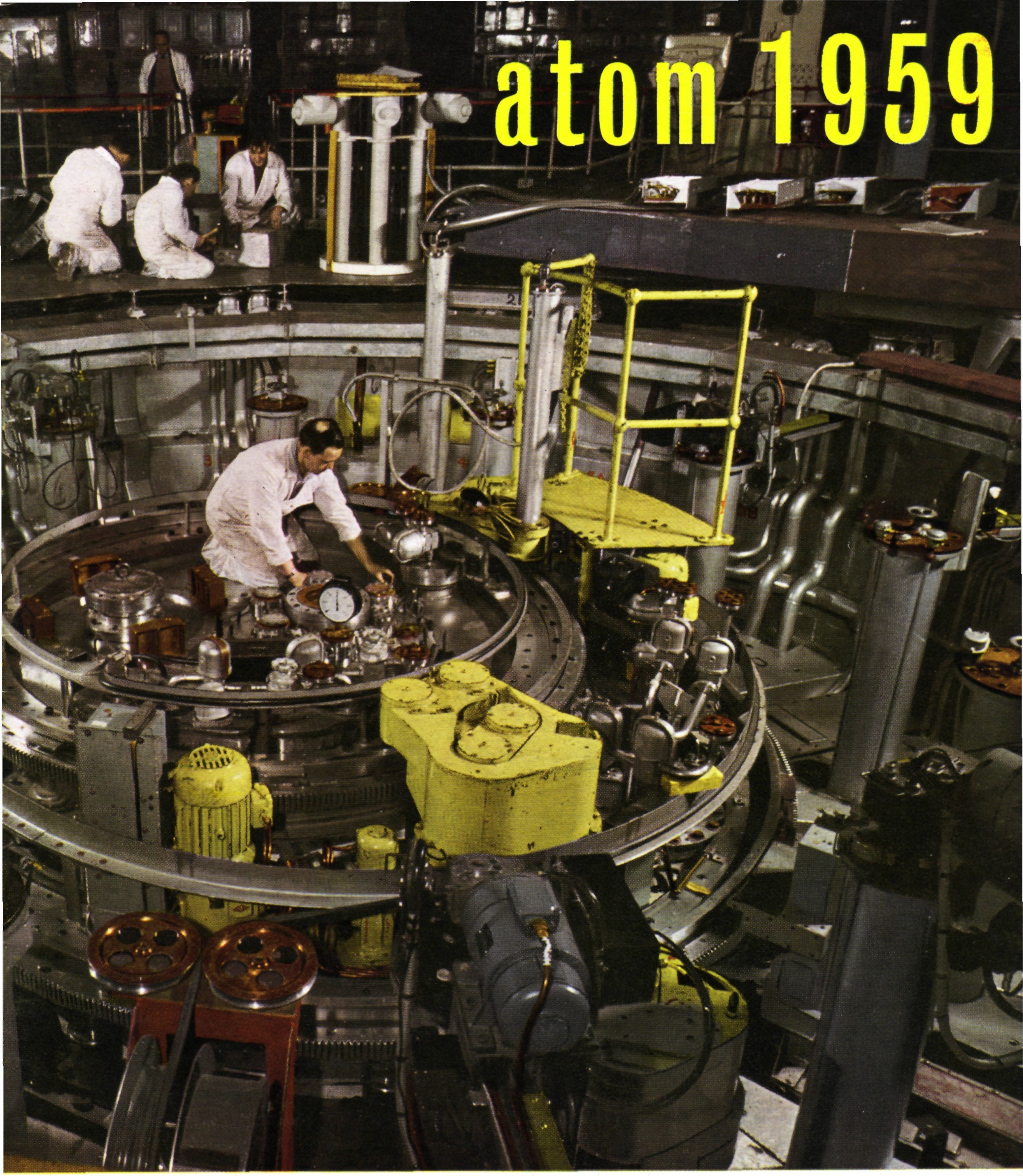
atom 1959



An illustrated summary of the Fifth Annual Report - from 1st April 1958 to 31st March 1959 - of the

UNITED KINGDOM ATOMIC ENERGY AUTHORITY

atom 1959

Up to 1955 much of the research and development work in atomic energy was carried on, if not in secret, at least without attracting any large degree of attention except among the technologists directly concerned.

1955 was the first year of great publicity: it saw the publication of the British "Programme of Nuclear Power" and the first United Nations Conference on the Peaceful Uses of Atomic Energy. The many spectacular achievements which were announced then and have been announced since were the fruit of ten years' work which till then had been largely unnoticed.

The rate of advance continues to be rapid; but further progress can only come from research that is increasingly complex and expensive both in money and in men, and it takes time.

The opening of Calder Hall in 1956 and its successful operation since then have demonstrated conclusively that electricity can be produced from nuclear power on an industrial scale. We are now in a period of consolidation.

The next step is to improve the economics of nuclear power, and intensive work is being carried on to this end.

Power Reactors: the Objectives

The first aim of the United Kingdom Atomic Energy Authority's work on reactor development has continued to be that of ensuring the successful construction and operation of the first nuclear power stations now under construction for the electricity boards in this country. Apart from this immediate task the Authority are devoting extensive resources to the development of more advanced types of reactor, the aim of which is to provide progressively cheaper sources of nuclear power.

Because of their low fuel costs, nuclear power stations will be operated at the highest load factor possible in the generating system. (The *load factor* of a station is its *energy output in a year* as a percentage of the output it would have achieved had it worked *continuously at full load throughout that year.)*

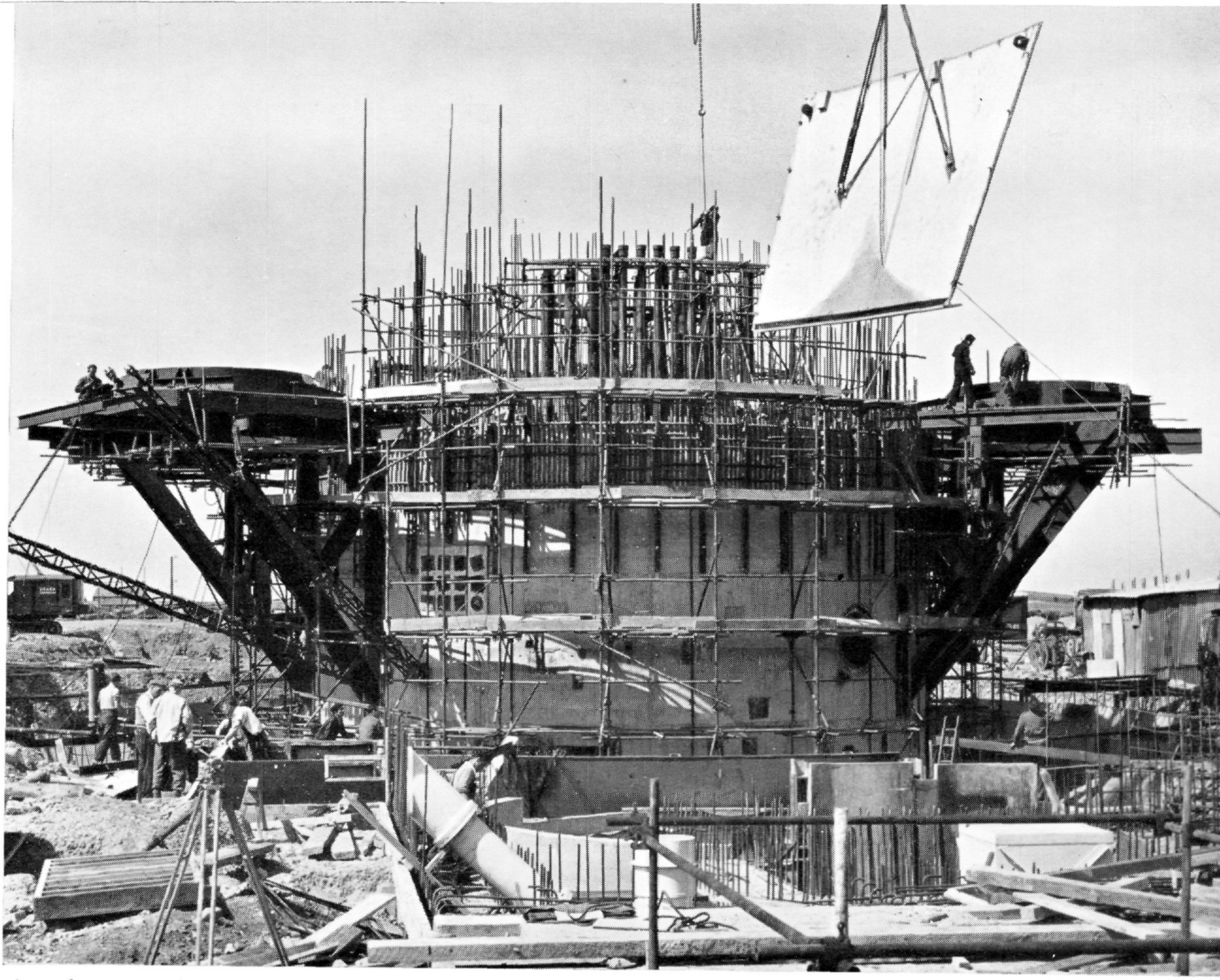
The effect of the high capital costs of the early stations will thus be minimised by the fact that they will be operated on the base load.

Reductions in capital cost will be essential if nuclear stations are to be competitive at the lower load factors that will eventually obtain when the amount of nuclear capacity installed exceeds the base load on the electricity generating system.

Hence the achievement of lower capital costs is a major objective of the Authority's programme of reactor development.

Although experience in designing and constructing stations using Magnox canned natural uranium fuel elements is reducing the capital cost per KW of this type of station, further major reductions will depend on the development of the more advanced reactors.

To these considerations must be added the need to base plans as far as possible on the use of materials readily and cheaply available. Produc-



An early stage in the construction of the A. G. R. at Windscale.

tion of uranium enriched in the 235 isotope is expensive in the United Kingdom. Therefore, the enrichment of fuel, where essential, must be kept low and efforts are being made to develop ways of using as fuel the plutonium that will gradually become available from the burning of uranium in the early stations.

Beyond the natural uranium reactors, two stages of development are envisaged.

The first is represented by systems attaining lower capital cost by the use of slightly enriched fuel. These are the *advanced gas-cooled reactor* and the water moderated reactors *(steam-cooled heavy water* or *boiling water).*

The second aim is to introduce reactors which, besides having low capital costs, have negligible net fissile fuel consumption, i.e. reactors in which the production of fissile materials approaches or exceeds its consumption, and the fuel costs of which are low. The *high temperature gas-cooled reactor* and the *fast breeder reactor* are in this category.

Plans for reactor development must also be related to the possibilities of the export market. The present type of gas-cooled, graphite-moderated reactor may command a market overseas where large stations are required. Nuclear technology will, however, have to advance considerably before smaller reactors (e.g. 20-100 MW) become competitive in normal circumstances. Much of the Authority's work on the larger systems will have application to small reactors and will thus in the long run contribute to the possible development of the latter for export.

FRONT COVER. *Dounreay - The top of the stainless steel pressure vessel inside the fast-breeder reactor sphere.*

Reactors for Electricity Generation

In Operation

CALDER HALL, CUMBERLAND. *Four reactors* - 184 *MW*. *Officially opened* 1956. *Dual-purpose station for plutonium production and electricity generation.*

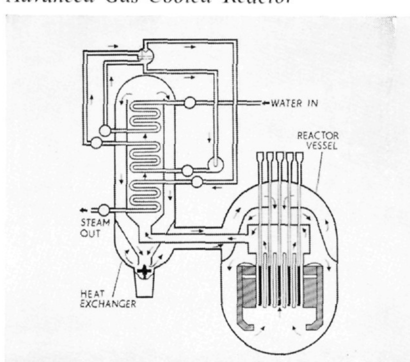
Power Programme Stations under Construction

BRADWELL, *Essex*. (*C.E.G.B.*) 300 *MW*.

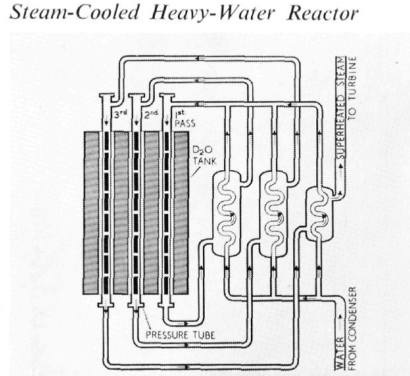
BERKELEY, *Glos*. (*C.E.G.B.*) 275 *MW*.

Possible Future Types for the Power Programme

Advanced Gas-Cooled Reactor



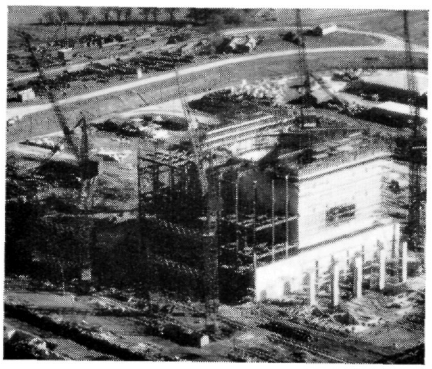
Steam-Cooled Heavy-Water Reactor



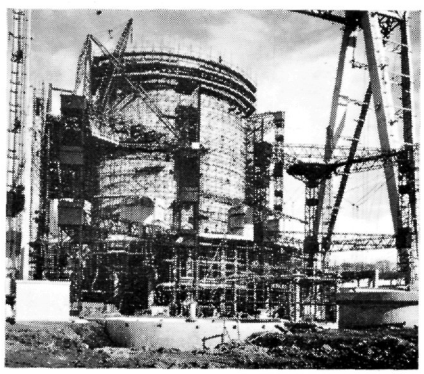
Reactors for Electricity Generation

CHAPELCROSS, *Dumfriesshire. Four reactor station identical with Calder Hall. One reactor in operation* 1958. *Three under construction. Officially opened* 1959.

These stations are operated by the United Kingdom Atomic Energy Authority. They are dual-purpose stations for the production of plutonium and for the supply of electricity to the National Grid.



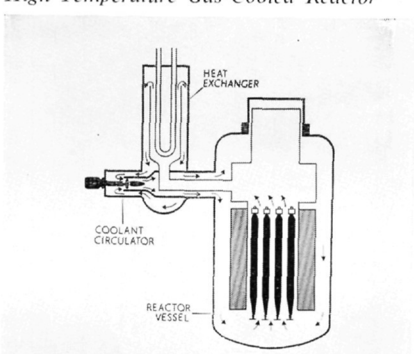
HINKLEY POINT, *Som.* (*C.E.G.B.*) 500 *MW.*



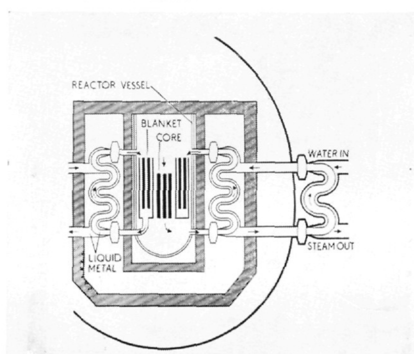
HUNTERSTON, *Scotland.* (*S.S.E.B.*) 320 *MW.*

These stations are being built by industry for the Central Electricity Generating Board and the South of Scotland Electricity Board. The 1966 target of the Nuclear Power Programme is 5-6000 Megawatts. Work has started on a fifth C.E.G.B. Station at Trawsfynnyd, North Wales

High Temperature Gas-Cooled Reactor



Fast-Breeder Reactor



A.G.R. and S.C.H.W. are being developed with a view to commercial use in the second half of the 1960's; H.T.G.C. and the fast-breeders in the 1970's.

Fission Reactors

1 **The essential parts of a fission reactor are:-**
Fuel
Moderator
Coolant

These three are interdependent:
the fuel to provide the fissions, the neutrons and the energy;
the moderator (in most cases) to provide the conditions necessary to maintain the chain reaction;
the coolant to extract the energy so that it can be used.

2 **There are:**

three possible fuels:-*	***Uranium* 235, *Plutonium* 239 and *Uranium* 233.**
five possible moderators:-	**Light Water (i.e. ordinary water), Heavy Water, Graphite (Carbon), Organic Liquid (Hydrogen and Carbon), Beryllium. (Or none - as in fast reactors).**
five possible types of coolant:-	**Gases, Light Water, Heavy Water, Organic Liquids and Liquid Metals.**

3 **With these groups of components there are theoretically some 150 different types of reactors. With three classes of "enrichment" for each fuel the total possible number of reactor types amounts to 400 in all.**
In practice the number of possible reactor types is smaller because some of the theoretical types are not practicable.

* The fuel of a nuclear reactor is called *fissile* material, i.e. its nuclei can be split to produce heat. The only naturally occurring fissile material is Uranium 235. In "natural uranium" (the kind used in Calder Hall type reactors) only 0.7 per cent of the metal is Uranium 235. The other 99.3 per cent is Uranium 238.

Uranium 238 is a *fertile* material, i.e. if it is put into a reactor with *fissile* material it can be turned into *new fissile material.* Uranium 238 treated in this way becomes Plutonium. Thorium 232 becomes Uranium 233.

"Natural uranium" can be treated so that the percentage of Uranium 235 in the U.235-U.238 mixture is higher than 0.7 per cent. This process is called "enrichment." Reactor fuels are often divided into three broad categories: "natural uranium," "slightly enriched" and "highly enriched."

Calder Hall, the world's first commercial-scale nuclear power station.

Reactors Present and Future

CALDER HALL. A thermal output of over 200 MW per reactor is now consistently obtained with electrical generation of 46 MW (gross) and some excess steam production. A considerable amount of experimental work to assist the nuclear power programme has been carried out in the reactors. The excess reactivity has been used to manufacture isotopes and has enabled an experimental programme to be carried out to determine the effects of radiations on reactor materials. Commissioning of the third reactor started at the beginning of 1958. The fourth reactor attained criticality during the year and will shortly be in full production.

CHAPELCROSS. The first reactor has been commissioned and a thermal output of over 200 MW with an electrical generation of 46 MW (gross) has been obtained.
During the year a number of Authority staff has continued to be engaged on improvements in the design of gas-cooled, graphite-moderated natural uranium reactors. The consortia of firms engaged in constructing power reactors have joined in this work as part of the programme of collaboration between them and the Authority. Experience with the Calder Hall reactors and work in the Authority's materials testing reactor played an important part in an intensive programme to ensure that the fuel in the civil stations attains an average life of at least 3,000 megawatt days per tonne.
The Authority continued to act as consultants to the Central Electricity Generating Board and to the South of Scotland Electricity Board on the nuclear parts of the power stations which are at present being built for them. They also provided the Boards with information about the latest techniques affecting the design, construction and operation of the stations, and assisted them in drawing up codes of practice for the safe and efficient operation of each reactor.

ADVANCED GAS-COOLED REACTOR. Preliminary work on the prototype, advanced gas-cooled reactor (A.G.R.), began on the Windscale site on 1st October, 1958. A supporting programme of irradiation experiments has been started which will begin to yield information from the autumn of 1959 onwards, particularly upon the behaviour of beryllium-canned, uranium-oxide fuel. The results of this work will be available in time for any necessary modifications to be incorporated in the prototype and its fuel.

The basic reactor physics problems are being studied by the Research Group at Harwell but for the full development of the A.G.R. type of reactor for power generation more extensive experimental facilities are necessary. The most important of these is the zero energy, high temperature research reactor, HERO, being built at Windscale. A distinctive feature of HERO will be its flexibility; a variety of core assemblies can be built up to study the reactor physics of different designs. Initially beryllium-canned uranium-oxide fuels will be studied, but later studies will include plutonium-bearing oxide fuels for more advanced applications of the A.G.R. system. The reactor will be heated by hot carbon dioxide so that it can be operated at temperatures up to 500 deg. C. Industry is associated with the development of the advanced gas-cooled reactor. Technical and professional staff drawn from industry have been seconded to work with Authority staff on its design and construction.

HIGH-TEMPERATURE GAS-COOLED REACTOR. Steady progress has been made with the research and development programme for the high-temperature gas-cooled reactor (H.T.G.C.). The immediate emphasis of the present work is on the development of a reactor based on graphite as the moderator and container for the fissile material. Considerable advances have been made in the production of new types of graphite, both in the experimental plant at Harwell which has produced samples of high density graphite, and by outside contract, where methods of rendering the graphite impervious to gases and fission products have shown considerable promise. An intensive programme was put in hand to determine the resistance of these new graphites to radiation, and small sample fuel elements using these materials were undergoing tests in the research reactors at the end of the year.

A series of exponential experiments to measure certain basic physics constants of the system was in progress at Winfrith Heath. Construction of the high-temperature, zero-energy experiment ZENITH at Winfrith Heath was almost complete. Physics experiments, initially directed towards elucidating conditions for the reactor experiment, will begin later in the year.

WATER MODERATED REACTORS. Progress with the study of the gas-cooled, heavy-water moderated reactor system, has shown that the use of steam as the coolant in a pressure-tube design would enable evaporators to be used in place of heat exchangers three times as large. Moreover, the capital cost of the steam-cooled, heavy water reactor should be lower than that of the gas-cooled, heavy-water moderated reactor. Further development potential of the system appears to be considerable.

The Authority have therefore begun to study the design of an experimental plant, which could be modified in due course for electricity generation, in which a 100 MW (Heat) experimental steam-cooled heavy-water (S.C.H.W.) reactor could be operating by the end of 1962. This plant would contain common services for a second reactor, and if the Authority decided to do so, a boiling light-water reactor (B.W.R.) could be added in due course.

Because of its simplicity, and its use of light water as a moderator, the potentialities of the B.W.R. have attracted attention in a number of countries, particularly the U.S.A., where enriched uranium can be produced more cheaply than in this country. For use in the U.K., however, the chief disadvantage of the B.W.R. is that, even with zirconium fuel cans, enrichment to about 1½ per cent is necessary, and a large programme of B.W.R.s would, therefore, require supplies of fissile material in substantially greater quantities and at lower cost than are at present available in the U.K.

FAST REACTOR. The Authority's major effort in the fast reactor field is the construction and operation of the fast reactor at Dounreay. During the year it was possible to increase the effort on this and the construction was completed. The reactor was handed over to the operating group in December, 1958. Commissioning was proceeding at the end of the period under review with electrical and mechanical testing of controls and instrumentation. Charging of the liquid metal circuits with sodium potassium alloy was almost complete and the breeder blanket fuel elements had been loaded. This work will be followed by loading with core elements and then by approach to criticality. The reactor should begin a period of low power testing during the summer of 1959.

RESEARCH REACTORS. During the year the new high flux reactor PLUTO at Harwell came into operation and has been brought up in stages to a power of 10 MW (H). Experiments were made to determine the possibility of increasing the power to 15 MW (H). Mock-ups of various experimental loops were put in the reactor at low power. The other high flux reactor DIDO continued to run at 10 MW (H). New hollow fuel elements were developed for use in both DIDO and PLUTO. These elements were successfully used at high power in DIDO and provide a large fast neutron flux for irradiation experiments.

The materials testing reactor at Dounreay (DMTR) was commissioned and became critical in May, 1958. The programme of bringing the reactor up to its full power of 10 MW was successfully completed, and the first experimental rigs installed.

At the Atomic Weapons Research Establishment, the light-water moderated research reactor HERALD, which will be used for neutron physics and radiochemical studies, was in an advanced stage of construction at the end of the period under review. Throughout the year the zero energy light water reactor HORACE has been the main preoccupation of the reactor team at Aldermaston. This work has proved of value in the basic study of HERALD characteristics. One of the primary objects is to shorten the time taken to run HERALD up to full power.

MARINE PROPULSION (SURFACE PROPULSION.) During the year the Authority's collaboration arrangements with industry were strengthened by the institution of quarterly meetings at which progress in the investigation of reactor systems for their suitability for marine propulsion has been reported and discussed. At the invitation of the Admiralty Committee on the Application of Nuclear Power to Marine Purposes, which was established to study these matters and on which the Authority have two representatives, the Authority conducted detailed studies of the advanced gas-cooled reactor system as applied to surface propulsion. A general appraisal of these and other studies was nearing completion at the end of the year.

SUBMARINE PROPULSION. Under the 1958 Defence agreement with the United States a "Skipjack" pressurised water reactor and its fuel are to be supplied for installation in a British hull, and Rolls Royce Limited are to receive information under licence from the Westinghouse Electric Corporation (U.S.A.). The Authority will advise on safety problems associated with the "Skipjack" reactor.

Loading fuel elements into No. 1 reactor, Chapelcross.

PLUTO, a Harwell reactor for testing radiation effects on materials.

Fuels of the Nuclear Age

Modification of existing plants and commissioning of new plants have resulted in an increased output of all materials produced by the Operations Branch of the Industrial Group. In particular, the output of fissile material has increased by more than 50% during this year.

On 7th June, 1958, the second Springfields uranium plant was opened. It is designed to satisfy all the fuel element demands of the first civil power reactors, and to provide uranium and uranium oxide fuel elements for experimental and prototype reactors.

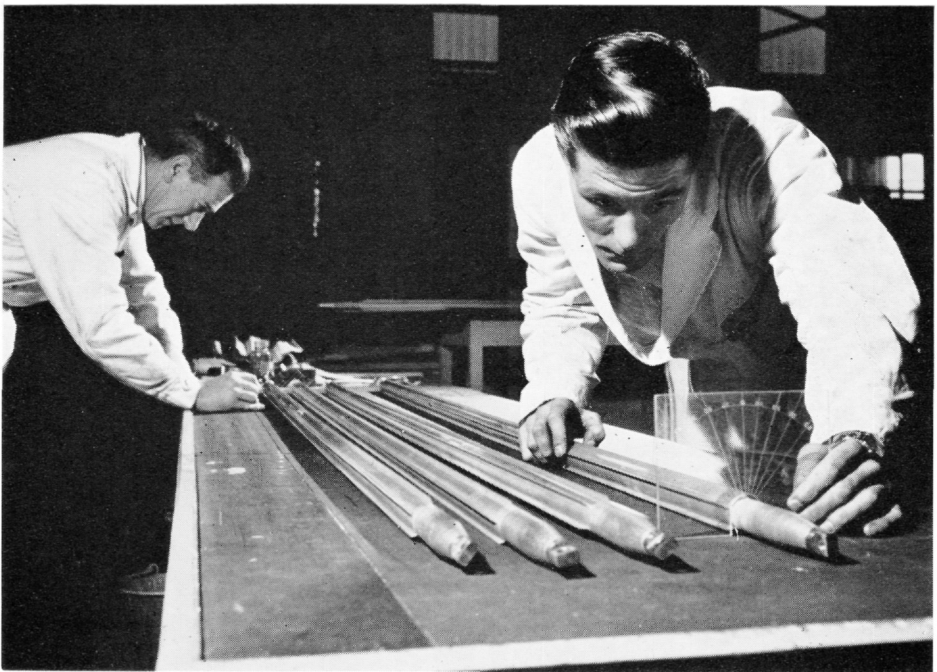
The production of Calder and Chapelcross fuel elements at Springfields has continued throughout the year. The first fuel element assembly line on the second uranium plant has been commissioned and is being used for the production of experimental thermal reactor fuel elements. Fuel elements for the Harwell reactors have been supplied and various types of isotope cartridges have been produced for irradiation in the Calder reactors.

The diffusion plant at Capenhurst, which produces uranium hexafluoride highly enriched in the uranium-235 isotope, has been extended by the addition of units of large size.

An essential step in the development of fuel elements is the detailed examination of standard and experimental fuel elements after service in the Authority's and, in due course, the electricity boards' reactors. Techniques have been successfully developed throughout the year for dimensional, X-ray and metallurgical examination of fuel elements by remote operation behind heavy shielding of facilities known as caves. Based on this experience an extensive set of caves is being designed for installation at Windscale which initially will enable the examination of about 2,500 Calder and civil fuel elements to be made each year.

The most significant contribution to further development has been derived from detailed examination of Calder fuel elements after they have been irradiated in the reactors. During the past year major advances have been made in the techniques for the examination of irradiated fuel elements and a large effort has been expended on regular examination. Over 800 fuel elements have been examined. Precision measurements on the fuel show that even after long periods of irradiation and thermal cycling in reactors, the changes which occur are small, and that the dimensional stability of the fuel has been maintained over long periods.

A further requirement of fuel element development is to be able to predict with greater accuracy the statistical behaviour of fuel elements under operating conditions. Basic studies of the metallurgy of uranium are being undertaken so that production methods may be con-



Inspecting fuel elements for the Norwegian heavy water moderated reactor at Halden before despatch from the Springfields factory of the U.K.A.E.A. where they were manufactured.

trolled more precisely to yield a fuel of great uniformity and consistency. The experience gained with Calder type fuel elements is being applied to the design of fuel elements for the civil reactors.

FUEL ELEMENTS FOR A.G.R. Following the choice of beryllium as a canning material for the A.G.R., the Research and Development Branch of the Industrial Group embarked on an extensive programme to solve the many technological problems of processing the metal powder to the finished fuel assembly. The metal can now be formed into a wide variety of shapes, and the properties of these fabricated components are such that they can be incorporated into a satisfactory fuel element design. Progress has also been made with welding and pressure welding techniques. Attention is now being paid to the effect of irradiation on the behaviour of the metal itself and also on specimens representative of fuel element assemblies.

The uranium dioxide fuel will be contained in the beryllium cans in the form of high density pellets. A method of making the fuel on the laboratory scale has been established by the Research Group at Harwell. In the Research and Development Branch the process has been scaled up for the production of ton quantities. This experimental plant has been used to produce dense uranium dioxide pellets, to close tolerances, for the nuclear physics experiments for this type of reactor. The experience gained from this experimental plant has been applied to the formulation of a flowsheet for the production of the fuel for the A.G.R. prototype.

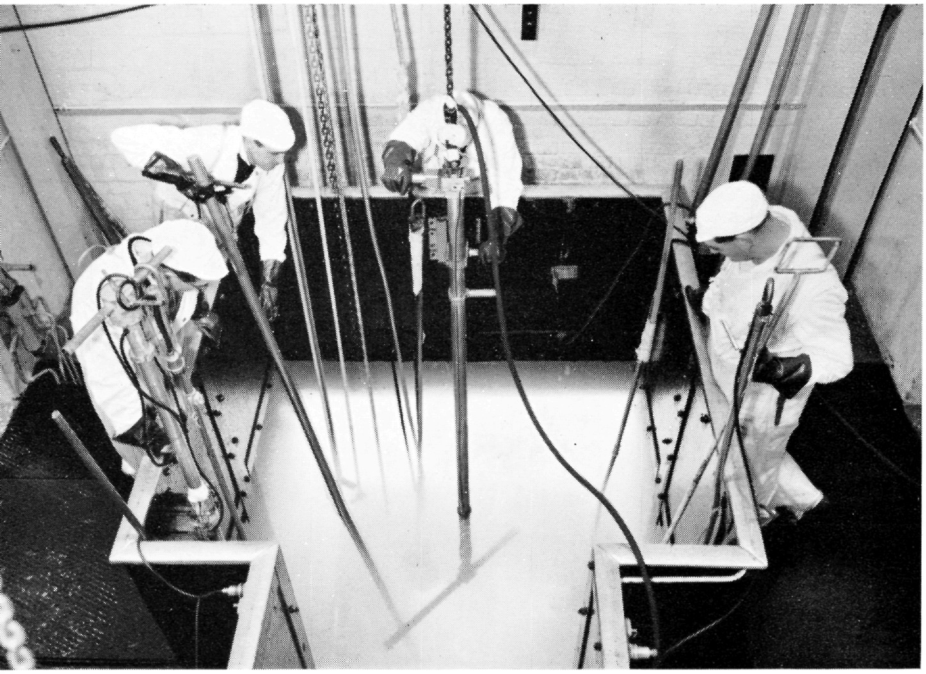
The study of plutonium utilisation in reactors has continued. In addition to the long term objective of using plutonium as the initial fuel for the fast reactor, a more immediate study is aimed at completing our understanding of how the generation of plutonium by irradiation of uranium in existing thermal reactors affects their performance. This will be followed also by an appraisal of the various possibilities of using plutonium for enrichment (as an alternative to U.235) in later thermal reactors.

COMMERCIAL ARRANGEMENTS. The Authority are at present the only manufacturers of fuel elements for the Calder Hall type of reactor. Contracts are being negotiated with the electricity boards for the supply of new fuel elements, and for the repurchase of the fuel after irradiation. To enable the Authority to plan

Calder Hall fuel elements in production at Springfields.

appropriate manufacturing and reprocessing capacity, the contracts may cover periods of ten years for each station; provision will be made, however, for selling and repurchase prices to be varied from year to year. The first deliveries of fuel for the U.K. nuclear power programme will begin towards the end of 1959.

The Authority also undertake to supply natural uranium fuel elements for any U.K. designed gas-cooled reactor constructed overseas, and to repurchase the fuel after irradiation. A statement of their terms has been made available for use by potential overseas customers. Contracts may be made either directly with a reactor operator, e.g. an electricity undertaking, or with a government agency in the purchaser's country. The Authority expect the contracts to be for a reasonable minimum period. Fuel supply contracts are dependent on the conclusion beforehand of a bilateral agreement between the U.K. and the overseas government concerned. This agreement includes an undertaking by that government that the fuel, equipment and information supplied, and the fissile material derived



A used and highly radioactive Calder Hall fuel element being carried under a protecting water-shield to a machine for stripping the uranium rod from its Magnox alloy can.

from the use of the fuel and the equipment, will be used only for peaceful purposes. During the year the Authority negotiated such a fuel supply contract with Agip Nucleare in respect of their Latina station. This fuel supply contract is the first overseas order of its kind to be placed in the U.K. Deliveries of the initial fuel charge will take place during 1961/62. Negotiations are also in hand for a fuel element supply contract for a nuclear power station which the Japan Atomic Power Company proposes to order from the G.E.C./Simon Carves Group of Companies.

OTHER PRODUCTS. The Authority have made and sold enriched uranium fuel elements for research reactors of British design which have been and are being built in Australia, Germany and Denmark, and natural uranium elements for the Halden reactor in Norway. They have also sold, both at home and overseas, limited quantities of natural uranium, thorium, beryllium and zirconium. Some special chemical compounds have also been supplied. The Authority are also supplying the graphite moderator for the nuclear reactors of power stations. This nuclear quality graphite is manufactured under contract to the Authority, but the Authority assume responsibility for its inspection and testing as the graphite required for a nuclear power programme must meet an exacting specification.

The irradiated fuels from the civil power stations will be processed in a new separation plant to be built at Windscale. New developments since the original separation plant was built have resulted in much improved processes.

To help British industry to compete for export business in the design and manufacture of radioactive chemical processing plant, the Authority arranged, through the British Chemical Plant Manufacturers' Association, for the training in Authority establishments of scientists and engineers from chemical plant manufacturing companies. A course of training for selected staff started in September, 1958.

Research and Development

The functions of the Research Group centred on Harwell, and now extending to the Atomic Energy Establishment at Winfrith, are, broadly, to obtain basic knowledge in all the physical sciences upon which atomic energy depends, to use this knowledge to determine the technical and economic feasibility of new or different methods for developing nuclear power and also to widen and increase the applications of radioisotopes.

The aim of research and development in the Industrial Group is to provide the information needed by the Group to discharge its commitments, particularly in support of the efficient operation of its factories and of the reactor design programme. The Calder Hall type of reactor and its immediate development are being studied so that the Group may continue to advise and guide the electricity boards and the industrial consortia.

The Weapons Group has continued to play a vigorous part in the Authority's contribution to scientific research.

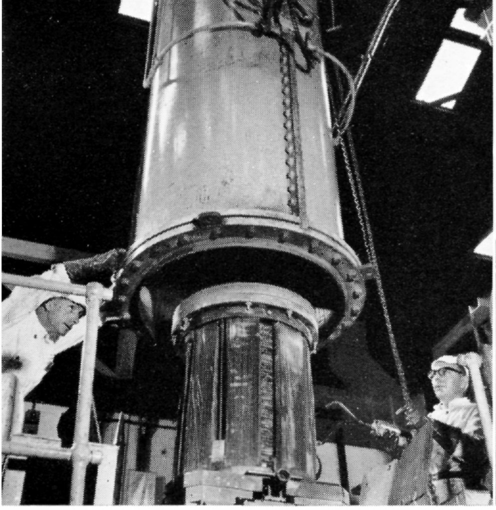
The Group has ensured that its specialist knowledge and techniques are applied to problems outside the weapons research and development field.

Much research and development work was carried out for the Authority by industry under extra-mural contracts. During the last five years the number and value of such agreements between the Industrial Group and universities, research associations and industry have increased, until they now account for about a tenth of the Group's annual expenditure on research and development.

METALLURGICAL RESEARCH. The fuel of a nuclear reactor is a metal, or a metallic compound. Other metals, some of them unusual, are used in the fuel element can, in the control mechanism and in structural parts of the reactor, and in its pressure vessel. These metals are subject to bombardment with neutrons and other types of radiation. It is essential to understand the effects produced in these metals by these processes. One of the most important metals being studied is steel.

The work on steels is being carried out collaboratively with the consortia and C.E.G.B. and

A high temperature furnace in the Harwell graphite research plant used for transforming carbon into graphite.



LEFT: *A vacuum furnace being prepared for melting and casting uranium at the Research and Development Section, Springfields.*

RIGHT: *The Tandem Electrostatic Accelerator at A.W.R.E. Aldermaston, used for the study of the behaviour of nuclear particles.*

covers three fields: the development of techniques for inspecting the reactor vessel during construction; a study of the behaviour of pressure vessels under the temperature and irradiation conditions encountered during the life of the reactor; and the development of improved steels with the particular object of meeting the demands of more advanced reactor designs.

IRRADIATION EFFECTS. In all these investigations into irradiation effects, the essential tools are strong sources of neutrons produced by high-flux reactors, and apparatus in which highly radioactive samples can be examined and their physical properties measured. These are available at Harwell, at Calder Hall, and at Dounreay.

A feature of current work is that by irradiating small samples of graphite inside special fuel elements in the highly rated reactors DIDO and PLUTO, it has become possible to produce irradiation damage at a rate about twelve times greater than will occur in any existing or projected graphite-moderated reactor.

WORK ON PARTICLE ACCELERATORS. Research into atomic particles is carried out at Harwell for the benefit both of the establishment and, through the National Institute for Research in Nuclear Science, of the universities.

Four new machines are either in course of commissioning or construction. The largest of these, the 7 GeV* proton synchrotron, is being built for the Rutherford Laboratory of the National Institute by the Authority, with a team of physicists and engineers from the Atomic Energy Research Establishment and with the constructional assistance of the Industrial Group. The energies of the particles from this machine will lie between those of the American Bevatron at Berkeley and the Russian 10 GeV machine at Moscow, but it is expected that the current in the beam will be somewhat higher than in the case of either of these machines. Construction is proceeding rapidly. The huge monolithic concrete foundation for the 7,000 ton, 150 ft. diameter magnet, the arched concrete roof over the magnet room, and the shield bridge, 28 ft. thick, which forms part of the shielding between the magnet room and the experimental area, have been completed. The major components of the machine have been designed and ordered, and production items are being delivered. Among the latter are the 20 ton magnet blocks, of which there are about 350, to be delivered at the rate of one each working day.

This machine is a co-operative venture between British universities and the Authority, working through the National Institute, which will enable the universities to take a prominent place in high-energy nuclear physics. It is expected to be in operation by 1962.

A second machine being built at Harwell by A.E.R.E. and industry for the National Institute is the 50 MeV proton linear accelerator.

The two other machines are being commissioned for use by A.E.R.E. The first is a 25 MeV electron linear accelerator for nuclear physics experiments.

The second new machine is one of two vertical 12 MeV tandem electrostatic generators jointly designed by the Atomic Weapons Research Establishment, the Atomic Energy Research Establishment and an industrial firm for use at Aldermaston and Harwell. These accelerators will be in operation in mid-1959.

* *7 giga-electron-volts, i.e. 7,000 million electron volts.*

Fusion

The power reactors described so far derive their energy from the splitting of heavy atoms, uranium and plutonium. Energy is also released by joining together, or fusing, light atoms. One of the most challenging technical problems of our time is to find practical ways of releasing this fusion energy in a controlled manner.

Controlled thermonuclear research is aimed at solving the problem. The idea is to give to atoms of the heavy isotopes of hydrogen, called deuterium and tritium, very large amounts of energy by heating them—enough energy to make them join together when they collide; more energy would then be released than had to be supplied to the colliding atoms. Heavy hydrogen is contained in ordinary water, so the solution of the fusion problem would mean that mankind would have an inexhaustible source of fuel. But the problem is a formidable one. Before the rate of fusion in a mixture of isotopes could increase rapidly enough to release useful amounts of energy, it would be necessary to heat the mixture to enormously high temperatures, of the order of tens or hundreds of millions of degrees —far higher than in the centre of the sun. At these temperatures all forms of matter are gaseous and behave quite differently from matter at ordinary temperatures. The differences are so great that the special name " plasma " has been given to matter in this form.

A great deal more must be known about the properties of plasma before a successful fusion reactor can be built and research in this subject is occupying scientists throughout the world. In Britain, research is directed to studying ways of forming, containing, and heating plasma and to finding out more about the detailed behaviour of its constituent particles. This work is going on at the Atomic Research Establishment, Harwell, the Atomic Weapons Research Establishment, Aldermaston, and the laboratories of Associated Electrical Industries Ltd., at Aldermaston Court.

In the Harwell research apparatus ZETA, large electric currents are passed through a ring-shaped tube, like the inner tube of a motor tyre, containing deuterium gas. The gas is heated to about a million degrees and at the same time pinched inwards, away from the walls of the tube, by the magnetic effects of the electrical current.

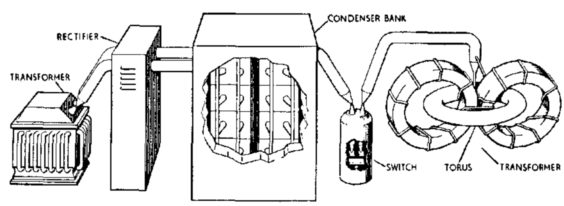
ZETA began working in August 1957 and during last year improvements were made to the apparatus which enabled a larger current of electricity—270,000 amperes—to be passed through the gas without increasing the supply of electricity stored in its condenser bank. Recently a new condenser bank was installed, capable of delivering 10 times as much energy as the original. The new condenser bank will shortly be tested.

The results of experiments on the improved ZETA, and on the smaller but similar machine, Sceptre III, at the laboratories of Associated Electrical Industries Ltd., have shown that although the plasma is pinched by its own magnetic field, an excessive amount of energy from the plasma is nevertheless being lost to the walls of the tube. This loss means that less energy is available to raise the temperature to the high levels required: it is rather like trying to pump up a tyre with a puncture.

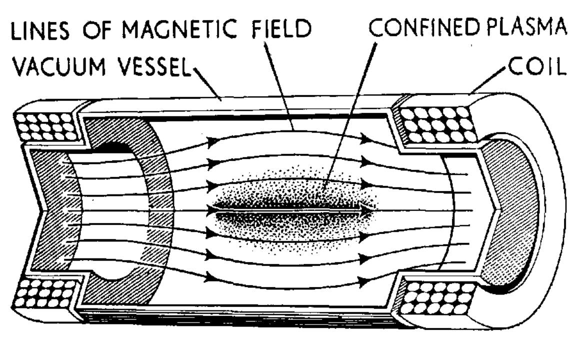
The reasons for this energy loss are not clearly understood and the main object of the present experimental programme is to discover them. Some of the results already obtained have been unexpected. Instabilities in the discharge also cause energy losses but some of these problems may be overcome by working at higher pressures.

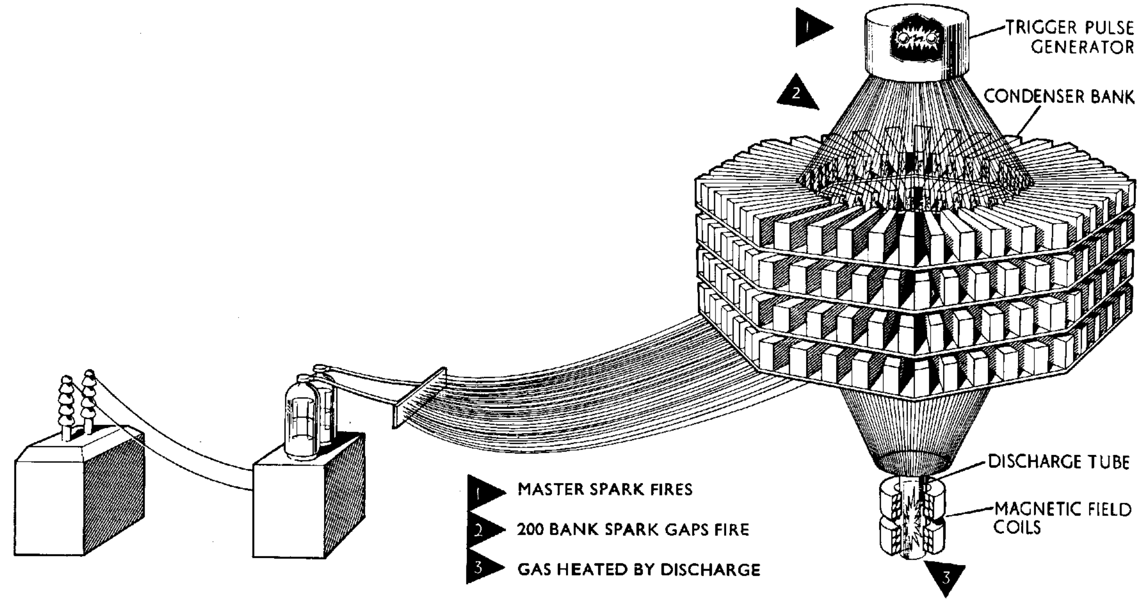
Higher pressure operation will be possible when

EXPERIMENTAL APPROACH TO FUSION - 1. *The Torus, in which a gas is heated electrically in a ring-shaped tube.*



EXPERIMENTAL APPROACH TO FUSION - 2. *The Mirror Machine, in which gas particles are trapped and heated by compression.*





EXPERIMENTAL APPROACH TO FUSION - 3. *The rapid discharge, produced by condensers which all fire within a few thousand-millionths of a second. The discharge passes through a gas producing very high temperatures by rapid compression.*

the higher electrical currents are used from ZETA'S new condenser bank and when Sceptre IV, an improved version of Sceptre III, begins working in the near future. However the knowledge already gained suggests that a more radical attack must be made than can be achieved on ZETA. Consequently designs are being prepared for a system which will enable the heated gas to be maintained at higher pressures and allow the electrical current to be fed into the gas at a much faster rate.

A different type of approach is being made at the Atomic Weapons Research Establishment, Aldermaston. The aim here is to achieve high gas temperatures by very rapid compression using a fast rising magnetic field to drive in the gas. The energy is put into the gas before instabilities can develop.

To produce the fast rising magnetic field a special type of high voltage condenser bank has been developed which has 200 spark gaps in parallel to overcome the " bottle neck " that arises if a single switch is used. The gaps all fire within a few thousand-millionths of a second and the current builds up at a rate of five million million amperes per second.

Most of the experiments have been carried out using straight tubes because the simple shape facilitates the experimental techniques and the analysis of results. Experiments so far have demonstrated that although sufficient energy has been put into the gas to heat it to interesting temperatures, these temperatures are not being reached because in some way energy is being lost. The reasons for this loss of energy are now being studied.

Quite a different method of containing and heating deuterium gas is being studied at Aldermaston, involving the building of a new experimental device. In all the other systems described, a gas of deuterium or mixture of deuterium and tritium, is first introduced into either a circular or cylindrical tube and then heated by some means. In this new system, which is known as a mirror machine, one starts with an empty containing-chamber. This chamber is surrounded by current-carrying coils generating a magnetic force which will reflect into the centre, and away from the chamber walls, any charged particles of gas. By an ingenious mechanism, the chamber, with its magnetic fields " guarding " all points of exit, is filled with the required gas. Once the particles of this gas are trapped inside the container these magnetic fields may be increased and the gas heated by compression.

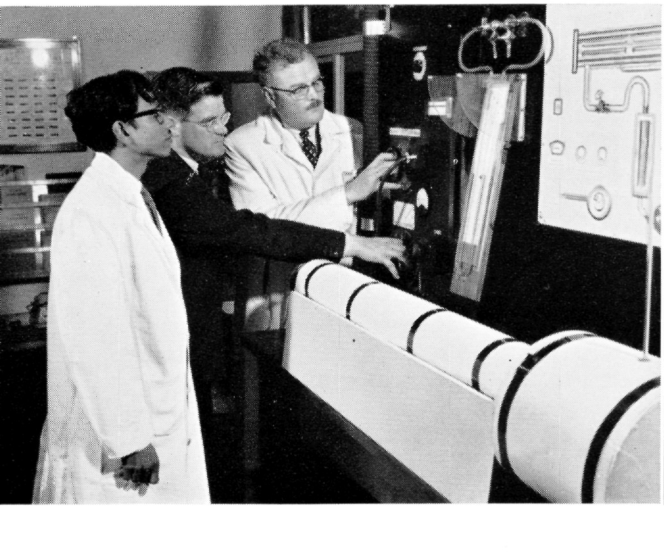
International Relations

With the continuing growth of interest in nuclear power and the steady expansion throughout the world of nuclear energy facilities, the extent and variety of the Authority's international commitments continue to increase. International collaboration should lead to speedier development of the application of nuclear energy in the collaborating countries than if each country worked entirely in isolation.

INTERNATIONAL ORGANISATIONS. An agreement between H.M. Government and the European Atomic Energy Community (Euratom) was signed in London in February, 1959. The agreement is intended to provide a comprehensive framework within which the U.K. and the Community can co-operate in nuclear energy matters. During the year the Authority have agreed to participate in two joint projects sponsored by the European Nuclear Energy Agency, under the aegis of O.E.E.C.

In June, 1958, the Authority and representatives of Norway, Sweden, Denmark, Switzerland, Austria and the Euratom Commission signed an agreement to operate the boiling water reactor at Halden, in Norway, as a joint project for three years beginning 1st July, 1958. (Since then Finland has also become associated with the work). Two scientists from the Research Group are working at Halden. The Authority are pro-

Top left: The Rt. Hon. Selwyn Lloyd at the signing of the U.K.-Euratom co-operation agreement. Right: Lord Plowden signing the O.E.E.C. High Temperature Reactor Project agreement in Paris. Below left: A Canadian and a Pakistani student at Harwell's Reactor School. Right: Japanese Trade delegates see a DIDO fuel element at Harwell.



Members of the U.S. fast reactor team inspect Britain's fast reactor, Dounreay.

viding the first fuel charge.

An agreement to develop the high temperature gas-cooled reactor, which it is proposed to build at Winfrith Heath, as a joint project with other member countries of the European Nuclear Energy Agency, was signed at O.E.E.C. Headquarters in Paris on 23rd March, 1959. The participants, in what has come to be known as the "Dragon" project, are the Authority, the Euratom Commission, the Governments of Switzerland and Austria, and the national atomic energy organisations of Norway, Sweden and Denmark.

The joint project, which is to operate in the first instance for five years, will carry development to the stage of building an experimental power producing reactor which at the end of the joint programme will belong solely to the Authority. This type of reactor, if successfully developed, could be used for central power station generating plant or as a small system for isolated or mobile units. A detailed programme of work is now being drawn up; it is expected that part of the experimental work will be carried out in other European countries.

The programme of the International Atomic Energy Agency, which held its second General Conference in September, 1958, is making good progress. Increasing requests have been made to the Authority to supply experts, and several students nominated by the Agency have already been selected to fill free places offered by the Authority at their Wantage Laboratory.

The Second United Nations Conference on the Peaceful Uses of Atomic Energy was held in Geneva in September, 1958. The United Kingdom sent a strong team consisting of five delegates headed by Sir John Cockcroft, and nearly 300 advisers, many of whom were concerned with the oral presentation of scientific papers. The total number of papers presented by the U.K. was over 200. There were also about 400 U.K. observers. The advisers and observers were drawn from the universities, other research bodies, hospitals, Government Departments, electricity boards and industry generally, and from the Authority.

Events in Iraq in July, 1958, resulted in the closing of the Bagdad Pact Nuclear Training Centre in Bagdad. The Centre had trained about 60 students in radioisotope techniques. The Centre was re-opened in Tehran in April, 1959.

THE COMMONWEALTH. Following the Geneva Conference, Her Majesty's Government invited representatives of Commonwealth countries to attend a conference in the U.K. and to make a tour of the Authority's establishments. Forty representatives from nine Commonwealth countries took part.

Several senior members of the Authority's staff, including Sir Leonard Owen, the Managing Director of the Industrial Group, visited Australia and New Zealand during the year and discussed common problems with colleagues in these countries. The Authority were represented at the inauguration of the Australian HIFAR reactor in April, 1958, by Sir Donald Perrott. HIFAR is of the same type as the DIDO reactor at Harwell.

Following discussions with the President of Atomic Energy of Canada Limited, further attachments of Canadian engineers to Authority establishments were arranged. In January, 1959, a Liaison Officer appointed by Atomic Energy of Canada Limited, was posted to London where he is in close touch with the Authority. The Authority have for some time had a liaison officer at the principal Canadian atomic energy research establishment at Chalk River.

The Authority continue to collaborate with the Indian Atomic Energy Commission to tackle the problems of a young and rapidly growing atomic energy project by lending specialist staff for short term advisory visits and for extended attachments. There were discussions with leading members of the Commission on their plans for introducing nuclear power into India.

UNITED STATES OF AMERICA. On 3rd July, 1958, a new bilateral agreement was signed by representatives of the U.K. and U.S. Governments which permitted much more far reaching and valuable exchanges of information on the military uses of atomic energy than have been possible since 1946. Under the agreement, the U.K. Government is also permitted to acquire a nuclear submarine propulsion plant and the necessary fuel core. This agreement followed on an amendment of the U.S. Atomic Energy Act enacted by Congress in July, 1958.

The year was also marked by an extension of co-operation in the civil uses of atomic energy into a number of new fields.

There were further meetings at which U.S. projects and designs for gas-cooled, graphite-moderated reactors were discussed in the light of U.K. experience of this system; and the technical collaboration between those involved in the U.S. and U.K. fast reactor programme grew even closer.

In the fast reactor field also, the Authority concluded an agreement on the 8th August, 1958, with the Power Reactor Development Company which, in conjunction with Atomic Power Development Associates Inc. and the Detroit Edison Company, is building a large fast reactor power station near Monroe, Michigan. The agreement provides for the exchange of experience gained in the planning and construction of the Dounreay and Monroe reactors and it is already clear that both sides will benefit greatly from these exchanges.

JAPAN. The intergovernmental agreement with Japan was signed in June, 1958, and ratified by the Japanese Government in December, 1958. Throughout the year the Authority were in close touch with the Japanese Atomic Energy Commission, the Japan Atomic Power Company, and the other Japanese organisations concerned with atomic energy, and information and advice were given on many technical questions arising out of the decision to construct a U.K. type nuclear power station in Japan.

Early in 1959 the Japan Atomic Power Company issued a letter of intent to the G.E.C./Simon Carves Group of Companies for the construction of a gas-cooled reactor of 150 MW (E) capacity. The Authority thereupon concluded a technical assistance agreement with the Japanese company. The Authority also issued a letter of intent relating to the supply of fuel elements for the reactor.

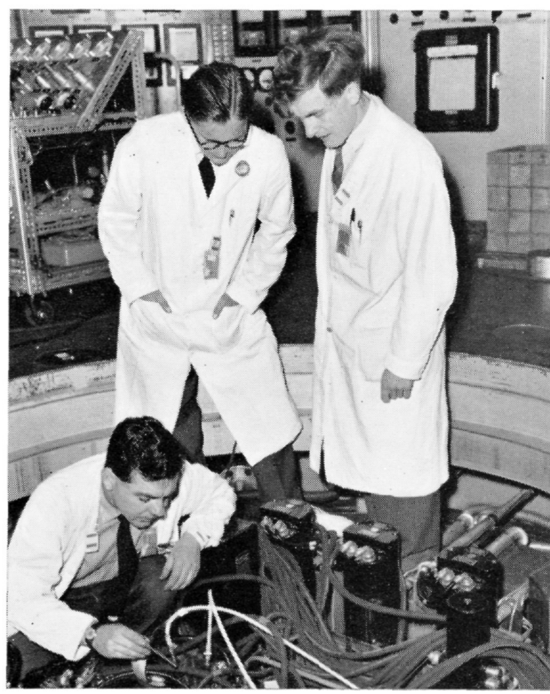
ITALY. The Authority provided consultancy services to Agip Nucleare in connection with nuclear power plant which is being built by the Nuclear Power Plant Company Limited at Latina in Italy.

The Authority also gave technical assistance, in reviewing tenders, to the international panel of experts appointed to assist the Italian SENN organisation in selecting a nuclear power plant for Project ENSI.

OTHER COUNTRIES. An agreement between the governments of the U.K. and Portugal for co-operation in nuclear research was concluded in July, 1958.

Close and friendly relations also have been maintained with Belgium, Brazil, Denmark, France, the Federal Republic of Germany, the Netherlands, Norway, Spain, Sweden, Switzerland and many other countries, both by direct contacts and by sharing in the work of the European Atomic Energy Society, of the Conseil Européen pour la Recherche Nucléaire (CERN), and other international bodies.

A Danish scientist (right) attached to Harwell inspecting the PLUTO reactor.



Producing a radioactive form of one of the B vitamins at the Radiochemical Centre, Amersham.

Radioisotopes

Now firmly established as an important, expanding industry based on the by-products of nuclear reactors is the development, production and marketing of "radioisotopes"—the radioactive substances which are being increasingly used in medicine, industry, agriculture and research.

Sales of radioisotopes manufactured by the Authority at Amersham and Harwell again rose during the year, reaching a total value of £800,000, compared with £650,000 last year. Sixty per cent of these sales were exported to 55 countries.

Because of this growing demand for radioisotopes the Authority in March reorganised their radioisotope services. Production and marketing have now been concentrated at the Radiochemical Centre with its headquarters and main laboratories at Amersham and irradiation facilities at Harwell and other Authority establishments. The annual rate of radioisotope deliveries from the Radiochemical Centre increased from about 2,000 in 1950 to over 30,000 a year in 1959. Research to find out new uses for radioisotopes and to examine their properties is carried out by the Isotopes Research Division. Previously known as the Isotope Division, and at present located at Harwell, the reconstituted Division will soon occupy new premises at the Wantage Radiation Laboratories.

More and more firms are turning to radioisotopes to provide them with gauges to measure and control accurately and continuously the thickness of sheets of material produced in rolling mills; the inspection of flaws in welds and castings by means of the penetrating gamma rays of certain radioisotopes is now standard practice; the logging of boreholes in oil prospecting is greatly assisted by using radioisotopes.

As more nuclear reactors come into operation larger supplies of intensely active radioisotopes become available. One such is radioactive cobalt, whose radiation in sufficient quantities will kill germs. This property is being put to effective use in Australia where the first industrial gamma-ray sterilisation unit in the world is now being built. Using radioactive cobalt supplied by the Authority it will sterilise animal fibres, to safeguard against the possibility of spreading the killing disease, anthrax.

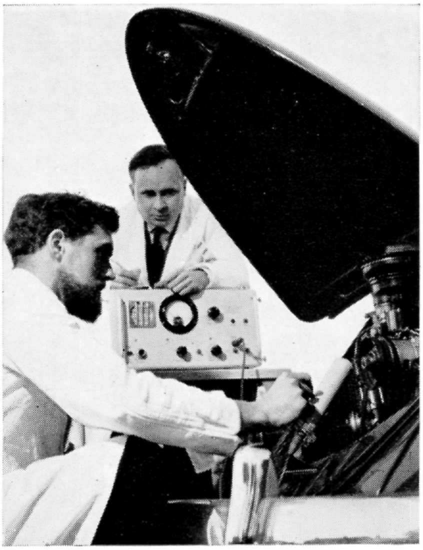
As part of the work of the Wantage Radiation Laboratories a special installation at Harwell uses the highly radioactive spent fuel elements from the DIDO and PLUTO reactors. Various tests have been carried out on materials subjected to the irradiation produced by these sources which have been used to treat 20 miles of polythene tubing to make the material more heat resistant and to sterilise many different items of hospital equipment.

Two hundred delegates representing 20 nations came to Harwell last November to discuss the application of ionizing radiations, such as those produced by radioactive cobalt, to the preservation of food. The meeting, which was sponsored by the Food and Agriculture Organisation of the United Nations, came to the conclusion that the most promising way of treating food was by combining radiation with other sterilisation methods.

Several new industrial applications of radioisotopes are being studied. A method has been devised for testing industrial filters in which tiny radioactive particles are graded according to size, thus enabling measurements to be made to within one per cent of the quantity passing through the filters. Another device has been developed for measuring small gas leaks in systems working at temperatures up to 350° C. The use of water, in which some of the normal hydrogen atoms have been replaced by radioactive hydrogen atoms, is opening new ways of studying the processes of drying oils as well as providing means of tracing water movements underground.

It is not only industry which is benefiting from the adaptable radioisotope. Biologists studying the basic processes within the living cell have for several years been using compounds which include a radioactive form of carbon. As these compounds are incorporated into living tissue, their assimilation can readily be detected in the smallest amounts. The demand for such compounds, of which over 200 different varieties are available, has increased 25 per cent since last year. A more recent development, and one that is of similar importance, is the production of compounds in which the normal hydrogen atoms have been replaced by radioactive hydrogen atoms. Because the presence of radioactive hydrogen in these compounds can be detected with great accuracy, their use is of particular value to the study of hereditary processes.

Examples of work outlined above, and many others, were displayed at the Geneva conference last year where half the Authority's stand in the Industrial Exhibition was devoted to radioisotopes. Radioisotopes were also shown by the Authority at four other exhibitions, and travelling exhibitions sponsored by them have toured Western Germany and South America.



LEFT: *A thickness gauge in use at the Steel Company of Wales, Velindre Works, Swansea.*

RIGHT: *Inspecting a car engine for fuel leaks, using a radioisotope dissolved in petrol.*

Health and Safety

During the past year the Authority have carried out a major review of their health and safety organisation in the light of the recommendations contained in the report of the committee (the Fleck Committee) appointed by the Prime Minister to examine the Organisation for Control of Health and Safety in the United Kingdom Atomic Energy Authority, which was published as a White Paper in January, 1958.

As a result of this review, the Authority have reiterated, as a fundamental principle, that all their staff are responsible, through the normal management chain of command, for the safety of operations under their control. To assist the management in this task, specialist health and safety branches (whose functions are advisory) are located at the sites of all hazardous operations.

The policy to be followed by the specialist branches is evolved by a simple committee structure. This is under the general supervision of a small committee comprising members of the Authority under the chairmanship of Sir John Cockcroft. The Health and Safety Branch at Risley, in addition to its responsibility for controlling the Industrial Group health and safety organisation, acts as the executive organ of the health and safety committee structure. Its responsibilities include the preparation of Authority codes of practice and initiating assessments of the design, construction, operation and maintenance of reactors, and of radioactive chemical plants and laboratories. The diversity and scale of these responsibilities have called for a considerable expansion of the specialised staff required for this work.

The Authority have also reviewed and extended their arrangements for liaison with local authorities, and with their own non-industrial and industrial staff, in health and safety matters.

SHORTAGE OF SPECIALIST STAFF. The acute shortage of people possessing the requisite qualifications was regarded by the Fleck Committee as "one of the most important points that has emerged from our review." The reason for this shortage is that there is no general pool of experience in this type of work. Consequently, the Authority are rarely able to obtain trained men from outside and, in general, have had to train their own staff. In view of the great importance of this matter, the Fleck Committee recommended that the Authority should take the lead in building up the supply of specialised staff required to meet the needs of the nation as a whole. The Authority have set up a Committee under the chairmanship of Sir Douglas Veale, to advise them on this problem. The Veale Committee recognised the immediate urgency of providing for post-graduate studies in radiobiology and radiological physics, and submitted an interim report to the Authority recommending the initiation of courses at selected universities and the provision of studentships, if possible in time for the 1959/60 academic year. This recommendation has been accepted in principle by the Authority and details of the scheme are being worked out.

PROTECTION OF THE STAFF. In much of the work done by the Authority there are potential radiological hazards against which the most stringent precautions are taken. For the development of new reactors and plant the Authority need to produce, test and use materials which hitherto have not been handled by industry on a large scale, and in connection with which many special problems arise. For example, beryllium has highly toxic qualities. In addition to the health and safety problems which are peculiar to atomic energy development, the Authority, in common with other large industrial undertakings, have to take precautions against normal industrial hazards.

In protecting their employees and the general public from the effects of radiation, the Authority are guided by the maximum permissible levels of exposure laid down by the Medical Research Council on the basis of the recommendations of the International Commission on Radiological Protection.

The Authority's record stands up well to measurement against these maximum permissible levels, which relate both to external and to internal radiation. In general, the maximum permissible levels are now lower than those in force at the time when most of the Authority's existing plant was designed. Nevertheless, by modifications to plant and methods of operation the average level of exposure of Authority employees has been kept at only a small fraction of the recommended levels. All workers thought to be liable to receive significant doses of radiation wear film badges, and during the whole of 1958 the average dose received by all Authority employees wearing film badges was 0.44 rad. (A rad is a unit of absorbed dose arising from any form of radiation. It is defined as 100 ergs per gram in a specified medium.) In fact, about 90 per cent of these employees received, on average, doses not exceeding 25 per cent of the maximum permissible level recommended by the International Commission on Radiological Protection (3 rads for a period of thirteen weeks). The level of exposure of Authority employees varies according to the nature of their work. During the past year there were twenty-five occasions when the figure of 3 rads in thirteen weeks was exceeded. This is an improvement on the fifty-four occasions during the preceding year. Steps were taken in each case to ensure that long term dose levels were not exceeded.

Measurement of radiation levels plays a major part in keeping the radiation exposure of the Authority's employees to a minimum. Over 60,000 surveys of the level of surface contamination have been carried out, and over 200,000 air samples have been taken, in the past year. Continuing attention has been given in the design of plants and buildings to prevent the escape of radioactivity into working areas. By creating safe working conditions the necessity for special protective clothing and equipment has been reduced to a minimum.

Similarly, great care has been taken to control the hazards arising from non-radioactive materials with toxic qualities. For example, about 12,000 surveys were made during the year at Springfields to measure the concentration of beryllium in air to ensure that the recommended safe level was not exceeded.

NON - RADIOACTIVE HAZARDS. Records of industrial accidents are maintained by the Authority in a form similar to those in use in industry. The accident frequency rates during 1958 (i.e. the number of lost-time accidents per 100,000 man hours worked) were 0.98 for the Industrial Group, 0.48 for the Research Group and 0.53 for the Weapons Group. These figures compare with the average frequency rate in 1957 of 1.71 for all industries which supply this information to the Factories Inspectorate, and of 2.02 for the non-ferrous metal extraction, refining and conversion industry.

CO-OPERATION WITH GOVERNMENT DEPARTMENTS. During the past year the Authority have continued to co-operate closely with the Government Departments concerned with health and safety problems in the atomic energy field.

The Authority were consulted by the Ministry of Power in the preparation of the Nuclear Installations (Licensing and Insurance) Bill. They have advised on the form of organisation the Ministry will need to carry out the functions to be laid upon the Minister. In practice, the Authority have in the past exercised a limited control, on the lines proposed in the Bill, to which private reactor owners have submitted voluntarily.

The Authority continued to provide advice to the Ministry of Labour and National Service in the preparation of draft Regulations under the Factories Acts. They were also represented on the Ministry of Transport and Civil Aviation's Committee on the Safety of Nuclear Ships, which has been carrying out preparatory work for the 1960 Convention on the Safety of Life at Sea, to be held under the auspices of the International Maritime Consultative Organisation.

Members of the Authority's staff have continued to work in close collaboration with the staff of the Medical Research Council and of the Agricultural Research Council.

INTERNATIONAL CO-OPERATION. The Authority have continued to play a full part during the past year in the work of international organisations concerned with atomic energy health and safety problems. Regular contributions were made to the work in this field of the International Atomic Energy Agency and also to that of the United Nations Scientific Committee on the Effects of Atomic Radiation, the World Health Organisation, the European Nuclear Energy Agency (operating under the auspices of O.E.E.C.) and the International Commission on Radiological Protection.

Revised Health and Safety Organisation

A revised form of health and safety organisation was introduced by the Authority on the 1st July 1959. A new Health and Safety Branch was established as part of the Headquarters organisation of the Authority and separate health and safety organisations in each Group Headquarters were eliminated. The principle that all Authority staff are responsible, via the normal management chain of command, for the safety of operations under their control remains unchanged, however, and heads of establishments continue to receive advice from their own specialist health and safety organisations.

Organisation of the Authority

1st JULY 1959

THE PRIME MINISTER

THE ATOMIC ENERGY OFFICE

Chairman of the United Kingdom Atomic Energy Authority — LORD PLOWDEN, K.C.B., K.B.E.

PART-TIME MEMBERS

Sir John Cockcroft, O.M., K.C.B., C.B.E., F.R.S.
Sir Ivan Stedeford, K.B.E.
Mr. C. F. Kearton, O.B.E.
Sir A. Rowland Smith
Sir James Chadwick, F.R.S.
Rt. Hon. Lord Citrine, P.C., G.B.E.

MEMBER FOR SCIENTIFIC RESEARCH
Sir William Penney K.B.E., F.R.S.
RESEARCH GROUP

MEMBER FOR DEVELOPMENT AND ENGINEERING
Sir William Cook, C.B.
DEVELOPMENT AND ENGINEERING GROUP

MEMBER (Designate) FOR PRODUCTION
Sir Leonard Owen, C.B.E.
PRODUCTION GROUP

MEMBER FOR WEAPONS RESEARCH AND DEVELOPMENT
Sir William Penney K.B.E., F.R.S., (temporarily)
WEAPONS GROUP

MEMBER FOR FINANCE AND ADMINISTRATION
Sir Donald Perrott K.B.E.

MEMBER FOR EXTERNAL RELATIONS AND COMMERCIAL POLICY
Sir Alan Hitchman K.C.B.

SECRETARY
Mr. D. E. H. Peirson

During the year a number of changes were effected or announced in the full-time membership of the Authority. Mr. W. Strath relinquished his appointment as Member for External Relations and Commercial Policy on becoming Permanent Secretary to the Ministry of Supply, and was succeeded on 1st April, 1959, by Sir Alan Hitchman. Sir John Cockcroft, who has been appointed Master of Churchill College, Cambridge, will be succeeded as Member for Scientific Research by Sir William Penney as from 1st July, 1959. Sir John will remain on the Board of the Authority as a part-time Member, and will continue to represent the Authority on a number of international organisations.

Two further changes were announced on 20th March, 1959. Firstly, the Authority have decided to divide the Industrial Group into two. The two Groups are to be entitled respectively 'Development and Engineering' and 'Production'. Sir William Cook will be the Member for Development and Engineering; Sir Leonard Owen will be the Member (Designate) for Production. The Authority consider that this division of responsibility will make for better management, having regard to the size and diversity of activities of the Industrial Group.

Secondly, the Authority have decided to restore to their technical Members executive as well as functional responsibility. Experience has shown that the separation of functional from executive responsibility does not suit the particular circumstances of the Authority as well as the previous arrangement, which will accordingly be restored from 1st July, 1959. Sir William Penney will then have executive responsibility for the Research Group as well as functional responsibility for scientific research throughout the Authority. Sir William Cook will have executive responsibility for the Development and Engineering Group as well as functional responsibility for these subjects throughout the Authority. Sir Leonard Owen will have executive responsibility for the Production Group. Air Chief Marshal Sir Claude Pelly, G.B.E., K.C.B., M.C., A.D.C., R.A.F., whose appointment as Member (Designate) for Weapons was announced in August, 1959, will have executive responsibility for the Weapons Group

Publications

Details of publications on nuclear energy and allied subjects can be obtained from Public Relations Branch, U.K.A.E.A., 11, Charles II Street, London, S.W.1.

The following libraries in Britain are depositories for U.K.A.E.A. documents:—

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 St., Nottingham.
Central Library, Surrey Street, Sheffield, 1.

Films on Atomic Energy

A number of films has been made for the U.K.A.E.A. dealing with aspects of their work. Additions to these since April, 1958, include:—

Chapelcross
The Dounreay Fast Reactor
The Dounreay Project
Metals of the Nuclear Age
More Power from the Atom
Operating a Calder Hall Reactor—Full Power
Operating a Calder Hall Reactor—Refuelling
Radioisotopes in Industry
Reactors at Calder Hall

A list and descriptions of Authority films can be obtained from the Public Relations Branch, U.K.A.E.A., 11, Charles II Street, London, S.W.1.

A full list of 145 films on atomic energy and related subjects has been prepared by the Scientific Film Association. This list is given in Scientific Film Review, Vol. 2, No. 4 (October, 1956), which may be obtained from the Editorial Office, 3, Belgrave Square, London, S.W.1.

Another catalogue, listing over 200 films, British and foreign, on atomic energy, was given as a supplement to the June (1959) issue of the technical journal, Nuclear Energy Engineer, whose editorial office is at 147, Victoria Street, London, S.W.1.

Events of the Year April 1, 1958, to March 31, 1959

There was steady progress in both civil and defence applications of atomic energy in the United Kingdom.

On the civil side, work started during the year on construction at Windscale of the advanced gas-cooled reactor prototype. A zero energy reactor, HERO, is to be built to complement the work of the A.G.R. prototype.

An agreement with the United States for exchange of a wide range of nuclear defence information was concluded on July 3, 1958. This agreement, also permitting purchase from the United States of machinery and fuel for a nuclear submarine prototype, makes possible close collaboration between the two countries on weapon development.

The last of the four Calder Hall reactors became critical on December 8, 1958, and the first reactor at Chapelcross came into use for electricity generation on February 25, 1959.

The millionth uranium fuel rod was produced at Springfields in January, 1959, and the thousandth student was enrolled at the Authority's Isotope School in November, 1958. During the year the Authority's staff increased from 30,341 to 35,260.

Construction work on the site at Winfrith Heath in Dorset for the Atomic Energy Establishment, Winfrith, has continued satisfactorily.

The Final Report of the Committee appointed by the Prime Minister to make a technical evaluation of the information relating to the design and operation of the Windscale piles, and to review the factors involved in the controlled release of Wigner energy, was presented to Parliament in July, 1958. The Authority subsequently decided to close the piles and seal them, in view of the expense which would have been involved in rehabilitating No. 1 pile and in altering No. 2 pile to conform with the recommendations made by the Committee, and also because both piles were approaching obsolescence.

The total number of visitors to the Authority's establishments during the year was 60,889.

Internationally, the most important event of the year was the second Geneva Conference on the Peaceful Uses of Atomic Energy, held in September, 1958. Following the Geneva Conference, arrangements were made for representatives of Commonwealth countries to tour some Authority establishments.

An agreement for co-operation between the United Kingdom and Euratom was signed at the Foreign Office on February 4, 1959. Collaboration between twelve European countries in the development at the Atomic Energy Establishment, Winfrith Heath, of the high temperature gas-cooled reactor experiment - Dragon - is the subject of an agreement signed in Paris on March 23, 1959, under the auspices of the European Nuclear Energy Agency. During the year, bilateral agreements were concluded also with Japan and Portugal.

The terms of the first contract for the supply of fuel for a nuclear power station overseas were negotiated when the Authority agreed to supply fuel to Agip Nucleare for their Latina station in Southern Italy, being built under a contract between the Nuclear Power Plant Co. Ltd. and Agip Nucleare.

Research and development work on nuclear and thermonuclear weapons for Her Majesty's Government continued. After the weapon tests carried out in 1957, further devices in the megaton range were exploded in the Central Pacific during the year. Three rounds were fired in 1958, one in April and two in September. All were burst high up to minimise the possibility of significant radioactive contamination in the Pacific Ocean or on its islands. In addition, tests of kiloton devices suspended from balloons were successfully fired on Christmas Island in August and September, 1958.

A conference of experts to study methods of detecting violations of a possible agreement on the suspension of nuclear tests met in Geneva during July and August, 1958. The United Kingdom members of the Western Delegation were Sir William Penney and Sir John Cockcroft.

The Authority regret to report the death of two of their employees following an explosion at Aldermaston on February 26, 1959. No radioactive materials were involved in the accident.

The Board of Inquiry set up by the Prime Minister issued an interim report on March 10, 1959, which concluded that the explosion must be regarded as an accident.

ABOVE. *The United Nations Second International Conference on the peaceful Uses of Atomic Energy, Palais des Nations, Geneva, September, 1958.*

BACK COVER. *Chapelcross - High and low pressure steam pipes leading from a reactor to the turbine hall.*

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The Authority's Reactors

RESEARCH AND EXPERIMENTAL REACTORS

31st MARCH 1959

Name	Location	Date of Start-up	Peak Neutron Flux	Maximum Heat Output	Moderator	Coolant	Fuel	Purpose
1. GLEEP	Harwell	1947	$3 \cdot 7 \times 10^{10}$ thermal n/cm²/sec	100 kW	Graphite	Air	Natural uranium metal and oxide	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. DIMPLE	Harwell	1954	about 10^8	100 Watts	Heavy water	None	Varies	Thermal reactor and pile oscillator studies
4. LIDO	Harwell	1956	10^{12}	100 kW	Light water	Light water	Uranium 235	Thermal reactor studies, including shielding
5. DIDO	Harwell	1956	10^{14}	10 MW	Heavy water	Heavy water	Uranium 235	Nuclear reactor material studies, isotope production, neutron physics, radiation chemistry
6. NERO	Harwell	1957	about 10^8	Less than 100 Watts	Graphite	None	Enriched uranium	Investigations for advanced graphite-moderated reactors
7. PLUTO	Harwell	1957	10^{14}	10 MW	Heavy water	Heavy water	Uranium 235	Studies on nuclear reactor materials, isotope production
8. NEPTUNE*	Harwell	1957	about 10^8	Less than 100 Watts	Light water	None	Enriched uranium	Studies by an Admiralty team at Harwell, in association with Authority staff, on water-moderated core designs
9. D.M.T.R. (PLUTO type)	Dounreay	1958	10^{14}	10 MW	Heavy water	Heavy water	Uranium 235	Studies on nuclear reactor materials
10. HORACE	Aldermaston	1958	about 10^8	10 Watts	Light water	Light water	Uranium 235	To obtain basic nuclear information on HERALD

** Admiralty experimental reactor*

RESEARCH AND EXPERIMENTAL REACTORS UNDER CONSTRUCTION

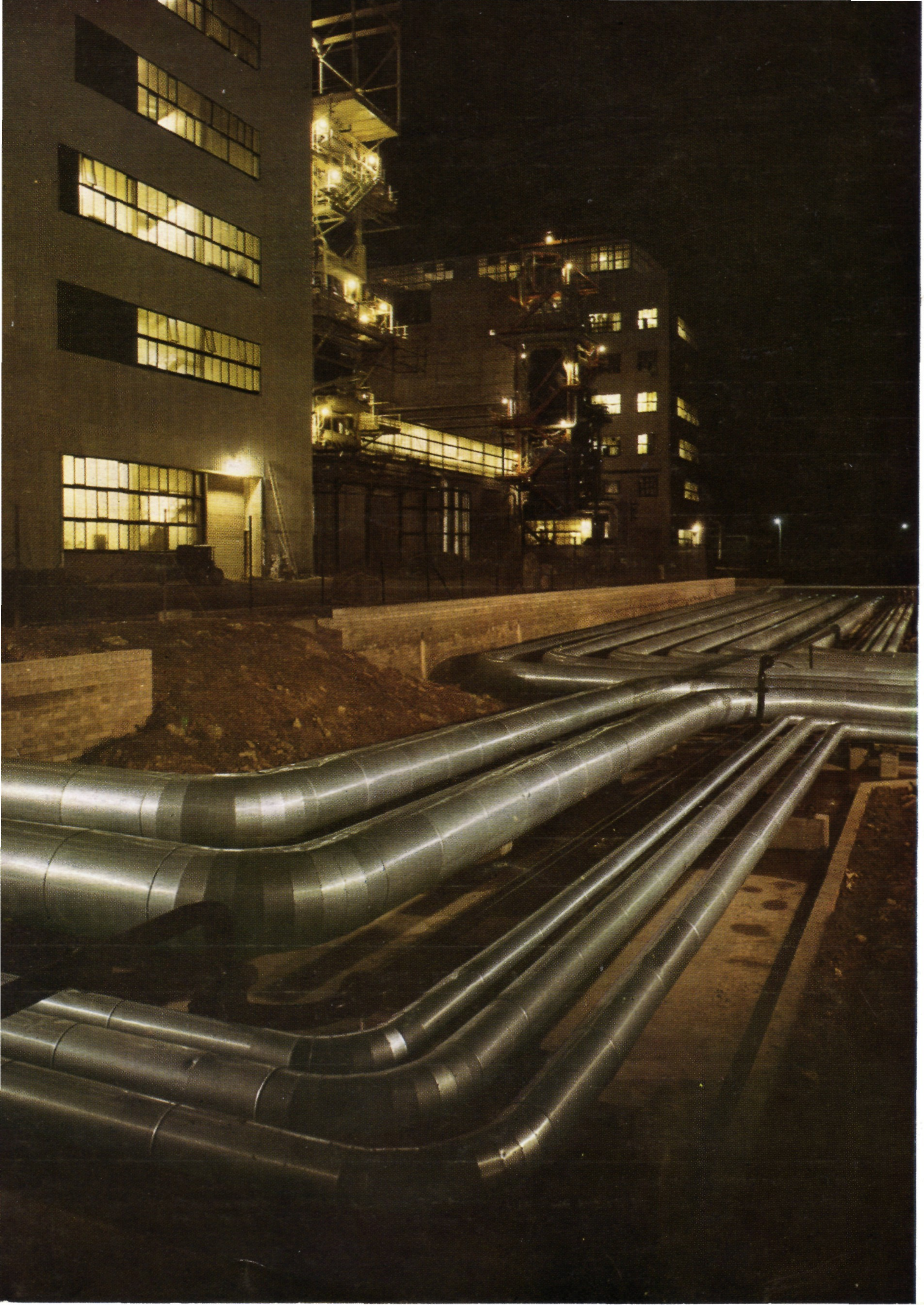
Name	Location	Date of Start-up	Peak Neutron Flux	Maximum Heat Output	Moderator	Coolant, or heating gas	Fuel	Purpose
11. Fast Reactor	Dounreay	1959	—	60 MW	None	Sodium potassium alloy	Enriched uranium/ plutonium	Fast reactor breeding studies
12. HERALD	Aldermaston	1959	10^{14}	5 MW	Light water	Light water	Uranium 235	Neutron physics, radio-chemical studies, isotope production
13. ZENITH	Winfrith Heath	1959	10^8	100 Watts	Graphite	Nitrogen used as heating gas	Ceramic elements containing highly enriched uranium oxide	Reactor physics investigations for high temperature gas-cooled systems. (800°C in core, 400°C in reflector)
14. A.G.R	Windscale	1961	$3 \cdot 5 \times 10^{13}$	100 MW	Graphite	Carbon dioxide	Enriched uranium oxide	Study of advanced power reactors (Maximum fuel temperature 600°C)
15. HERO	Windscale	1961	—	A few Watts	Graphite	Carbon dioxide used as heating gas	Enriched uranium oxide	Nuclear studies for advanced power reactors

PLUTONIUM/POWER-PRODUCING REACTORS IN PRODUCTION AND UNDER CONSTRUCTION

16 to 19 Calder ('A' and 'B') (2 stations each of 2 reactors)	Calderbridge	Station 'A' 1956, Station 'B' 1958	—	200 MW per reactor (37 MW (E) net)	Graphite	Carbon dioxide	Natural uranium	Plutonium and electricity production
20 to 23 Chapelcross (4 reactors) (i) 1st reactor critical, 1958. (ii) 3 reactors under construction.†	Annan	1958 (1st reactor)	—	200 MW per reactor (37 MW (E) net).	Graphite	Carbon dioxide	Natural uranium	Plutonium and electricity production

† The second reactor at Chapelcross went critical in May, 1959.

NOTE: *ZEUS was dismantled in September 1957, and the fuel has been transferred to Dounreay. ZEPHYR was dismantled in June 1958. HAZEL was dismantled in September 1958 after completion of some measurements with U 233 solution and the equipment was transferred from Harwell to Dounreay.*



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