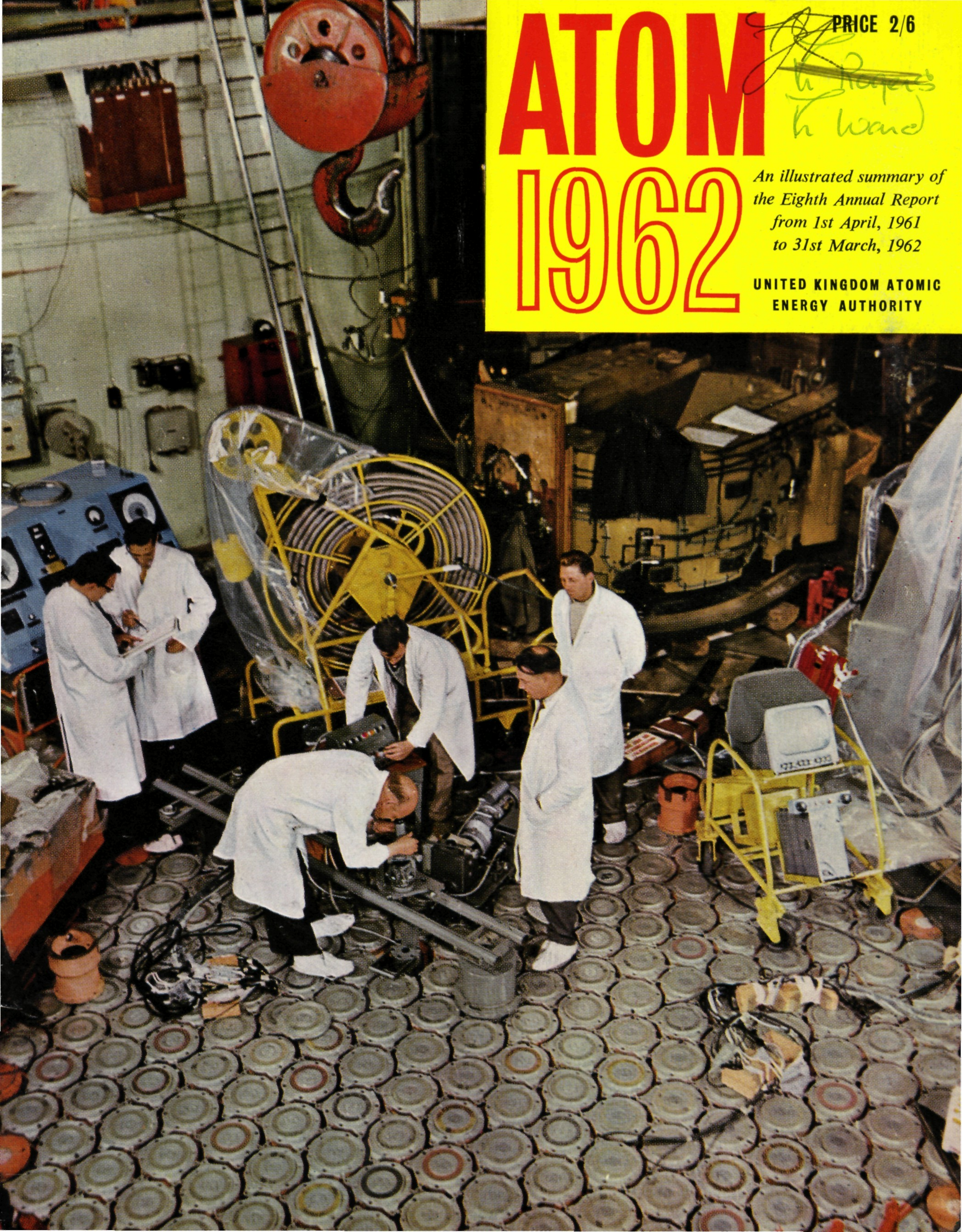
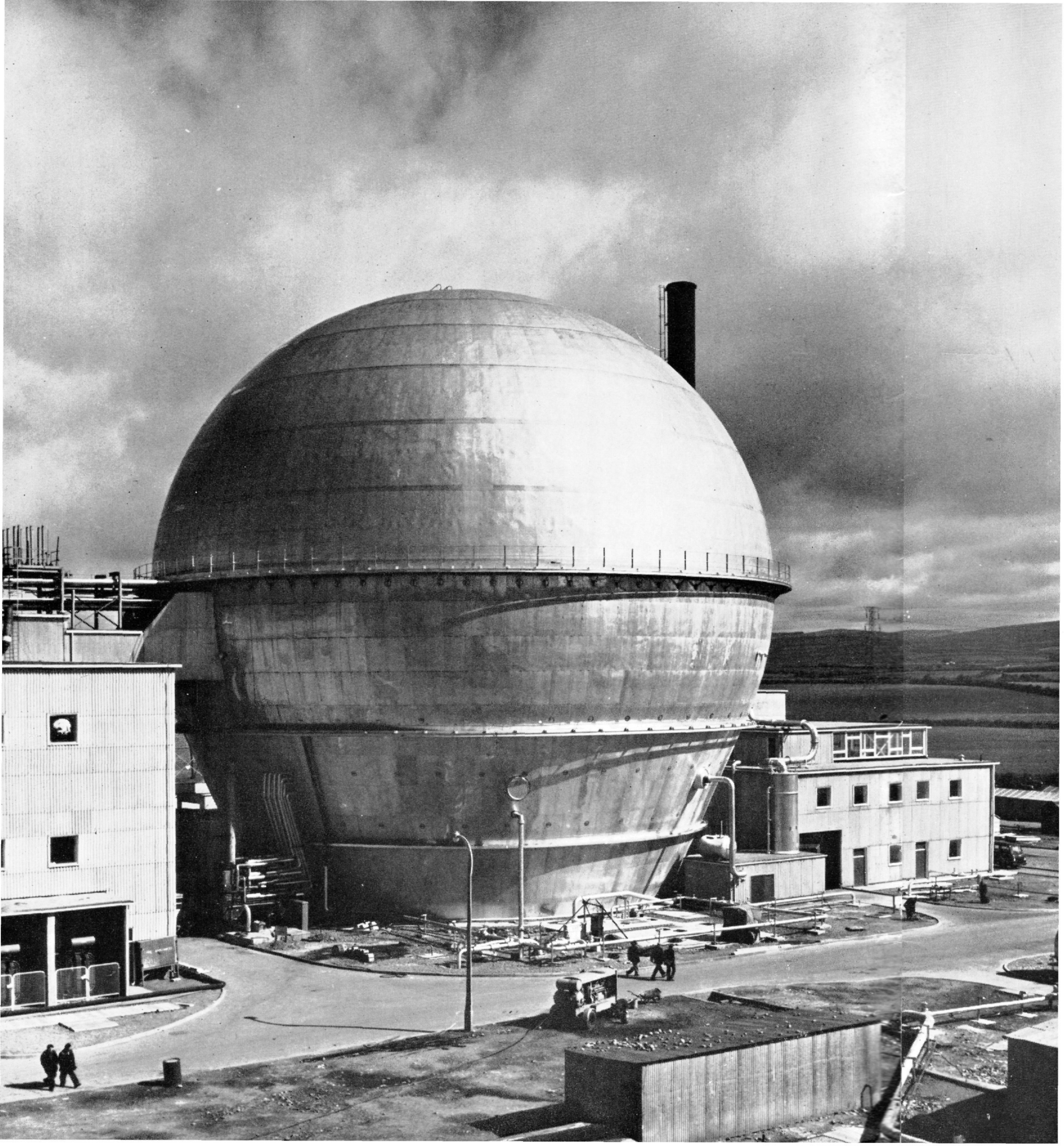
PRICE 2/6

ATOM 1962

An illustrated summary of the Eighth Annual Report from 1st April, 1961 to 31st March, 1962

UNITED KINGDOM ATOMIC ENERGY AUTHORITY





LANDMARKS

Three important landmarks on the road to economical nuclear power generation were passed in 1961-62

1 17th October, 1961, was the fifth anniversary of the opening of Calder Hall—the world's first nuclear power station on an industrial scale—by Her Majesty the Queen.

2 The chain reaction in the first reactors of the nuclear power stations at Bradwell and Berkeley started on 19th and 27th August, 1961, respectively. These stations are being built by British industry for the Central Electricity Generating Board as part of the national power programme.

3 Construction has been completed of the Authority's Advanced Gas-Cooled Reactor at Windscale. The Authority are confident that electricity from A.G.R. stations will be as cheap as, and later cheaper than, electricity from stations fuelled by coal or oil in the United Kingdom.

Left: The Advanced Gas-Cooled Reactor, Windscale (May, 1962).

FRONT COVER: Re-fuelling floor of A.G.R., Windscale.

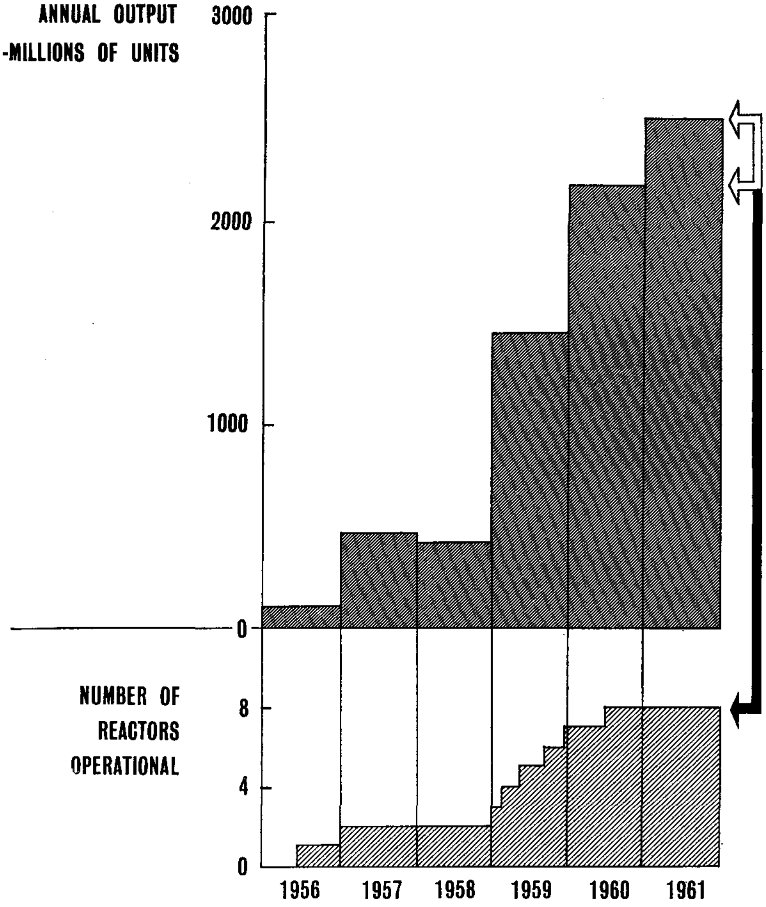
CALDER HALL AND THE POWER PROGRAMME

The first nuclear power station at Calder Hall has shown an outstanding performance during its five and a half years of operation and the information which is becoming available on the prospective life of the reactors themselves is also encouraging.

Comprehensive inspection has shown no evidence to suggest that the life of magnox stations will be limited to twenty years, the period hitherto chosen, with deliberate caution, for amortising the capital cost of the civil stations.

The reactors have shown a high and increasing availability and no more maintenance is required now than when they were first commissioned. The proportion of the year during which the station is generating electricity has steadily increased. **Availabilities of 85 per cent are normal and 90 per cent availability has been demonstrated over a period of twelve months.** Such availabilities compare well with those achieved by the latest conventional coal-fired power stations. This is

Calder Hall, 1962.



The 15% growth of output in 1961 (a period when no new reactors were commissioned) resulted from increased efficiency of operation, due principally to higher output and improved reactor availability.

NUCLEAR ELECTRICITY GENERATION FROM CALDER HALL AND CHAPELCROSS.

a notable achievement because the reactors are *not* designed for continuous refuelling.

Since the first reactor was commissioned in 1956 three more have been built on the Calder Hall site and four at Chapelcross in Scotland. The combined electricity output of these stations has now exceeded **six thousand million kilowatt hours** and one eighth of the South of Scotland Electricity Board's requirements were met in 1961 from the output of the Chapelcross reactors. During the autumn of 1961 a storm interrupted the national grid and the West Cumberland area was supplied for a time exclusively with electricity produced from nuclear reactors.

Development of operating techniques, coupled with a better understanding of the behaviour of uranium-magnox reactors, has enabled their heat output to be increased by nearly one quarter compared with the design rating. Since the turbo-alternators were unable to accept the additional steam, it has been necessary at Chapelcross to increase their capacity to the maximum by reblading. Half the turbines at Calder Hall have been rebladed and the remaining surplus steam will be used for process heating on the adjacent Windscale site. The cost of reblading the turbines was recovered within a few months from the increased electrical output.

Major reactor shut-down periods have fallen from over 9 per cent in 1960 to under 8 per cent in 1961. Also the time required for the detection and discharge of faulty fuel has been more than halved during the year. The mean load factor has increased from 79.2 per cent in 1957 to 88.1 per cent in 1961.

An extensive experimental programme in Production Group reactors supports the civil power programme. Of particular importance is the life of the standard Calder fuel element which, although it was designed for a much shorter life, has remained in some cases in the reactor for four and a half years, giving an average output of 3,000 Megawatt-days (Heat) per tonne. This is significant because it is equal to the life assumed in calculating the performance of the civil reactors, which will contain improved and stronger fuel elements. Although prototypes of the latter have not yet remained on test for as long as the standard Calder element, a few channels have attained 2,300 MWd(H)/t and the results so far obtained justify complete confidence that an average irradiation of 3,000 MWd(H)/t will be attained.

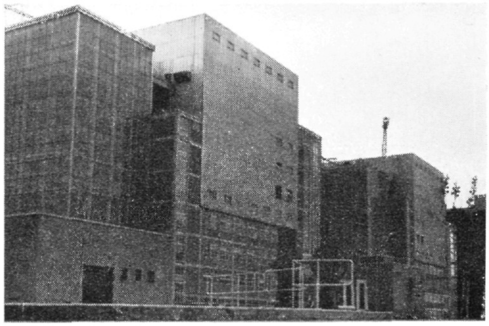
The recent results from production reactors give assurance that the assumptions used in assessing the cost of nuclear power were not optimistic but rather that **in some respects they were unduly pessimistic.** The high load factors achieved at Calder Hall without continuous refuelling indicate that the continuously fuelled reactors of the generating boards may well exceed the 75 per cent load factor assumed for economic comparisons.

THE POWER PROGRAMME

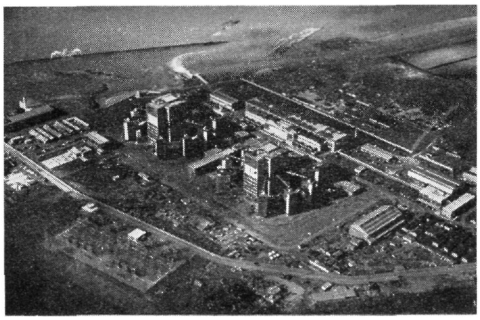
Nuclear power stations now being built for, or authorised by, the Central Electricity Generating Board and South of Scotland Electricity Board are as follows:—

Name	*For*	*Capacity*	*Start-up Date*
Berkeley	C.E.G.B.	275 MW.	1962
Bradwell	C.E.G.B.	300 MW.	1962
Hinkley Point	C.E.G.B.	500 MW.	1963
Hunterston	S.S.E.B.	320 MW.	1964
Trawsfynydd	C.E.G.B.	500 MW.	1964
Dungeness	C.E.G.B.	550 MW.	1964
Sizewell	C.E.G.B.	580 MW.	1965
Oldbury-on-Severn	C.E.G.B.	550 MW.	1966
Wylfa	C.E.G.B.	800 MW.	
		4,375	

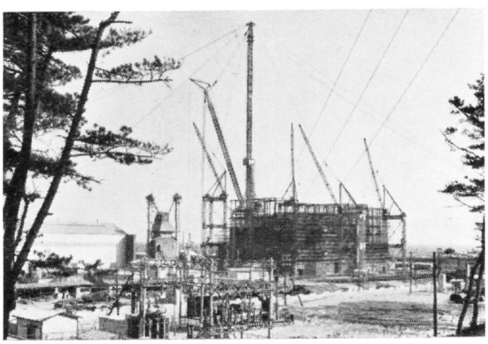
(In addition, nuclear power stations of the Calder Hall type are being built at Latina, Italy, and Tokai Mura, Japan.)



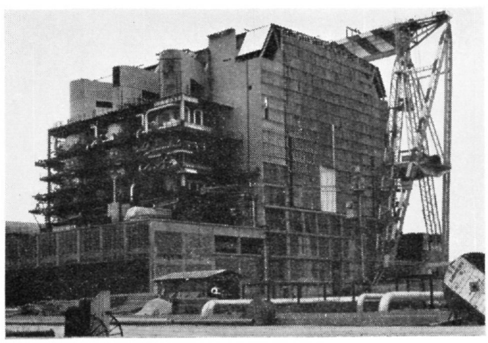
Bradwell.



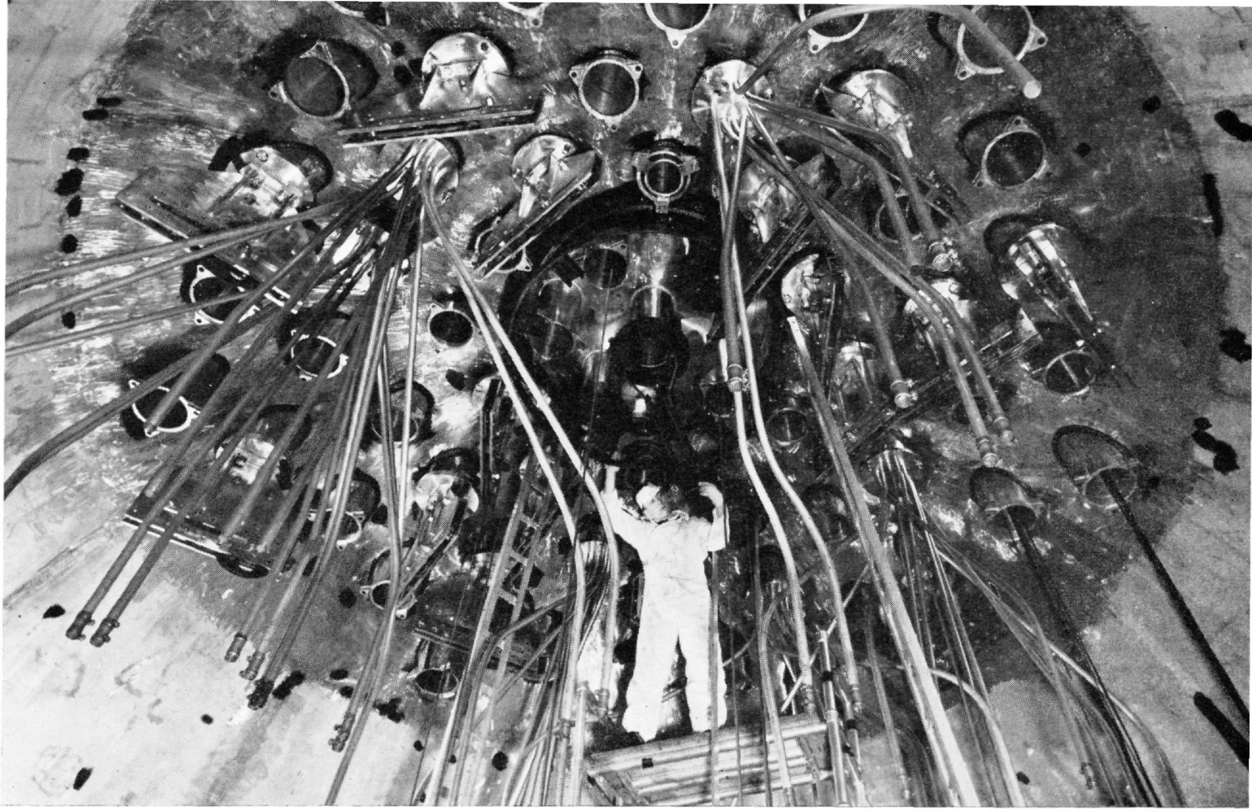
Berkeley.



Tokai Mura.



Latina.



The HERO reactor provides experimental data for advanced gas-cooled reactors.

REACTORS: PATTERN OF THE FUTURE

The Authority have devoted considerable effort to the long-term planning of reactor development work and the deployment of resources available for this purpose.

The programme is kept under continual review with the object of maintaining, in the light of progress and experience, a correct balance of effort between the reactor projects.

To illustrate the balance of effort between the reactor projects under development, the percentage deployment of the qualified staff in the Reactor, Research and Weapons Groups (including supporting services), engaged on advanced systems at 31st March, 1962, was as follows:

System	*Percentage*
Advanced Gas-Cooled Reactor	26
Fast Reactor	37
High Temperature Gas-Cooled Reactor*	18
Heavy Water Reactors	13
Civil Marine Propulsion Reactors	6

*Including staff seconded to or supporting the Organisation for Economic Co-operation and Development Dragon Project.

Summary of Progress

The construction of the Advanced Gas-cooled Reactor (the A.G.R.) at Windscale is complete, commissioning is in progress and the reactor should start operation this summer.

The difficulties encountered during the start-up of the Dounreay fast reactor have been overcome and a power level of 11 MW(H) was reached early in December, 1961. This was more than double the power reached previously by any other fast reactor anywhere else in the world. The reactor is now being recharged with improved fuel elements and will be operated at higher power in the next few months.

The next important step in the fast reactor programme is the building of a prototype fast reactor (P.F.R.) which will lead directly to fast reactor generating stations in the mid 1970's. Design and development work is in hand and progress has been made with suitable plutonium fuels.

Studies during the year have led the Authority and the consortia jointly to conclude that the development of a prototype steam generating heavy-water-moderated reactor of pressure tube construction—with boiling light water cooling and provision for superheating would be a valuable addition to U.K. reactor technology.

The organisation to carry out the programme of work approved by the Government in support of nuclear marine propulsion has been set up. A detailed programme has been determined and work has begun. By 1st April, 1962, negotiations with the Belgium consortium, Belgonucleaire, for a joint development programme in support of a compact marine reactor known as Vulcain were well advanced.*

Advanced Gas-cooled Reactor

The advanced gas-cooled reactor is a development of the carbon-dioxide-cooled, graphite-moderated reactor system to higher operating temperatures and ratings. The higher operating temperatures will lead to steam conditions comparable with those prevailing in the latest turbine practice and overall thermal efficiencies of 40 per cent should be achieved.

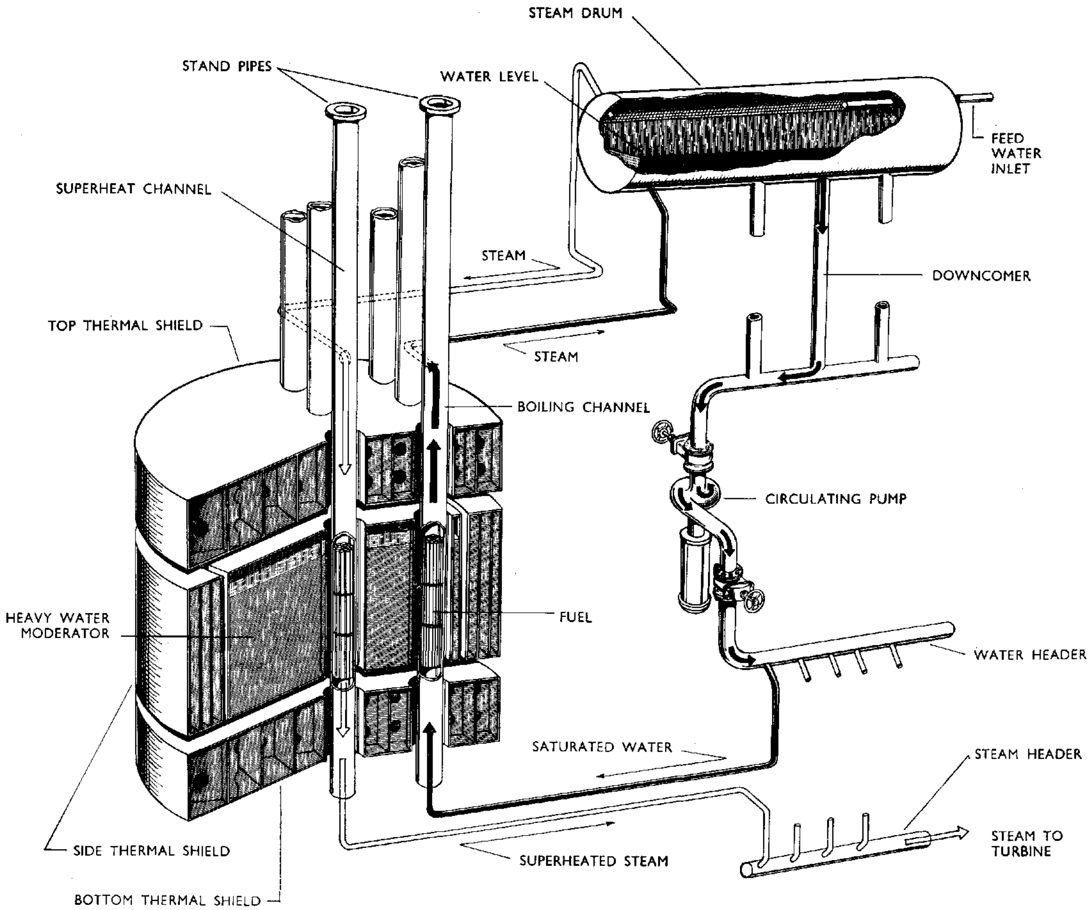
The Windscale A.G.R. should start up this summer and—after initial physics experiments—should be operating at power later this year.

The construction and commissioning of the heated zero energy reactor, HERO, have been completed. It is intended to use HERO to provide essential experimental physics data for various core arrangements for large A.G.R. generating stations.

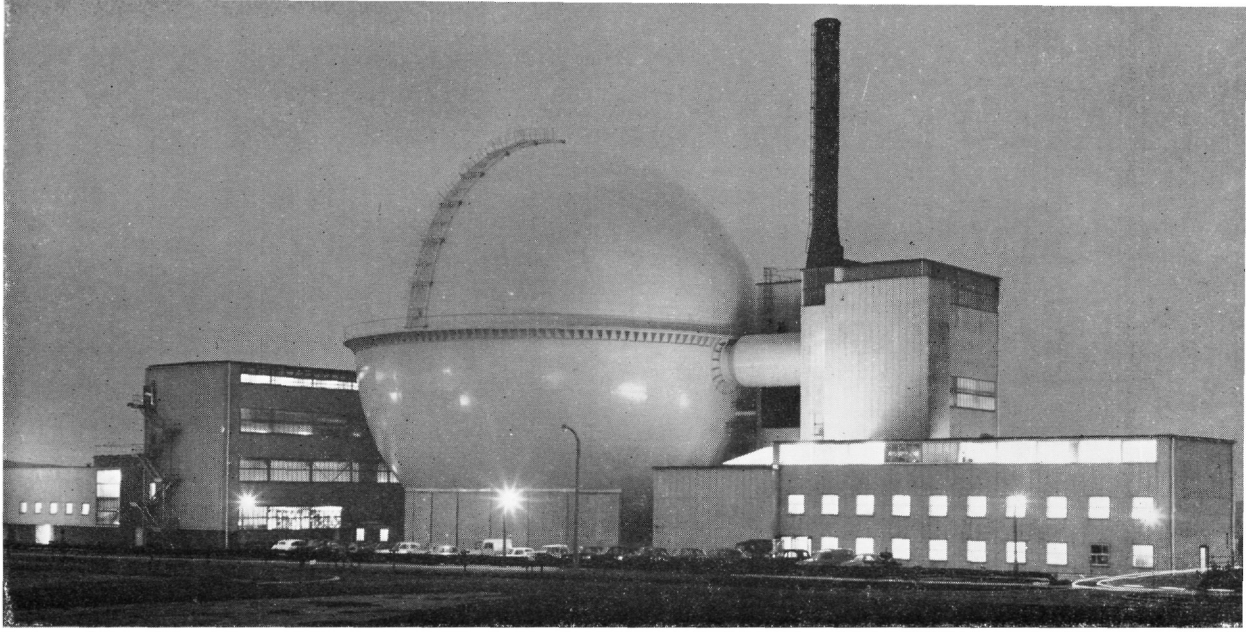
The manufacture of the complete first charge of fuel elements for the Windscale A.G.R. was completed in February, 1962.

These fuel elements are of conservative design. There is considerable scope for further development

*This Agreement was signed on 16th May.



A TYPICAL DESIGN OF A STEAM GENERATING HEAVY WATER MODERATED REACTOR



Dounreay has achieved double the power-level of any other fast reactor.

leading to improved thermal efficiency and reduction of generating costs. Batches of improved fuel elements are now being made and will be tested in the Windscale A.G.R. as soon as the reactor is on power.

Work on the development of beryllium as a canning material for A.G.R. fuel has been stopped.

Uncertainties on the irradiation behaviour and likely limitations upon can temperature made doubtful the achievement of a burn-up much in excess of 6,000 MWd(H)/t at a can temperature of 600°C. On the other hand, confidence in the irradiation performance of the stainless steel canned fuel is increasing and **there seems no reason why 20,000 MWd(H)/t should not be achievable.** On this basis beryllium-clad fuel ceases to be economically attractive.

Estimates have been made of the cost of generating electricity from A.G.R. stations consisting of two reactors each of 500 MW(E). The assumptions used were: overheads would be spread over a programme of at least 6,000 MW of A.G.R. stations; the reactors would be used on base load at 75 per cent load factor; a station life of 20 years; and an interest rate of 6 per cent.

The estimates indicated that the capital cost of such a station should be about **£80 per kilowatt** installed and the generating costs about **0.45d.**

To this figure an addition would have to be made for the recovery of the costs of development. The cost of electricity from the first station in the programme would be higher than 0.45d. and the cost would reduce below 0.45d. as the development potential of the system was exploited.

Fast Reactor

During the visit of Her Majesty the Queen Mother, on 14th August, 1961, the low power operation of the Dounreay Fast Reactor was demonstrated.

By October experiments at low power had confirmed that gas entrainment had been eliminated and measurements of the pressure coefficient of reactivity established that the small residual amounts of gas in the core were operationally insignificant. In accordance with the scheduled physics programme, the reactor power was gradually increased from 13th November.

On 22nd November a power level of 5 MW(H) was reached and on 23rd November, 7.5 MW(H); with each power increment, tests were carried out to demonstrate the operational stability of the reactor until, on 13th December, a power level of 11 MW(H) was recorded.

With the completion of the power run on 16th December the reactor was shut down for the replacement of the present fuel core with one of improved design, to enable the reactor to be run at higher powers during 1962.

This period of operation of the D.F.R. has demonstrated the satisfactory operation of the plant, and the reactor proved to be very stable.

The magnox power stations now being commissioned or built will produce large quantities of plutonium from the early 1970's onwards. At the present time it seems that the most effective way of using this plutonium fuel is to burn it in fast reactors, which have particularly suitable nuclear properties.

It is important to have an economic and proven design of fast reactor available to match the production of plutonium. The power producing fast reactors will differ in design and in fuel from the D.F.R.

The next stage will be the development, design and construction of a fast reactor incorporating these changes and large enough to serve as a prototype for large civil stations. Compared with the design of the experimental D.F.R. the prototype will have a smaller number of primary coolant circuits with large mechanical sodium pumps and large heat exchangers.

Experimental data in support of the most promising fast-reactor designs will be obtained from the new zero energy reactor ZEBRA, now being completed at Winfrith and expected to operate in the latter half of 1962.

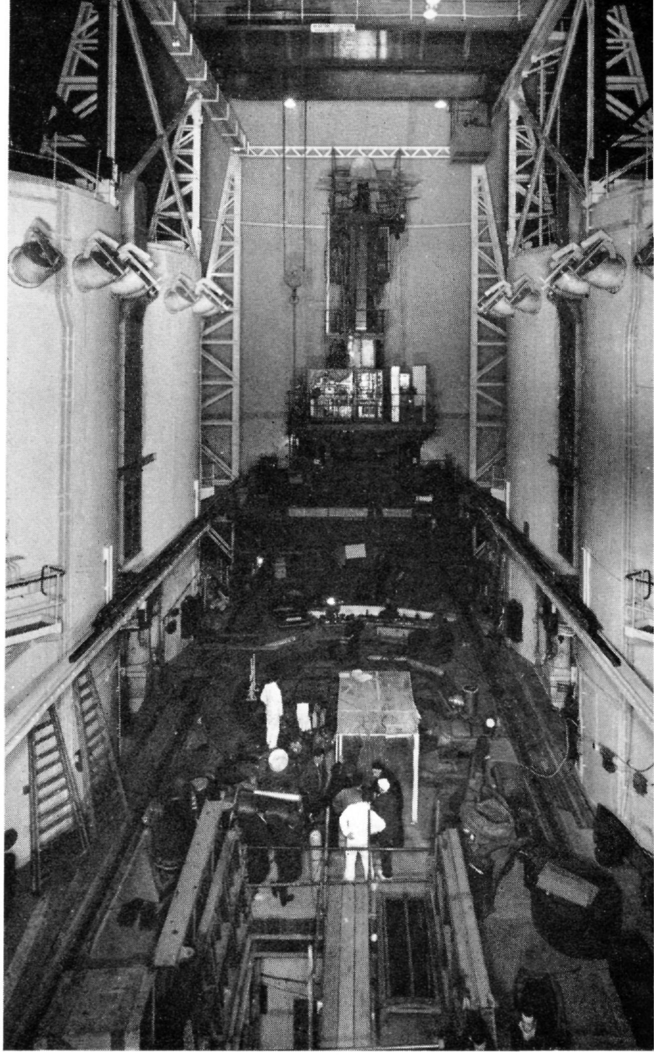
High Temperature Gas-cooled Reactor

A large proportion of the Authority's effort on the High Temperature Reactor (H.T.R.) system has continued to be in support of the Dragon Project—a 20 MW(H) reactor experiment at Winfrith in Dorset, under the auspices of the Organisation for Economic Co-operation and Development.

Experimental work with the zero energy reactor ZENITH in support of the Dragon reactor was completed during 1961.

The Authority's economic assessments of H.T.R. systems have included a study of a 1,000 MW(H) land-based design, using fuel elements which do not retain fission products. The estimated generating costs were comparable with those for an A.G.R. station and did not show the improvements expected from such a major extension of gas-cooled reactor technology.

This was largely because of design limitations on the core imposed by the involved and costly design of fuel element and because of the expensive chemical plant required to purge the coolant system



Interior of the A.G.R. reactor building at Windscale. The machine in the background is for loading and unloading fuel elements.

of fission products. Thus an essential requirement of a satisfactory fuel element design would appear to be its ability to retain fission products.

Theoretical studies have shown that the H.T.R. system has the potential of operating satisfactorily with a range of highly enriched fuel cycles; plutonium as well as highly enriched uranium may be used for the initial fissile material, and uranium-238 as well as thorium-232 for the fertile material.

Steam Generating Heavy Water Reactor

A limited programme of research and development designed to elucidate certain key problems of the Steam Generating Heavy Water (S.G.H.W.) reactor system has continued in collaboration with

Atomic Energy of Canada Limited.

Satisfactory progress has been made with the commissioning of a large heat transfer rig for burn-out and hydrodynamic instability tests of designs of S.G.H.W. fuel rod clusters. The steam-cooled loop in reactor NRX at Chalk River has been commissioned and irradiation has begun of the first design of stainless steel-clad fuel element rated at 42 MW(H)/t at 640°C can surface temperature.

The zero energy reactor DIMPLE has now been moved from Harwell to Winfrith. DIMPLE will now be used for the study of the reactor physics of a range of water-moderated cores; these experiments will include safety and control experiments.

Merchant Ships

The Ministry of Transport announced on 8th November, 1961, that Her Majesty's Government had decided not to proceed at present with the construction of a nuclear powered ship.

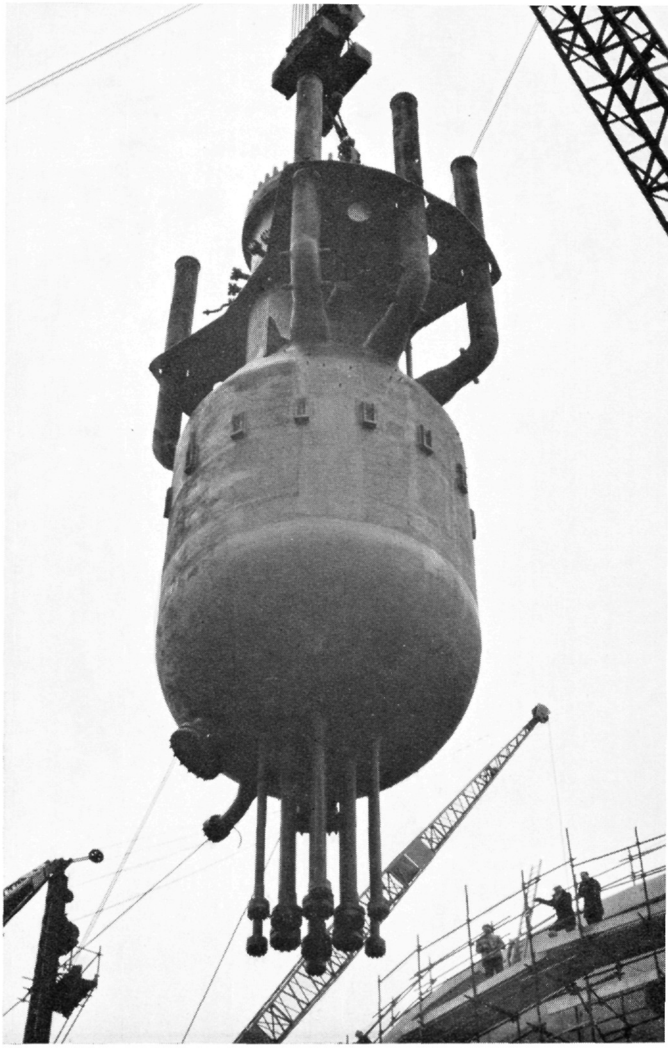
It was considered that, although it was technically feasible to build a nuclear powered ship, available designs of marine nuclear propulsion units did not offer sufficient economic promise to justify building a merchant ship at the present time.

Instead, a vigorous programme of research, aimed at an economically attractive marine propulsion unit, had been authorised by the Government. The programme is being carried out by the Authority in conjunction with United Kingdom industry. A working group on marine reactor research, chaired by the Permanent Secretary of the Ministry of Transport, has been set up to advise and make recommendations on the programme of research required to advance nuclear propulsion for merchant ships.

Economic studies of a 65,000 deadweight tanker, with a propulsion unit of 20,000 shaft horsepower, have indicated that, to be competitive with conventional propulsion, reactor costs as estimated in 1961 would need to be reduced by a factor of about three and fuel costs by about one-third.

It is with this ultimate objective that a number of water reactor systems are being studied. These include the steam-cooled heavy water reactor, the steam generating heavy water reactor and versions of the pressurised water reactor.

The long-term reactivity changes of one version of the P.W.R., initially heavily under-moderated, are controlled by the technique of "spectral shift", in which the ratio of heavy water to light water in the moderator is reduced with increasing burn-up.



The 48-ton pressure vessel being loaded into the DRAGON high temperature reactor at Winfrith.

In addition to the work on water-moderated systems, the Authority are making a design assessment of the high temperature gas-cooled reactor system for marine propulsion applications.

A marine reactor design team has been formed within the Authority and a team of engineers has been seconded from the British Shipbuilding Research Association to study the special features of the design, operation and safety of a nuclear ship. Contracts have been let to The Nuclear Power Group, The United Power Company Limited, Rolls-Royce Limited, and Babcock and Wilcox Limited for design studies of a series of water-moderated reactors.

A.G.R. fuel rods being prepared for weld-testing.

200,000 FUEL ELEMENTS A YEAR

The Springfields fuel-element production plant has been greatly expanded in recent years. From a small plant, making the earliest fuel element assemblies by what are now relatively crude methods, it has become a substantial and efficient factory producing annually about 200,000 fuel elements. In addition to their commitments for the national nuclear power programme, the Authority are under contract to supply the first fuel charge for the British-built reactor at Latina near Rome and negotiations are currently under way for the supply of fuel to the power station being built by a British consortium at Tokai Mura in Japan.

The extended fuel element production plant is now operating well. It has produced the first charges for the Bradwell and Berkeley reactors and some 62,000 elements have been despatched. In total about 2,000 tonnes of natural uranium have been fabricated during the year and approximately 200 tonnes of uranium have been converted into other forms for sale to a variety of customers.

A second but smaller plant has been commissioned during the year to produce pellets of sintered uranium dioxide for advanced gas-cooled reactor fuelling. This plant converts enriched uranium hexafluoride from the Capenhurst diffusion plant into uranium dioxide which is compacted and sintered into pellets of high density. The pellets are then loaded into stainless steel tubes which are sealed and assembled into clusters for loading into the reactor. Procedures to ensure a consistent product of high density have been evolved during the year.

During 1961 attention has been paid to improving the efficiency of the processes used at all stages of fuel manufacture. A 40 per cent increase in throughput has been achieved at the solvent extraction stage needed to purify the uranium solution before conversion into metal, and a concentrated development effort on the new fluidised bed plant commissioned last year has greatly reduced maintenance costs and markedly raised throughput.

Windscale

Although it is over ten years since the plutonium extraction plant at Windscale was first commissioned, it has operated during 1961 at a higher throughput despite some major maintenance required for the first time.

Considerable technical effort has been devoted during 1961 to developing continuous processes to replace small scale batch processes for plutonium production.

As more nuclear power stations are commissioned, increasing quantities of spent nuclear fuel will arise. This will require chemical reprocessing to remove plutonium and fission products and a new plant is under construction for this purpose, since the existing plant would be overloaded. A major effort in aid of the design of a new separation plant is nearing completion and considerable experimental work has been done on a pilot plant simulating the activity conditions to be encountered in the main plant.

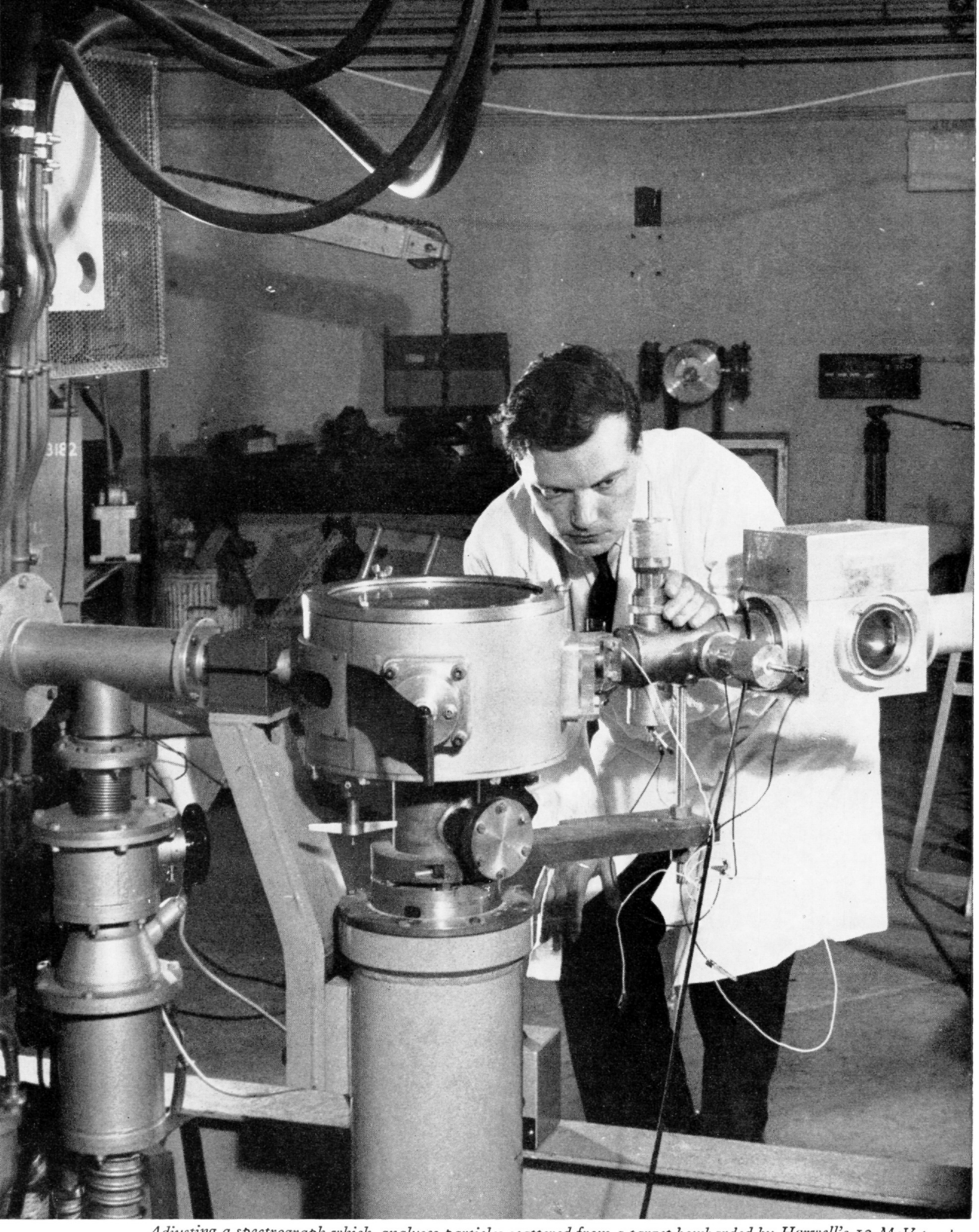
Capenhurst

The Capenhurst diffusion plant for the separation of uranium isotopes fulfilled all commitments for delivery of enriched uranium during the year.

It will be recalled that the plant was built during the decade 1950-60 to meet the military demands for enriched uranium. Following the completion of the final extensions towards the end of 1959, it has been possible to devote increasing attention to improvements in efficiency and a reduction in the operating costs.

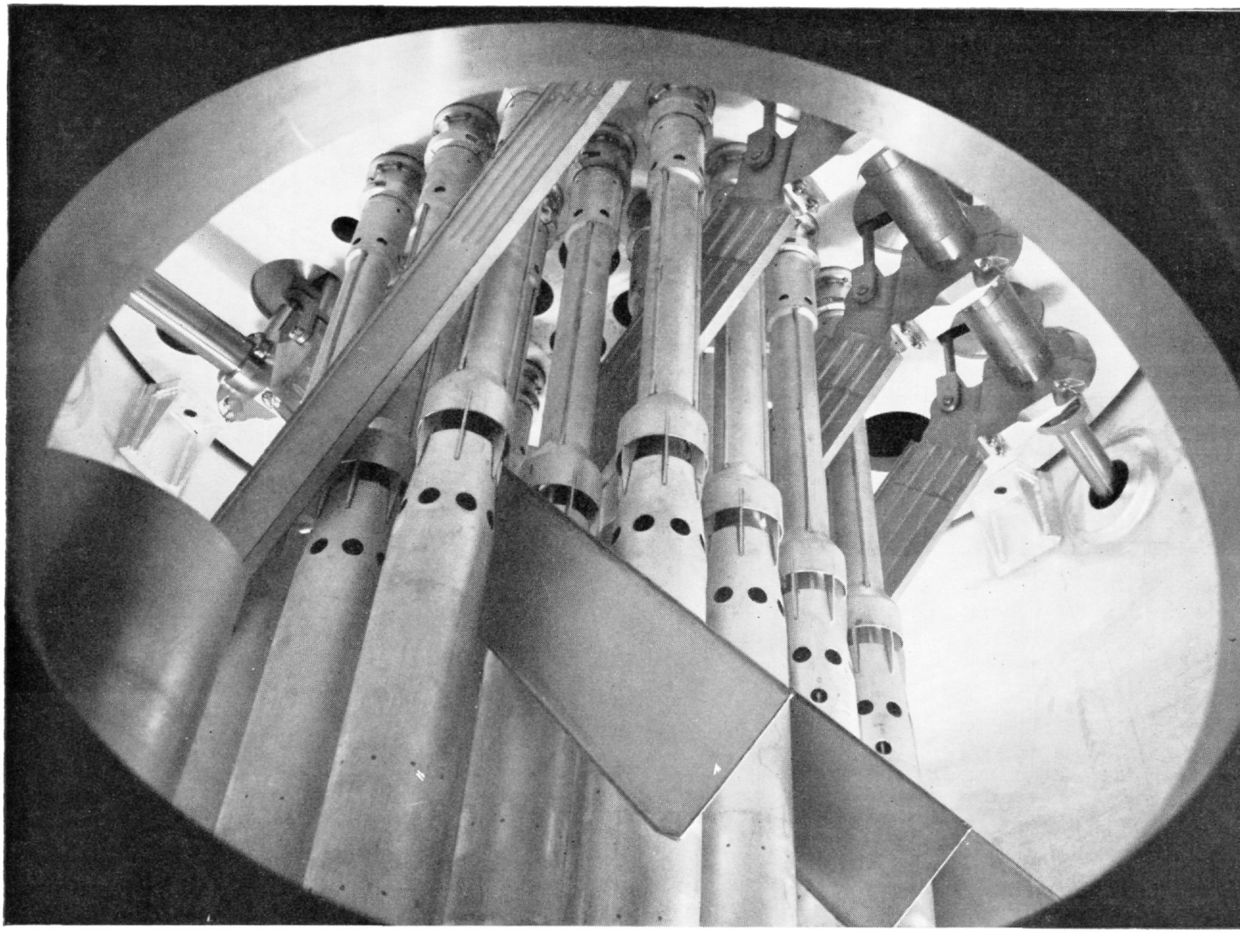
Study has continued of the gas centrifuge which might, in the long term, find an application as an alternative to the gaseous diffusion plant or as a means of supplementing its output for the production of enriched uranium.

An operator (background) is fitting a uranium rod into a Calder Hall-type fuel can.



Adjusting a spectrograph which analyses particles scattered from a target bombarded by Harwell's 12 MeV tandem accelerator (used for nuclear research). Aldermaston has a similar machine.

RESEARCH AND DEVELOPMENT



It is not often possible to see the "heart" of a reactor. The core of Harwell reactor, DAPHNE, seen through an inspection port in the reactor vessel.

The level of general research in the Authority is designed to provide the necessary effort on fundamental problems in fields such as nuclear physics, chemistry and metallurgy, together with the essential scientific base for the Authority's development activities including those on reactors.

The general work in the field of reactor technology, on which the successful development of individual reactor systems largely turns, includes work on materials both for reactors and for fuel.

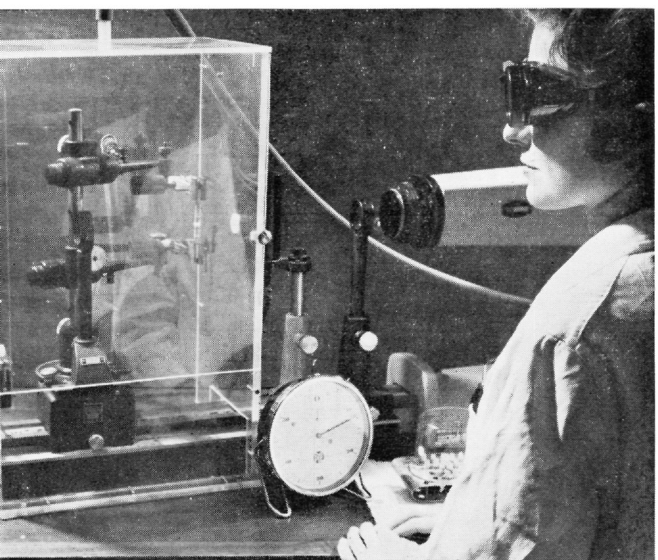
It is the Authority's policy to make the results of unclassified research available widely. During 1961/62 332 unclassified reports were issued and 390 papers by members of the Authority's staff published in journals.

The main programme of scientific research must be supported by advanced technology. Developments range from a welding machine for fuel elements to an epoxide resin glass laminate evolved to form a ring-shaped vacuum vessel, 150-ft. in diameter, for the Nimrod accelerator of the National Institute for Research in Nuclear Science.

Many techniques developed to further the Authority's work have wider applications in other

Measurement of stored energy in irradiated graphite at Culcheth.

Spectrographic examination at Chatham of water samples from a Harwell reactor.



industries or fields of work.

Reactor Materials

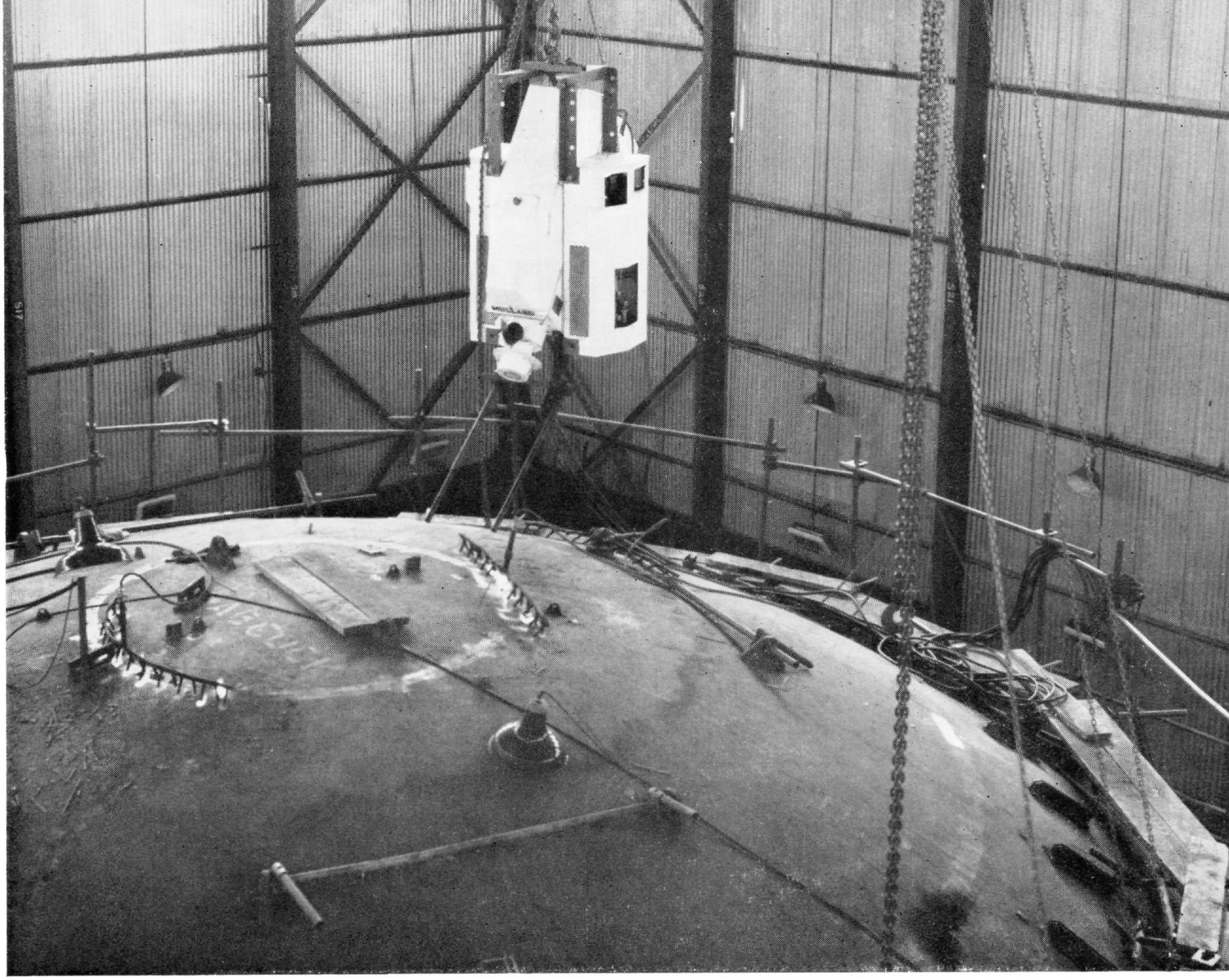
Penetrating radiation, particularly neutron radiation, can damage materials through which it passes; for example uranium may grow or swell, steel become brittle, graphite expand, and ceramic fuels release fission gases. The detailed understanding of the causes that underly these effects is therefore of major importance and a great deal of research is directed to acquiring such an understanding.

Research at Culcheth on radiation damage in stainless steels containing niobium has given interesting results. The steels were subjected to high temperature tensile tests after neutron irradiation at temperatures over the range 450 to 750°C. The irradiation temperatures were too high for damage caused by the usual atomic mechanism to remain, because atoms displaced from their normal positions by collision with neutrons would, at these temperatures, be sufficiently mobile to return to those positions. Despite this expectation, the ductility at 750°C decreased from 59 per cent to 18 per cent elongation, which is still adequate for the service required. This behaviour is similar to that of a material which has been heated at high temperature for a short time, for example 1350°C for one second; the mechanisms also may be similar since irradiation results in small regions of very high temperature which last for short times. Another possible mechanism is suggested by the observation at Harwell that, in stainless steels, carbides precipitate under irradiation at a temperature at which they would not form in the absence of radiation: these precipitates could account for substantially decreased ductility. The investigations are continuing to obtain a clearer understanding of the phenomena and to determine methods of fabrication and heat treatment which will eliminate embrittlement.

The high promise of oxide and other ceramic fuels for power reactors is responsible for a wide programme of general research into these materials. This includes investigation of the release of fission products, research on the fabrication of carbide and oxide fuels.

Nuclear Physics

The work of Authority nuclear physicists may be aimed at obtaining information needed in reactor design or to obtain more fundamental knowledge of nuclear structure and interactions. Advances in nuclear physics depend upon, and so generate



A 4·3 MeV linear accelerator developed by a commercial firm in conjunction with the Authority, and capable of penetrating 10 inches of steel, has been used for the radiography of welds at Trawsfynydd nuclear power station.

advances in techniques of accelerating and detecting elementary particles. These are often of value in other branches of science and engineering.

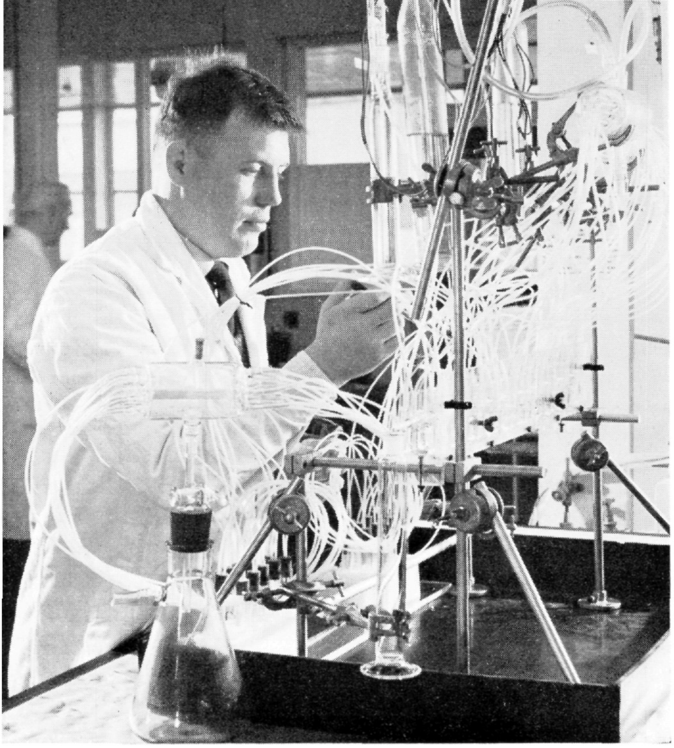
At Harwell one development has been an improved particle detector made from a semi-conductor. This responds rapidly to radiation, producing a signal within a hundred millionth part of a second and is able to discriminate between particle energies of closely similar values. Such detector systems have revolutionised work with low-energy particles. Their small size is of particular value in the design of target chambers; outside the field of nuclear physics they have proved of value in the detection of radioactive contamination in confined spaces, even within the human body.

Harwell also has a new accelerator known as IBIS. This is a 3 MV electrostatic generator producing ions in pulses lasting as little as one thousand millionth of a second but of very high intensity. The short duration of the pulse enables the energy of particles scattered by a sample to be calculated very accurately by measuring the time taken to cover a fixed distance.

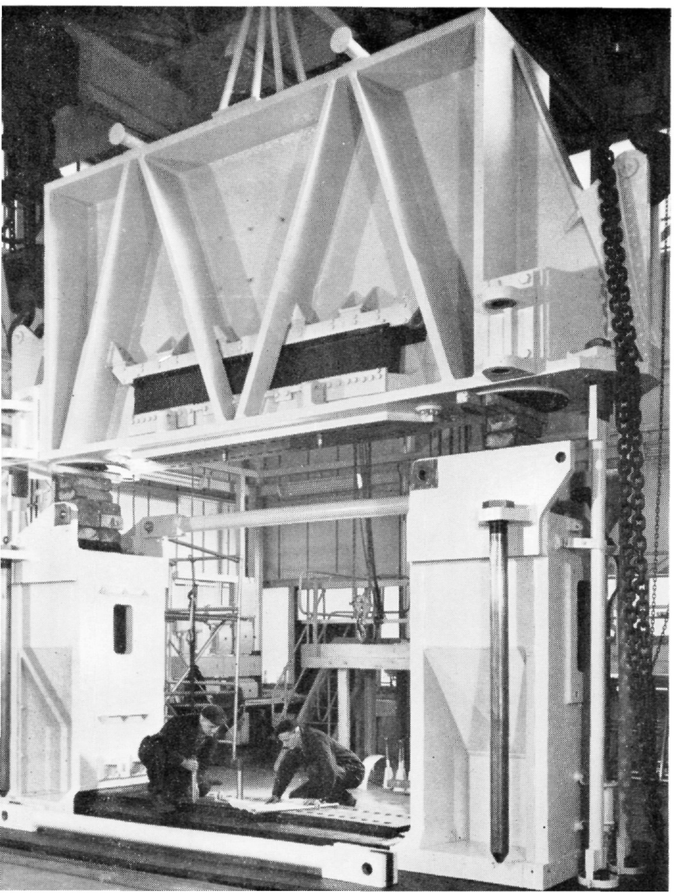
Other accelerators have continued to be used not only in the main research programme but for purposes ranging from measurement of the amount of silicon in coal to the irradiation of solar cells to enable the Royal Aircraft Establishment to assess the effects of the Van Allen radiation on artificial satellites.

X-Rays v. Gamma Rays

The problems of radiographing radioactive materials have been studied at Dounreay. The main difficulty is that gamma rays can blacken film as



Experiment with a miniature "mixer-settler" at Dounreay as part of a fuel re-processing programme.



effectively as X-rays. Following a series of experiments a new technique has been developed. The film is now protected from the radioactivity by a rotating lead disc in which is cut a number of collimating slits. The rotation of the disc causes the slits to scan the active specimen allowing the exposure to be made. The lead in the disc protects the film from most of the gamma rays except those emanating from the portion of the specimen exposed by the slits. This improves the discrimination, that is the ratio of X-rays to gamma rays reaching the film, by a factor of at least ten.

Neutron Tubes

An inexpensive, portable, fast-neutron generator is available commercially, built round the "K" type neutron tube derived from designs sponsored by the Authority. Up to now, neutron generators have been large and expensive installations but this portable generator can be used to produce very short lived radioactive isotopes for local use in both industry and medicine. The generator is also suitable for educational and training purposes and for research work.

Materials Testing Reactors

The Authority operate four reactors whose main purpose is the testing of materials under irradiation; these are DIDO, PLUTO and BEPO at Harwell and D.M.T.R. at Dounreay.

The operation of these reactors costs about two million pounds a year and employs about 250 staff (including about 60 qualified engineers and scientists). The Authority have therefore devoted a great deal of attention to making the maximum use of these important machines.

Many of the difficulties in securing high utilisation arise simply from lack of space. For example, the average number of experiments in DIDO at any one time is about 45, all of which must be fitted into a cylinder of about 7 ft. in diameter. These difficulties are minimised by careful design of the rig and its associated instruments, which wherever possible are miniaturised, and by planning the sequence and arrangement of different experiments.

One way of saving valuable operating time in DIDO and PLUTO is by using a cheaper zero energy reactor in which preliminary measurements can be made of the effects of loading experimental equipment into the bigger reactors. Construction

In this crack-arrest-testing machine at Culcheth 4 in. steel plate can be subjected to a tensile load of 4,000 tons.

of such a reactor, called DAPHNE (Dido and Pluto Handmaiden for Nuclear Experiments) began in February, 1961, and the reactor began operating on 20th February, 1962.

Plasma Physics and Fusion Research

The objective of the programme of the Authority's Culham laboratory is the generation of power from fusion reactions. Fusion is the joining together of light elements. (Existing nuclear power stations are based on the fission or splitting of uranium which is a heavy element.)

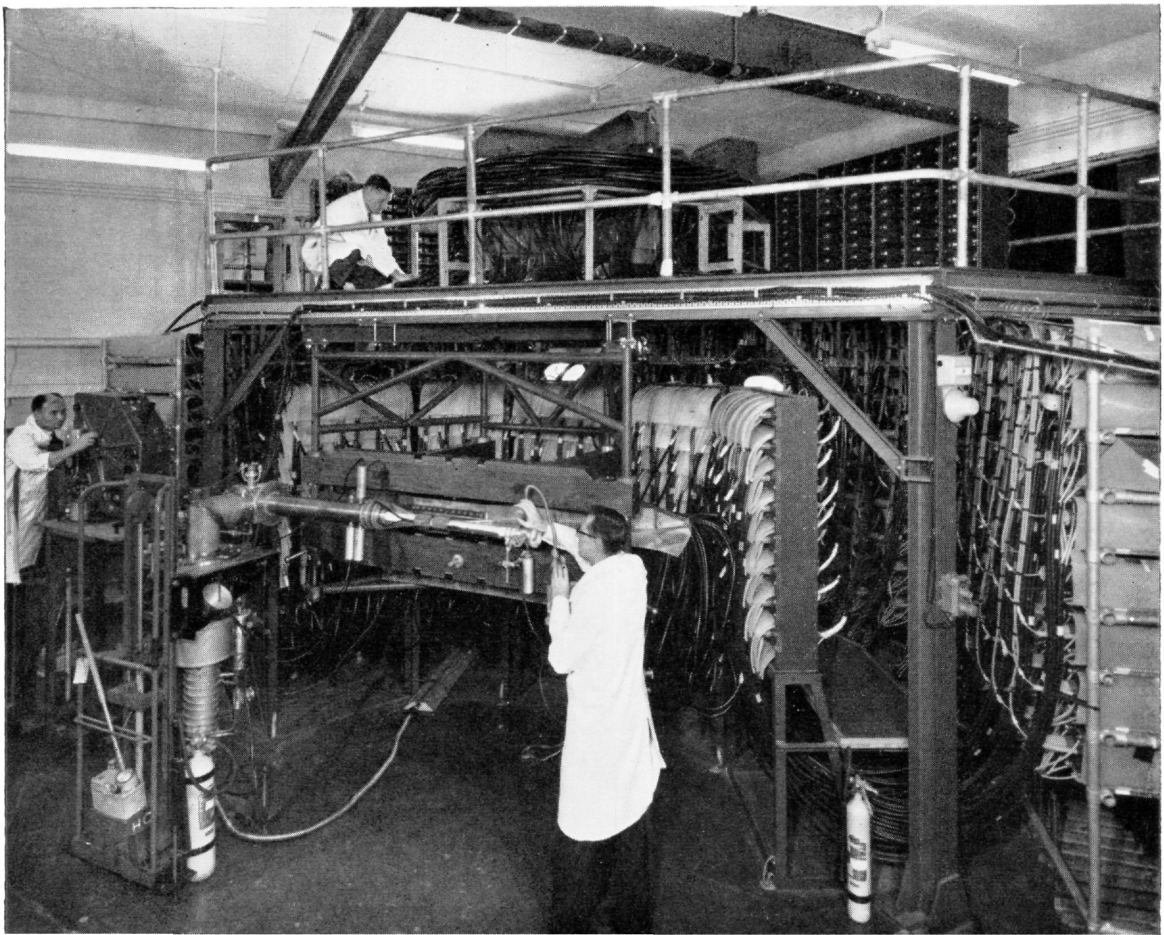
The most likely source of such power is a plasma, i.e. a hot ionised gas, comprising a mixture of the heavy isotopes of hydrogen.

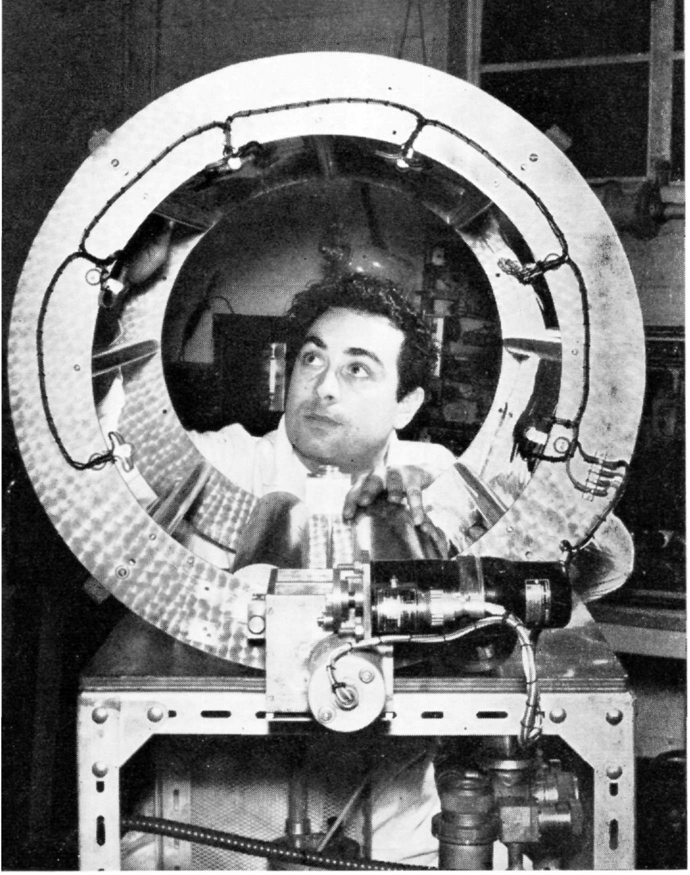
Well established data show that to get useful power from such a plasma, the product of the particle density (n) and the time in seconds for which it is contained (t) must exceed a hundred million million seconds/cc, while at the same time mean ion temperatures of about a hundred million degrees centigrade are required.

For a decade now, attempts have been made to obtain systems of heating and confining plasma for times long enough for an appreciable number of the nuclei to fuse together. Although different methods have been developed for obtaining hot plasma, all attempts at confining it in thermal isolation within a vessel rely on interaction with magnetic fields. Judged against the criteria given above, the existing Authority devices, in common with those developed elsewhere, still call for improvements of several orders of magnitude.

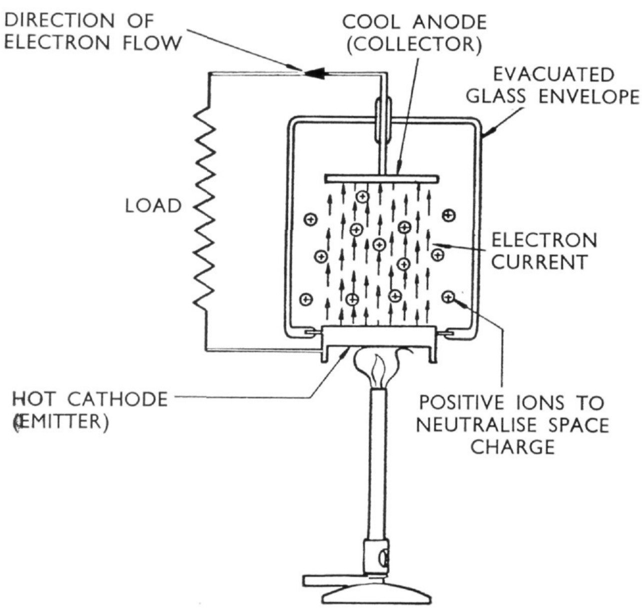
Progress in making these improvements must depend upon an understanding of the plasma state, and hence upon extensive research in plasma physics. Such research is as essential to the fusion work as nuclear physics has been to the fission

This condenser bank used at Aldermaston for plasma research provides peak currents of two million amperes rising to a peak in two-millionths of a second.





At Woolwich, apparatus is prepared before measuring very small amounts of alpha-activity in an ionisation chamber.



1. PRINCIPLE OF SIMPLE DIODE GENERATOR

power programme, and it is upon this fact that the broad experimental programme of the Culham Laboratory is based.

The past twelve months have seen considerable progress in the building of the Culham Laboratory and the total staff on site now numbers about three hundred, including the first research teams from Harwell. The Culham Laboratory organisation includes staff engaged on fusion research at Harwell and at the Atomic Weapons Research Establishment, Aldermaston, who will ultimately move to Culham. By 1963 the whole of the staff and experiments will be at the Culham site.

It is a measure of the usefulness of the research apparatus, ZETA, that, after four years' service, it is still in continuous experimental use. The number of electrical discharges through this deuterium filled, ring shaped apparatus now exceed half a million, and observations on these have enabled the Authority to make the most comprehensive study yet attempted of conditions in a toroidal pinch system. During the last few months of the year under review, ZETA has been fitted with new primary windings which will permit an extended range of working conditions.

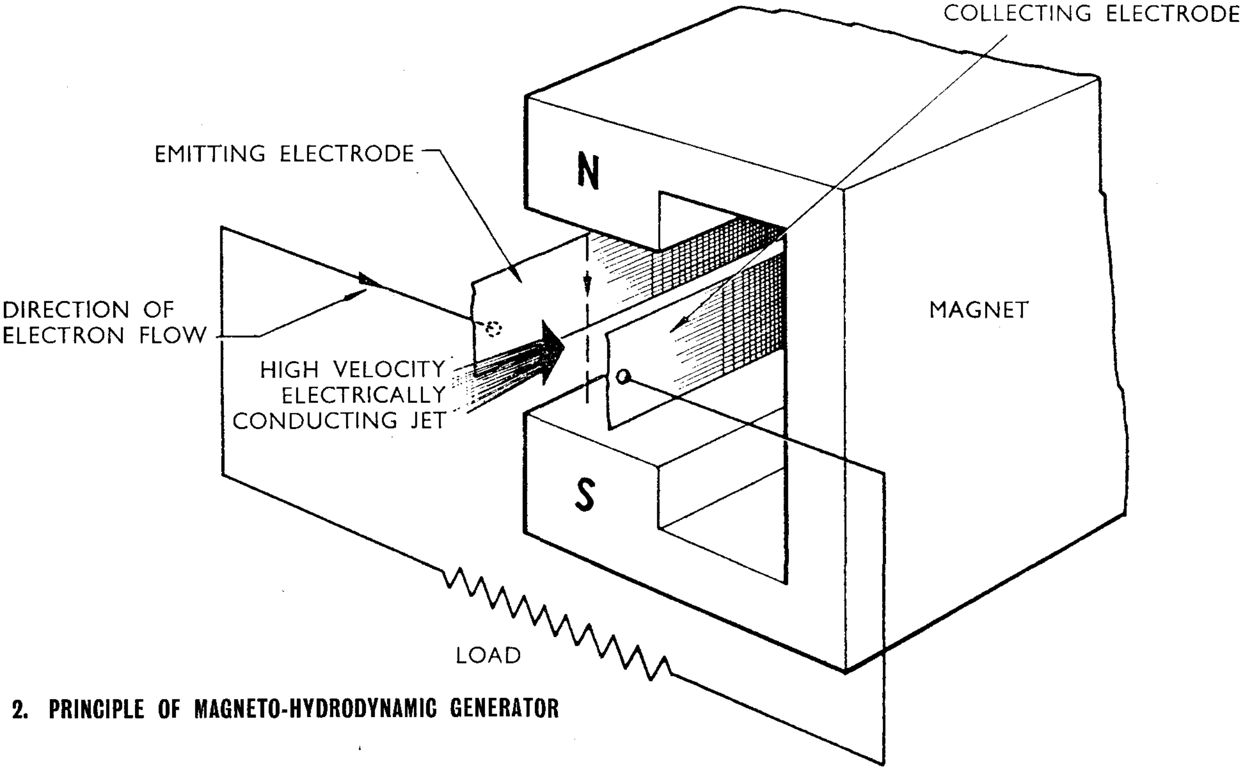
The fusion research programme as a whole consists of about a dozen related experiments covering nearly the whole range of possible "geometrical systems" in which the plasma can be confined and the ways in which it can be kept stable. They include Pinch and Unpinch stability studies, Theta Pinch and Cusp configurations.

Preparations have been made for solar coronal and chromospheric plasma studies by means of far ultra-violet observations. This work has been accepted as part of the Royal Society's space research programme.

Direct Conversion of Heat to Electricity

Britain's electrical supplies are mostly derived from a heat source raising steam for a turbo-electric alternator. A simpler system directly converting heat to electrical energy would have obvious advantages. Such a system might be applied to nuclear reactors and for this reason the Authority are making exploratory studies of the possibilities. At present it seems unlikely that any method could be used in a reactor to supplant the steam cycle entirely but might augment it and increase the overall efficiency.

The thermionic diode method of direct conversion (Fig. 1) shows greatest promise. Nuclear fuel elements at high temperature can act in a similar way

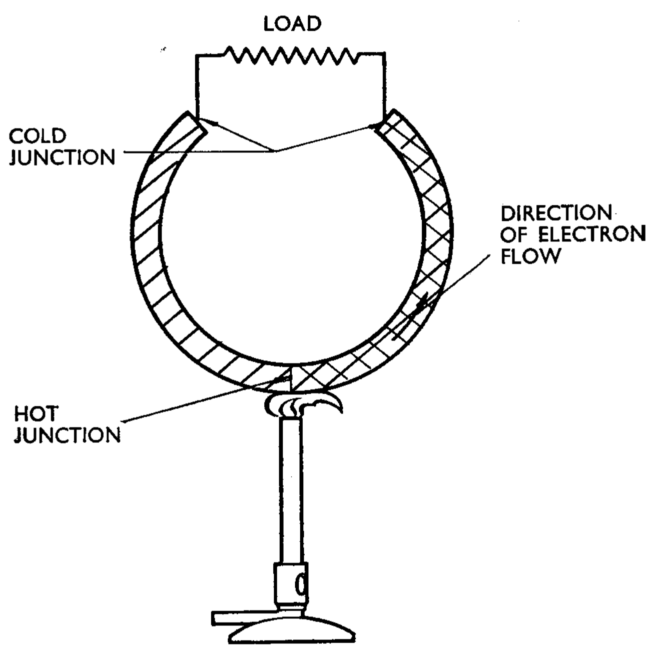


2. PRINCIPLE OF MAGNETO-HYDRODYNAMIC GENERATOR

to the electron emitting cathode of a diode valve. Current might be drawn from a collecting plate to increase the efficiency of the normal steam cycle by perhaps 10 to 15 per cent. In the year under review two experimental diodes of this sort were prepared for test in a reactor.

An alternative system known as magneto-hydrodynamic conversion (Fig. 2) depends on an ionised gas passing at high speed across a magnetic field. An electro motive force can be induced on a pair of electrodes in much the same way as an electromotive force is produced when the coils of a dynamo cut a magnetic field. It would be possible to produce either direct or alternating current. The research programme includes experimental measurements of the electrical conductivity of gases in the region of 2000°C and theoretical studies of gas ducts.

The production of electricity at a thermo-couple (Fig. 3) may, with improved materials, prove useful on a small scale but is unlikely to be suitable for large scale electricity generation. Developments in solid materials, particularly semi-conductors are being studied and experimental work using existing materials is being carried out.



3. PRINCIPLE OF SIMPLE THERMOCOUPLE

Gamma radiography is being used by the R.A.F. to check defects in aircraft.

The Wantage plant for sterilising pre-packed goods. Two plants of this type are now being built by private industry.

ISOTOPES AND IRRADIATION

Forty-two thousand consignments of radioisotopes and labelled compounds were despatched during the financial year 1961-62 from the Radiochemical Centre, Amersham, and from Harwell.

The proportion exported was a little over 50 per cent. The principal overseas markets were the U.S.A., Canada, Federal Germany, France and Japan.

A new rig for irradiating iridium in DIDO has greatly improved the specific activity of iridium-192, which is used extensively for **radiography of welds** in pipes or pressure vessels, and similar non-destructive testing. The intensity of these sources has been increased about five-fold, so allowing the radiographer to use shorter exposure time or to obtain higher definition.

Interest in those isotopes which can conveniently be made only in the cyclotron has continued to grow, and with the collaboration of the Medical Research Council Radiotherapeutic Research Unit at Hammersmith, the Department of Physics at the University of Birmingham and the Oak Ridge National Laboratory, the availability of these isotopes has been greatly improved. Their special properties make them of particular value in **medical diagnosis,** where accurate location of them in the body is important.

Rapid progress was made with synthesising additional tritium compounds and the Centre's list of compounds of this isotope was extended to about one hundred and forty items. The possibility of making certain compounds at extremely high specific activity is being exploited, particularly for the drug "Synkavit" which is a possible chemo-therapeutic agent for some forms of cancer. This has been prepared at nearly the theoretical maximum activity, which is about a thousand times higher than is usual for tracer use.

Advice to Industry

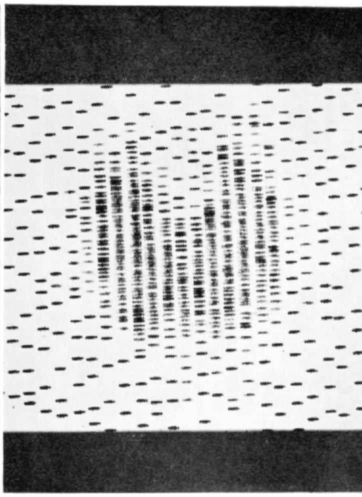
The function of the Authority's Wantage Research Laboratory is to do research into, and advise upon, the applications of radioisotopes. The demand upon the laboratory's services has continued at a high level, as is evidenced by the fact that over 100 representatives of industry visited the laboratory each month during the year. In addition, one-day courses and lectures were given to senior management in various industrial areas. These activities led to practical investigations by the laboratory both at enquirers' works and at Wantage.

A typical example of an on-site investigation was the **measurement of large water flow rates** in 5 ft. square culverts at the C.E.G.B.'s Uskmouth generating station, in connection with acceptance tests on cooling-water pumps. The accuracy was estimated as better than $\pm$ 2 per cent.

A large-scale application of radioactive tracers, which is now well established, is their use for investigating the **movement of coastal silt** or of surface or underground water. In the Firth of Forth it was desired to study the movement of material which is dredged from the upper part of the estuary, and then deposited in a deep cut seaward of the Forth Bridge. Glass particles labelled with scandium-46 were used to trace the movements of the silt over a period of two months. After the first tide an upstream movement became evident and after six days traces of radioactive material were found in the dredging area. This result was similar to that found in the Thames estuary by pioneer experiments in 1955.

The commercial use made of the Wantage Research Laboratory's pilot Package Irradiation Plant (in which radiation from a large cobalt-60 source is used to **sterilise pre-packed goods** as a continuous process) has increased steadily. More than a thousand packages are irradiated each week. The Army are using the plant for sterilising medical dressings intended for home and overseas use and more than fifteen industrial firms are using the plant regularly.

Licensees of the Authority are now constructing the first two commercial plants of this kind to be built in the U.K. and they have high hopes of selling irradiation plant overseas. One of the first commercial plants to operate outside the U.K. was built in Australia with the Authority's assistance, and uses 600,000 curies of cobalt-60, supplied by the Radiochemical Centre, Amersham, to kill the anthrax bacillus found in goat hair used for the manufacture of carpets.



A small tracer dose of radioactive iodine can be used in diagnosis to assess the position, size and shape of the thyroid. The apparatus (left) provides a colour picture or "scan" of the thyroid. The black and white print (above) shows a normal thyroid.

(Photos by courtesy of Hammersmith Hospital)

Miss D. Bartlett (U.K.) and Mr. L. Podo (Italy) work together on fission-product studies in the Dragon Project at Winfrith.

Delegates from the Japanese Atomic Energy Research Institute visited Dounreay in April, 1962.

INTERNATIONAL

As part of their general support of the work of the International Atomic Energy Agency, the Authority continued to release members of their staff for service as consultants, and on panels and working parties convened by the Agency.

The topics discussed during the year, at the meetings of this kind which Authority experts attended, have included: the disposal of radioactive waste into the sea and fresh water; basic health and safety standards; the application of radioisotopes in hydrology, agricultural research and industry; the costing of nuclear power; and international co-operation in the compilation of nuclear data.

Authority staff also attended a number of meetings convened by the I.A.E.A. jointly with the Food and Agriculture Organisation (F.A.O.) of the United Nations and the World Health Organisation (W.H.O.), and a conference held jointly with the International Standards Organisation (I.S.O.).

Authority representatives also attended ten scientific conferences and symposia held by the Agency during the course of the year. The subjects included nuclear electronics, plasma physics and power reactor experiments.

Early in the year Sir William Penney succeeded Sir John Cockcroft as a member of the I.A.E.A. Scientific Advisory Committee.

The Chairman of the Authority led the United Kingdom delegation to the Fifth Annual General Conference of the Agency, held in Vienna in September and October, 1961.

During the year holders of I.A.E.A. Fellowships continued to be accepted for attachments at the Authority's establishments and for training at the Authority's schools.

United Nations

In March, 1962, Sir William Penney replaced Sir John Cockcroft as the U.K. representative on the Scientific Advisory Committee of the United Nations. The Authority have continued to send members of their staff to attend meetings convened by the specialised agencies of the United Nations Organisation.

The Commonwealth

The annual meeting to review collaboration between the Authority and Atomic Energy of

CO-OPERATION

Canada Limited was held in November, 1961, at Chalk River in Canada. Co-operation between the two organisations has recently been increasing in basic and applied research, reactor technology and other fields. The opportunity was accordingly taken to place on record the arrangements under which the co-operation is effected. This was done in the form of letters exchanged during the conference between the Chairman of the Authority and Mr. J. Lorne Gray, President of A.E.C.L.

In September, 1961, an extension of the Authority's arrangements with the Australian Atomic Energy Commission was agreed, providing for increased co-operation in fields in which both organisations have active programmes.

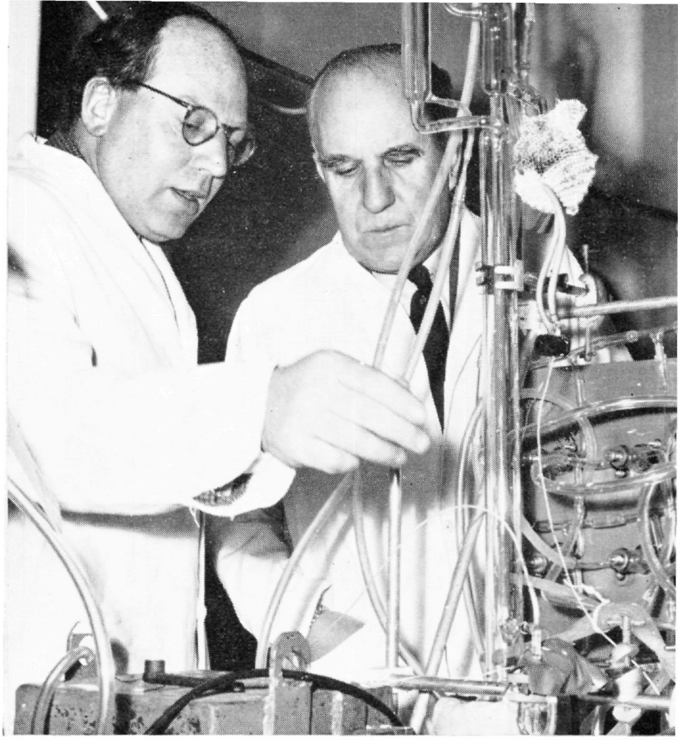
Discussions were held in London in June, 1961, with Dr. Usmani, the Chairman of the Pakistan Atomic Energy Commission, about ways and means of increasing co-operation between the Authority and the Commission. Letters were exchanged in September between the Authority's and the Commission's respective Chairmen which made provision for exchanges of unclassified reports, for visits by scientific staff and for assistance to be given by the Authority in the training of scientists and the provision of radioisotopes and research materials.

The Indian Government are now considering the tenders submitted to them in response to their invitation relating to a 300 MW nuclear power station which they propose to construct at Tarapur. Two of the nuclear power consortia of British industry tendered. Discussions have taken place during the year between the Authority and the Indian Department of Atomic Energy on consultancy services and fuel supplies which could be provided by the Authority for this project, and the possibility of the Authority granting licences for the manufacture of fuel elements.

E.N.E.A.

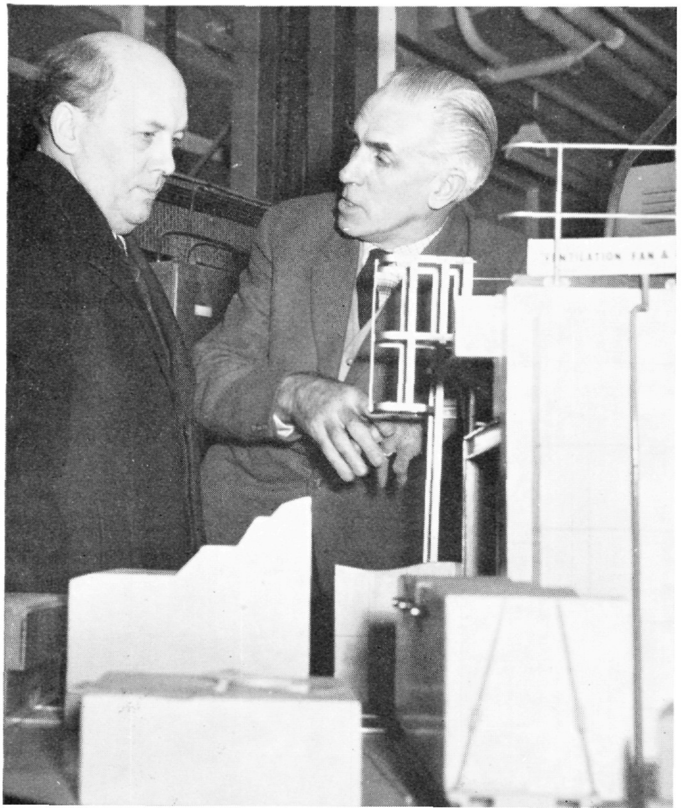
"Dragon" is a twelve-nation project, under the auspices of the European Nuclear Energy Agency, for the development of a High Temperature Reactor. The participants are the United Kingdom, Euratom (Belgium, France, Germany, Holland, Italy and Luxembourg), Austria, Denmark, Norway, Sweden and Switzerland.

Progress on the reactor site at Winfrith in



Admiral A. G. Spanides (right), President of the Greek A.E.C. at Harwell. Greece and Britain are co-operating in the peaceful uses of atomic energy.

The Authority and AB Atomenergi, Sweden, are increasing their exchanges of information on heavy-water reactors. Dr. H. Brynielsson, of Sweden (left) is seen at Winfrith.



Dorset, by the joint team consisting of staff from the Authority and the other European signatories, has been good on both the engineering and the research and development sides.

The main pressure vessel was delivered to the reactor site in March, 1962, just two years after the construction work began.

The present Dragon Agreement will come to an end in March, 1964, but by then the reactor will have operated for only a short time. Negotiations are already under way to prolong the life of the joint project so that the signatories to the agreement will obtain greater benefit from it.

The joint programme for the experimental operation of the Norwegian boiling water reactor at Halden by E.N.E.A. member countries has made satisfactory progress during the year. Norwegian proposals for a future international research programme, after the conclusion of the present Halden Agreement in December, 1962, are being studied.

Euratom

The third meeting of the U.K.-Euratom Continuing Committee for Co-operation—which is held at Ministerial level—took place in April, 1962.

The U.K.-Euratom Joint Working Group met twice during the year—in July, 1961, and February, 1962.

Two members of the Euratom staff began attachments of six months at Harwell in November, 1961.

On 5th March, 1962, Her Majesty's Government applied formally to open negotiations with the object of acceding to the Treaty establishing the European Atomic Energy Community (Euratom).

CERN

Mr. J. B. Adams, Director of the Research Group's Culham Laboratory, was succeeded as Director-General of the European Organisation for Nuclear Research (CERN) by Professor V. F. Weisskopf on 1st August, 1961. Four members of

Miss J. Kay (U.K.) is working in the 12-nation "Dragon" Project.

the Authority's staff presented papers at a conference held by CERN in September, 1961, on fission and spallation phenomena and their application to cosmic rays.

CENTO

Dr. M. L. Smith of the Authority's Research Group succeeded Mr. H. A. C. McKay as Director of the Central Treaty Organisation Institute of Nuclear Science at Teheran. With the development of national institutes in the individual CENTO countries, the work of the CENTO Institute is now directed more towards research, and the provision of advice and assistance, than to teaching and the organisation of training courses as in the past.

U.S.A.

Discussions between the Chairman of the Authority and Dr. Glenn Seaborg, Chairman of the U.S. Atomic Energy Commission, took place in London in September and in Washington in November. A survey of exchanges was also made when an American team visited the U.K. in June. Numerous meetings and visits on specialist topics, both civil and military, have taken place at the working level between representatives of the two organisations during the year. On the civil side, these included a conference in the U.S.A. in October, 1961, on plutonium recycling; and conferences in the U.K. in September, 1961, on feed materials and in December, 1961, on advanced gas-cooled reactor systems.

U.S.S.R.

A collaboration agreement between the Authority and the U.S.S.R. State Committee of the Council of Ministers for the Utilisation of Atomic Energy was signed in London in May, 1961. The agreement covers exchange of visits, exchange of unclassified reports and assistance in the provision of nuclear equipment and radioisotopes. Proposals for a programme of visits were also agreed. The first two such visits took place during the year. A Soviet team visited the U.K. in July for discussions on solid state physics and an Authority team, led by Sir William Cook, visited the U.S.S.R. in September for discussions on reactor physics and fast reactors.

Japan

The Chairman of the Authority visited Japan for discussions with the Japanese atomic energy authorities. During his stay he visited the nuclear power station which is under construction by British industry at Tokai Mura; and various installa-

Dr. Glenn Seaborg (left) Chairman of the U.S. Atomic Energy Commission, visited the Chairman of the Authority in September, 1961.

Engineers from the French Atomic Energy Commission on the charge-floor of one of the Calder Hall reactors.

Sir William Cook (centre) with a Russian delegation at Hinkley Point nuclear power station.

tions of the Japanese Atomic Energy Research Institute.

France

Co-operation between the Authority and the French Commissariat a l'Energie Atomique on a variety of technical subjects continued to be close and fruitful. A meeting in Paris in June, 1961, reviewed the progress of exchanges between the two countries.

Sweden

During a visit to London in December, 1961, by Dr. Brynielsson, Chairman of the Swedish organisation, AB Atomenergi, it was agreed that the exchange of information between the Authority and AB Atomenergi in relation to heavy-water-moderated reactor systems should be increased.

Greece

In March, 1962, Admiral Spanides, Chairman of the Greek Atomic Energy Commission, came to the U.K. for discussions. During his visit he and the Chairman of the Authority exchanged letters providing for co-operation in the peaceful uses of atomic energy. The Authority have undertaken to assist the Commission on the use of isotopes and by providing information, when requested, on nuclear power station construction.

Spain

The contacts between the Authority and the Junta de Energia Nuclear, which were formalised in the 1960 agreement between H.M. Government and the Spanish Government on the peaceful uses of atomic energy, have led to a number of further visits and to arrangements for Junta staff to be attached to Authority establishments.

Denmark

Regular visits by Authority's staff to the Danish Atomic Energy Commission's Risø establishment have taken place in connection with the irradiation programme which is being undertaken there on behalf of the Authority in the DR.3 reactor.

Brazil

Only one country, Brazil, has announced specific plans during the last twelve months for the introduction of nuclear power. These plans are for a 300 MW nuclear power station which is to have a single gas-cooled, graphite-moderated reactor, fuelled with natural uranium. Eight companies, including the three British consortia, have now been selected by the Brazilian Government to be invited to tender in due course.

HEALTH AND SAFETY

The Authority devote a substantial effort to health and safety. The basis is good operational housekeeping to ensure that the exposure of workpeople and the public to ionising radiation does not exceed the internationally recognised standards. At each site there are health and safety staff who provide specialist services and advise the local management.

About 20,000 Authority employees are classified as radiation workers. The maximum permissible whole-body dose (3 rems in 13 weeks) was exceeded by a small margin on eight occasions in 1961; this compared with nine occasions in 1960, fourteen in 1959 and twenty-five in 1958. In all cases arrangements were made to reduce subsequent exposure and to ensure that long-term dose limits were not exceeded.

A wide variety of non-radioactive materials is also handled by the Authority's staff. Some of these are highly toxic but, in the year under review, there were no cases of illness from this cause.

The Authority are responsible every year for many thousands of consignments of radioactive materials in transit. During the year there have been no incidents involving any hazard from radioactivity to the public or employees of transport undertakings.

Three minor incidents involving the release of radioactivity beyond the confines of the Authority's establishments occurred during the year. In no case was there any hazard to the public, although it was necessary to impose minor and temporary local restrictions.

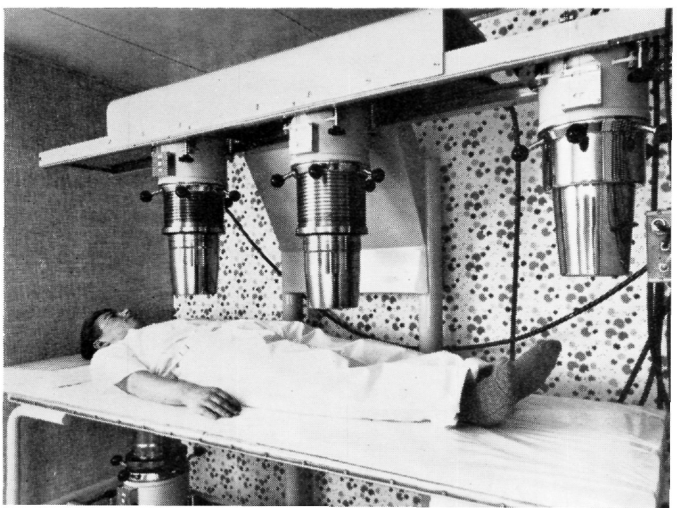
The Authority have continued to provide advice and assistance to government departments. In particular, the Safeguards Division of the Authority Health and Safety Branch has continued to carry out work on behalf of the Chief Inspector of Nuclear Installations, Ministry of Power, and to advise the Admiralty and Ministry of Transport on the safety aspects of nuclear propulsion of ships.

The Sealed Sources Regulations made by the Ministry of Labour under the Factories Act came into full operation on 1st February, 1962. These provide for the protection of persons handling sealed radiation sources or X-Ray and similar apparatus in industrial premises and apply to those of the Authority's premises which are classified as factories. No significant changes in the Authority's existing control procedures were necessary to comply with the requirements of the regulations.

The Authority have continued to support the work of the International Atomic Energy Agency in the health and safety field. During the year Authority staff have taken part in most of the Agency's scientific conferences and symposia concerned with health and safety. The Authority have also collaborated with other international organisations and with other countries in the health and safety field.

Health and safety research is important to provide data for the design, development and operation of nuclear installations. Some of the Authority's research work in the radiological protection field has been carried out by the health and safety staff at works and establishments. This is particularly valuable in the field of applied or operational research, and the work has included improvements in the methods of measuring radiation both to improve the accuracy of measurement and to reduce the labour involved.

Improved methods for assessing possible uptake of radioactive material into the body have been studied. These include the development of analytical techniques for detecting plutonium and the commissioning of whole-body monitors at Windscale, Dounreay and Winfrith to supplement the installation already in service at Harwell. The whole-body monitor is a valuable facility for use in research; for establishing that any accumulation of artificial radioisotopes in the body is at safe levels; and, in the event of suspected accidental intake of radioisotopes, for diagnosing the quantity, nature and location in the body.



Whole-body monitors are installed at four A.E.A. establishments

Experiments by the Weapons Group are designed to improve the ability to discriminate between earthquakes and explosions at great distances. Selected signals recorded by a large array of seismometers are processed in the magnetic tape equipment shown above before being fed into a large analogue computer.

DETECTION OF NUCLEAR TESTS

With the continued support of the Ministry of Defence, which has a central interest in the effectiveness of all measures for controlling and verifying any possible Disarmament Agreement, including a nuclear test ban, the Authority have been extending their work on test detection described in last year's report.

"Operation Seagull" was carried out early in 1961 by the Weapons Group of the Authority in collaboration with the Admiralty. In this operation two similar tests were performed, one in the English Channel and one in a Scottish loch. A series of depth charges was detonated and the resulting seismic waves were recorded at various sites in the United Kingdom.

The records obtained in these experiments have demonstrated the possibility of measuring the depth at which a disturbance has occurred within the earth's crust. Since the epicentres of many earthquakes occur at much greater depths than those at which the detonation of nuclear devices is likely to be possible, measurements of the depth where seismic signals originate provide a means of distinguishing between, on the one hand, deep earthquakes, and on the other hand, shallow earthquake or weapon tests (but not between these two).

The method can be applied at distances up to 1,000 kilometres provided that the direct waves transmitted through the earth's crust can be identified and distinguished from the waves refracted at the Mohorovicic discontinuity (the Moho). This discontinuity is situated at a depth of about 25 to 50 kilometres and refraction of seismic waves occurs there because there is a sudden increase in the velocity of transmission of body waves at this boundary. The seismometer arrays now in use or being installed by the Authority are designed to identify these signal components by velocity filtering.

American seismologists are currently examining the application of this technique in an extensive programme which includes detailed investigation in fold mountain areas of recent geological origin where propagation paths are more diverse than in the European plain and similar areas. An opportunity for the Authority to participate in this investigation was presented by "Project Gnome" in the U.S.A. This project involved the explosion of a 5 kiloton nuclear device 1,200 ft. below ground level in a salt formation near Carlsbad, New Mexico, and was the first nuclear explosion of "Operation Plowshare," the U.S.A. programme on the peaceful uses of atomic energy.

With the co-operation of the U.S.A. authorities, two linear arrays were established on Pole Mountain near Laramie, Wyoming, at a distance of about 1,000 kilometres from the Nevada Test Site and from Carlsbad. The Pole Mountain array has since continued in operation, to study focal depth measurements in the mountain area of the U.S.A. and also to study techniques for improving signal to noise ratio.

A criterion for distinguishing between the signals from the earthquakes and nuclear explosions is based on the fact that the first motion in the seismic wave from an explosion is outwards in all directions, whereas in earthquakes the first motion will be outwards in some directions from the source and inwards in others. It has been demonstrated by both "Seagull" and "Gnome" that it is possible by combining measurements on all instruments in an array to obtain a composite record which shows the waves more clearly and thus improves the registration of the first motion. In technical language, the cross correlation integral from summed outputs of groups of seismometers improves the identification of the onset of the first arrival.

First motion detection may also be improved by recording in deep boreholes. The amplitude of microseisms of the surface wave type decreases with depth and thus the "noise level" at the bottom of a deep hole is less than it is at the surface. A borehole seismograph has just been completed and is to be compared with surface arrays for the first motion detection.

Students from Japan, Thailand and the Philippines at the Calder Operation School.

ISOTOPE AND REACTOR SCHOOLS

Isotope School

The policy of the Isotope School at Wantage has continued to be that courses will be given for which a need is apparent and that courses shall not duplicate the work of universities and technical colleges.

Accordingly, two new courses were given, on industrial radiation processing and on radioisotopes in non-destructive testing, but there were only two basic general courses. The period included three medical courses and three short (one week) courses on radiological protection. Other courses were given on radioisotope methods in chemistry and on autoradiography for biologists. There was also an advanced course in physics and measurements, and a general course with special reference to radiobiochemistry.

For the third time, the school held a course, for the World Health Organisation, on public health aspects of radiation protection.

The number of students attending the school during the year was 325 of whom 115 were from overseas. During the eleven years of its existence, a total of 2,846 students, of whom 1,052 were from overseas, have attended 130 courses.

Harwell Reactor School

During the year the Reactor School held two standard courses and two for senior technical executives, together with two radiation protection courses.

New courses included one for senior engineering staff of universities and one for journalists.

In place of the control and instrumentation courses of previous years, a new course was held on instrumentation of reactors.

Another new course was for science masters, held in the Easter vacation; this was designed to help those teaching science to keep up to date with recent developments at Harwell in the nuclear physics and reactor fields.

There was an increase in the number of courses held for Authority staff only. The reactor engineering induction course has been held six times. Further series of courses, designed for reactor engineer control officers and for technical and non-technical classes, have been started.

That part of the standard course held at the Colleges of Advanced Technology has been extended by three weeks, the other ten weeks taking place at Harwell, and in the new Reactor School premises at the Atomic Energy Establishment, Winfrith.

A total of 338 students attended the Reactor School during the year, of whom 289 were British and 49 were foreign. Of the British total, 113 were Authority staff. Since the school began, 2,062 British and 657 foreign students have attended courses there.

Calder Operation School

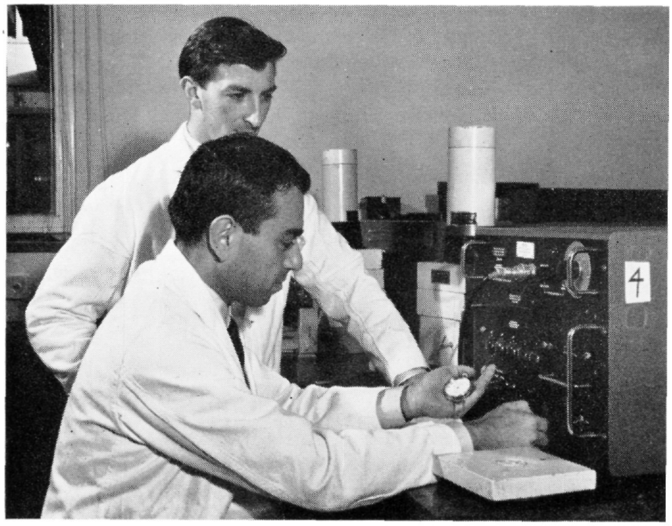
During the year, five standard courses, for professional engineers and physicists, were held at the Calder Operation School. Thirty-four of the ninety-eight students came from overseas. Over 600 students have now attended this course.

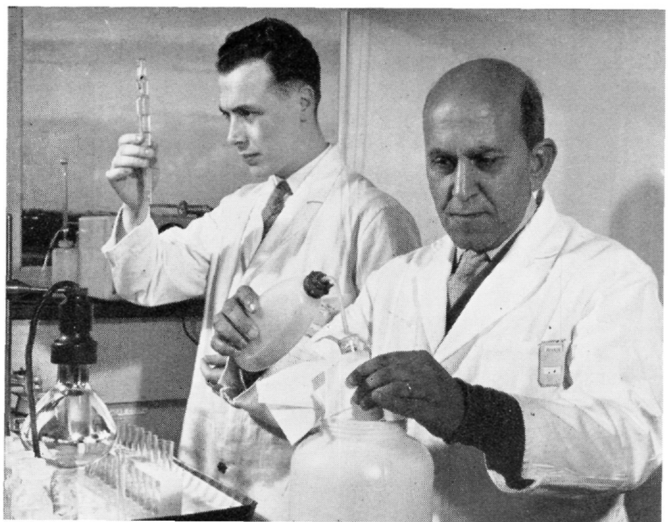
In addition three short reactor practise courses for technician grade operators were attended by twenty-one students; and four special two-week courses were attended by thirty-nine Authority professional engineers and physicists. A summer school in August, 1961, for science teachers and technical college lecturers proved a successful experiment.

A new type of course is being planned which will deal with all the reactor systems under development in this country. This course is designed to appeal particularly to executives from overseas.

Dr. P. P. G. L. Siriwardene, lecturer in chemistry at the University of Ceylon, attended the Isotope School at Wantage under the auspices of I.A.E.A.

Dr. G. Vassilacopoulos (foreground), from the University of Athens, at the Isotope School.





Holder of a W.H.O. Fellowship, Dr. N. Sorour, Ministry of Health, Cairo, conducts a radiochemical experiment at the Isotope School.

BOARD MEMBERSHIP

Membership of the Atomic Energy Authority as at 1st April, 1962, was:—

Chairman
Sir Roger Makins, G.C.B., G.C.M.G.

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

Full-time Members
Sir William Cook, C.B., F.R.S.
(Member for Reactors)
Sir Alan Hitchman, K.C.B.
(Member for Finance and Administration)
Sir Leonard Owen, C.B.E.*
(Member for Production and Engineering)
Air Chief Marshal Sir Claude B. R. Pelly, G.B.E., K.C.B., M.C.
(Member for Weapons Research and Development)

Part-time Members
Sir John Cockcroft, O.M., K.C.B., C.B.E., F.R.S.
Mr. C. F. Kearton, O.B.E., F.R.S.
Sir James Chadwick, F.R.S.
Rt. Hon. Lord Citrine, P.C., G.B.E.
Mr. S. J. Pears, F.C.A.
Mr. R. M. Geddes, O.B.E

Secretary
Mr. D. E. H. Peirson

*The appointment of Sir Leonard Owen as a full-time Member of the Authority expired on 30th June, 1962. He has been re-appointed as a part-time Member for the two-year period 1st July, 1962, to 30th June, 1964. Sir Leonard will continue as chairman of the Boards of Management of the Production and Engineering Groups.

The Minister for Science re-appointed Lord Citrine as a part-time Member of the Authority for the calendar year 1962.

In March, 1962, the election of Sir William Cook to Fellowship of the Royal Society was announced.

AUTHORITY ESTABLISHMENTS

London Office
11 Charles II Street, S.W.1

Research Group
A.E.R.E., Harwell, Didcot, Berks.
A.E.A. Factory, Western Road, Bracknell, Berks.
Chatham Outstation, Riverside, Chatham, Kent
Culham Laboratory, Culham, Abingdon, Berks.
Radiochemical Centre, White Lion Road, Amersham, Bucks.
Wantage Research Laboratory, Grove, Berks.
Woolwich Outstation, Building C.37, Royal Arsenal, Woolwich, S.E.18.

Engineering Group
H.Q., Risley, Warrington, Lancs.
Southern Works Organisation, Building 220, Newchurch Road, Tadley, Nr. Basingstoke, Hants.

Weapons Group
A.W.R.E., Aldermaston, Reading, Berks.
A.W.R.E., Foulness, Southend-on-Sea, Essex
A.W.R.E., Orfordness, Woodbridge, Suffolk
A.W.R.E. Woolwich Common, Ha Ha Road, Woolwich Common, S.E.18

Production Group
H.Q., Risley, Warrington, Lancs.
Capenhurst, Chester, Cheshire
Chapelcross Works, Annan, Dumfriesshire
Springfields Works, Salwick, Preston, Lancs.
Windscale and Calder Works, Sellafield, Seascale, Cumberland

Reactor Group
H.Q., Risley, Warrington, Lancs.
Dounreay Experimental Reactor Establishment, Thurso, Caithness
A.E.E., Winfrith, Dorchester, Dorset
Reactor Materials Laboratory, Culcheth, Wigshaw Lane, Culcheth, Nr. Warrington, Lancs.
Reactor Engineering Laboratory, Risley, Warrington, Lancs.
Reactor Fuel Element Laboratories, Springfields Works, Salwick, Preston, Lancs.
Reactor Development Laboratories, Windscale Works, Sellafield, Seascale, Cumberland

INFORMATION SERVICES

Libraries

The libraries of the Atomic Energy Research Establishment, Harwell, Berkshire, and of the Risley Group 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, Ratcliff 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
- 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 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 Ltd., 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 Ltd.).

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.

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.

Films

U.K.A.E.A. films include:—

- "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)
- "Industrial Uses of Radioisotopes"
- "Dounreay Symposium"
- "Winfrith Pipeline"
- "Operation Undersea"
- "Chapelcross"
- "Metals of the Nuclear Age"
- "Criticality"
- "Great Day" (opening of Calder Hall)
- "How a Thermal Reactor Works"

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

THE AUTHORITY'S REACTORS AS AT 31st MARCH, 1962

		Name	Location	Date of start-up	Peak neutron flux thermal N/cm^2 sec.	Maximum heat output	Moderator	Coolant	Fuel	Purpose
RESEARCH AND EXPERIMENTAL REACTORS										
	1	GLEEP	Harwell	1947	0.167×10^9	3 kW	Graphite	Air	Natural uranium	Routine graphite and uranium quality testing, research with oscillator, biological irradiations.
	2	BEPO	Harwell	1948	2×10^{12}	6 MW	Graphite	Air	Natural uranium	Nuclear reactor material studies isotope production, neutron physics, radiation chemistry.
	3	LIDO	Harwell	1956	10^{12}	100 kW	Light water	Light water	Enriched uranium-aluminium alloy	Thermal reactor studies including shielding.
	4	DIDO	Harwell	1956	2×10^{14}	13 MW	Heavy water	Heavy water	Highly enriched uranium-aluminium alloy	Nuclear reactor material studies, isotope production, neutron physics, radiation chemistry.
	5	PLUTO	Harwell	1957	1.8×10^{14}	10 MW	Heavy water	Heavy water	Highly enriched uranium-aluminium alloy	Nuclear reactor material studies, isotope production, neutron physics, radiation chemistry.
	6	D.M.T.R.	Dounreay	1958	1.2×10^{14}	10 MW	Heavy water	Heavy water	Uranium 235	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 on HERALD.
	8	FAST REACTOR	Dounreay	1959	—	60 MW	None	Sodium potassium alloy	Enriched uranium; plutonium	Development of fast reactor technology (reactor physics, fuel elements and coolant handling).
	9	ZENITH	Winfrith	1959	10^8	100 Watts	Graphite	None; Nitrogen used as heating gas	Ceramic elements containing highly enriched uranium oxide.	Reactor physics investigations for high temperature gas-cooled systems. (Max. temp. 800°C in core, 400°C in reflector.)
	10	NERO	Winfrith	1960	3×10^8	Less than 100 Watts	Graphite	None	Enriched uranium	Investigations for advanced graphite-moderated reactors and pile oscillator studies.
	11	HERALD	Aldermaston	1960	5×10^{13}	5 MW	Light water	Light water	Uranium 235	Neutron physics, radiochemical and nuclear reactor materials studies.
	12	VERA	Aldermaston	1961	—	100 Watts	None	None	Highly enriched uranium	Experimental studies of fast reactor systems.
	13	NESTOR	Winfrith	1961	10^{11}	10 kW	Light water	Light water	Enriched uranium-aluminium alloy	Sources of neutrons for sub-critical assemblies giving thermal fluxes of 10^8 in the assemblies.
	14	DIMPLE	Winfrith	1962	3×10^8	Less than 100 Watts	Light water, heavy water or organic liquid or mixtures	None	Uranium or plutonium	Testing a wide range of lattices at uniform temperatures up to about 80°C.
	15	HERO	Windscale	1962	—	A few Watts	Graphite	Carbon dioxide used as heating gas	Enriched uranium oxide	Reactor physics studies for the advanced gas-cooled reactor system.
	16	DAPHNE	Harwell	1962	2×10^9	Up to 100 Watts	Heavy water	Heavy water	Enriched uranium-aluminium alloy	To simulate DIDO and PLUTO and to provide basic physics information in support of these reactors.
RESEARCH AND EXPERIMENTAL REACTORS UNDER CONSTRUCTION										
	17	AGR	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.
	18	HECTOR	Winfrith	1963	3×10^8	Up to 100 Watts	Graphite	Carbon dioxide used as heating gas	Permanent fuel: enriched uranium-aluminium alloy. Central core: variable.	Oscillator reactor—reactivity measurements on materials and fuel elements.
	19	ZEBRA	Winfrith	1962	5×10^9	100 Watts	None	None	Uranium 235; plutonium	A flexible system intended primarily to investigate the physics of large, fast reactors.
PLUTONIUM/POWER PRODUCING REACTORS (IN PRODUCTION)										
	20-23	Calder (2 stations) ("A" & "B") (4 reactors)	Calderbridge	Station "A" 1956 Station "B" 1958	—	225 MW (heat) per reactor (45 MW (E) net)	Graphite	Carbon dioxide	Natural uranium	Plutonium, power production, and experimental work in aid of the U.K. nuclear power programme.
	24-27	Chapelcross (4 reactors)	Annan	1958 (1st reactor) 1959 (reactors 2, 3 and 4)	—	225 MW (heat) per reactor (45 MW (E) net)	Graphite	Carbon dioxide	Natural uranium	Plutonium, power production, and experimental work in aid of the U.K. nuclear power programme.

NOTE: *ZEUS was dismantled in September,* 1957. *ZEPHYR was dismantled in June,* 1958. *HAZEL was dismantled in September,* 1958. *NERO was dismantled at Harwell and re-erected at Winfrith in* 1960. *NEPTUNE ceased operation in June,* 1959. *DIMPLE was dismantled at Harwell and re-erected at Winfrith in* 1961.

H.M. Queen Elizabeth the Queen Mother visited Dounreay in August, 1961.

The Rt. Hon. Edward Heath, Lord Privy Seal (first from left) toured Harwell in January, 1962.

REVIEW OF THE YEAR

1st APRIL, 1961 TO 31st MARCH, 1962

During the year 1961/62 several landmarks were passed on the road to economical nuclear power generation. 17th October, 1961, was the fifth anniversary of the opening of Calder Hall by Her Majesty the Queen. The first reactors of the nuclear power stations at Bradwell and Berkeley achieved criticality on 19th and 27th August, 1961, respectively. Construction of the Authority's advanced gas-cooled reactor at Windscale was completed.

On the defence side, the Authority's research, development and production activities continued in accordance with the directions of Her Majesty's Government.

Also in accordance with Government decisions, the Authority have embarked on a vigorous programme of research aimed at a reactor system which will be economically attractive to a wide range of shipping. This programme will be carried out in conjunction with industry.

During the year the Authority completed a review of all their civil research and development programmes. These programmes were submitted to Ministers and given general approval. This gives a stable basis for the planning of the Authority's research and development effort, which is estimated to cost about £50 million per annum over the next five years.

The Authority's grant for 1961/62 was a net total of £78,071,000 (including a sum of £6,211,000 for the National Institute for Research in Nuclear Science).

Within the grant for 1961/62 some £49 million was spent on the Authority's civil research and development programme, including £33 million of current expenditure and £16 million on capital facilities. The programme includes the reactor programme, the work on plasma physics and fusion research, general reactor technology and general research including isotopes research.

The number of graduate or professional engineers or scientists employed on the whole programme at 31st March was 2,740.

The current expenditure during 1961/62 on the various civil research and development programmes and the deployment of qualified staff at the end of the year were broadly as follows.

	£m. Current Expenditure	*Qualified Scientists & Engineers**
Reactor Programme (including both preliminary work and major development)	21	1460
General Reactor Technology	4	300
General Research	5	520
Plasma Physics and Fusion Research	2	170
Isotopes Research	1	90

The production reactors and the processing plants have continued to perform satisfactorily; process efficiencies have been improved during the year.

Progress on the advanced gas-cooled reactor supported the expectation that electricity generated from A.G.R. stations will be as cheap as, and later cheaper than, electricity generated from conventional stations in the United Kingdom.

The Dounreay fast reactor reached a power level of 11 MW(H) in December, 1961, more than double the power reached previously by any other fast reactor.

The Authority and the industrial consortia have made further cost studies of various types of water-moderated reactor systems.

The Authority's commercial sales during the year realised over £20 million, with an additional £500,000 for consultancy services and royalties. The first two contracts with the Central Electricity Generating Board for fuel elements (for Bradwell and Berkeley) were signed in May, 1961. A contract to supply fuel for the Latina nuclear power station in Italy was signed in December, 1961.

The Authority's net expenditure in 1962/63 is estimated at £67,875,000 compared with £78,071,000 for 1961/62, a fall of over 13 per cent.

The Authority's staff now numbers 40,560.

* (i) The staff figures relate to Reactor, Research and Weapons Groups, and include staff providing supporting scientific, engineering and administrative services.

(ii) In addition to the staff shown, there were 200 scientists and engineers doing civil research and development for outside bodies on repayment.

(iii) Supporting services are also provided by the Production Group in fabricating and processing fuel, and by the Engineering Group in constructing capital facilities for the civil research and development programme.

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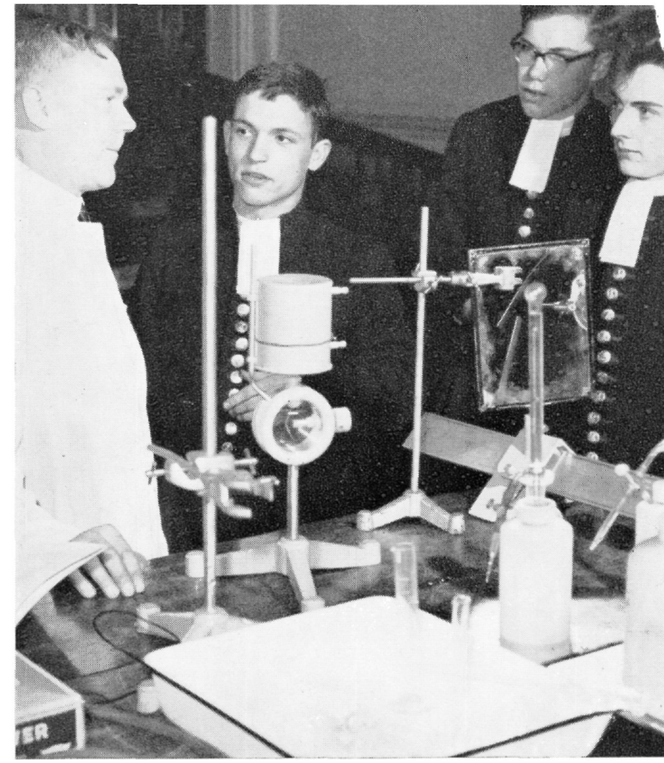

Mr. R. A. Faires (Isotope School) gave a series of lectures to Sixth Formers at the Science Museum in March, 1962

An "open day" for the Lords and Commons was held at Harwell in June, 1961.