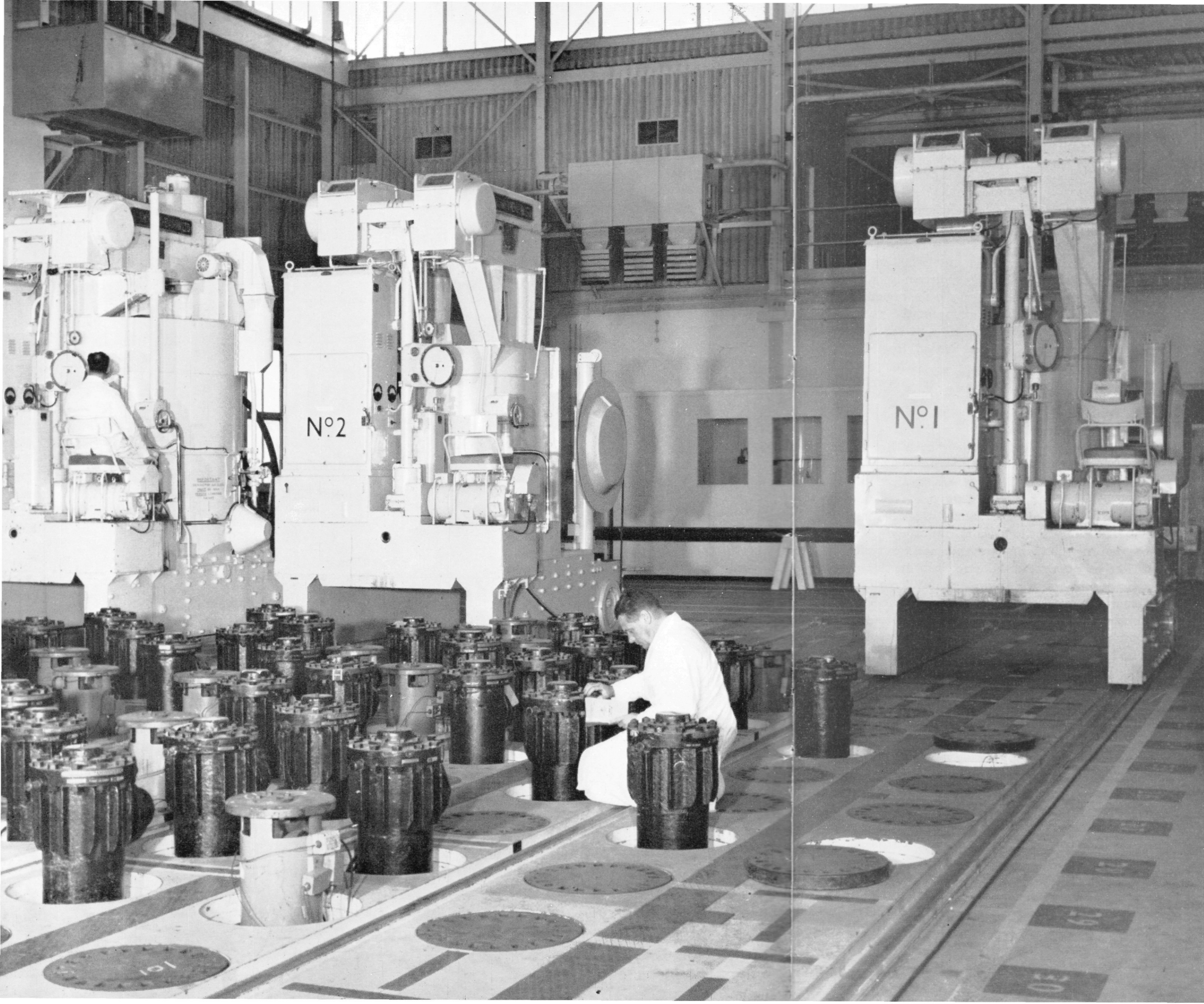
UNITED KINGDOM ATOMIC ENERGY AUTHORITY An illustrated summary of the Seventh Annual Report from 1st April 1960 to 31st March 1961 PRICE 2/6 NET

ATOM 1961



CALDER HALL 1956-1961

17th October, 1961, will be 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

There are now eight Calder Hall-type reactors in operation—four at Calder Hall itself and four at Chapelcross.

All eight reactors gave almost trouble-free operation throughout the year, 1960-61.

Although these reactors were designed primarily for the production of plutonium, more than 2,000 million units of electricity are being sent out to the grid annually, and at the same time the reactors are providing a most valuable test facility for large scale development work in aid of the stations being built by the electricity authorities for the Government's programme of nuclear power.

CALDER HALL: increased efficiency

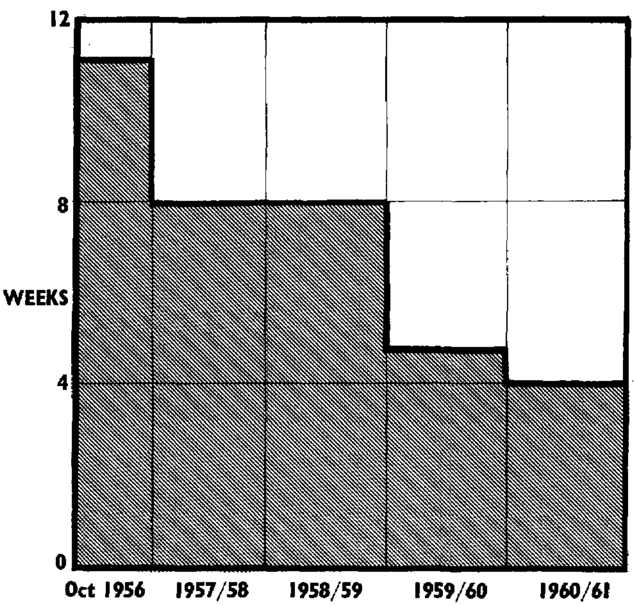
Improved efficiency of operation of the Calder Hall and Chapelcross reactors has been sought in two ways: by raising the level of heat output, and by reducing the off-load time required for refuelling and scheduled maintenance.

Considerable success has been achieved in both these directions.

Heat Output

An improvement in heat output, which has had no adverse effect on fuel element life, has been obtained by raising the fuel element operating temperature, and by adjusting the loading of the reactors to obtain a more even distribution of heat in the reactor core. Electronic computers have been used to calculate optimum loading patterns of fuel elements and absorbers to achieve this heat distribution. As a result of this progressive development work, the gross heat output has been raised year by year and is now about 20 per cent above the design figure.

Further small improvements in the heat output can be expected, but the limit of development with these particular reactors is now in sight.



Average time taken to complete the scheduled refuelling and maintenance of Calder and Chapelcross reactors.

Fuel Change

The Calder and Chapelcross reactors are so designed that fuel can be replaced only when the reactor is shut down. A fuel change involves the removal from each reactor of about 10,000 radioactive fuel elements, and their replacement with new elements. By careful attention to the organisation of this work, and the planning of the maintenance carried out at the same time, it has been possible to reduce the off-load period from the eleven weeks to carry out the first recharge of Calder Reactor No. 1 to the present period of about four weeks.

Electricity Generation

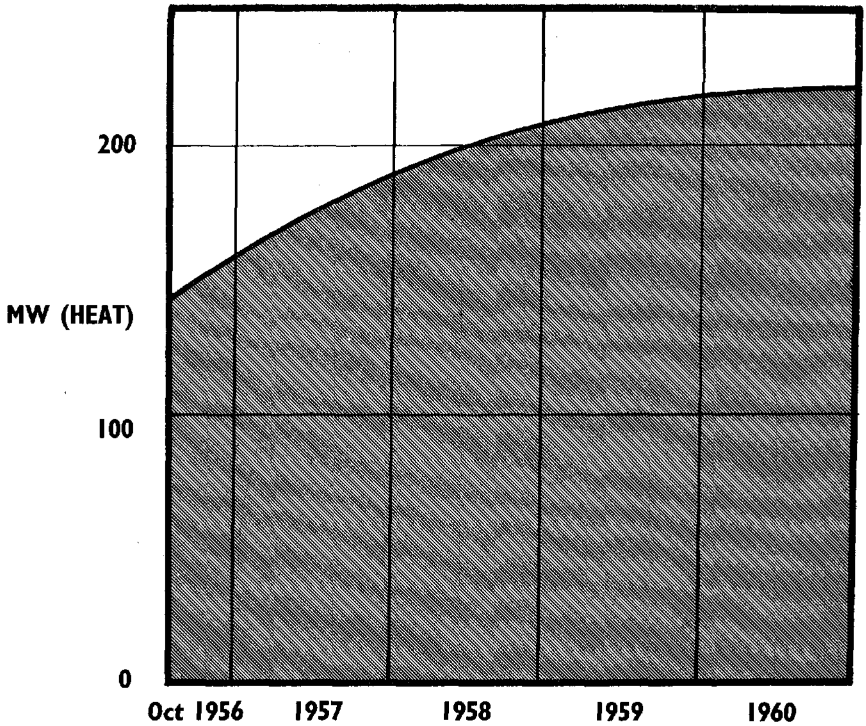
On 31st January, 1961, Calder Hall Reactor No. 4, completed twelve months continuous operation, during which period it was generating electricity at full load for 95.6 per cent of the time. No shut down due to fuel element failure was necessary during the period, the reactor ultimately being discharged for routine maintenance and change of fuel. The 4.4 per cent of the time when the reactor was not on full load was composed of: 2.5 per cent on experimental work; 0.7 per cent on scheduled maintenance of ancillary equipment; 0.6 per cent on unscheduled blower maintenance; 0.4 per cent on unscheduled maintenance of other equipment; and 0.2 per cent on special tests on fuel elements.

The net generation of electricity at Calder and Chapelcross has increased steadily over the last five years.

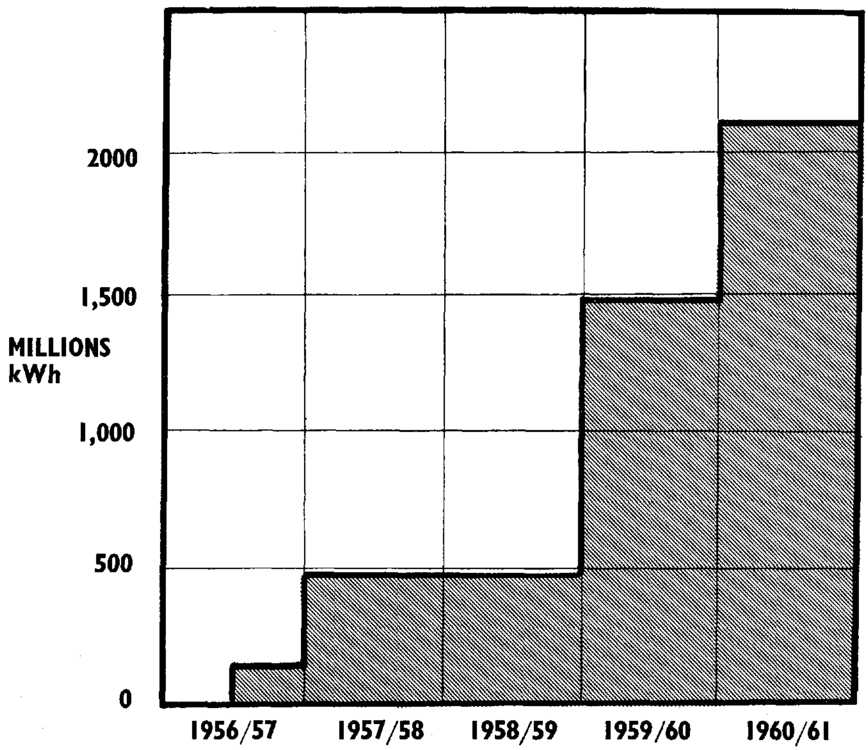
The stage has now been reached at which the reactors are capable of generating more steam than can be used by the installed turbine capacity.

Modifications were made during the year to some of the turbo-alternators to enable the excess steam to be utilised and the generation of electricity increased; the remainder will be modified during the course of the next eighteen months.

Moreover, *it is planned during* 1961 *to commence the utilisation of surplus steam available at Calder in the chemical plants and for space heating on the adjacent Windscale site.*



Increase in average reactor power (heat) since start of operation.



Total annual nett generation of electricity at Calder and Chapelcross works.

CALDER HALL and the power programme

Increasing use has been made of the Calder Hall and Chapelcross reactors for experimental and proving purposes.

Work has been directed principally towards the proving of the serviceability of the fuel elements for the first civil nuclear power stations and providing irradiation information on which more advanced fuel element designs can be based. As a result of these trials, small but important changes have been made in the design of the fuel elements for the Bradwell and Berkeley stations.

The irradiation of specimens of various materials used in the construction of reactors and of fuel elements has been carried out to provide information on irradiation behaviour.

An experiment of considerable importance was concluded successfully last autumn in Calder Reactor No. 3. This reactor was operated without

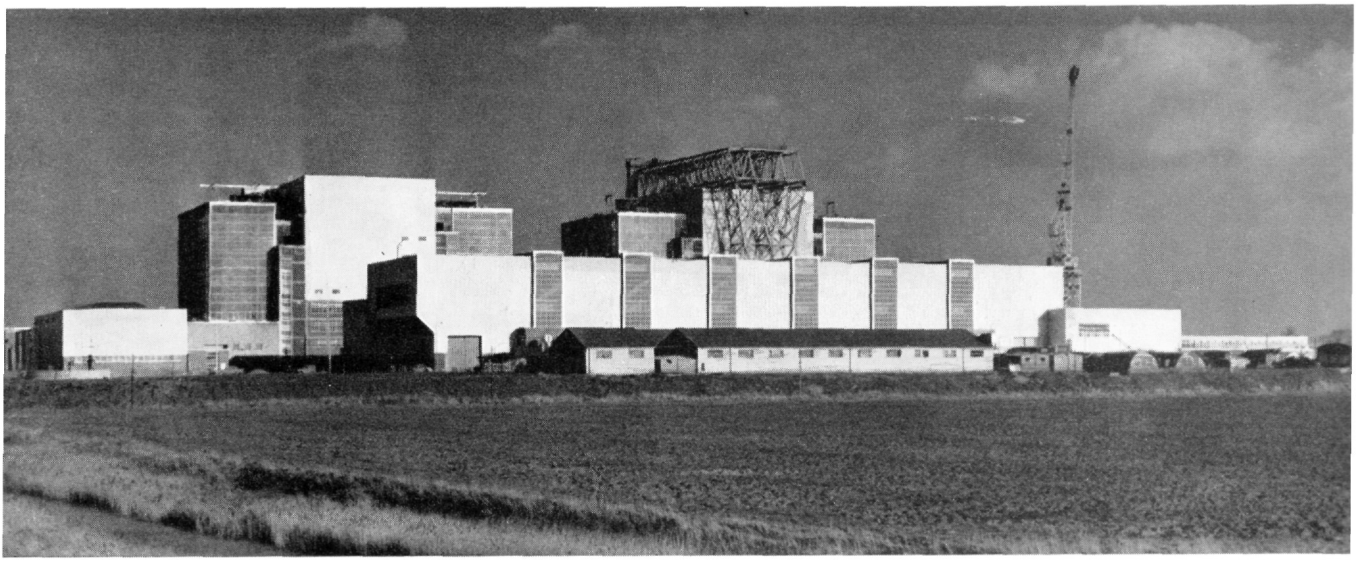


Photo by courtesy Nuclear Power Group.

Bradwell (Essex) nuclear power station, being built by British industry for C.E.G.B.

Another C.E.G.B. station under construction at Berkeley (Gloucester).

changing fuel from mid-1958, when it first started operation, until August, 1960. The experiment had two principal objectives. The first was to establish the probable operating characteristics which would be encountered in a large civil reactor, and the second was to obtain, by a large-scale test, further information on fuel element performance after prolonged irradiation.

The operating characteristics of the Calder reactor at an average exposure of 1,000 Megawatt-days (Heat) per tonne were calculated to simulate in several important aspects the operational characteristics of the Bradwell and Berkeley reactors. Nuclear reactors such as those of Calder and Chapelcross, and the types being constructed for the electricity generating boards, are "self-regulating" when loaded with new uranium fuel. "Self-regulating" means that the reactors will run initially at a steady power virtually in the absence of control from a control circuit or from the reactor operator. As the fuel becomes progressively more highly irradiated the characteristics of the reactor change and it is necessary to control the reactor by adjustment of the control-rod positions if a steady power level is to be maintained. Theoretical predictions had been made on the control problems of large power reactors, but it was felt necessary to establish on a full-scale operating reactor that the practical problems of control did not lead to reductions in efficiency of operation or to a deterioration in safety. The results obtained from this work confirmed in full the theoretical predictions and showed that the practical problems of control in no way detracted from the operating performance of the reactor, and no new problems of safety were revealed.

The information which the experiment provided on the performance of fuel elements was similarly reassuring. During this period the fuel reached an average exposure of more than 1,000 Megawatt-days (Heat) per tonne. A number of channels in the central region of the core reached an exposure of about 1,500 MWd(H)/t and a number of elements had been irradiated to over 2,000 MWd(H)/t. The standard fuel for the Calder and Chapelcross reactors was not designed specifically to withstand the level of irradiation achieved in this experiment. The fact that it did so, and that the fuel element failures which developed (approximately 2.3 per cent) were of a type which could be recognised at an early stage and withdrawn at convenient times, gives a measure of increased confidence.

THE NUCLEAR POWER PROGRAMME

"Despite the present world surplus of coal and oil, we still face the eventual prospect that our growing energy demands will call for more and more supplies of nuclear power.

. . . In these circumstances the Government has decided, in agreement with the Authorities concerned, that the national interest will best be served by continuing, for the time being, to place orders for nuclear stations at the rate of roughly one every year. The capacity of individual stations is likely to increase, so that the effect of this decision should be a steadily rising rate of nuclear commissioning which should give the country about 5,000 Megawatts of capacity in 1968."

"The Nuclear Power Programme", presented to Parliament by the Minister of Power in June, 1960.

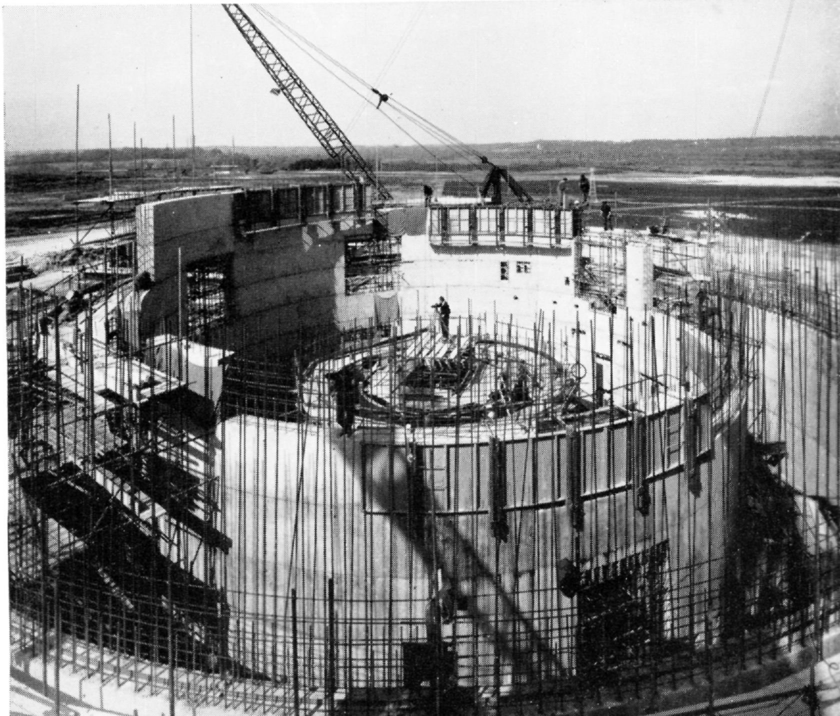
Nuclear power stations now being built for or authorised by, the Central Electricity Generating Board and the South of Scotland Electricity Board are listed below:—

NAME	FOR	CAPACITY	START-UP DATE
Berkeley	C.E.G.B.	275 MW.	1961
Bradwell	"	300 MW.	1961
Hinkley Point	"	500 MW.	1962
Hunterston	S.S.E.B.	320 MW.	1962
Trawsfynydd	C.E.G.B.	500 MW.	1964
Dungeness	"	550 MW.	1964
Sizewell	"	580 MW.	1966
Oldbury-on-Severn	"	550 MW.	
		3,575	

This total represents about one-tenth of the generating capacity already installed in the United Kingdom.

In a further long irradiation experiment in another Calder reactor a number of fuel channels had reached 2,250MWd(H)/t and some individual fuel elements had exceeded 3,000 MWd(H)/t by early 1961. In the case of the civil power stations an irradiation of 3,000 MWd(H)/t has been assumed. While the Authority have no reason to doubt these assumptions, sufficient time has not yet elapsed to test the civil reactor fuel elements to this irradiation.

The experimental Advanced Gas-cooled Reactor at Windscale. which is planned to begin operation towards the end of 1961.



An O.E.E.C. team (Dragon Project) is building an experimental high-temperature gas-cooled reactor at Winfrith.

REACTORS: the future

The main aims of the Authority's programme of reactor development are to provide support for the first nuclear power stations now under construction for British, Italian and Japanese electricity undertakings and to pioneer more advanced types of reactor systems for the progressively cheaper generation of nuclear power.

The division of effort between these two objectives is under continuous review and, while the first civil nuclear stations remain the major commitment, it has become possible to deploy an increasing number of staff on the longer-term aims of the Authority's programme of reactor development.

Although the early civil nuclear power stations will not achieve costs of power as low as originally forecast, the latest stations are expected to do so despite the rise in the general price level which has occurred since the forecast was first made. This fall in the cost of nuclear power will continue as more advanced systems are introduced.

Further comparative cost studies have been made of various reactor systems. The potential of the magnox system will be restricted by inherent limitations of the fuel materials. The advanced gas-cooled reactor using oxide fuel will operate at higher temperatures and ratings and has the potential of producing power at lower costs. The studies have also shown that the development of both gas-cooled reactors and of some forms of water-moderated reactor could lead to still further reductions in cost.

In the lower power range it is more difficult for nuclear power cost to compete with conventional generation, but further development and mastery of the technology of these reactor systems may lead to useful application to smaller nuclear stations. The results of these comparative studies are being used in planning the Authority's reactor programme.

The Authority have the major responsibility for investigating and establishing the scientific, technical and economic possibilities of reactor systems involving in some cases the construction of an experimental prototype. Thereafter, the main responsibility for technical development and commercial exploitation rests with industry (except for the further development work on fuel and safety).

The Authority associate the British "consortia" (groups of industrial firms in the atomic energy field—see footnote) with work on the development of new reactor systems to ensure the early transfer of technological information.

Advanced Gas-Cooled Reactor

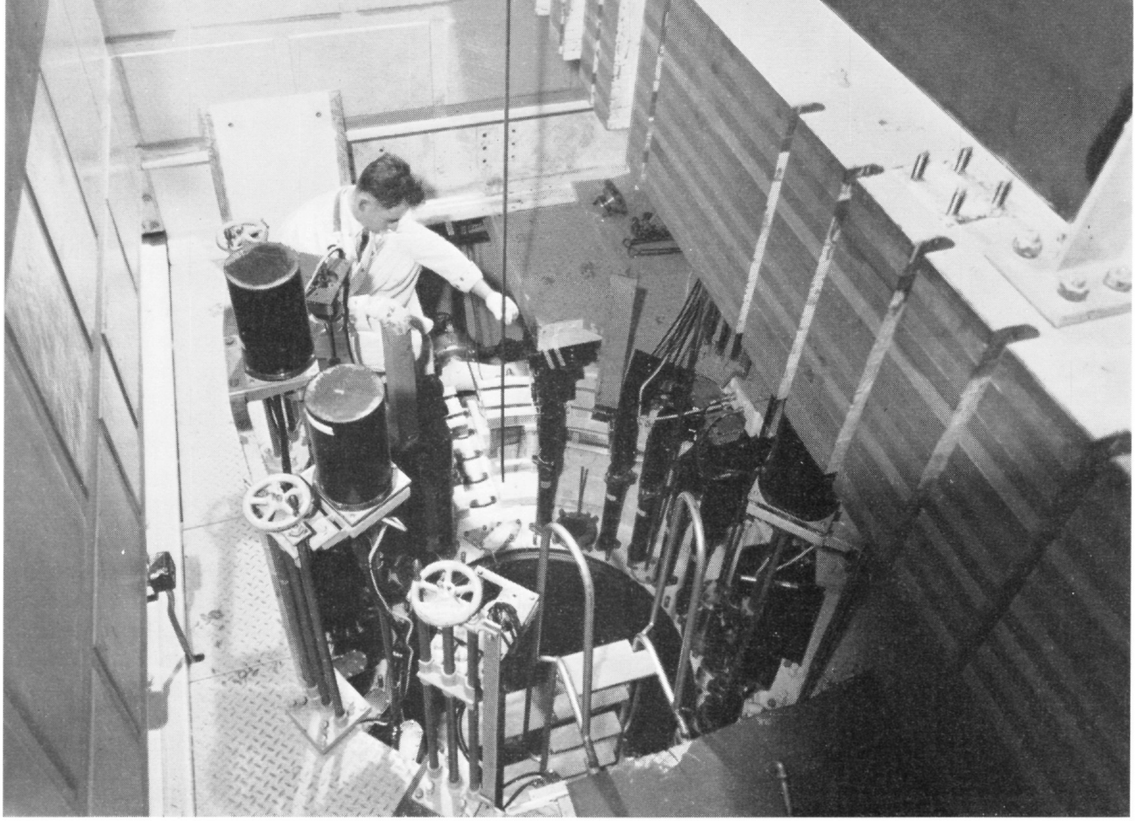
The next phase of development of the graphite-moderated gas-cooled reactor concept beyond the basic Calder Hall type is represented by the Advanced Gas-Cooled Reactor.

The construction of an experimental prototype based on this A.G.R. system is being carried out at Windscale and was virtually complete by March, 1961. It is planned to begin operation towards the end of 1961.

The main objective of A.G.R. is to reduce the capital cost of the reactor installation. This is done by raising the steam temperature and thus the thermal efficiency, and by increasing the heat generation rate from a given size of reactor. It is possible to reach the necessary high temperature by using uranium oxide instead of uranium metal as fuel. To extract the heat at the required high rate, the fuel is sub-divided into clusters of small rods. Uranium oxide also has the advantage of standing up to irradiation much better than uranium metal and thus has a longer life. However, the use of uranium oxide involves enriching the fuel in the isotope uranium-235. Further studies carried out during the past year confirm the development potential of the A.G.R. for the generation of electricity at competitive costs.

A.G.R. fuel elements will be canned either in beryllium or in stainless steel. One of the main concerns about beryllium cans in the past was the formation of helium arising from the transmutation of beryllium when bombarded by neutrons. It was thought that the helium atoms would cause brittleness and swelling of the material. However, irradiation tests in the Harwell materials-testing reactor, PLUTO, taken to a burn-up of 7,000 MWd(H)/t at 600°C show neither swelling nor increase of

NOTE: The three Consortia are:—
The United Power Corporation
The Nuclear Power Group
The English Electric-Babcock & Wilcox-Taylor Woodrow Atomic Power Group



ZENITH, a "zero energy" reactor at Winfrith, used to study the physics of high-temperature gas-cooled systems.

brittleness; at 300°C there was some decrease in ductility. Further tests of the effects of irradiation on the mechanical properties of beryllium are being carried out in the Dounreay materials-testing reactor and in a similar reactor, Hifar, in Australia, and by electron microscope techniques.

On the other hand, tests on the corrosion of beryllium in carbon dioxide (which is used as a coolant) have shown that, under the higher temperature conditions in the A.G.R., more corrosion can take place than can be tolerated in an A.G.R. Until the condition under which beryllium stands up to A.G.R. environment is clearly understood and can be specified, it has been decided to delay the introduction of a large number of beryllium-canned fuel elements into the Windscale A.G.R. Thus, instead of loading a large proportion of the initial charge of the Windscale A.G.R. in the form of beryllium-clad elements it is now proposed to charge mostly with stainless steel-clad elements. Some beryllium-clad elements will be loaded into the cooler parts of the reactor followed by a gradual loading of beryllium-clad elements into the hotter parts as material of better corrosion resistance is obtained.

A stainless steel of better corrosion resistance in carbon dioxide than the standard 18 per cent chromium/8 per cent nickel alloy has been developed with the co-operation of the British steel industry. The wall of the fuel can for the Windscale A.G.R. is only 0.015 ins. thick, and it is hoped to reduce the wall thickness of subsequent designs of fuel element even further in the interests of neutron economy.

Stainless steel and beryllium should provide about the same generating costs; but beryllium development is important because it demands lower enrichment of fuel.

The design study for a large civil A.G.R. was carried forward in more detail during 1961.

The smaller size of the A.G.R. for a given power output relative to the size of the magnox station makes it possible to provide containment without undue economic penalty. The combination of containment and fission product clean-up plant is under investigation as it may prove possible to advise that the siting restrictions applicable to the magnox stations could be relaxed for the A.G.R. civil stations. Whether such advice can be given depends on the outcome of present investigations.

Fast Reactor

The fast reactor is one of two systems on which the Authority are working with a view to commercial application in the 1970's. It is likely to provide the most economic way of using the plutonium produced in present-day reactors.

During 1960-61 modifications were completed to the core structure of the experimental fast reactor at Dounreay. These modifications were made in order that more advanced fuel element components could be tested at high temperature and high flux. The reactor was then restarted at low power, and physics experiments with the modified core arrangement were continued. Good agreement was obtained between theoretical predictions and the experimental results obtained in the reactor. The prediction of critical loading of the reactor was accurate to within one fuel element and reactivity controlled by the control rods was closely forecast. In the course of these physics experiments the reactor has operated at powers up to 1.5 Megawatts (heat).

The Dounreay Fast Reactor is experimental and is intended to develop the technology of fast reactors generally. It is already fulfilling this purpose. In such a novel and complex reactor using new techniques, it was not surprising that certain modifications were needed to obtain full design performance.

Valuable operating experience on the operation of liquid metal circuits is being gained even with low power operation of the reactor. For example, it was found difficult to operate the cold trap by-pass circuits for oxide removal, and a new pumped circuit had to be installed to effect the initial clean-up before the originally installed traps could be brought into operation. Later, when running at high coolant velocities, it was found that bubbles of the nitrogen cover gas were entrained in the liquid metal coolant, causing undesirable reactivity changes within the core. The cause for this has been found and the necessary modifications to eliminate this fault are in hand.

The next stage in fast reactor development is intended to be a plant from which commercial fast reactors will be designed. Work on this has been concerned mainly with reactor physics with the engineering design study and with the development of the fuel element.

The Zero Energy Breeder Reactor Assembly, (ZEBRA), designed to study the reactor physics of large size fast assemblies, is now under construction at Winfrith.

High Temperature Gas-Cooled Reactor

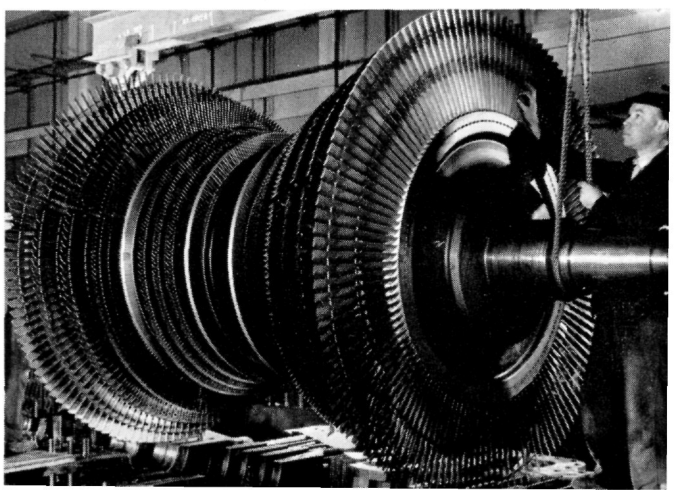
The other candidate for commercial nuclear power in the 1970's is the High Temperature Gas-Cooled Reactor which represents a further development—beyond the A.G.R.—of the gas-cooled, graphite-moderated reactor system. H.T.G.C. requires a far-reaching extension of the technology. By using helium as coolant and dispensing with metals in the core, gas outlet temperatures can be taken much higher than in the A.G.R. This results in a higher thermodynamic efficiency in converting heat to power and also, a more compact reactor system. The primary fuel would be highly enriched uranium-235. Dispersion of the uranium-235 in graphite and its continuous replacement by uranium-233 generated from thorium is expected to give a very long life to the fuel.

The major part of the Authority effort in support of the H.T.G.C. concept has been directed towards the 20 MW(H) Dragon reactor experiment now being built at Winfrith under the auspices of the Organisation for European Economic Co-operation. Over the five-year life of the Dragon Project the Authority are likely to contribute almost 60 per cent of the total financial budget. They are providing, on payment, about the same proportion of the staff engaged on the project as well as site services. In addition, supporting research work is being carried out by the Authority under contract to the Dragon project.

The zero-energy reactor ZENITH has been used in support of Dragon.

In addition to their work in support of the Dragon project, the Authority are investigating the possible

Turbine blades for the Windscale A.G.R. being installed (February, 1961).



applications of the high-temperature gas-cooled reactor systems to both marine propulsion units and to large, land-based power stations. Particular attention will be paid to the fuel cycle. Whereas the fuel cycle proposed for the Dragon reactor starts with uranium-235 and thorium and, in a large reactor, would be theoretically almost self-maintaining through the production of uranium-233 from the thorium, the Authority are extending the investigations to the plutonium/thorium/uranium-233 cycle.

Steam Generating Heavy Water Reactor

The Authority have completed a design-study of another reactor concept, the Steam-Generating Heavy Water Reactor and are now engaged on solving some of the key problems. Some of these problems apply equally to other heavy-water-moderated reactors using pressure tube construction, so a development programme has been formulated which will be carried out in collaboration with *Atomic Energy of Canada Limited*. The Authority have not yet taken a decision whether or not to construct a reactor experiment.

As part of the preliminary studies on the S.G.H.W. system, a series of reactor physics experiments was performed in the DIMPLE and LIDO research reactors. These experiments were designed to investigate problems posed by the use of fuel elements consisting of large numbers of thin uranium dioxide rods, and by the presence of two moderating materials (the light water coolant and the heavy water moderator). The effects of a mixture of steam and water in the boiling zone of the reactor were simulated by the use of a mixture of light and heavy water in proportions which gave equivalent nuclear properties. These experiments confirmed theoretical predictions; more refined calculations of the power which can be extracted from the system are now being developed.

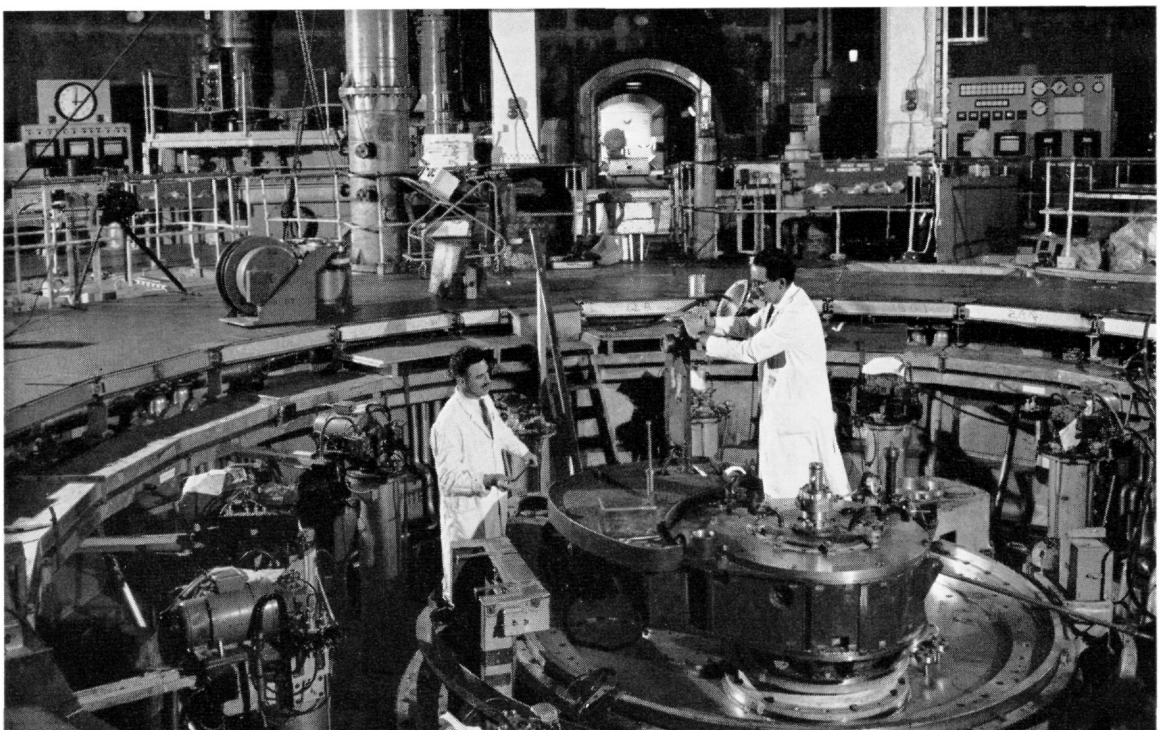
Merchant Ships

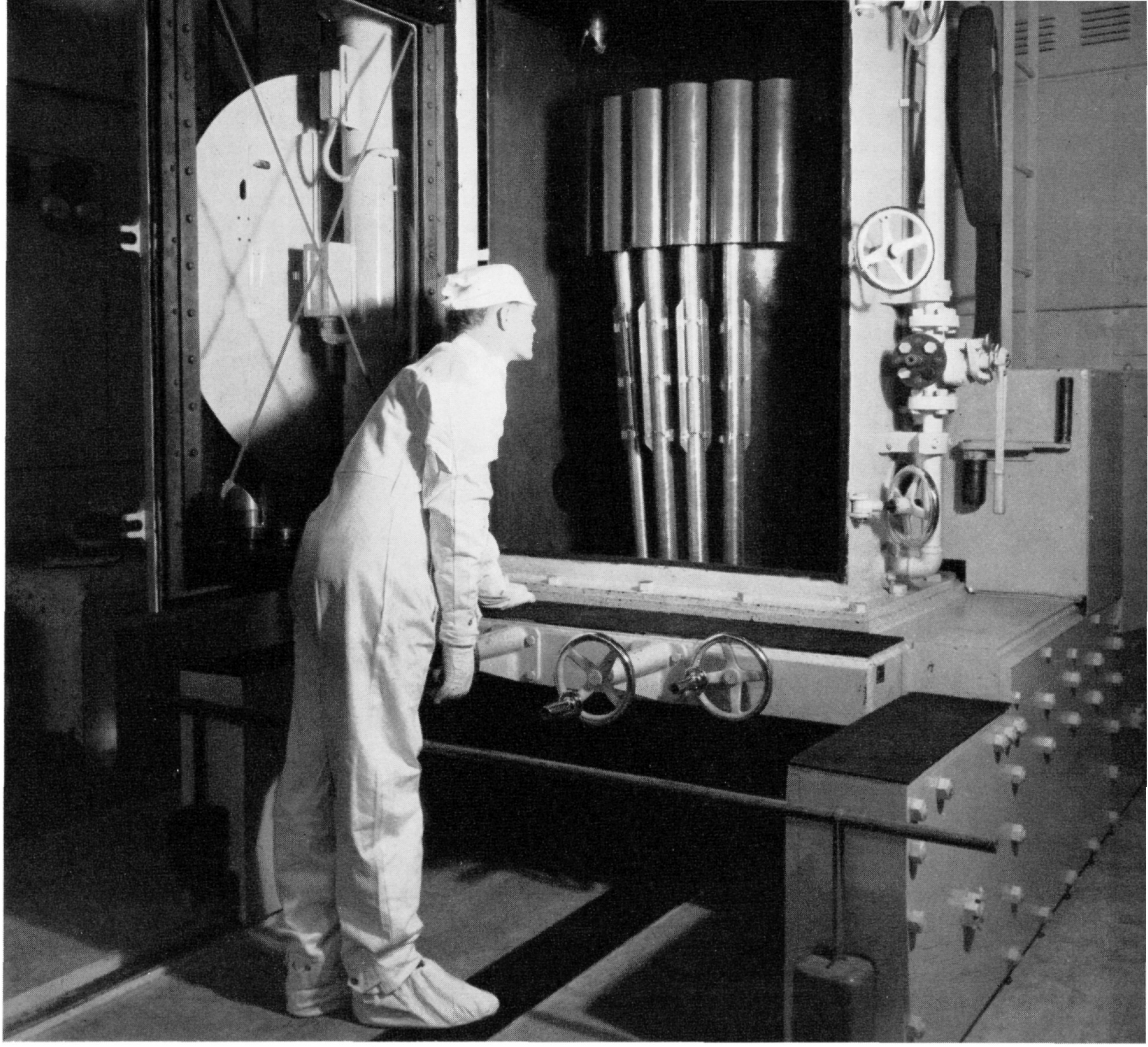
A comparative economic study of various reactor designs for merchant ships was carried out during 1960-61.

The main conclusion drawn from the studies is that, because of the comparatively small size of reactors required for marine propulsion and the stringent safety precautions necessary if present reactor designs were installed in a ship, none of the reactor designs at present in an advanced state of development is economic.

However, the systems so far proposed are essentially adaptations of reactors originally developed for large land-based power stations. The Authority are now considering the use of more advanced systems which are in a much earlier stage of development (such as the high-temperature gas-cooled systems) to see whether these show potential for economic marine use.

The top of the Dounreay fast reactor while modifications were in progress to eliminate problems of gas entrainment in the liquid metal coolant.





Examining a fuel element "basket" on the charge floor of No 4 Reactor, Chapelcross.

FUEL ELEMENTS

The nuclear power stations under construction for the Central Electricity Generating Board at Berkeley and at Bradwell are due to be commissioned in 1961. During 1960-61 the new fuel element factory at Springfields was brought into full-scale production and delivered the complete first charge of fuel for one of the two reactors at Berkeley, and part of the first charge for the other reactor. Delivery of the first charge for one of the Bradwell reactors was due to be completed in April. The quantity of fuel delivered was approximately 600 tonnes and comprised some 80,000 fuel elements.

During the year the C.E.G.B. announced their intention to place contracts for the building of nuclear power stations at Dungeness, Kent, and at Sizewell, Suffolk. Preparations are in hand for the supply by the Authority of magnox-clad natural uranium fuel elements for these stations and for the stations already under construction for the C.E.G.B. at Hinkley Point and Trawsfynydd and for the South of Scotland Electricity Board at Hunterston.

The fuel elements which are being manufactured for the civil power stations are considerably improved versions of those originally adopted for Calder in 1956. Although changes have increased the complexity of the fuel elements and of the manufacturing processes, operating labour per ton of product is little greater than had previously been required for the simpler design of Calder fuel.

Production has begun of a much more advanced type of fuel for the prototype advanced gas-cooled reactor at Windscale. The starting material is uranium hexafluoride (produced at Springfields and enriched in the Capenhurst diffusion plant). This is converted at Springfields to uranium oxide powder which is then compressed and sintered into ceramic pellets, which are canned in tubes of either stainless steel or beryllium. In addition to elements for the prototype A.G.R., considerable quantities of fuel were manufactured for other research and development projects.

The main plant at Springfields for manufacturing uranium tetrafluoride by fluidisation techniques came into full production and is now yielding good quality material at the designed throughput.

In addition to supplying enriched uranium fuel for their own materials testing and research reactors, the Authority continued to sell fuel to the Australian Atomic Energy Commission for the Hifar materials-testing reactor, and to the Danish Atomic Energy Commission for use in their DR.3 materials-testing reactor at Risø. The Authority have also undertaken to carry out the reprocessing of irradiated fuel from these reactors. A quantity of fuel was supplied by the Authority to the Land Nordrhein-Westfalen for use in the Merlin-type reactor in Jülich, Germany, and negotiations are proceeding with this organisation for the supply of fuel for the DIDO-type reactor which they are building.

Natural uranium fuel was provided to Imperial College and Queen Mary College, London, to the Royal Naval College, Greenwich, and to the universities of Birmingham, Manchester and Southampton for use in sub-critical assemblies.

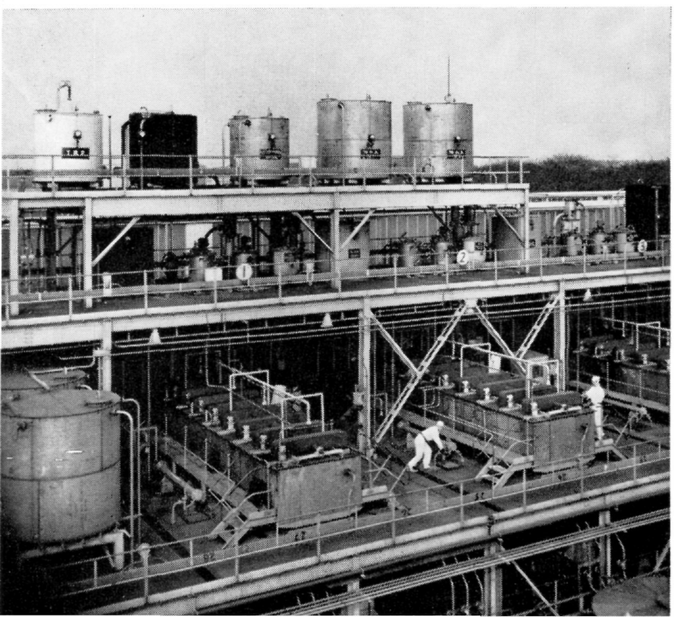
Re-processing

The main chemical extraction plant at Windscale, which was constructed to deal with the fuel from the two original Windscale reactors, has successfully processed all the irradiated fuel arising from the eight Calder and Chapelcross reactors and small quantities from other sources. This increase in throughput was achieved by modifying the main separation unit and constructing additional facilities for processing the increased quantity of plutonium now being fed to the plant.

Work is proceeding on the construction of the new separation plant required to process the irradiated fuel which will arise from the nuclear power stations operated by the electricity boards.

Isotope Separation

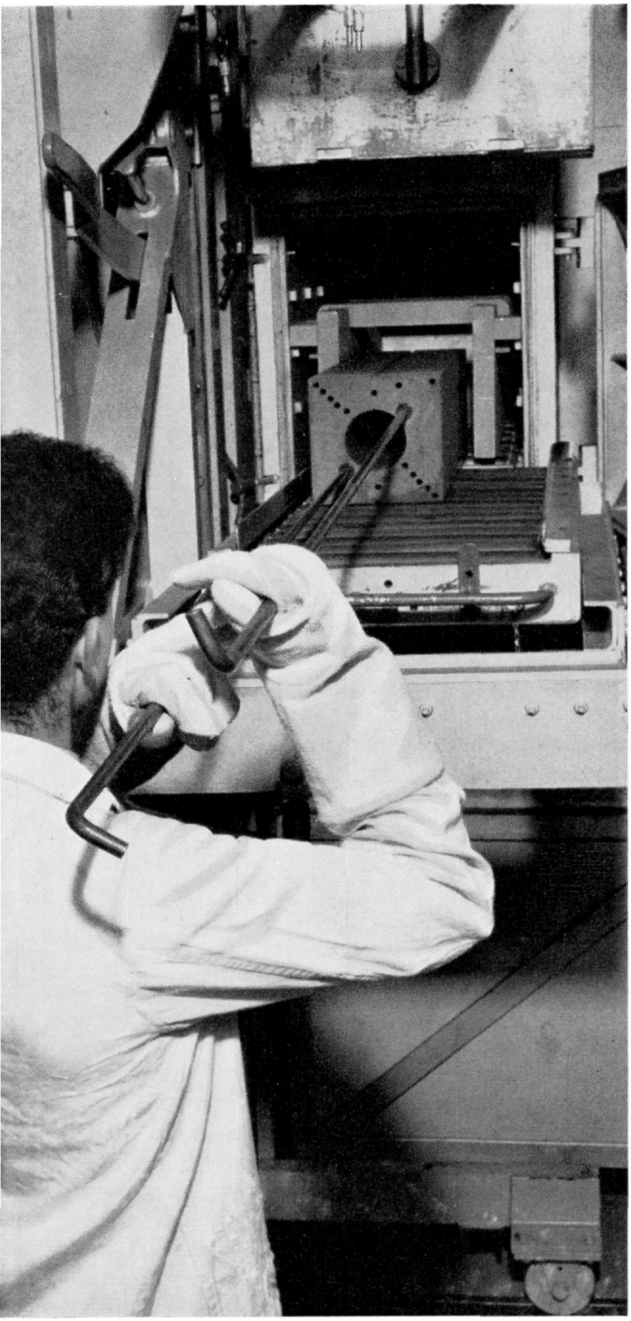
In 1960-61 there was an improvement of 4 per cent in efficiency (compared with the previous year) at the Capenhurst diffusion plant.



Solvent extraction plant, Springfields.

Manufacturing fast-reactor fuel, Dounreay.

RESEARCH AND DEVELOPMENT



Experiments at Winfrith help to predict reactor behaviour after plutonium build-up in fuel.

General research and development (i.e. work with wider objectives than the problems connected with specific reactor systems) falls into three categories.

(*i*) A broad attack on the scientific problems arising from nuclear power—and especially those concerned with materials. (These problems include the effects of radiation on materials; the nuclear properties of materials and their effect on reactor performance; the chemical behaviour of materials in a reactor; and engineering problems such as heat transfer).

(*ii*) Fundamental research in the many branches of science of importance to the Authority.

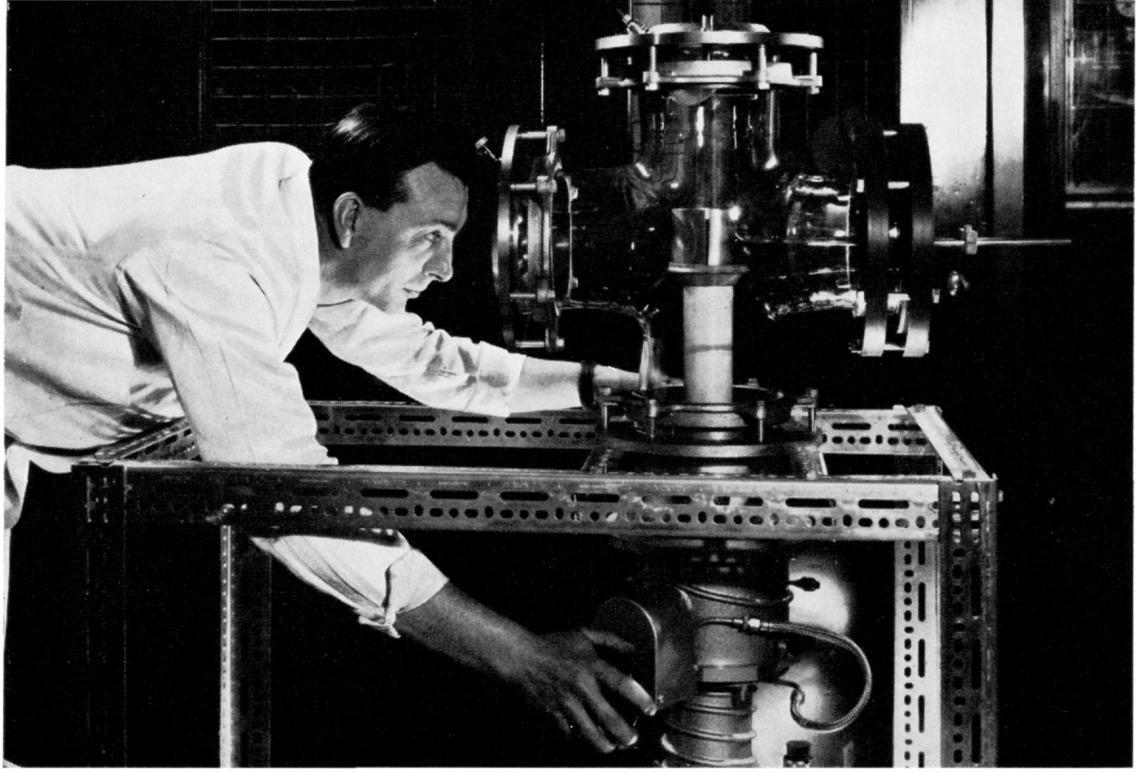
(*iii*) Research on isotopes or large sources of radiation. This work is now centred on Wantage but use is made of several Authority reactors, especially those at Harwell.

During 1960-61 the Authority made publicly available 517 technical reports. In addition, Authority staff contributed 335 research articles to scientific journals.

Nuclear Fission

The theory of nuclear fission is still far from complete and further progress in understanding the details of the process depends mainly upon the accumulation of more experimental information. The fission process is being studied in detail at Harwell in a programme of work which was started a few years ago. For example, the way in which different fission fragments penetrate aluminium foils has been studied. This work has shown that if a nucleus undergoes nuclear fission then more kinetic energy is released when the fragments are of unequal size than when they are equal.

Radiochemical studies of the nuclear fission process have been started at Aldermaston. Novel apparatus has been built to permit rapid chemical separations and purifications to be carried out according to a pre-set programme. The times for separation and purification vary between ten seconds and a minute. These chemical techniques are now being applied to study the fission process.



Vacuum-testing a ceramic specimen at Bracknell. The Authority are interested in ceramic fuels for power reactors.

Reactor Physics

Reactor physics research is designed to establish the conditions under which a reactor will operate, to find out how much heat will be generated in each part of an operating reactor, to discover how to control it and to determine the character and intensity of the radiations emitted from the reactor core.

The data required are obtained by making direct measurements on "models" of the cores of possible reactors. These models may be made just large enough to sustain a nuclear chain reaction (critical assembly) or they may be smaller than this so that an external source of neutrons is needed to drive them (sub-critical assembly).

Recent work has included experiments at Winfrith on the characteristics of plutonium/water and uranium oxide/organic liquid systems using sub-critical assemblies (HELEN I and HELEN II).

Daphne

The research reactors DIDO and PLUTO are expensive pieces of equipment and it is important to make the best possible use of available experimental time and space in them. In order to avoid this loss of high-power operating time, a zero-energy reactor DAPHNE is being designed and built at Harwell having a core which simulates the DIDO/PLUTO core. DAPHNE will be used, for example, to measure the effect on reactivity of particular experiments, the interaction of one experiment with another and the effect of fuel disposition and burn-up.

Vera

A new low-powered reactor called VERA (Versatile Experiment Reactor Assembly) started operating at A.W.R.E., Aldermaston, in February, 1961. It is being used in reactor physics experiments to improve nuclear data and methods of calculation for fast critical assemblies.

New Isotope

An interesting result in the field of fundamental nuclear physics has been the discovery, at Aldermaston, of a new isotope of carbon, carbon-16. The isotope was formed in the bombardment of a carbon-14 target with a beam of tritium ions (hydrogen nuclei having a mass of 3 units). The mass of the isotope formed was determined indirectly from measurements of the energies of the protons emitted in the reaction. It was also shown that carbon-16 is a delayed neutron emitter, i.e. it decays by Beta emission to an excited state of nitrogen-16 which then immediately emits a neutron. Nuclei which have similar properties are produced in fission and delayed neutron emission is important in the control of nuclear reactors.

Radiation Damage

The study of radiation damage is important in the development of fuel elements, solid moderator materials, and structural components for reactor cores.

Studies of the effects of irradiation on graphite have continued using the high flux research reactors DIDO and PLUTO. The results show an extremely complex behaviour and suggest that the changes produced by irradiation are essentially due to atoms which congregate in the interstices of the crystal lattice if the graphite is heated during or after irradiation. Direct evidence in support of this theory has recently been obtained by using the electron microscope. Thin sections of irradiated graphite crystals have been examined and clusters of what are thought to be groups of interstitial atoms have been observed. These grow when the graphite is heated and they sometimes form regular patterns. A full explanation of these phenomena must await further experiment.

The effect of neutron irradiation on the physical and mechanical properties of beryllium is being studied, using electron microscope "thin film" techniques. At Harwell the beryllium is electrolytically thinned; at Windscale cleavage flakes for examination have been produced by fracturing. By these methods bubbles smaller than 10^{-6} cm have been seen in beryllium irradiated to very high neutron doses. The presence and size of these bubbles depend both on dose and temperature; they are believed to be the main cause of the changes in mechanical properties. For example, the bubbles are thought to be responsible for the decrease in the ductility of beryllium which takes place at high neutron doses. On present evidence, however, neither bubble formation nor loss of ductility appear likely to be substantial in the dose and temperature ranges of current interest in reactors.

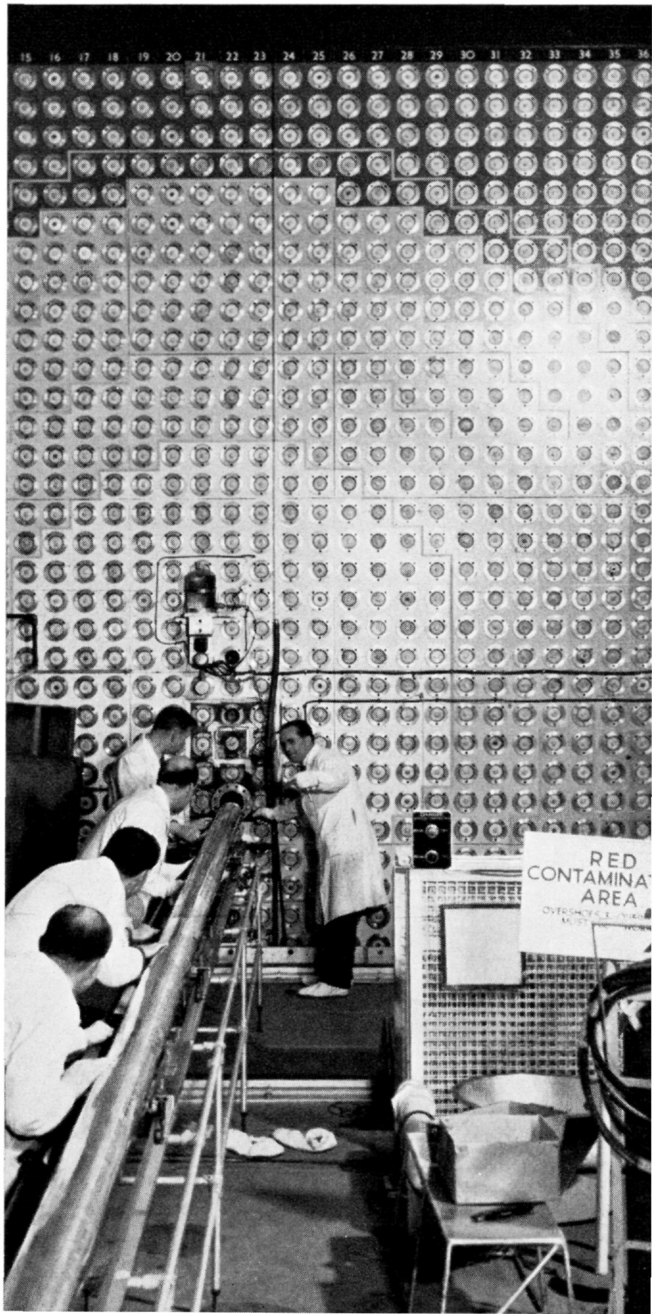
Fuel Elements

Development work on improved equipment for the examination of irradiated fuel elements continues. For example, for the successful examination of a suspected failed fuel element it is essential that the point at which the leak occurred can be identified.

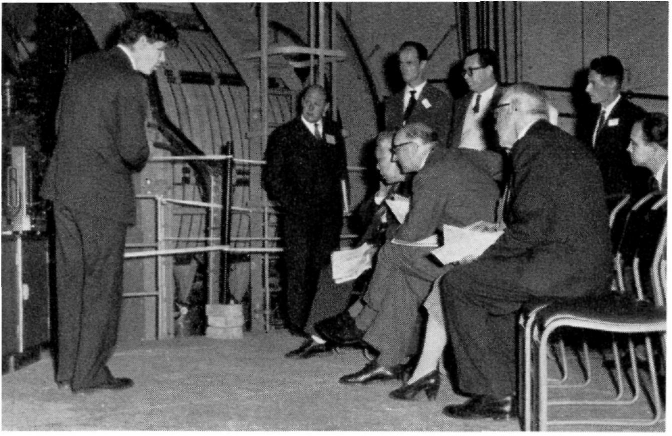
If it is faulty, the sensitivity of the inspection equipment is such that a hole 1/5000th of an inch in diameter can be located to within an area of 1/6th of a square inch.

Ceramic Fuels

In recent years the Authority have become increasingly interested in the use of ceramic fuels in power reactor systems. Most research has so far been done on uranium oxide systems although uranium carbide, mixed uranium and plutonium

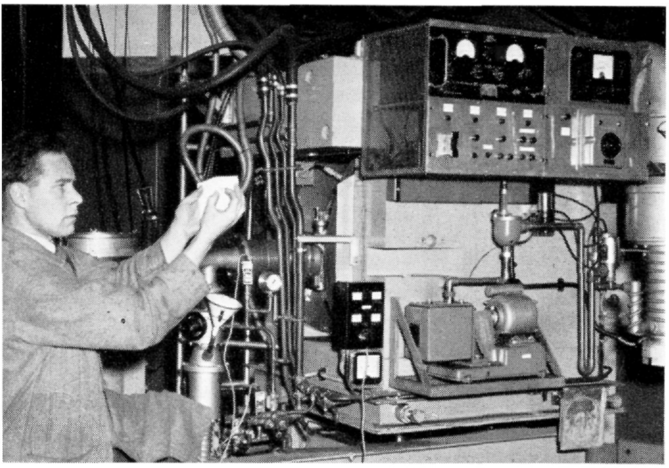


A thermally-insulated tube, to contain materials at high temperatures, is loaded into Harwell's research reactor BEPO.



Royal Society Tercentary. Fellows of the Society and their guests are shown ZETA (July, 1960)

The semi-conductor counter (small white box) may render obsolete the spectrograph (background.) It measures the energies of nuclear particles.



oxides, and dispersions of mixed oxides in steel (cermets) are also of interest.

The first step in the examination of the properties of ceramics and cermets is to establish the conditions required to obtain homogeneous bodies of low porosity. Successful techniques of preparation have been devised by paying close attention to the mechanism of sintering and to the behaviour of the materials concerned over a wide range of experimental conditions.

Thus, a novel technique has been developed at Harwell for the preparation of uranium carbide, with low open-pore space, by the "reaction sintering" of uranium and carbon powders; this is based on the retention of liquid uranium for a closely-controlled and limited time. This method is of considerable potential interest since it would replace expensive arc-melting and casting methods.

4,000 ton Crack Tester

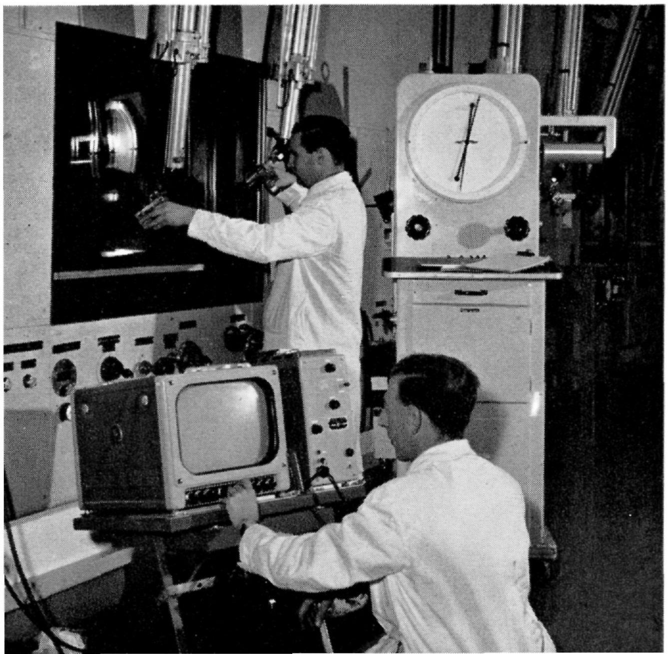
To investigate the qualities of steel used in the construction of pressure-vessels for reactors a 4,000 ton crack-testing machine is under construction at the Authority's Culcheth Metallurgical Laboratories. This machine, which is the largest of its kind in the world, will enable a variety of brittle fracture tests including the Robertson and Wells tests to be carried out on full-scale pressure vessel plate. In this machine, steel plate of up to four-inch thickness is subjected to a tensile load of 4,000 tons; a bullet is fired from a gun into a tapered hole and the conditions under which a crack is propagated are studied.

Radioactive Wastes

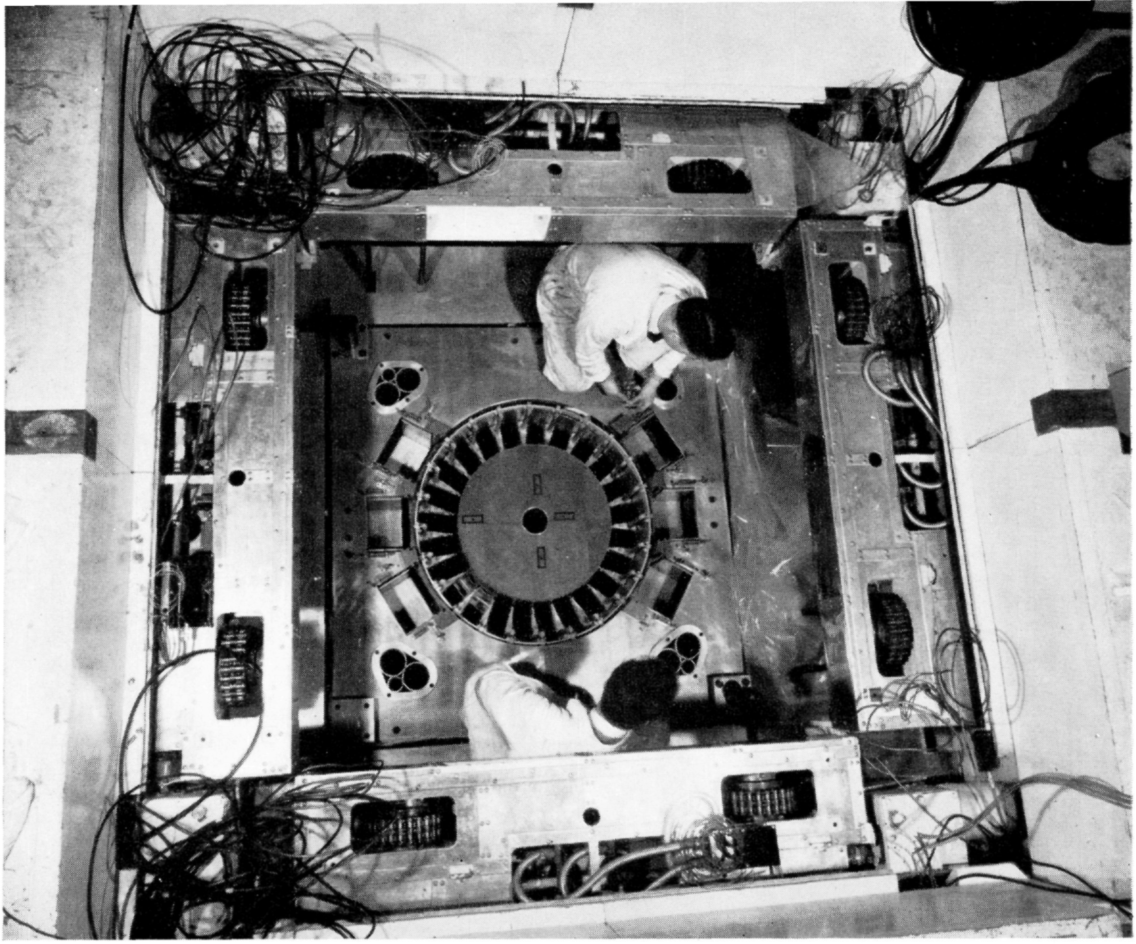
Research at Harwell on radioactive wastes has been directed towards developing methods for separating radioactive constituents from waste solutions and for converting them into a form which can be stored cheaply and safely until the natural process of radioactive decay reduces their activity to harmless levels.

The most highly active wastes, such as those deriving from fuel element treatment plants, are evaporated to small volume for storage in stainless steel tanks. Laboratory work over the last few years has shown that it may be possible to store these materials more conveniently by incorporating them into insoluble glass-like solids.

A pilot-plant study (1,000 curies per batch) is now being carried out to obtain data on which the design of a full-scale plant could be based.



Closed-circuit television is used at Dounreay to examine radioactive materials.



The research reactor, NESTOR, began operation at Winfrith in March, 1961. It can take five sub-critical assemblies representing various reactor types.

Electronics

A good deal of the Authority's research depends on the detection, identification and measurement of the various types of radiation involved in nuclear energy work. The techniques of electronics are essential for these purposes. Much basic research at Harwell is therefore directed towards improving existing electronic techniques or developing new ones. For example, the electrical and optical effects produced by individual nuclear particles as they pass through matter are being studied, paying special attention to the possibility of exploiting these effects. Similarly, means for the measurement of time intervals between one thousandth and less than one thousand millionth part of a second are being investigated.

Nuclear Tests

The Weapons Group have been studying the technical problems which were raised by the Geneva Conference of Experts in their examination of the methods of detecting violations of a possible agreement on the suspension of nuclear tests.

A new programme of seismic work has the object of improving ability to discriminate between signals from underground explosions and those from earthquakes. The programme includes a basic study of the mechanisms controlling the transfer of explosive energy into seismic signals and of the mechanism of propagation of these signals through the earth, the design of improved types of seismometer and a study of the characteristics of the signals from earthquakes and explosions.

Controlled Thermonuclear Reactions

The prospects of eventually achieving magnetic containment of plasma for thermonuclear power generation remain difficult to assess because the conditions for obtaining stable confinement are insufficiently understood.

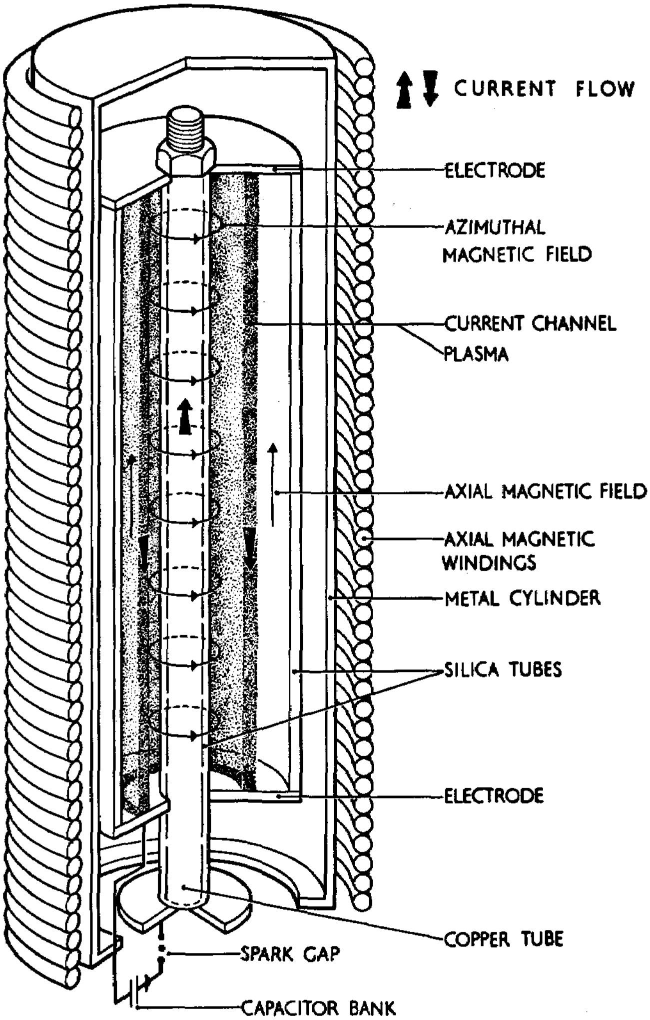


Figure 1: Hard Core Geometry

The shapes of the containing magnetic field are important variables at the command of the experimenter. The principal ones so far considered are (*a*) stabilised pinch, (*b*) hard-core geometry, (*c*) stellarator geometry, (*d*) mirror geometry and (*e*) cusped geometry. All of these, with the exception of (*c*), are under active study by the Authority. All are theoretically stable under certain conditions but only the mirror geometry has yielded observations, carried out in the U.S.A., which are consistent with stability.

STABILISED PINCH. Work has continued on the containment properties of the toroidal pinched discharge in ZETA, the ring shaped apparatus in which deuterium gas is heated to high temperatures by an electric discharge. Improvements in the apparatus have been used to study energy losses and other phenomena over a wide range of plasma densities. An important condition for hydromagnetic stability is that the current should flow in a thin skin on the surface of the column of plasma. At low pressures, such as those used in early work on ZETA, this skin current could not be obtained. Measurements of the magnetic fields have now been made at higher pressures and good skin currents have been found. These skin currents often disappear more rapidly than expected, particularly at high discharge powers. Experiments are proceeding at Harwell on straight tubes incorporating fast-rising pinch discharges with trapped axial magnetic fields. A new apparatus has been brought into operation, which is longer than any used hitherto.

HARD-CORE GEOMETRY. In this cylindrical geometry, the hot plasma is confined between an external magnetic field and an azimuthal field

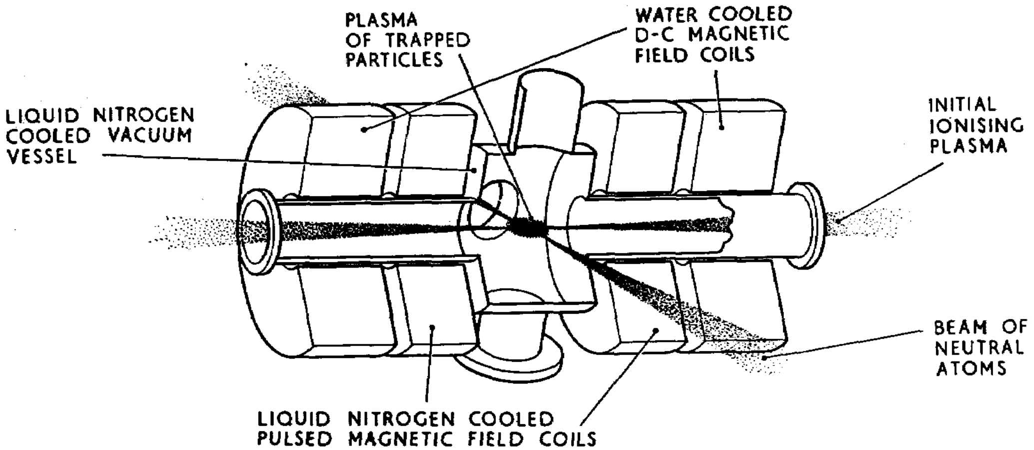


Figure 2: Mirror Machine with neutral injection

generated by a current flowing through a central conductor and returning through the plasma. Figure 1 shows a diagrammatic representation of a hard-core apparatus at Harwell. A toroidal version of the hard-core geometry is being built, under an Authority contract, at the research laboratories of Associated Electrical Industries Limited at Aldermaston.

MIRROR MACHINES. Experiments both at Harwell and at the Atomic Weapons Research Establishment (the Phoenix Programme) are aimed at determining the conditions under which a clean, dense plasma with high ion temperature, can be built up in a mirror machine by injecting and trapping a beam of high-energy particles. At Aldermaston, the externally injected particles are neutral atoms and are trapped within the mirror machine by being ionised there. Figure 2 shows the principal characteristics of this machine. At Harwell, charged particle injection is studied.

CUSPED GEOMETRY. An apparatus for studying containment in cusp geometry has been built and brought into operation at Harwell. Figure 3 illustrates the method of operation. Plasma, obtained by shock pre-heating and pre-ionisation, is compressed by fast-rising cusped-shaped fields. Measurements on the stability and leakage properties have just begun.

THETA PINCH. A.W.R.E. have been studying theta-mode discharges in which current flows in a circular path around the axis of the discharge tube. A number of these "Thetatron devices" have been operated and attention is being given to the use of magnetic mirrors of increased field strength at the ends of the tube in order to prevent the escape of plasma along the axis of the tube.

I.C.S.E.

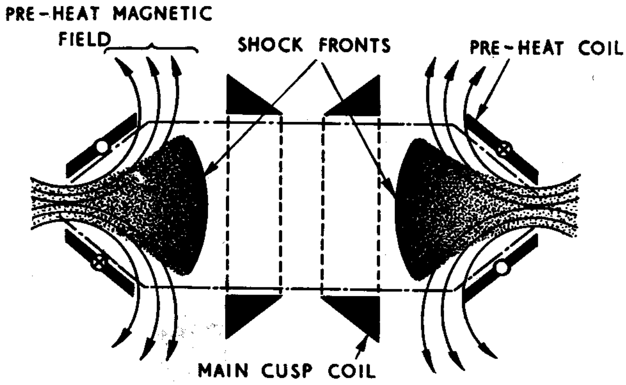
The Intermediate Current Stability Experiment, designed to investigate the stability of an improved pinch configuration, has been discontinued because it would take more effort and resources than were justified for a single experiment in the present state of knowledge of plasma physics.

Development work related to I.C.S.E. is continuing, however, because the technology is needed for existing and future experiments.

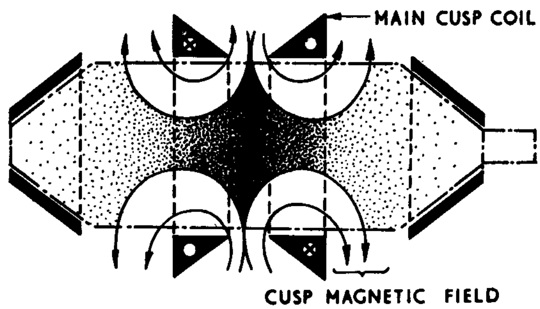
Culham

Experimental C.T.R. work now in progress at A.E.R.E., Harwell and A.W.R.E., Aldermaston, will be transferred over the next three years to a new laboratory of the Research Group, now under construction at Culham, near Oxford.

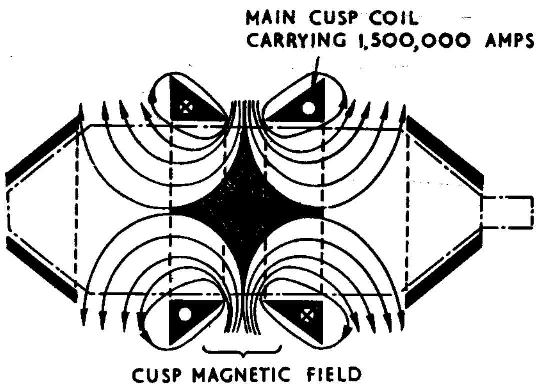
Figure 3
Cusped Geometry Containment



Stage I: Pre-heating by shockwaves

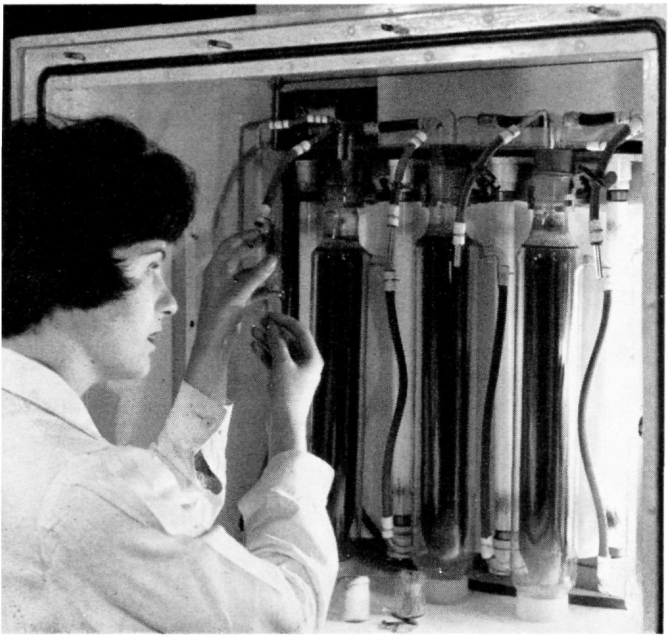


Stage 2: Collision of shockwaves and beginning of main compression



Stage 3: Final compression of plasma

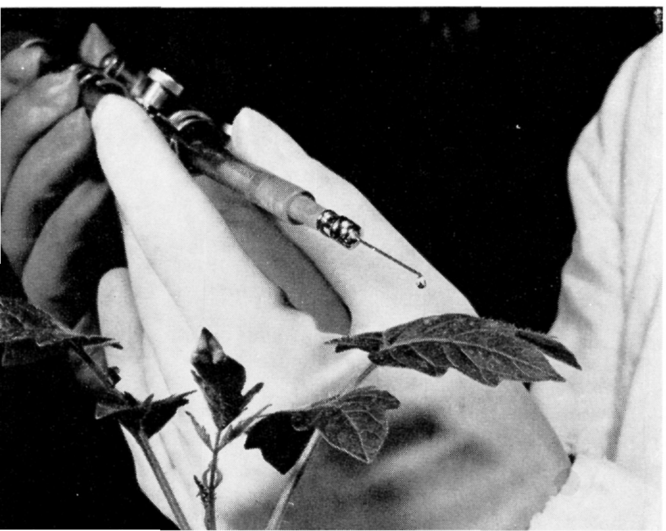
ISOTOPES AND IRRADIATION



Chlorella (pond slime) is used at Amersham to produce "labelled" (i.e. radioactive) carbon compounds.

Radioactive "tracers" are used to test the properties of insecticides.

Photo by courtesy Fison's Pest Control Ltd.



The Radiochemical Centre at Amersham is responsible for the sales of radioisotopes, labelled compounds and radiation sources. Demand for these products continues to increase steadily and the total value of sales rose by about ten per cent during the year to over £1,300,000. In the face of expanding overseas production, the proportion exported was maintained at about sixty per cent, and the Centre had dealings with some sixty countries, the principal buyers being Federal Germany, the United States, France, Canada and Japan. The number of consignments despatched from Amersham and from Harwell was about forty thousand, varying in size from a few millionths of a curie to 150,000 curies. The new laboratory at Amersham for handling alpha-emitting isotopes is now in full use.

Radiation Sources

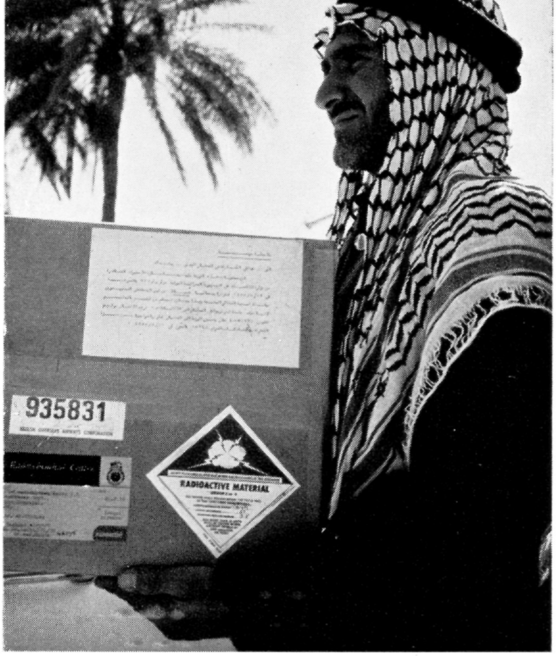
Commissioning of the Wantage Research Laboratory pilot plant for irradiating packages of materials with gamma rays was completed in December, 1960, by which time several thousand cubic feet of material had been processed. Contracts for the use of the plant have been let to a number of firms; the bulk of the material being processed is disposable medical equipment. The radiation source has recently been increased from 130,000 curies of cobalt-60 to 270,000 curies. The shielding provided will accommodate 500,000 curies, thus giving room for further expansion of capacity.

Medical support for radiation sterilisation has increased during the year and the use of gamma-radiation sterilisation for disposable medical equipment, such as hypodermic needles and plastic syringes, is expanding rapidly.

The number of gamma-radiation sterilised lines that are commercially available in quantity has increased from two or three to more than a dozen during the year. In common with other sterilisation processes, gamma-irradiation does not impart immunity from further infection and, to obtain maximum advantage, the items must be individually packaged. Industrial firms have mastered the consequent packaging problems for a wide range of products. Extended trials on the sterilisation of dressings are going forward successfully.

The use of radiation to eliminate salmonella food poisoning organisms from various food products is being investigated. A high degree of inactivation of salmonella in frozen whole egg and desiccated coconut can be achieved using relatively low radiation doses. Extensive tests are being carried out on the quality of the treated product at Wantage, by the

Army medical supplies being delivered for irradiation at the Wantage plant.



Isotopes from Amersham are brought to a Bagdad hospital.

British Baking Industries Research Association, and by various industrial users. Most results indicate no quality change but there are indications of flavour changes which require further investigation.

To meet the expected demand for large quantities of cobalt-60 for industrial irradiation processes, the Authority have built up a stock of about two million curies of this isotope. During 1960-61, some 500,000 curies were processed and delivered to industrial and experimental installations. The nuclear power stations of the Central Electricity Generating Board will have the capacity to make very large quantities of cobalt-60 in the future; the use of these reactors for this purpose was authorised by Parliament under the Electricity Generating (Amendment) Act 1961. The Authority and the C.E.G.B. are making arrangements to produce radioactive material in the Board's reactors in due course. The Authority will be responsible for the processing, distribution and sale of this material.

The Isotope Advisory Service at Wantage has continued to assist firms to solve industrial problems with the aid of radioisotope techniques. Using standard equipment to detect characteristic X-radiation, it has proved feasible to measure the thickness of gold paint on titanium, the thickness of zinc plating on steel and the thickness of silver plating on copper wire. For example, the thickness of gold paint could be measured to an accuracy of about 2 per cent, in about 10 seconds, for thicknesses in the range 0-50 millionths of an inch. The methods employed are being further developed for routine application.

The use of isotopically labelled compounds as tracers in pure and applied research, particularly in biology and biochemistry, continues to grow. Carbon-14 remains pre-eminent and the demand for its compounds increased by about thirty per cent during the year. The Radiochemical Centre's list of carbon-14 compounds now includes 230 items and on average over ninety per cent of these were immediately available on demand throughout the year.

Interest in labelled compounds of isotopes other than carbon-14 is growing rapidly. In particular, tritium is being used to supplement it as a tracer in biochemical research.

Altogether some hundred and fifty different compounds containing sixty-five different isotopes were synthesised during the year, indicating a growing awareness that in the testing of *detergents*, *drugs*, *antibiotics*, *insecticides*, *weedkillers* and other technical chemicals, the tracer method has become exceedingly important.

Indeed, examination of the corresponding labelled compound may now be said to be an essential preliminary to the general use of new chemicals of this kind.

HEALTH AND SAFETY

The United Kingdom has played a prominent part from the outset in the development of international health and safety standards for atomic energy work and in insisting on the application of the required elaborate precautions. The Authority have made a major contribution to this work. They will continue to keep the public fully informed on their safety experience.

In December, 1960, a committee appointed by the Medical Research Council published their second report on "The Hazards to Man of Nuclear and Allied Radiations". This report provides a detailed summary of the biological effects of radiation and assesses existing and foreseeable levels of exposure to radiation of the population in the United Kingdom.

The report endorsed, in general, the recommendations of the International Commission on Radiological Protection, which have been adopted by the Authority; where the committee recommended changes from the I.C.R.P. recommendations, the Authority have applied these changes.

The Committee commented on the contribution to the total "population dose" (i.e. of radiation) from the occupational exposure of workers to radiation. They reported that this dose, at present, is the equivalent of 15 "millirads" per generation, which is some sixty times lower than the allowance suggested for this purpose by I.C.R.P.

Protection of the Public

The Radioactive Substances Act, 1960, will make permanent and extend to all users of radioactive materials the requirement for the authorisation by Ministers of all discharges of radioactive waste and for the inspection of premises and records.

The Authority assisted in the preparation of the International Atomic Energy Agency regulations for the safe transport of radioactive materials by all forms of transport. These are intended to provide agreed standards for international traffic and to form a basis for national legislation. The Authority are also assisting in preparing regulations governing the transport of radioactive materials in the U.K. and have established machinery for approving and standardising designs of containers to meet these regulations.

Protection of Staff

Owing to the expansion of the work of the Authority there has been an increase in the number of employees classed as radiation workers; these now total nearly eighteen thousand. The maximum permissible "whole body dose" (3 "rems"* in 13 weeks) was exceeded by a small margin on nine occasions in 1960. This compares with fourteen occasions in 1959 and twenty-five in 1958. In every case arrangements were made to reduce subsequent exposure and to ensure that long-term dose limits were not exceeded.

Co-operation has been maintained with the Factory Inspectorate of the Ministry of Labour, and information on safety techniques and training methods is exchanged through the medium of local industrial safety organisations and the Royal Society for the Prevention of Accidents.

Training

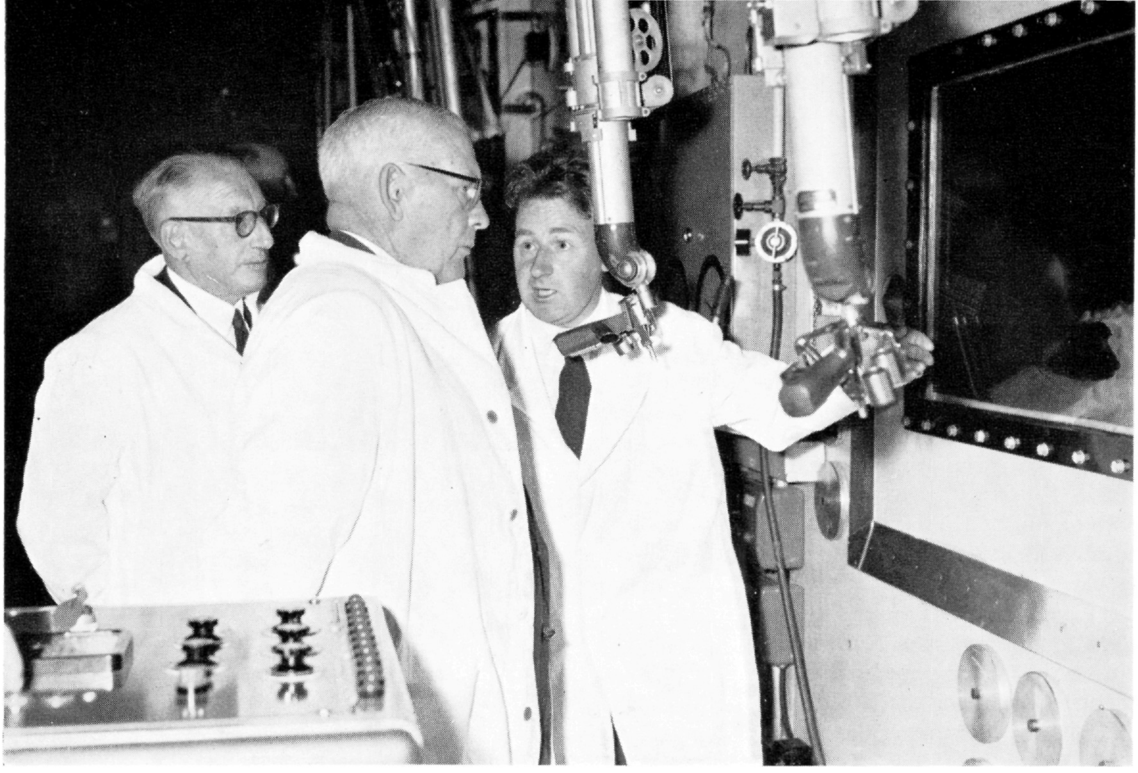
The Report to the Authority of the Veale Committee recommended that the Authority should not be required to undertake an extensive part in a national training scheme but that their main contribution should be the provision of specialised courses, colloquia and conferences. The specialised courses in radiation protection were continued during the year.

The proposal in the Veale Report to establish a National Radiological Advisory Service would relieve the Authority of many tasks which they undertake at present. The Authority are collaborating with other interested bodies in discussions to determine the form which such a Service might take. Legislation would be necessary before such a body could be established.

New Legislation

The Nuclear Installations (Licensing and Insurance) Act, 1959, was brought into force by Order in Council on 1st April, 1960. From that date the functions of assessing and evaluating the safety of reactors and nuclear plant, other than those of the Authority, were formally assumed by the Chief Inspector of Nuclear Installations of the Ministry of Power.

*A unit of radiation dose.



Senator Spooner, Australian Minister for National Development, at Harwell.

RELATIONS WITH OTHER COUNTRIES

Overseas interest in British atomic energy activities has been maintained at a high level. There have been many visits and enquiries concerning British type power reactors and their fuel, while interest in possible licensing arrangements for uranium metal production and natural uranium fuel element manufacture led to detailed negotiations with firms in Federal Germany and in Belgium and to discussions with representatives of the official atomic energy organisations in India and in Japan.

The Commonwealth

Representatives of the Authority and Atomic Energy of Canada Ltd., had their annual meeting in October, 1960. In addition to reviewing the pattern of collaboration and considering the possibilities of co-ordinating work on the steam generating heavy water reactor system they exchanged views on the prospects for the reactor systems which are being developed independently in the two countries.

Following discussions in London in June and July, 1960, proposals were formulated for extending the exchange of information between the Authority and the Australian Atomic Energy Commission.

The Chairman of the Authority was the official representative of Her Majesty's Government at the inauguration of the Canada/India research reactor at Trombay in January, 1961. During a subsequent symposium he and Sir John Cockcroft spoke on the U.K. nuclear power programme.

In November, 1960, the Indian Government invited tenders for a 300 MW nuclear power station at Tarapur to be constructed as part of their third Five-Year Plan.

In December a team from the Tarapur project visited the U.K. and had discussions with the Authority on commercial aspects of possible fuel supply and nuclear consultancy for the station.

Europe

The O.E.E.C. project (Dragon) has continued to make good progress in the design of the experimental H.T.G.C. reactor and in the associated research and development programme. By 31st March, 1961, the build-up of professional staff was substantially complete at a figure of 156, comprising 85 seconded from the Authority, two from British industry and 69 who had come from overseas. Work is being carried out by the project team and under contracts placed in the signatory countries including the U.K. Construction of the 20 MW reactor experiment was formally inaugurated on 27th April, 1960, by Dr. S. Eklund of Sweden, then Chairman of the Board of Management.

An agreement was signed on 14th June, 1960, extending the joint programme of experimental operation of the Norwegian boiling water reactor at Halden by European Nuclear Energy Agency member countries from three to four and a half years. The reactor produced its first steam at a power rating of 2 MW(H) in October. Two members of the Authority's staff and a representative of U.K. industry are attached to the project.

The O.E.E.C. Convention on Third Party Liability in the field of Nuclear Energy was signed during the year by the great majority of member countries, including the U.K.

The U.K./Euratom Continuing Committee for Co-operation considered the possibility of further collaboration, particularly in the fields of the development of research and power reactor systems and the pooling of basic data in reactor and engineering physics. They also arranged for discussions to be held on the economics and costing of nuclear power projects.

The U.K./Euratom Joint Working Group met twice during the year, in October, 1960, and in February, 1961. A joint symposium on the advanced gas-cooled reactor, attended by 46 representatives from the Authority and from Euratom member countries, was held at Risley in April, 1960. A group of Euratom Commission staff and experts in the field of nuclear and reactor physics from national atomic energy organisations in Euratom countries visited Harwell and Winfrith in March, 1961. Members of the Authority's Health and Safety staff took part in an international symposium on the legal and administrative problems of radiation protection organised by Euratom in September, 1960. Two Euratom engineers have each spent six months at Harwell working on irradiation loops; three others have been studying heat exchange at Winfrith. It has also been agreed that Authority staff should assist in the commissioning of the BR.2 reactor at Mol in Belgium.

An exchange of notes between the Governments of the U.K. and of Denmark in May, 1960, formalised the arrangements agreed between the Authority and the Danish Atomic Energy Commission covering the British-type research reactor, DR.3 Arrangements were made for the Authority to use irradiation space in DR.3

Staff of the Authority and of the French Commissariat made many visits in both directions under the agreed programme of collaboration on the peaceful uses of atomic energy.

Under the agreement between the Authority and the Netherlands atomic energy organisation, the Reactor Centrum Nederland, arrangements were made for an exchange of staff to work on aqueous slurry loops.

H.M. the Queen of the Hellenes paid a private visit to Harwell in November, 1960.

Mr. Sterling Cole, Director General of I.A.E.A., visits Isotope Research Division with Dr. Henry Seligman.

Teams from the Authority and the Spanish Junta de Energía Nuclear exchanged visits to discuss research and development work on the manufacture of natural uranium fuel elements for civil purposes. The Authority also continued to keep in touch with the Spanish consortia interested in the development of nuclear power.

The possibility of establishing arrangements to facilitate continuing exchanges concerning the peaceful uses of atomic energy (especially through visits between scientists and other experts) between the Authority and the U.S.S.R. Council of Ministers State Committee on Atomic Energy, was discussed with Russian representatives during the year.

A Yugoslav team, reviewing the nature of atomic energy programmes in other countries and engaged upon an assessment of reactor systems, spent ten days in the U.K. in June 1960, and visited a number of Authority establishments. Sir John Cockcroft was the guest of the Federal Nuclear Energy Commission in March, 1961, and visited their establishments.

U.S.A.

American visitors to the Authority included members of the Congressional Joint Committee on Atomic Energy, who visited the United Kingdom at the end of November, 1960, and discussed matters of common interest with Members of the Authority.

The bilateral agreements between the Governments of the U.K. and of the U.S.A. provide the general framework under which exchanges of information and visits between the Authority and the U.S.A.E.C. take place. Subjects covered by team visits during the year included fast reactors, advanced gas-cooled reactor systems, the development of the gas centrifuge process for the separation of uranium-235, health and safety, and the design and equipment of facilities for plutonium fuel manufacture and feed materials technology. There have been many other visits in both directions by individual staff attending specialist discussions and conferences.

International Organisations

The International Atomic Energy Agency has continued to make considerable use of Authority experts, particularly in the preparation of international health and safety codes of practice, in the drafting of recommendations and manuals regarding the transport of radioactive materials and the consideration of problems of radioactive waste disposal. Authority staff have also attended panels and symposia on the planning and costing of atomic energy programmes, on the operation of research facilities and on the dissemination of scientific and technical information including the planning of a scientific library. Papers by Authority staff were presented at all the major conferences and symposia organised by the Agency during the year.

Sixteen holders of I.A.E.A. Fellowships from eleven countries in Europe, Asia and South America attended Authority schools or were attached to Authority establishments during 1960-61. The Authority have offered a further six free places for I.A.E.A. Fellows to undertake research projects at the Wantage Research Laboratory.

The CENTO Institute of Nuclear Science of Tehran, under the direction of Mr. H. A. C. McKay of the Authority's Research Group, held a general radioisotope course and a special short course for entomological field workers during the year.

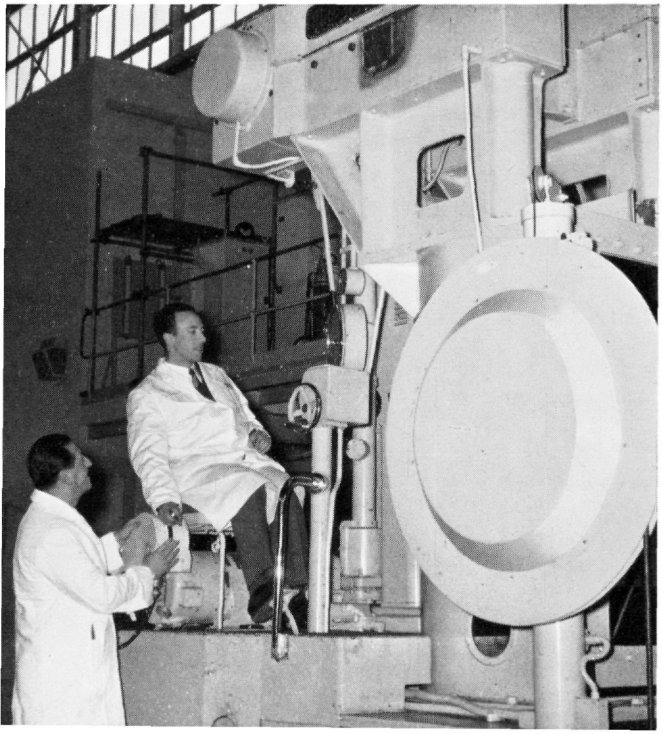
Sir John Cockcroft has continued to represent the U.K. on the United Nations Scientific Advisory Committee, and Dr. W. G. Marley is the U.K. alternative representative on the U.N. Scientific Committee on the Effects of Atomic Radiation. Sir William Cook and senior members of the staff of the Development and Engineering and Production Groups attended a sectional meeting of the World Power Conference in Madrid in June, 1960. Authority staff have taken part in the work of the European Atomic Energy Society and have attended specialised meetings of the International Standards Organisation, the World Health Organisation and the Fifth International Conference on Instruments and Measurements.

Representatives of Electricite'de France and the French atomic energy organisation at Calder Hall.

Senior executives from O.E.E.C. countries attending Harwell Reactor School visited Hinkley Point.

THE AUTHORITY'S SCHOOLS

Operating a Calder Hall charge-machine are two Italian engineers who will hold key posts at the British-designed nuclear power plant at Latina, near Rome.



Harwell Reactor School

Two standard, two senior technical executive and three control and instrumentation courses were held at the Harwell Reactor School during 1960-61 and in July there was an additional course for 25 senior technical executives from O.E.E.C. countries. The Colleges of Advanced Technology at Birmingham, Bradford and Salford continued to co-operate in running the standard course, the final three weeks of which is held at Warmwell, near Winfrith.

Two more courses on the principles of radiation protection were held.

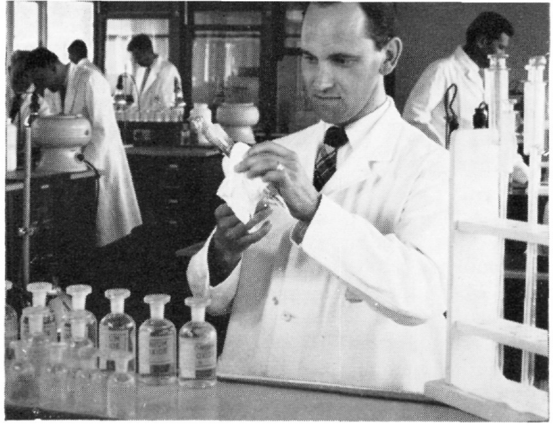
258 British and 80 foreign students attended the Reactor School during the year. Since the school began there have been 1,773 British and 608 foreign students.

Calder Operation School

The number of students who have passed through the Calder Operation School now exceeds 500. During 1960-61 seven courses for professional engineers and physicists were held and 137 students attended; 32 were from overseas countries.

The training of staff for nuclear power stations constructed overseas by British consortia has been

Students from Holland and Thailand at the Isotope School.



An isotope student from Sweden in the main Radiochemical Laboratory at Wantage.

Engineers who will operate Tokai Mura nuclear power station (Japan) study at the Calder School.

an important part of the school's activities. Thirty-three members of the operations staff for the Italian Latina station and seven members of the operations staff for the Japanese Tokai Mura station attended during the year and special courses were organised at technician level.

Isotope School

The successful introduction of radioisotope methods into industrial practice depends very largely upon the development of an informed opinion about their value throughout industry.

Over the last few years the Isotope School at Wantage has arranged several successful courses for members of the Institute of Directors to assist in creating an informed opinion. As a natural development of this series of courses, a four-day course for trades union officials was held in September, 1960, after discussion with the Trades Union Congress. The course programme was designed to give an objective account of the use of radioisotopes in industry and special attention was paid to the health and safety aspects. The course included lectures by senior staff of the Authority and by experts from elsewhere in addition to visits, demonstrations and a small amount of practical work. Forty trade union officials attended the course.

A total of 292 students, of whom 142 were from overseas, attended the school during the year. Of these, 110 attended general courses and the remainder attended special courses under the following headings: advanced chemistry; medical; advanced radiography; special chemistry; advanced biochemistry; radiological protection; trades unions.

REORGANISATION OF THE AUTHORITY

In their report dated July, 1959, on the Industrial Group of the Atomic Energy Authority, the Select Committee on Estimates recommended that certain aspects of the Authority's organisation should be reviewed after a reasonable period. This review took place during the year, and on 16th February, 1961, the Authority announced a number of organisational changes to take effect from 1st April, 1961.

Sir William Penney has been appointed Deputy Chairman, with primary responsibility for scientific and technical co-ordination throughout the Authority. The Authority's groups have been increased to five: namely, Research, Reactor, Engineering, Production and Weapons. The work of designing and developing nuclear reactors is concentrated, to the greatest possible extent, in the Reactor Group, and the major development facilities required for this purpose are under its control. The group is responsible for the design and development of reactors, and for relations in this field with industry at home and with overseas countries. The Winfrith Atomic Energy Establishment, which has responsibilities in the same field, is transferred from the Research Group to the Reactor Group.

The former responsibilities of the Development and Engineering Group for the design and construction of plant, works and buildings are transferred to the new Engineering Group, which also takes over from the Production Group its responsibilities for the design and inspection of fuel elements for production purposes.

As from 1st April, 1961, Sir William Cook became Member for Reactors. Sir Leonard Owen's responsibilities extend over the Production Group and the Engineering Group with the title of Member for Production and Engineering.

BOARD MEMBERSHIP

Membership of the Atomic Energy Authority, as at 1st April, 1961, 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.
(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

Mr. John Pears, F.C.A. was appointed a part-time Member of the Authority with effect from 1st May, 1960.

Sir Donald Perrott left the Authority on the expiry of his appointment, on 31st July, 1960. Sir Alan Hitchman, while retaining his existing responsibilities for commercial policy, assumed the responsibilities previously exercised by Sir Donald Perrott, and the title of Member for Finance and Administration.

Sir Rowland Smith relinquished his appointment as a part-time Member of the Authority on 16th October, 1960.

Mr. R. M. Geddes, was appointed a part-time Member with effect from 21st November, 1960. The appointments of Lord Citrine, Sir James Chadwick and Mr. C. F. Kearton as part-time Members were renewed until 31st December, 1961; 20th August, 1962; and 16th October, 1965, respectively.

Sir John Cockcroft, it was announced by the Ford Foundation in January, 1961, was selected as the recipient of the 1961 Atoms for Peace Award.

U.K.A.E.A. ESTABLISHMENTS

PRODUCTION GROUP
Risley
Calder Hall
Capenhurst
Chapelcross
Springfields
Windscale

WEAPONS GROUP
Aldermaston
Foulness
Orfordness
Woolwich Common

REACTOR GROUP
Risley
Capenhurst
Culcheth
Dounreay
Springfields
Windscale
Winfrith

ENGINEERING GROUP
Risley
Springfields
Tadley

RESEARCH GROUP
Harwell
Amersham
Culham
Bracknell
Chatham
Oxford
Wantage
Woolwich

THE AUTHORITY'S REACTORS AS AT 31st MARCH, 1961

		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	3.7×10^{10}	100 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	Isotope production and general radiation source.
	3	LIDO	Harwell	1956	10^{12}	100 kW	Light water	Light water	Uranium 235	Thermal reactor studies, including shielding.
	4	DIDO	Harwell	1956	2.2×10^{14}	12.5 MW	Heavy water	Heavy water	Uranium 235	Nuclear reactor material studies; isotope production; neutron physics; radiation chemistry.
	5	PLUTO	Harwell	1957	1.4×10^{14}	10 MW	Heavy water	Heavy water	Uranium 235	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. (Maximum temperature 800°C in core, 400°C in reflector).
	10	NERO	Winfrith	1960	2×10^{8}	Less than 10 watts	Graphite	None	Enriched uranium	Investigations for advanced graphite-moderated reactors; 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	Source of neutrons for sub-critical assemblies.
RESEARCH AND EXPERIMENTAL REACTORS UNDER CONSTRUCTION	14	AGR	Windscale	1961	2.5×10^{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.
	15	HERO	Windscale	1961	—	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	Uranium 235	To simulate DIDO and PLUTO, and to provide basic information in support of those reactors.
	17	HECTOR	Winfrith	mid 1962	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
	18	ZEBRA	Winfrith	1962	5×10^{9} fast flux	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)	19-22	Calder (2 stations) ("A" & "B") (4 reactors)	Calderbridge	Station "A" 1956 Station "B" 1958	—	200 MW per reactor (37 MW(E) Net)	Graphite	Carbon dioxide	Natural uranium	Plutonium and power production.
	23-26	Chapelcross (4 reactors)	Annan	1958 (1st reactor) 1959 (reactors 2, 3 and 4).	—	200 MW per reactor (37 MW(E) Net)	Graphite	Carbon dioxide	Natural uranium	Plutonium and power production.

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

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
- Department of Industrial & Forensic Science, Verner Street, Belfast
- 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) 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 the following:—

- "Principles of Nuclear Fission"
- "How a Thermal Reactor Works"
- "Great Day" (Opening of Calder Hall)
- "Chapelcross"
- "The Dounreay Project"
- "Criticality"
- "Radioisotopes in Industry"
- "R. & D." (Research and Development)
- "Britain's Atomic Power Stations 1960"
- "Nuclear Power Reactors"

A full list is available on request from Public Relations Branch, U.K.A.E.A., 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.

Designed by Ronald Terry.

Printed by Kent Paper Co. Ltd., London and Ashford, Kent.

AVAILABLE FROM H.M.S.O. 2/6 NET.

Front Cover: Remote argon-arc welding at R.C.C., Amersham.

Back Cover: Advanced Gas-Cooled Reactor, Windscale.

SUMMARY OF EVENTS

1st April, 1960—31st March, 1961

On the civil side, the development of nuclear reactors to generate electricity on an economic basis remains the Authority's principal objective. The Authority continued to meet their obligations under the weapons programme and also provided technical assistance in connection with the Geneva negotiations for nuclear weapon test suspension.

Production of fissile material was up to programme, and improvement in efficiency led to reductions in unit cost.

The Calder and Chapelcross reactors sent out more than 2,000 million units of electricity.

In an experiment in a Calder reactor, some of the standard fuel elements reached an exposure greater than 3,000 MWd(H)/t, far in excess of their designed endurance.

Fuel elements were manufactured at Springfields for the Bradwell and Berkeley reactors of the Central Electricity Generating Board, and also for the prototype advanced gas-cooled reactor at Windscale.

Modifications were carried out to the Capenhurst diffusion plant to improve efficiency of operation.

The Authority continued to devote a considerable development effort to the support of the civil magnox reactors. The programme was concerned mainly with design and testing of fuel elements and with control and safe operation of these reactors.

The experimental advanced gas-cooled reactor at Windscale was substantially completed during the year, and criticality is planned to take place during the autumn of 1961.

The HERO zero energy high temperature reactor reached an advanced stage of construction.

A considerable amount of background research and development in aid of the A.G.R. and its fuel element was carried out. The first fuel charge will be mainly of stainless steel-clad elements.

The Dounreay fast reactor core structure was modified to enable more advanced fuel element components to be tested. Operation of the reactor at low power has yielded valuable experience.

The zero energy breeder reactor assembly (ZEBRA) is under construction at Winfrith. Preliminary study of a prototype fast reactor continued during the year.

Construction of the experimental high temperature gas-cooled reactor by the O.E.E.C. Dragon project continued at Winfrith, and the zero energy reactor ZENITH was used in support.

A development programme on the steam generating heavy water reactor is to be carried out in collaboration with Atomic Energy of Canada Limited.

The Authority carried out a substantial programme of technical study in connection with the consideration by H.M.G. of the question of nuclear marine propulsion.

Various studies were carried out in the field of thermonuclear research, but the Intermediate Current Stability Experiment has not been continued. Construction began during the year on the new C.T.R. site at Culham.

Besides carrying out the programme of military development and production laid down by the Ministry of Defence, the Authority have set in hand a programme of seismological research bearing on the detection and identification of underground nuclear explosions.

The value of the Authority's sales totalled nearly £21 million during the year.

Sales of radioisotopes rose by about ten per cent.

The Authority delivered fuel elements for C.E.G.B. power reactors and for research reactors, both at home and overseas. The Authority continued to act as consultants to the electricity boards in the U.K. and to purchasers overseas of British designed nuclear power reactors.

Uranium supply and demand became even more out of balance during the year and further steps were taken to limit and stretch out the Authority's liabilities.

The Authority's links with overseas countries and with international organisations working in the nuclear field were strengthened by a large number of exchanges of visits and reports, by attendance at international conferences and by attachment of staff from other countries to the Authority's schools and establishments.

The Authority's Estimates for 1961-62 provide for a net expenditure of £78,071,000, compared with £93,293,000 for 1960-61.

The Authority's staff increased during the year from 38,500 to 40,840.