities and technical colleges. At the beginning of 1964 the Authority had 235 such contracts in being; 161 of these were for work for the Research Group. The total value of the contracts exceeds £1,500,000.

Desalination

A group has been set up at Winfrith to study new reactor systems and new applications of reactors. The economics of using a nuclear reactor as a heat source in a plant for generating electric power and producing fresh water from salt water are being examined. The Authority are represented on the Department for Scientific and Industrial Research committee on desalination research and on the International Atomic Energy Agency's panel which is studying desalination schemes using nuclear reactors.

Heat transfer equipment at the Dounreay Experimental Reactor Establishment is described to Sir John Cockcroft.

Fuel

The uranium metal used as fuel in the magnox stations swells under irradiation owing to the release of gaseous fission-products. As has been reported earlier, this swelling is greatly reduced if small amounts of iron and aluminium are added to the uranium. The effectiveness of these additions has now been confirmed over a wide range of power ratings in the fuel (up to twenty times the ratings encountered in magnox stations) and up to burn-ups of 7,000 Megawatt-days per tonne.

To provide the scientific information needed to prepare and use ceramic fuels efficiently, long-term research is being done on the physical and chemical properties, and the fabrication behaviour, of the oxides, carbides, nitrides, sulphides, and—recently—phosphides of fissile and fertile elements. At present most effort is devoted to the carbides.

Notwithstanding increased interest in ceramic fuels, some work continues on fissile metals. Various alloys of fissile metals have been studied in the search for radiation-resistant fuels.

Graphite

The fundamental problem in understanding the effect of irradiation on graphite, especially in changing the dimensions of graphite blocks, is to elucidate the structure of the defects produced in the crystalline lattice by radiation and the mechanism by which they are formed. Basic information on the behaviour of radiation defects is needed in order to be able to apply the results from irradiations in high-flux research reactors to the dose and temperature conditions in power reactors. The investigations are being extended to higher temperatures and higher doses to give more detailed predictions.

Waste

Work has proceeded at Harwell on an alternative method of storing highly-radioactive waste by converting it into insoluble glass-like materials. During the year the experimental plant FINGAL was brought into operation. Over a dozen experiments at varying levels of radioactivity have shown that the process can be operated safely. One experiment demonstrated that a 1000-curie glass block

The fabrication and properties of metals and ceramics are studied in the Metallurgy Division at Harwell.

can be made with the release of only 1 part in ten billion of the activity to the atmosphere and with no contamination of the shielded cell. Other experiments have shown that heating by radioactive decay will not limit the size of the vessel to the 6 inch diameter used in FINGAL: 12 inch diameter will be quite satisfactory.

Nuclear Physics

At Harwell the 12MV tandem electrostatic generator and the 5 MV Van de Graaf generator have yielded valuable information on nuclear dynamics and structure.

At Aldermaston a new injector and a neutron time-of-flight spectrometer have been added to the tandem generator. It will be possible to produce pulsed beams of monoenergetic neutrons of 2 nanosecond duration in the energy range from 8 to 12 MeV and these will be used to make precise measurements of neutron scattering and neutron-nuclear reactions.

Theoretical Physics

Research in theoretical physics is carried on in fields related to the experimental programme of the Authority: solid state physics, nuclear structure, neutron physics, atomic cross-sections, and defects in solids.

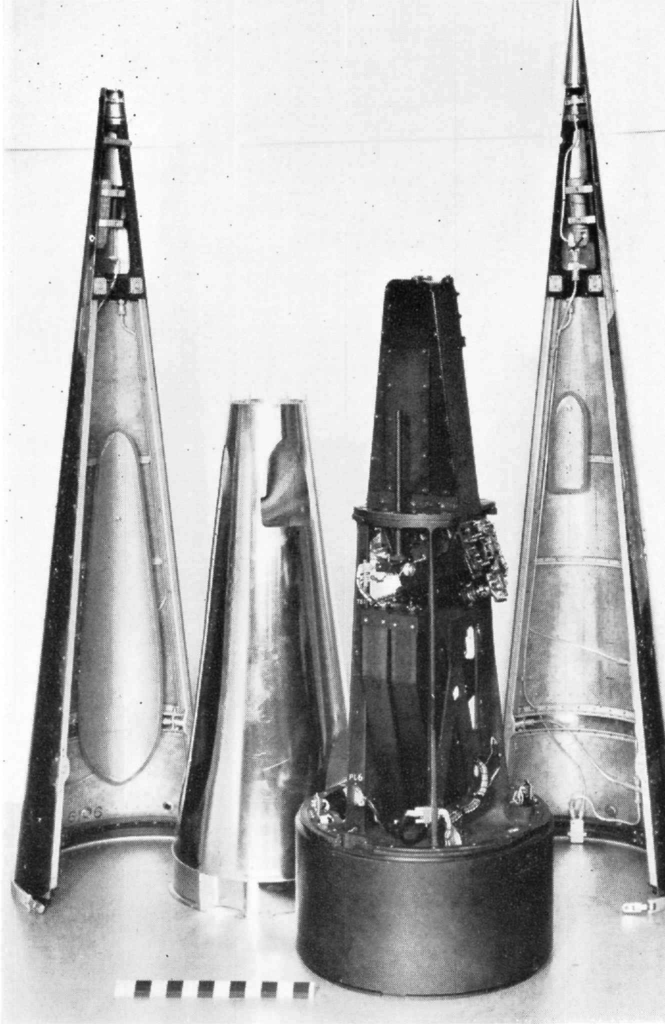
For example, a new method of calculating the behaviour of electrons in solids has been developed which combines two older theories (band theory and Heitler-London theory) into a single unified scheme and has particular application to transition metals.

Some research is directed to devising mathematical methods by which computers can be used more efficiently and applied to a wider range of problems. In preparation for using the Atlas computer a compiler has been written, i.e. a computer program which will translate programs written in FORTRAN (a widely-used computer language) into a form suited to Atlas.

Radiation Chemistry

Research in radiation chemistry is undertaken at Harwell to provide an understanding of the principles underlying the chemical effects of radiation, which are technologically important in reactors and other plant. Basic information bearing upon steam-cooled systems is being sought in studies of the radiolysis of water vapour, about which published results are sparse and contradictory.

Construction is well advanced of the variable-energy cyclotron which is being built at Harwell for general studies on the physical and chemical effects of radiation.



A rocket nose-cone assembly designed at the Culham Laboratory for observation of the solar corona.

Chemical Engineering

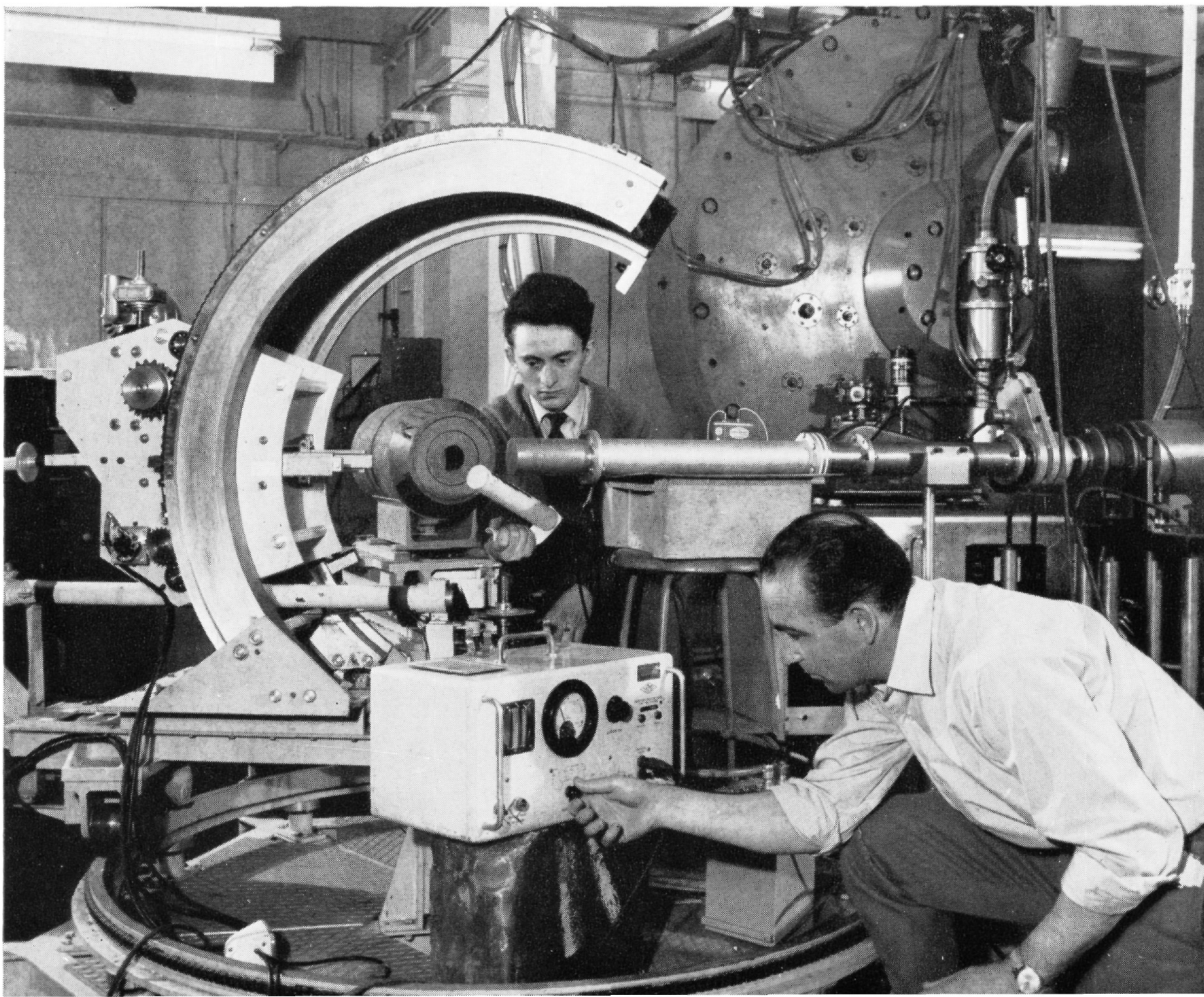
Research in chemical engineering operations at Harwell has included development of means for continuously blending powders to the high degree of homogeneity required for ceramic-fuel preparations. This work is of importance to proposals for the use of plutonium in reactor fuels.

Direct Conversion

Exploratory work, on a modest scale, continues at Harwell on methods for the direct conversion of heat to electrical energy. The three methods under investigation are: thermionic; magnetohydrodyna-

The neutron project at Harwell. In the right foreground are the flight tubes radiating from the target room.

Two research students from Oxford University conduct an experiment associated with the 15 Mev. tandem accelerator at Aldermaston.



mic (M.H.D.); and thermoelectric. Until recently most effort has been devoted to the thermionic system but lately the emphasis has moved towards the M.H.D. method.

In the M.H.D. field, laboratory experiments on non-equilibrium ionisation of an inert gas containing less than 1 per cent of an alkali metal now suggest that this is the method most likely to lead to a system employing the lowest gas temperature, though this is unlikely to be less than 1,300°C.

As the bulk coolant outlet temperature of A.G.R. is 650°C and of Dragon 750°C, it is clear that a very substantial advance in high-temperature gas-cooled reactor technology will be required before the application of M.H.D. to reactors is practicable and the time scale of the M.H.D. programme is related to this.

The Authority programme on M.H.D., which has been endorsed by the Ministry of Power's Advisory Committee on Research and Development, is concerned only with the development of such a closed-cycle system for application to a nuclear reactor and thus is complementary to the C.E.G.B. programme, which is concerned with an open-cycle fossil-fuelled system.

An M.H.D. generator has been built at Harwell, operating from a pulsed (non-nuclear) heat source of peak rating of 100 Megawatts, which uses as working fluid argon, seeded with potassium, at a temperature of about 1,100°C. The object is to demonstrate non-equilibrium ionisation produced by an electric field which is generated by the M.H.D. action.

During the year two further experimental thermionic diodes were put in the PLUTO reactor in each of which a single cylindrical fuel element, made of unclad fissile carbide, was used as cathode; from each a maximum output was obtained, in an external load, of 100 Watts at an efficiency of 5–7 per cent. Studies continue of the use of radioisotopes, as heat sources, in conjunction with thermoelectric generators and also with thermionic generators.

Plasma and Fusion

In plasma physics and fusion research the main problems are still to identify, understand and control the many instabilities which prevent magnetic fields from confining extremely hot ions and electrons (i.e. plasma) for more than a relatively brief moment. It is therefore not yet possible to identify the experimental approach with the greatest promise, and it is still necessary to maintain a broadly-based programme at Culham. Most of the possible systems for containing plasma are included, as well as basic studies on the plasma state and associated diagnostic and technological research.

Containment experiments fall into two categories, closed-line systems and open-ended magnetic traps. In the former the plasma is completely enclosed by magnetic field lines. Ideally the losses should be very small, but in practice this system has proved highly unstable. Open-ended magnetic traps, on the other hand, inevitably suffer from some end losses, but there appears to be more hope of achieving stability.

Particularly troublesome among the instabilities identified so far is one which involves the interchange of whole groups of magnetic field lines carrying their associated plasma with them. These interchange instabilities occur where the restraining magnetic field decreases outwards, as is implied by magnetic field lines curving round, rather than away from the centre of the plasma. Whilst these instabilities remain as a potential source of trouble in closed line systems, there are now strong indications that they can be overcome in the open-ended magnetic traps.

During the year preparations were completed for the first stages of the programme to study the solar corona and the chromosphere. The first complete payload has been sent to Woomera for its final operation schedule before being launched in the first prototype firing of a British stabilised rocket vehicle. Two further payloads for use in 1964 have also been prepared. Both types of spectrograph which they incorporate have been specially developed and built at Culham.

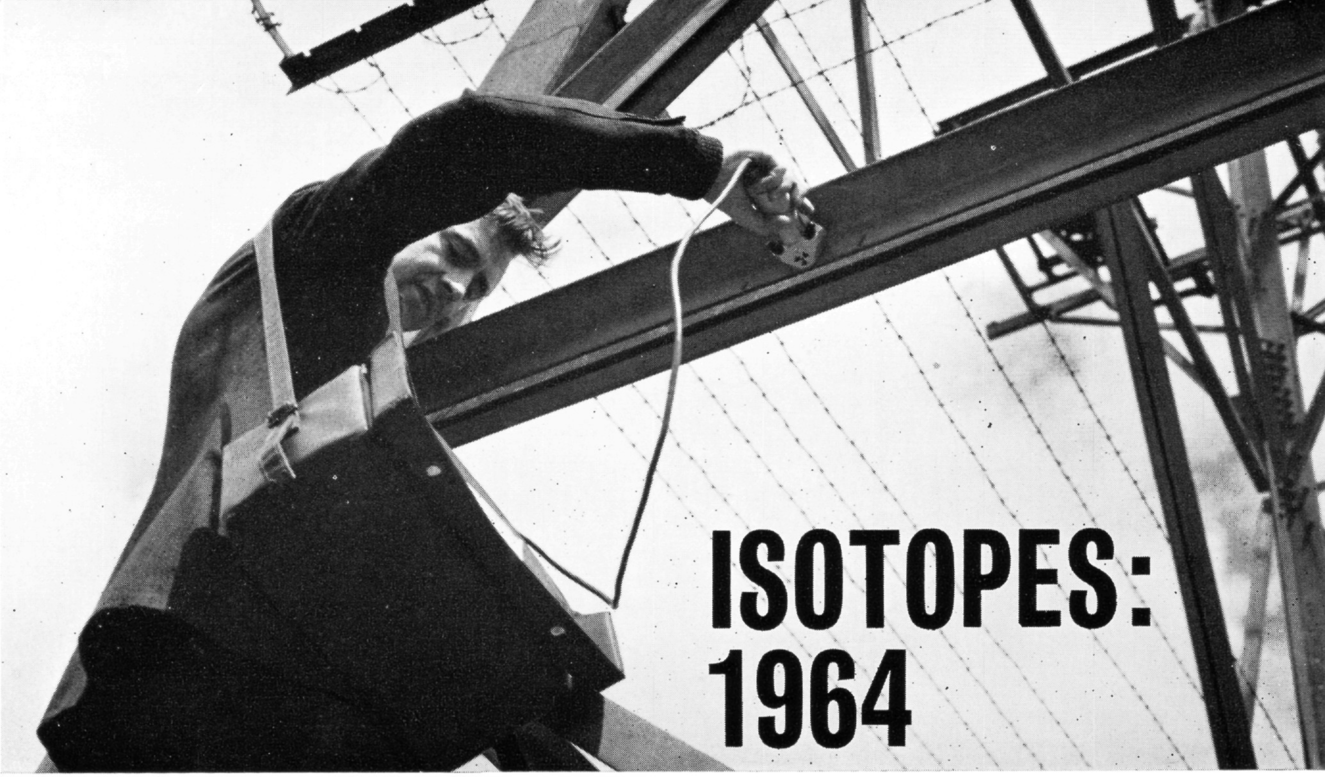
Test Detection

The Authority have continued their work on the establishment of methods for the detection and identification of underground nuclear explosions.

The experimental array at Eskdalemuir in Scotland has operated satisfactorily. The array station established in Canada by the Canadian Government, using techniques and equipment developed by the Authority, is now fully operational and its performance is up to expectation, and the temporary station which was established by the Authority in Wyoming, U.S.A., has now closed.

Studies are continuing on instrumental techniques, signal processing, and identification criteria.

Work is also proceeding on methods for detecting nuclear explosions in space and in the upper atmosphere by means of ground based stations.



ISOTOPES: 1964

An isotope thickness-gauge being used to measure the residual zinc coating on a pylon after atmospheric corrosion.
(Photo: Burndept Electronics Ltd.)

The Authority's isotope programme comprises two parts: processing and distribution of radioactive materials, based on the Radiochemical Centre at Amersham, and research into the properties and uses of isotopes, at the Wantage Research Laboratory.

Sales of radioactive products from the Radiochemical Centre in 1963/64 reached £1,621,000, an increase of 10 per cent over the previous year; 48 per cent of this total was represented by exports. The number of despatches rose from 46,000 to 49,000.

Although nuclear reactors are still the principal sources of radioisotopes, there is a growing demand for certain isotopes, having qualities that make them particularly valuable in medicine and research, which can be made only with the aid of a cyclotron. The Radiochemical Centre already makes part-time use of several research cyclotrons elsewhere to prepare about forty radioisotopes. As was announced in April, 1963, the Authority have been advised by the Medical Research Council and other institutions that a good supply of these cyclotron-produced isotopes is in the country's general scientific interest; accordingly a cyclotron designed specially for isotope production is to be installed at Amersham. The machine is expected to be operational in 1965.

The provision of an isotope with exactly the right radioactive properties and in precisely the chemical form required for the purpose, is often the key to a new line of research or technical development. Therefore, in addition to supplying an increasing variety of products to meet the general demand for isotopes in established applications, the Centre puts much effort towards developing new materials for use in research and development elsewhere, as for example in medical diagnosis and in molecular biology.

In medical diagnosis the technique of "radio-isotope scanning" is becoming more widely used as a means for examining from outside the organs that

A radiation monitoring system for medical isotope investigations at Addenbrooke's Hospital, Cambridge.

(Photo: E.M.I. Electronics Ltd.)

lie within the human body. Suitable equipment for observing and recording the location of radioactivity within a patient can now be bought, but successful application of the method depends largely on the choice of a radioactive compound that is concentrated selectively in the organ under examination.

The Centre supplies many such compounds of pharmaceutical quality; among those of current interest are organic compounds of mercury labelled with mercury-203 or with the short-lived (65-hour) mercury-197, for examining the brain and the kidneys, bismuth-206 for scanning brain tumours and L-selenomethionine labelled with selenium-75 for scanning the pancreas.

The growing interest in problems of protein structure and synthesis, and in the genetic code and heredity, calls for radioactively labelled nucleosides, nucleotides and amino acids, with specific activities much higher than have been generally available hitherto. The Centre has produced successfully many of these compounds with as much as 60 per cent of the natural carbon replaced by carbon-14.

Radioactive standards are increasingly in demand for calibrating laboratory instruments and their supply is a service provided by the Centre, with the support of the Wantage Research Laboratory and in close consultation with the National Physical Laboratory. Standardised solutions of fifty-seven nuclides are now available; about 800 of these solutions were distributed to many countries during the year.

The processing of materials in the package irradiation plant at Wantage is being maintained on a sufficiently large scale to enable individual firms to establish a market for their products.

Three firms in the United Kingdom are now operating their own gamma irradiation plants using cobalt-60 supplied by The Radiochemical Centre, principally for sterilising medical supplies.

The Army is one of the largest users of the package irradiation plant for treatment of dressings and other medical equipment either for stockpiling or for use in areas where steam sterilisation would be uneconomic. Sterilisation by gamma irradiation of the materials in sealed containers gives them a shelf life of several years compared with only a few weeks by the traditional methods.

A spent fuel-element irradiation pond is described to U.S.S.R. isotope experts visiting Harwell.

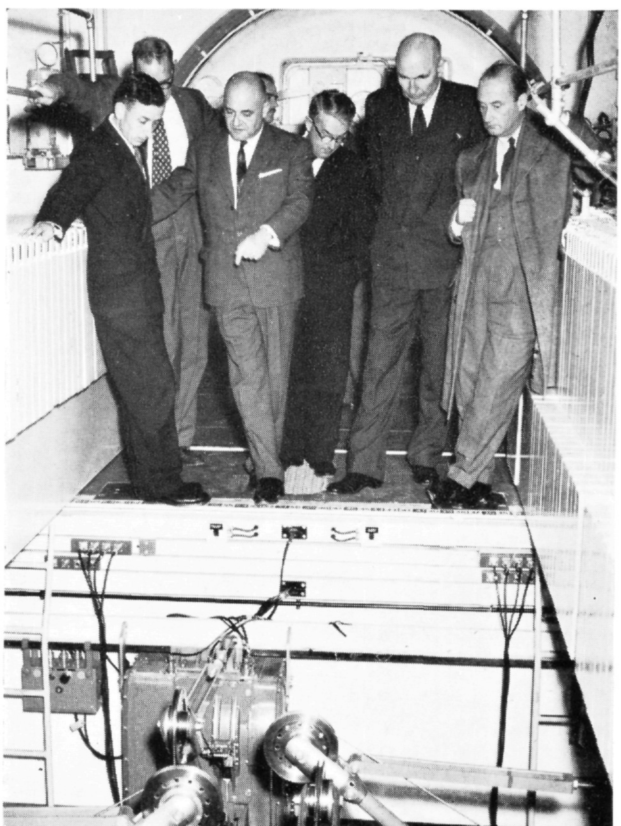
INTERNATIONAL RELATIONS: 1964

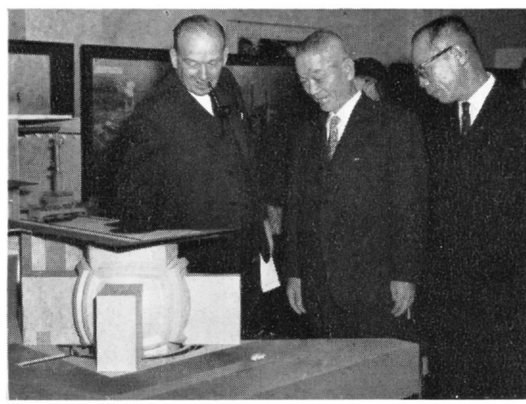
The Authority, whether directly on their own account or in an advisory capacity to Her Majesty's Government, have continued actively to collaborate with numerous other countries and international organisations to further the development of the peaceful uses of atomic energy. They have also supported the promotion of British nuclear exports.

The Scientific Advisory Committee of the Secretary General of the United Nations, on which Sir William Penney has continued to be the United Kingdom representative, has been planning the Third International Conference on the Peaceful Uses of Atomic Energy to be held in Geneva from 31st August to 9th September, 1964.

At the invitation of the Lord President, Sir William Penney has also undertaken to lead the United Kingdom delegation to the conference.

The Authority are providing a secretariat to co-ordinate the national preparations for the conference with the United Nations and the International Atomic Energy Agency in Vienna.





The leaders of a Japanese atomic power mission are seen with Sir William Cook (London, October, 1963)

Two visitors from the French Atomic Energy Commission—M. Robert Hirsch, Administrator-General, and M. B. L. Goldschmidt, Head of External Relations —examine the Zebra reactor at Winfrith in October, 1963.

Professor José Otero, president of the Spanish Commission (right), discusses fuel elements with Sir William Penney at a British exhibition in Barcelona.

Mr. R. W. Hartwell (left), General Manager of the Power Reactor Development Corporation (U.S.A.) visits Dounreay.

Dr. Sigvard Eklund (left), Director-General of the I.A.E.A., at Harwell with Dr. E. Bretscher and Dr. F. A. Vick.

United States scientists working at Harwell met the Earl of Bessborough, Parliamentary Secretary to the Minister for Science (right centre, with lapel badge) in February, 1964.

HEALTH AND SAFETY

Mr. J. P. Bishop and Mr. L. T. Williams (left and centre) were among trade unionists from 12 *O.E.C.D. countries who attended a health and safety course at Bournemouth in* 1963.

The number of Authority employees classified as radiation workers fell slightly from just over 20,000 in 1962/63 to about 19,500.

The maximum permissible whole body dose was exceeded on four occasions due to gamma radiation, and on one occasion due to inhalation of tritium. This compared with six occasions in 1962 and eight in 1961. In each case arrangements were made to reduce subsequent exposure and to ensure that the long-term dose limits were not exceeded.

The year has seen steady progress towards the objective of achieving compatibility in national and international regulations for the transport of radioactive materials; and a symposium at Harwell in September on the problems involved was attended by over 200 representatives of organisations with particular interests in transport.

Authority staff assisted in the preparation of draft national road and rail regulations, which are being modelled on the International Atomic Energy Agency "Regulations for the Safe Transport of Radioactive Materials". Other work has included the design and standardisation of transport containers; the Research Group, for example, have developed a small range of container designs suitable for most of the Group's shipments.

The Authority's research and their unique experience of the health and safety aspects of nuclear operations are widely drawn on as a source of specialist advice by government departments.

For example, the safety assessment of the Hinkley Point and Hunterston nuclear power stations was completed during the year on behalf of the Ministry of Power, and assistance was given with the evaluation of two university research reactors. Authority representatives have also advised a number of other government departments, including the Admiralty and the Ministry of Labour as well as the Ministry of Transport.

International co-operation in health and safety matters, in particular work in support of the I.A.E.A., has again been an important commitment.

INFORMATION SERVICES

Libraries

The libraries of the Atomic Energy Research Establishment, Harwell, Berkshire, and of the Risley Groups' Headquarters, Risley, Lancashire, provide a scientific and technical information service for industry, including the supply of unpublished reports and information of commercial value to organisations having appropriate agreements with the Authority.

Details of a Subscription Service for unclassified and declassified reports (i.e. those on which there are no security restrictions) can be obtained from the Librarian at Harwell.

Copies of unclassified reports, bibliographies and translations published by the Authority are supplied to the following Depository Libraries:—

Science Museum Library, South Kensington, London, S.W.7.
Central Library, High Street, Acton, W.3.
City Library, Royal Avenue, Belfast, 1.
Central Library, Ratcliffe Place, Birmingham, 1.
Central Library, College Green, Bristol, 1.
Central Library, The Hayes, Cardiff.
Central Public Library, George IV Bridge, Edinburgh, 1.
The Mitchell Library, North Street, Glasgow, C.3.
Central Public Library, Albion Street, Kingston-upon-Hull.
Central Library, Calverly Street, Leeds, 1.
Reference Library, Bishop Street, Leicester.
Central Library, William Brown Street, Liverpool, 3.
Central Library, St. Peter's Square, Manchester, 2.
Central Library, New Bridge Street, Newcastle-upon-Tyne, 1.
National Lending Library for Science and Technology, Boston Spa, Yorks.
Public Library, South Sherwood Street, Nottingham.
Central Library, Surrey Street, Sheffield, 1.
Stafford County Library, County Education Offices, Stafford.

Similar collections are deposited with the official atomic energy projects of most foreign countries.

Most of the reports and translations can be purchased from H.M. Stationery Office bookshops or agents.

All unclassified and declassified reports issued between 1947 and December 1956 are available in micro-form from Micro Methods Limited, of East Ardsley, Wakefield, Yorkshire. (On a continuing basis any similar report not put on sale at H.M.S.O., can be purchased from Micro Methods Limited).

All available reports are listed in the Authority's monthly list of Publications available to the Public, which is obtainable from the Librarian at Harwell. Annual cumulations can be purchased from H.M.S.O. bookshops or agents.

Weekly information bulletins of atomic energy literature references (from British and foreign sources) and library book lists are obtainable on request from the Harwell and Risley Librarians.

Publications

Details of illustrated booklets and reference material about the Authority's work can be obtained on request from Public Relations Branch, U.K.A.E.A., 11 Charles II Street, London, S.W.1. A monthly bulletin, "Atom", which contains press releases, Parliamentary Questions and a selection of recent speeches and lectures by Authority staff is available from this address.

Films

A film catalogue is available on request from Public Relations Branch, U.K. Atomic Energy Authority, 11 Charles II Street, S.W.1.

U.K.A.E.A. films, which are available on free loan, include:—

"Power from Fusion Part 1: The Principles"
"Eye for Isotopes"
"Windscale A.G.R."
"Welding by Tape"
"Testing Irradiated Steel"
"Power from Plutonium"
"Chemistry for the Nuclear Age"
"Harwell"
"Fuel for Nuclear Power"
"Explaining the Atom"
"Britain's Nuclear Power Programme"
"Nuclear Power Reactors"
"Steel for Nuclear Power"
"R. & D." (Research and Development)
"Dounreay Symposium"
"Winfrith Pipeline"
"Operation Undersea"
"Metals of the Nuclear Age"
"Criticality"

Photographs

A photographic library for the use of the press and members of the public is maintained at 11 Charles II Street, London, S.W.1.

Information Centre

An information centre at which members of the public may see Authority scientific and technical reports and other publications of a more general character is located on the ground floor of 11 Charles II Street, London, S.W.1. It also comprises an Isotope Information Bureau.

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

The production and marketing of radioisotopes.

Blacknest: near Aldermaston

Centre for seismological research.

Bracknell Factory, Berkshire

An outstation of the Atomic Energy Research Establishment which provides additional workshop capacity, especially for machining of graphite, and at which electronic equipment is manufactured on a small scale.

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. There is also a training service for reactor operators.

Chatham

Part of the Analytical Chemistry Branch of Chemistry Division, A.E.R.E.

Culcheth, Warrington:
Reactor Materials Laboratories

Investigation of physical and chemical properties of reactor and fuel element materials.

Culham Laboratory, Abingdon, Berkshire

The laboratory is being developed as a major centre for research into plasma physics and controlled thermonuclear fusion.

Dounreay Experimental Reactor Establishment, Caithness

Site of the Dounreay fast reactor. An experimental reactor establishment engaged on 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. The establishment also provides site services for the Admiralty submarine reactor project.

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

The largest establishment of the Research Group. The group is responsible for research into the non-military problems of atomic energy. Harwell is concerned mainly with 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. The establishment 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 United Kingdom Atomic Energy 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 and administrative services are centred on the London Office.

Orfordness, Suffolk

Development and application of environmental testing in the weapons field.

Oxford Office

Deals with accounts and contracts for A.E.R.E. and the Culham Laboratory.

Risley, Warrington, Lancs.

Headquarters of the Engineering, Production and Reactor Groups. The main tasks of the establishment are: commercial operations; construction, plant design and supply services; consultancy; co-ordination of the production activities of the Authority's works; reactor design; and technical and economic assessment studies. Design teams for reactors and other projects (e.g. chemical plant) are based here, together with their specialist technical services and the supporting design offices. The Reactor Engineering Laboratories, which are engaged on the engineering development of reactor components and irradiation test equipment, are also situated at Risley.

Springfields Works and Laboratory: Salwick, Preston

Uranium ore treatment and fuel element fabrication. The Reactor Fuel Laboratory works on the development of fuels and fuel elements for thermal reactors.

Tadley, Basingstoke, Hants.

Centre of the Southern Works Organisation, which undertakes most of the major capital construction schemes for the Authority's establishments in southern England, particularly Harwell, Aldermaston and Culham.

Thurso, Caithness: Superannuation Office

This office is responsible for the day-to-day administration of the Authority's superannuation schemes.

Wantage Research Laboratory, Berkshire

An outstation of A.E.R.E. which houses the Isotope Research Division. The task of the Division is to further the application of radioisotopes, especially in industry, by advice and by devising and developing new methods employing radioactive materials. The Laboratory houses the package irradiation plant for experimental and pilot-scale irradiation of material with gamma rays.

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

Work is done in the following fields: theoretical and experimental aspects of neutron physics, reactor physics and kinetics for a range of reactor types; heat transfer and transport in reactor coolants, reactor instrumentation and control; gas bearings; reactor assessments; and supporting design and manufacturing services. The establishment also provides site services to the Organisation for Economic Co-operation and Development Dragon Project.

Woolwich: Royal Arsenal

Part of the Analytical Chemistry Branch of the Chemistry Division, A.E.R.E.

Woolwich Common

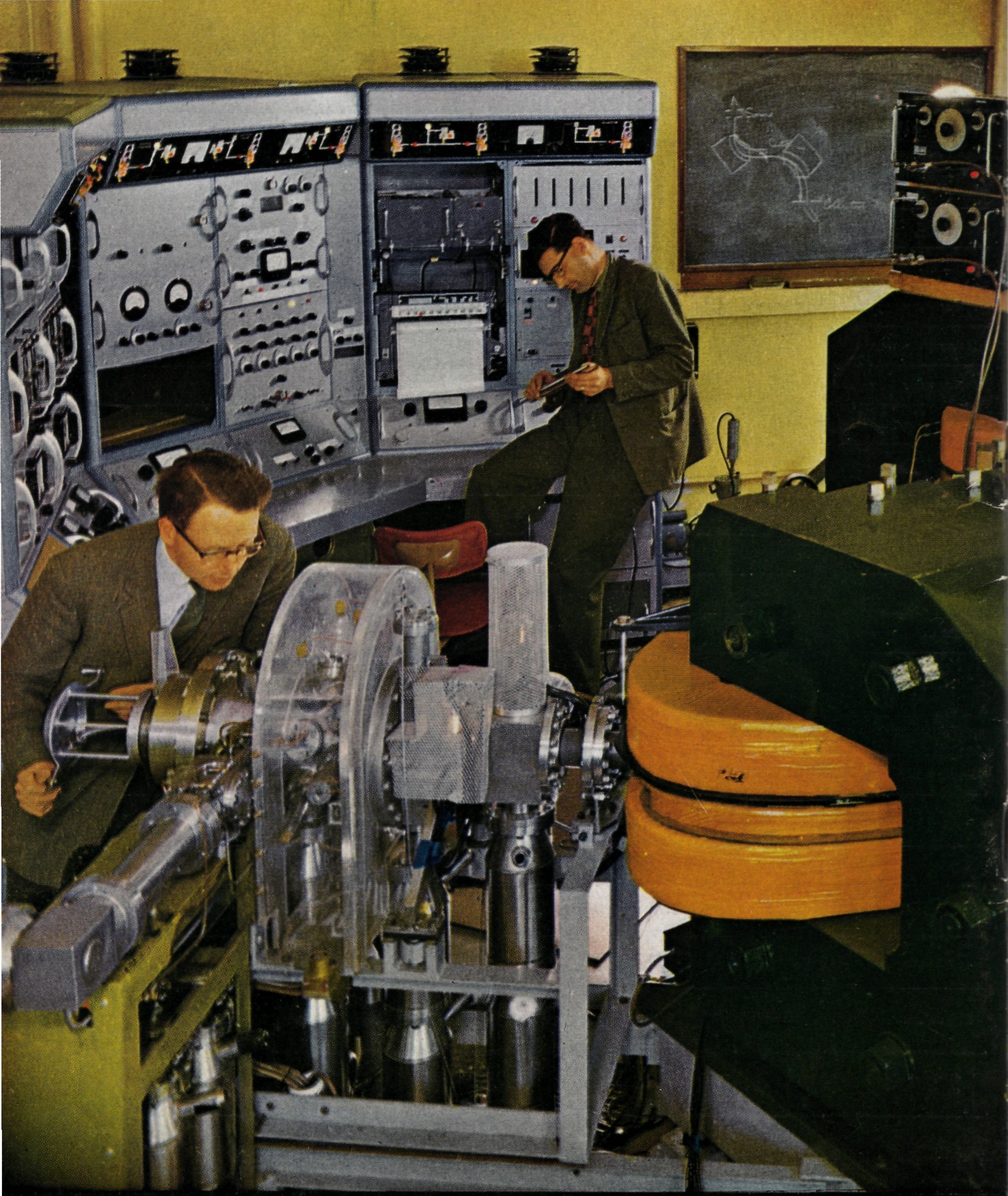
Provision of a prototype and pre-production service for electronic and light mechanical equipment, mainly for the Weapons Group.

One of the quadrangles which are a distinctive feature of the Culham Laboratory in Berkshire.

THE AUTHORITY'S REACTORS as at 31st March, 1964

		NAME	LOCATION	DATE OF START-UP	PEAK NEUTRON FLUX THERMAL N/CM² SEC.	MAXIMUM HEAT OUTPUT	MODERATOR	COOLANT	FUEL	PURPOSE
RESEARCH AND EXPERIMENTAL REACTORS	1	GLEEP	Harwell	1947	10^9	3 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 1.4×10^{12}	100 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 2×10^{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.
	6	D.M.T.R.	Dounreay	1958	$1.6\text{-}1.7 \times 10^{14}$	12-13 MW	Heavy water	Heavy water	Highly enriched uranium-aluminium alloy	Studies on nuclear reactor materials.
	7	HORACE	Aldermaston	1958	about 10^8	10 Watts	Light water	Light water	Uranium-235	To obtain basic nuclear information for HERALD.
	8	FAST REACTOR	Dounreay	1959	—	60 MW 15 MW(E)	None	Sodium-potassium alloy	Enriched uranium; plutonium	Development of fast-reactor technology (reactor physics, fuel elements and coolant handling).
	9	ZENITH	Winfrith	1959	2×10^8	100 Watts	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 Watts	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 Watts	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	3×10^8	A few Watts	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 Watts	Heavy water	Heavy water	Highly enriched uranium-aluminium alloy	Can simulate DIDO or PLUTO, to provide basic physics information in support of these reactors.
	16	A.G.R.	Windscale	1962	1.6×10^{13}	100 MW 28 MW(E) net	Graphite	Carbon dioxide	Enriched uranium oxide	To study the advanced gas-cooled power reactor system and to test fuel elements for the system.
	17	ZEBRA	Winfrith	1962	—	100 Watts	None	None	Uranium-235; plutonium	A flexible system intended primarily to investigate the physics of large, fast reactors.
	18	HECTOR	Winfrith	1963	3×10^8	100 Watts	Graphite	Carbon dioxide used as heating gas	Permanent fuel: highly enriched uranium-aluminium alloy.	Oscillator reactor: reactivity measurements on materials and fuel elements.
	19	JUNO (formerly NERO)	Winfrith	1964	3×10^8	Less than 100 Watts	Heavy water, light water or mixtures	None	Central core: variable Uranium or plutonium	Reactor physics investigations of marine systems or of the steam-generating heavy-water reactor.
	20	S.G.H.W.	Winfrith	1967	—	275 MW excluding super heat, 100 MW(E)	Heavy water	Light water	Enriched uranium oxide	To study the realiability, safe operation and economics of this type of reactor.
POWER PLUTONIUM PRODUCING REACTORS (IN PRODUCTION)	21-24	Calder (2 stations "A" and "B") (4 reactors)	Calderbridge	Station "A" 1956 Station "B" 1958	—	235 MW per reactor, 45 MW(E) including steam	Graphite	Carbon dioxide	Natural uranium	Power and plutonium production; experimental work in aid of the U.K. nuclear power programme. Output quoted includes 9 MW(E) equivalent of steam supplied to the Windscale site services.
	25-28	Chapelcross (4 reactors)	Annan	1958 (1st reactor) 1959 (reactors 2, 3 and 4)	—	One reactor at 235 MW, three reactors at 240 MW, 45 MW(E)	Graphite	Carbon dioxide	Natural uranium	Power and plutonium production; experimental work in aid of the U.K. nuclear power programme.

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.*



Two-stage mass spectrometer of high sensitivity designed and built at Aldermaston

Front cover : Trigger spark-gap for synchronous switching of condenser-bank feeding Thetatron coil at Culham