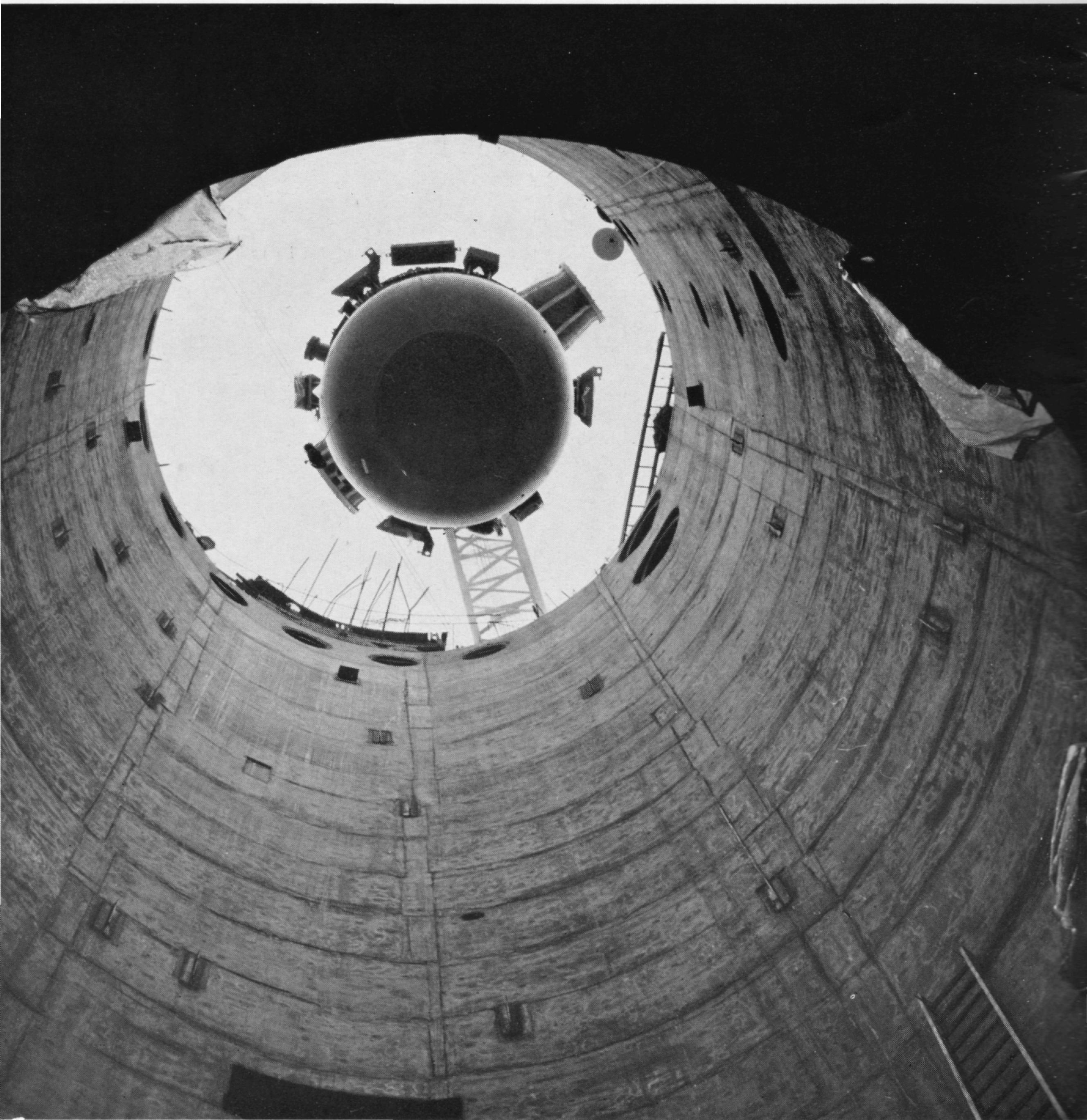
PRICE 2/6 NET

An illustrated summary of the Sixth Annual Report
from 1st April 1959 to 31st March 1960 of the
UNITED KINGDOM ATOMIC ENERGY AUTHORITY
with some additional material to 1st July 1960

atom 1960

REACTOR DEVELOPMENT

ADVANCED GAS-COOLED REACTOR, WINDSCALE. *Lowering first heat-exchanger into position, March,* 1960.



The first aim of the Authority's Reactor Development Programme is to ensure the successful construction and operation of the nuclear power stations now under construction.

At the same time advanced reactors must be developed that will provide progressively cheaper power.

During 1959-60 the national energy position became easier,* but this did not affect the objectives of the long-term reactor development programme.

The Authority have given the highest priority to their work in support of the electricity generating board's reactors. These reactors will have high capital costs but will operate at base load because of their high capital and low fuel costs. Reductions in capital costs are essential if nuclear power is to be competitive not only at base load but also at the lower load factors at which nuclear power stations will have to operate when substantial nuclear capacity has been built. Whilst there has been a steady reduction in the capital costs of the successive stations using magnox canned natural uranium fuel, the development of more advanced reactors provides the best method of achieving further substantial reductions.

The development of reactors beyond the present type falls into two stages. The first envisages reactors with low capital costs obtained with the aid of slightly enriched fuel. The second stage is the development of reactors having both low capital costs and small net consumption, or even a net gain (breeding), of fissile material. For the first stage the Authority have concentrated on the advanced gas-cooled reactor and for the second on the fast breeder reactor and the high temperature gas-cooled reactor.

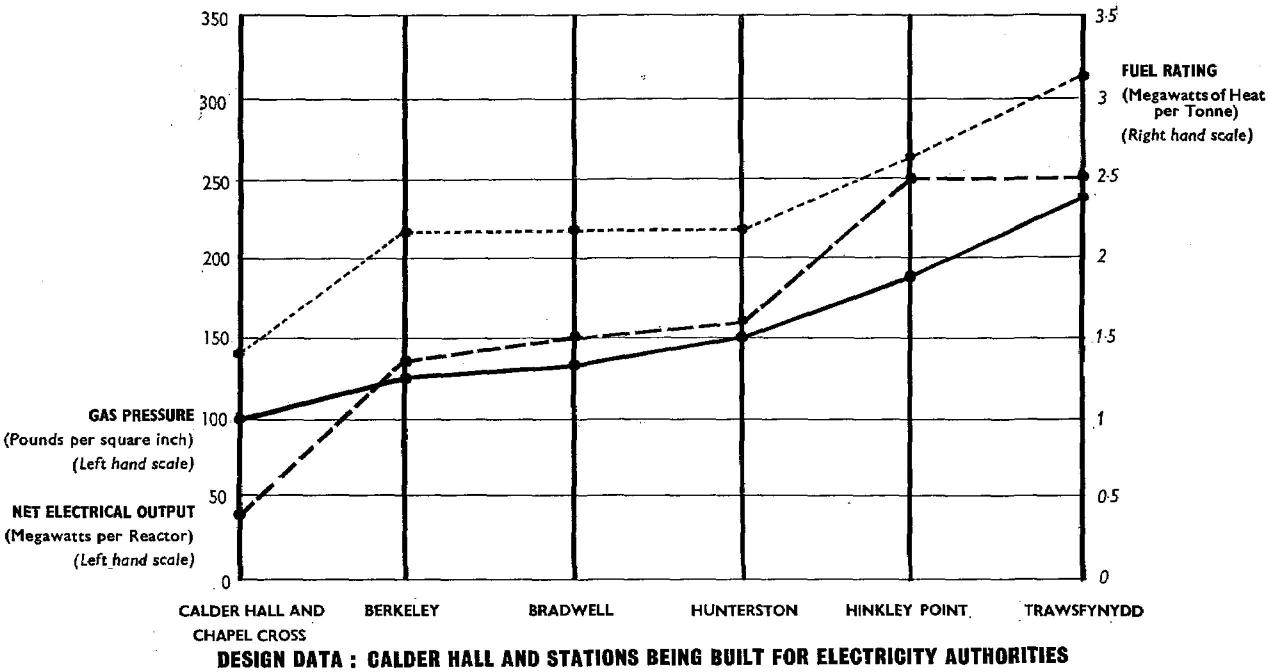
*In June, 1960, Her Majesty's Government decided that orders should continue to be placed for nuclear power stations (for the electricity authorities) at the rate of roughly one every year.

As the capacity of individual stations is expected to increase, the effect of this decision is likely to give the country some 5,000 Megawatts of nuclear capacity in 1968.

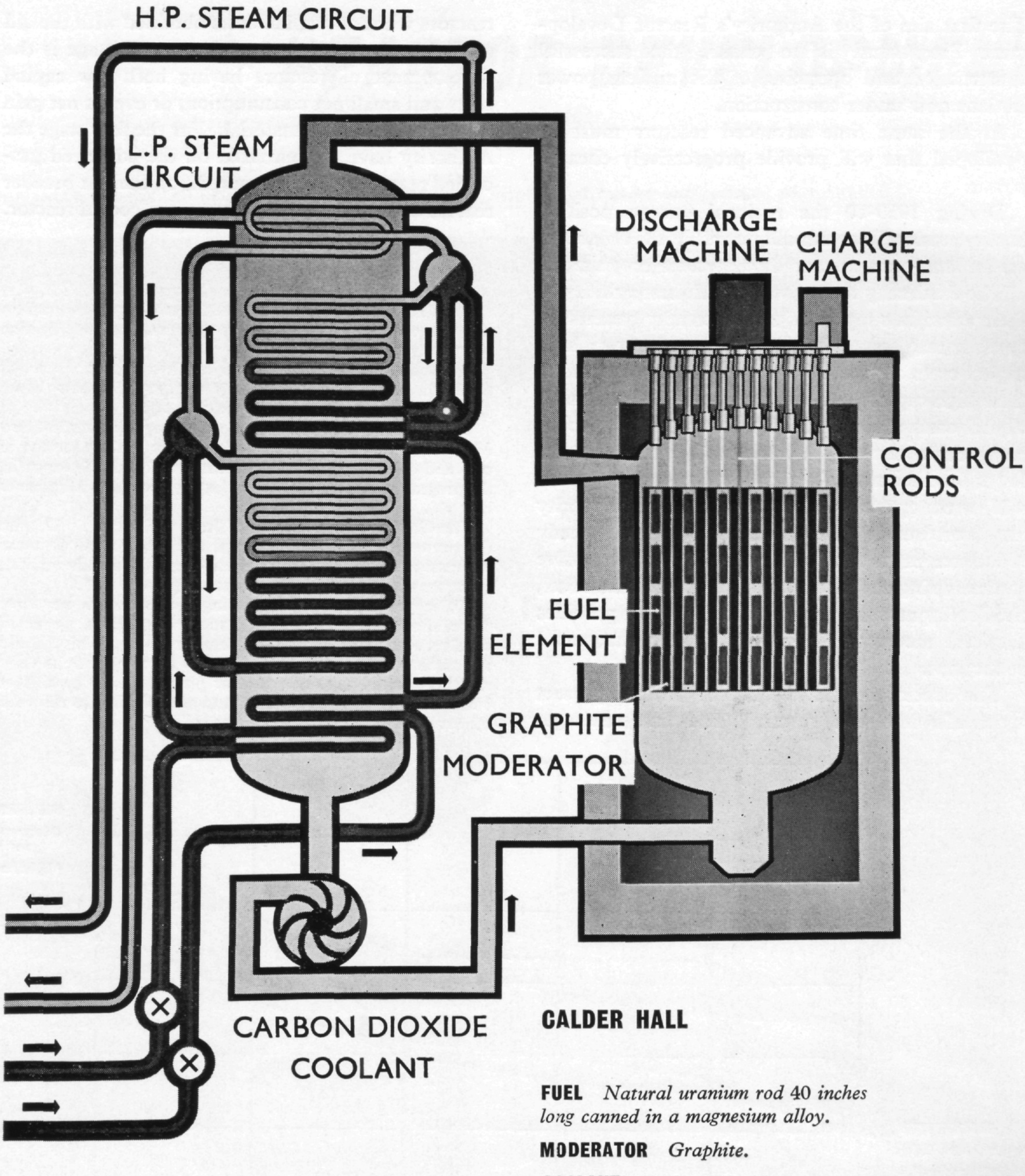
The original programme (1955) proposed 1,500-2,000 Megawatts by 1965. In 1957, when there was a shortage of coal and oil supplies had been disrupted by the Suez crisis, the programme was revised to envisage 5,000-6,000 Megawatts by 1966.

The Government statement of June, 1960, said : " 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 . . . ".

" The proposed rate of ordering means that at any time there should be five or six stations in various stages of development from design to commissioning. This should fully maintain the rate of development of our nuclear technology and should also sustain a nuclear plant industry capable of competing for overseas business and of expanding to meet the higher level of our own future needs."



DESIGN DATA : CALDER HALL AND STATIONS BEING BUILT FOR ELECTRICITY AUTHORITIES



CALDER HALL

FUEL *Natural uranium rod 40 inches long canned in a magnesium alloy.*

MODERATOR *Graphite.*

COOLANT *Carbon Dioxide.*

LOCATION *Calder Hall and Chapelcross*

START UP *October 17th,* 1956 (*First Calder Reactor*).

FIVE COMMERCIAL STATIONS *of this type are now under construction. The first two are due to come into operation in* 1961-62.

CALDER HALL TYPE REACTOR

By March, 1960, eight Calder Hall-type reactors were operating. They have a combined electrical output of 300 megawatts (net).

At the beginning of the year five reactors were in operation, four at Calder (Cumberland) and one at Chapelcross (Dumfriesshire). The remaining three reactors were brought to full power during the year. The electricity sent out from the Chapelcross station now represents some 20 per cent of the base load of the South of Scotland Electricity Board.

The year was one of noteworthy improvements in reactor operating procedures. Availability was increased by a 50 per cent reduction in scheduled shut-down time; this was achieved by streamlining charge and discharge schedules and planning their integration with maintenance schedules. Including closures for recharging, an operating availability of more than 80 per cent was achieved: this is important in view of the major use of this type of reactor as a base-load power station.

The thermal output of the reactors was increased to 15 per cent above the design capacity. Re-blading of the turbines is necessary to allow an equivalent increase in the electricity generation.

Reactor trials showed that the present maximum fuel element operating temperature can be raised with no loss of reliability. Modified operating conditions are therefore being introduced which will further increase the rating of the reactors.

The Calder and Chapelcross reactors have not only demonstrated the reliability of this reactor-system over several years; they have also been used for experiments in support of the development of the stations which industry is building for the electricity authorities at Bradwell, Berkeley, Hinkley Point, Hunterston and Trawsfynydd. (The Authority act as consultants to the Electricity Boards for the nuclear part of these stations).

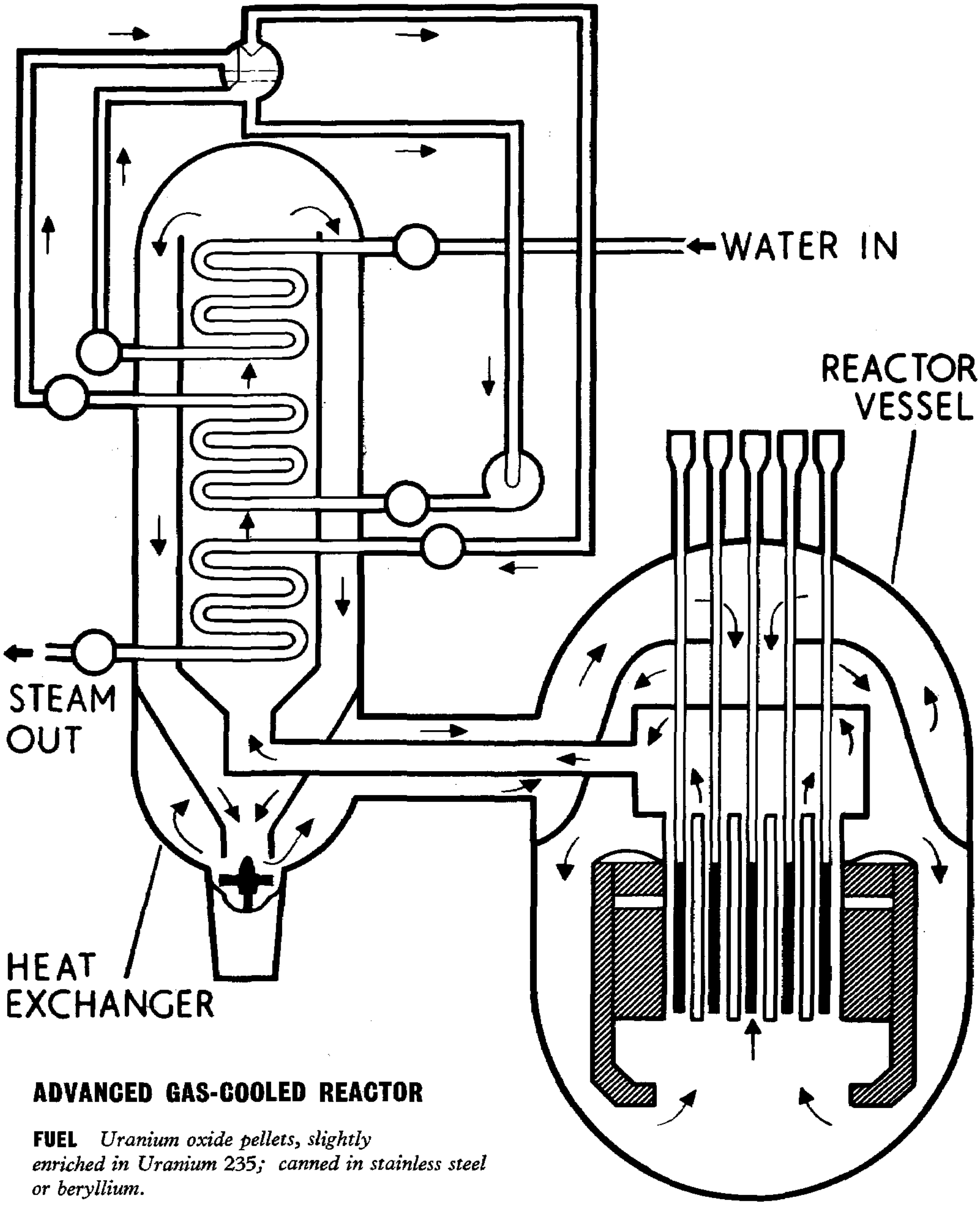
Work on this reactor system remained the largest element in the Authority's reactor development programme. It was directed to ensure the maximum reliability and the lowest possible generating costs for "magnox systems" (i.e. systems using a magnesium alloy can for the uranium fuel); for although the cost of power from the earlier magnox stations will be somewhat higher than that from the latest design of coal fired station, the magnox system still retains scope for substantial reductions in power costs.

Background information on the performance under irradiation of fuel elements (for the civil reactors) is provided by study of the performance of Calder fuel elements in the reactors at Calder Hall and Chapelcross. Since these reactors were commissioned nearly 200,000 elements have been loaded and irradiated. These large numbers provide a useful and statistically sound basis for assessing the reliability of the fuel elements; the failure rate has in fact been well below 0.1 per cent.

A programme has been set in hand for the testing of civil fuel elements in which groups of reactor channels have been loaded with fuel elements designed to simulate those proposed for the civil magnox power stations. These experiments have proved invaluable in revealing, at an early stage, weaknesses in design such as excessive vibration in the coolant gas stream and will enable remedial action to be taken before large scale production was due to start.

It is important to ensure that fuel in the civil stations has an available heat content averaging 3000 MWD/Te (Megawatt Days per Metric Tonne). One of the Calder Hall reactors is being used for a special experiment to investigate physics problems associated with long "burn-up". By March, 1960, the average irradiation level of Calder fuel elements in this reactor had reached over 700 MWD/Te; a number of channels had exceeded 1000 MWD/Te; and a number of elements had achieved 2000 MWD/Te. (The design life of Calder elements is much lower than that for civil station fuel.) Information from a continuing research programme indicates that civil fuel elements should have an available heat content equivalent to 3000 MWD/Te, when equilibrium has been achieved.

The fuel development programme increasingly requires the examination of large numbers of highly irradiated fuel elements. In order to deal with these and the very large numbers which will arise from the operation of civil magnox stations at home and abroad the Authority have begun the construction at Windscale of very large and heavily shielded fuel examination facilities and metallurgical laboratories.



ADVANCED GAS-COOLED REACTOR

FUEL *Uranium oxide pellets, slightly enriched in Uranium* 235; *canned in stainless steel or beryllium.*

MODERATOR *Graphite.*

COOLANT *Carbon Dioxide.*

LOCATION *Windscale.*

START UP *Summer* 1961.

COMMERCIAL STATIONS *based on this design are likely to come into operation in the late* 1960's.

THE ADVANCED GAS-COOLED REACTOR

As the next development in gas-cooled reactor systems, the Authority have proceeded with the advanced gas-cooled system (A.G.R.). This reactor is fuelled with slightly enriched uranium oxide pellets canned in stainless steel or beryllium, it is moderated by graphite and cooled by carbon dioxide. The coolant gas outlet temperatures will be about 150°C higher than those of the magnox system.

Recent studies have confirmed that the A.G.R. system offers the best prospect for the early achievement of competitive nuclear power in the United Kingdom. Studies indicate that the system should be capable of substantially lower capital costs than magnox stations and that its prospects are good.

Construction of the prototype advanced gas-cooled reactor at Windscale should be completed by the spring of 1961 as planned.

The most important role of the prototype reactor will be the study of the irradiation performance of large quantities of fuel elements. The experience gained in the development of fuels for the magnox system has underlined the necessity for such large-scale testing.

The construction at Windscale of the experimental zero energy, high temperature research reactor (HERO) was started in September, 1959. It will be used to study the physics of the A.G.R. system.

Initial experiments will be carried out on beryllium and stainless steel-clad uranium-oxide fuels. Later experiments will use reactor fuel containing plutonium so as to simulate the state of A.G.R. type reactors after prolonged burn-up of fuel. Differential heating and cooling arrangements will enable fuel and moderator temperature coefficients to be determined. Meanwhile, experimental work is in progress using existing stacks.

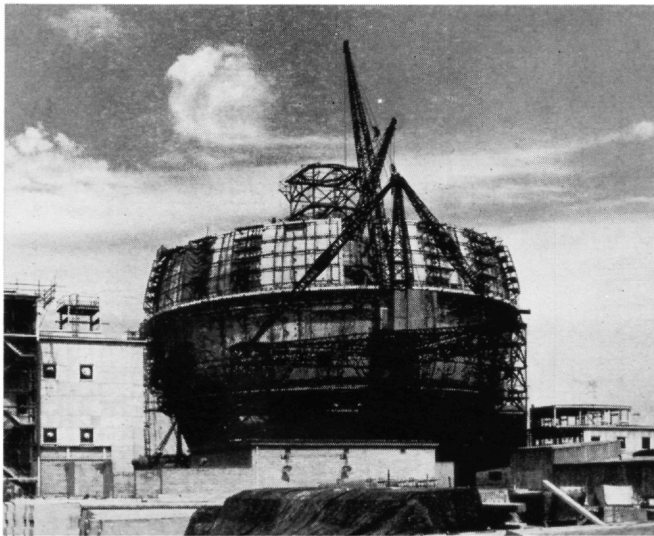
The formation of plutonium, as fuel burns, leads to a positive moderator temperature co-efficient of reactivity in the A.G.R. In view of the higher rating, and because the beryllium used as a canning material is also significant as a moderator, the problems of control are increased. From experimental and theoretical work that has been carried out, it has been shown that a simple system will suffice to control the power output of the Windscale prototype A.G.R. However, power producing A.G.R. reactors would be appreciably larger, and the situation would be more complicated. A considerable amount of work, both theoretical and experimental, has therefore been devoted to the control of large A.G.R. systems. To facilitate control the coolant gas may be passed through a moderator before introducing it to the fuel channels; by this means the temperature of the moderator is maintained at a level close to that of the inlet gas temperature, and thus suffers a much smaller temperature change with change of power level. This re-entrant core arrangement has also been adopted for the Windscale prototype A.G.R., in order to demonstrate its value for application to the larger power production reactors.

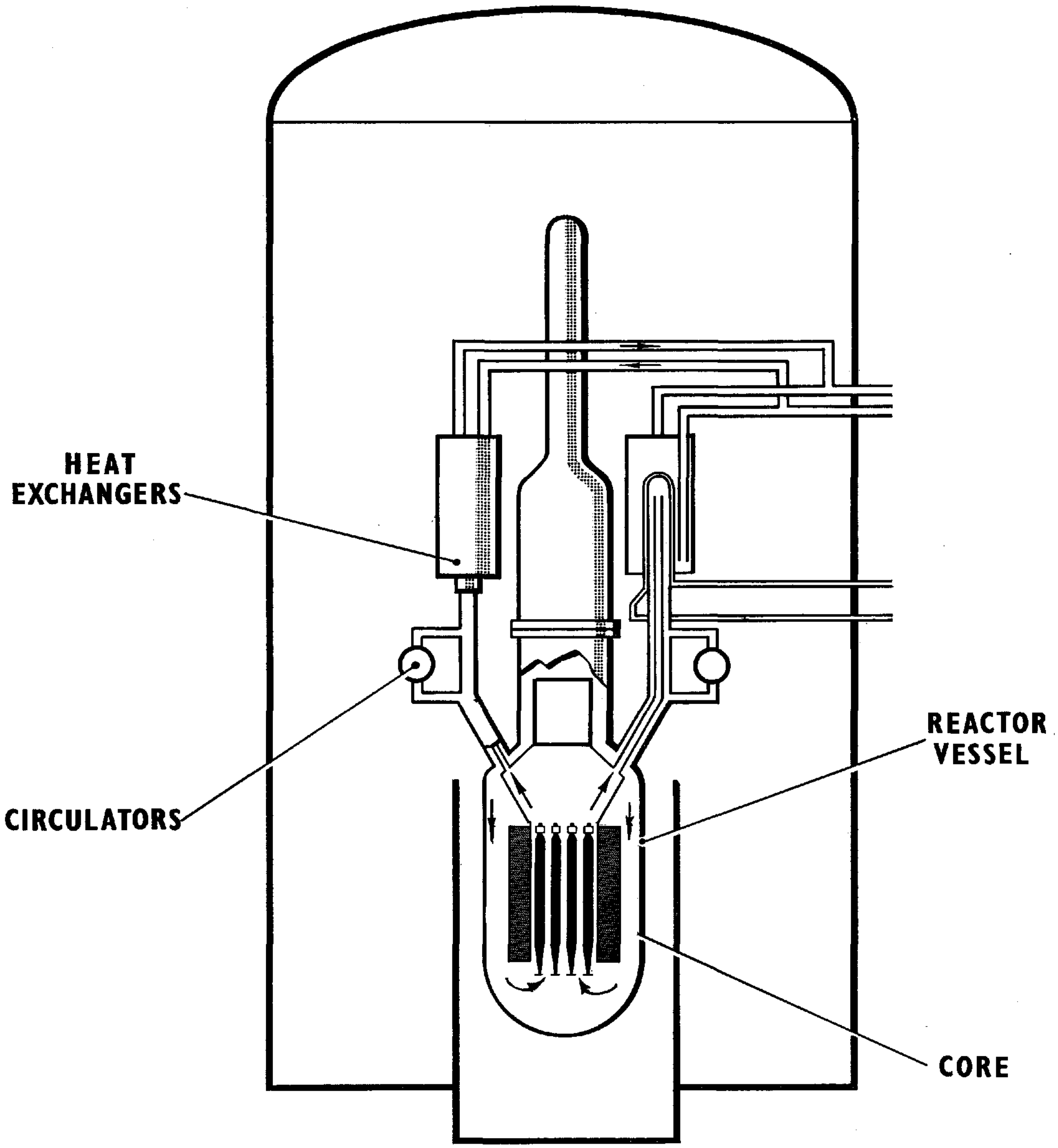
The adoption of the re-entrant core will still leave the temperature of the core sufficiently high to avoid the build up of amounts of stored energy in the graphite.

Civil A.G.R. Study

Design studies have been carried out to optimise the A.G.R. system for large stations. In order to check that forecasts for a civil A.G.R. power station were based on sound assumptions, a further study was carried out by the Authority jointly with the Central Electricity Generating Board. This has confirmed the promise of considerable reductions in capital cost and in total cost of power generated compared with magnox stations.

Advanced Gas-cooled Reactor under construction at Windscale.





HIGH TEMPERATURE GAS-COOLED REACTOR

FUEL *Pellets of enriched uranium, thorium and carbon in a graphite sheath* 8 *ft. long.*

MODERATOR *Graphite.*

COOLANT *Helium.*

LOCATION *Winfrith ("Dragon" Project).*

COMMERCIAL STATIONS *of this type may be introduced in the early* 1970*'s.*

HIGH-TEMPERATURE GAS-COOLED REACTOR

The high temperature gas-cooled reactor (H.T.G.C.) is an attempt to reduce nuclear power costs by carrying the technology of the gas-cooled graphite-moderated reactor system beyond the limitations of the A.G.R. *It looks an increasingly promising source of power for the* 1970's.

The DRAGON experiment, a joint project under the auspices of O.E.E.C. will test the principles of the H.T.G.C., and almost all the effort devoted by the Authority to this system during the year has been related to this experiment at Winfrith. Good progress was made during the year in setting up the project, in the design of an experimental H.T.G.C. reactor, and in the associated research and development work.

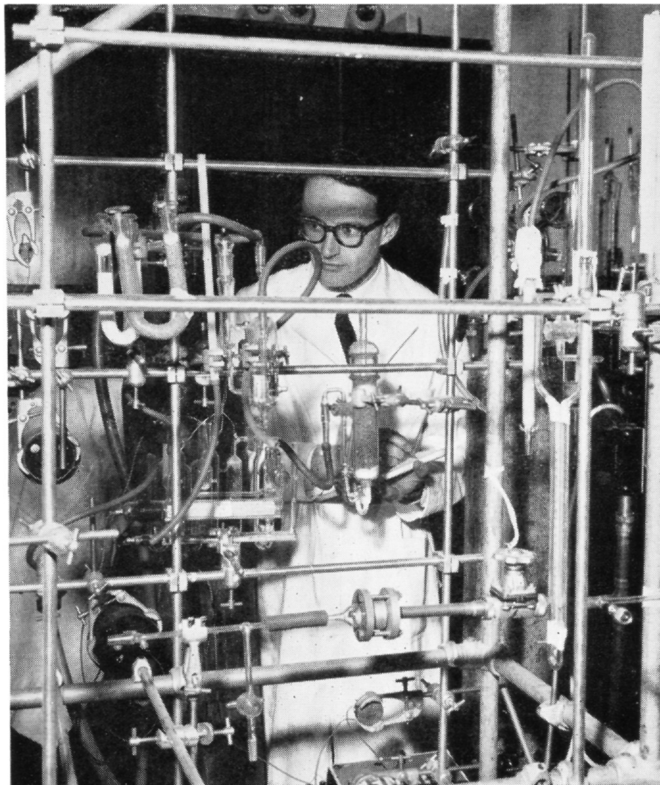
The DRAGON experimental reactor will test the major items of technology: fuel elements, gas-cooling circuits and methods for purging the system of fission products. It will operate initially with uranium highly enriched in the isotope 235 as fuel and thorium as fertile material. On account of its small size, the DRAGON reactor will not show a high conversion factor, but nevertheless should give valuable information on the physics involved and a reasonably long burn-up for the fuel elements.

Because of its high operating temperature, the H.T.G.C. system is designed to use graphite in place of metal for canning the fuel. Ordinary reactor graphite, however, is not suitable for the fuel-element can because it is permeable and would allow fission products to diffuse into the coolant gas and so require complex plant to purge the gas of the fission products. The Authority, therefore, initiated an extensive programme with the collaboration of industry and the Royal Aircraft Establishment for the development of graphite with low permeability but sufficiently free from neutron absorbing impurities. Graphite of the required degree of impermeability has now been made, but its performance under prolonged irradiation has yet to be established. The study of irradiation behaviour and of the mechanism by which fission products diffuse through graphite is, therefore, an important feature of the present programme.

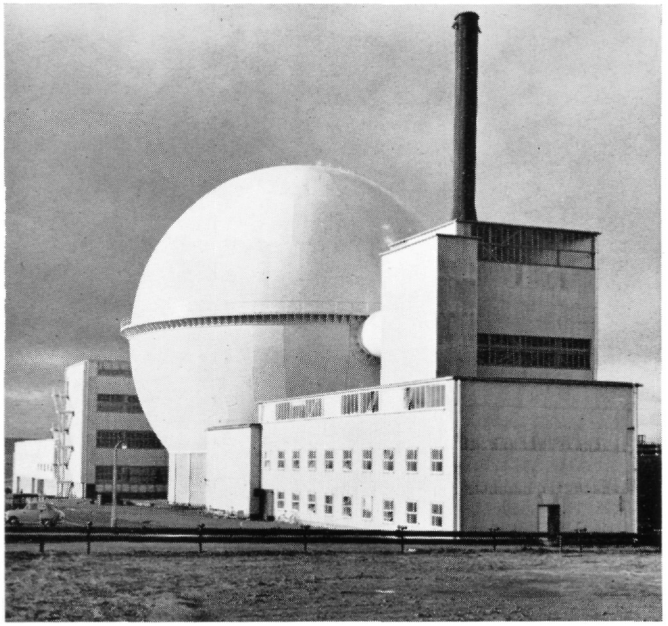
Uranium/thorium/graphite fuel elements have been irradiated at high temperatures up to a high proportion of their design life, and have given encouraging results; dimensional changes were small, and the permeability and thermal conductivity of the graphite container were established.

The zero energy reactor ZENITH, which was designed to support the work on the H.T.G.C., has been completed. Commissioning started in September, 1959 and over a period of a month the temperature of a dummy core was raised to 750°C by electrical heating of the circulating gas (nitrogen). It proved necessary to modify the heating arrangements but the reactor physics work continued with the reactor unheated. Fuel elements were loaded into the core during November and December, and the reactor became critical shortly before Christmas. Measurements have been made to determine the flux pattern and the effectiveness of the control devices in a core similar to that to be used in the DRAGON reactor.

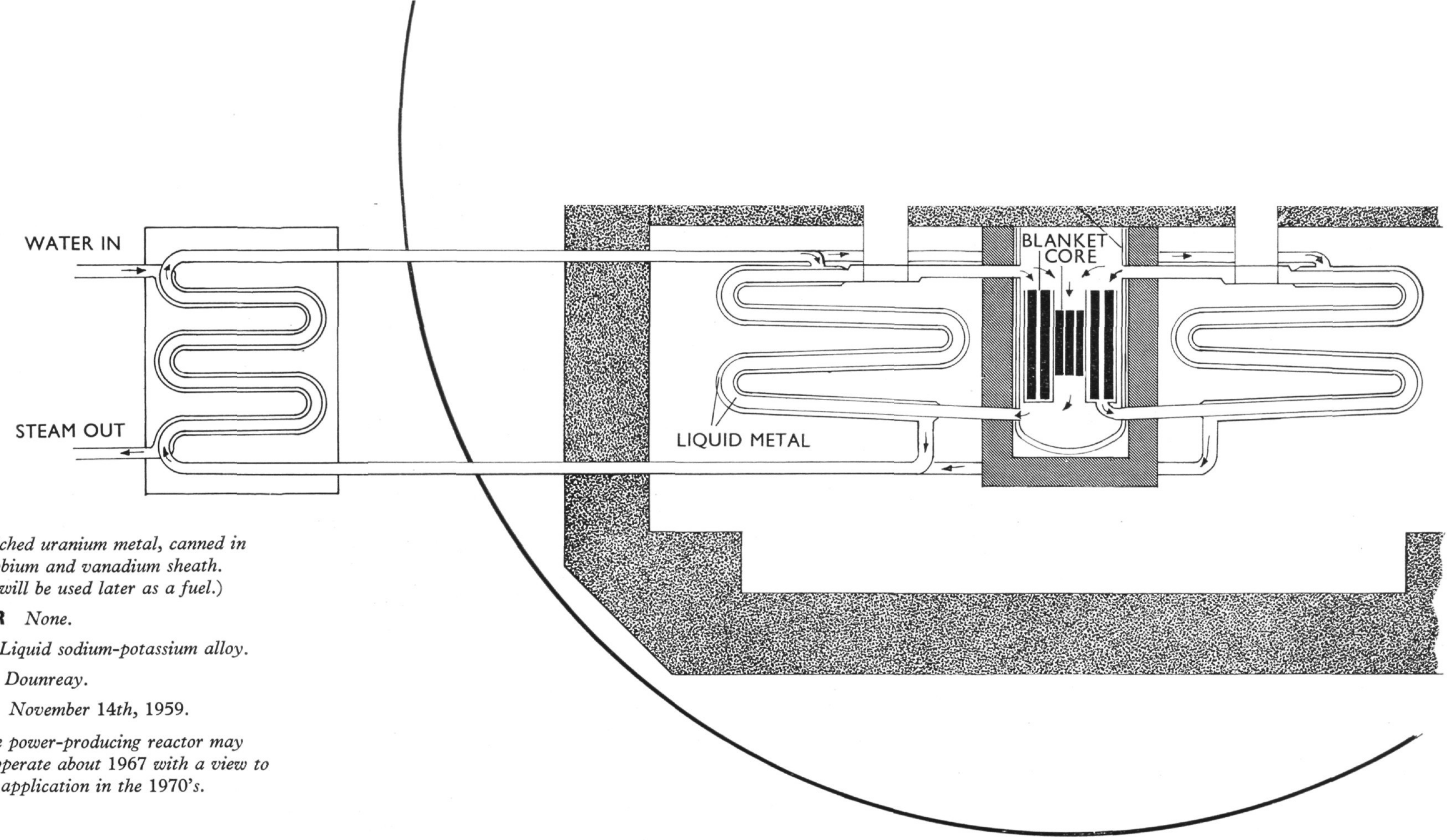
A Norwegian chemist, one of the scientists from 12 *European countries working on the "Dragon" project.*



FAST BREEDER REACTOR



Experimental Fast Breeder Reactor at Dounreay, Caithness.



FUEL *Enriched uranium metal, canned in a hollow niobium and vanadium sheath. (Plutonium will be used later as a fuel.)*

MODERATOR *None.*

COOLANT *Liquid sodium-potassium alloy.*

LOCATION *Dounreay.*

START UP *November 14th,* 1959.

A prototype power-producing reactor may be built to operate about 1967 *with a view to commercial application in the* 1970*'s.*

The fast breeder reactor system offers the prospect of low-cost power, because of the potentially low capital costs and low fuel cost.

The capital cost should be low, because the very high heat rating of the fast reactor leads to a small core and because a high operation temperature gives a high thermal efficiency. The eventual fuel cost should be low, because these reactors will breed more plutonium than they consume. These fundamental advantages are indisputable, but a great deal of work will be necessary to establish that they can be commercially exploited. However, on the basis of the present information, the Authority believe that a power-producing fast breeder reactor system will be the best and most economic way of using plutonium.

The plans for the development of fast breeder reactor systems are as follows. Information and experience are to be gained on the Dounreay Fast Reactor, which went critical in November, 1959. This reactor will gradually be worked up to full output. It will then provide the necessary environment for testing various designs for fuels and fuel elements suitable for a full-scale power-producing fast reactor. *A prototype power-producing reactor may be built for operation about the year* 1967, *the development of which will enable a commercial power station to be specified.*

Whereas the fuels for the prototype will be tested in the Dounreay Fast Reactor, the neutron physics will require study in a facility which allows ready reassembly of the core into various configurations. It will not be possible to do this in the Dounreay Fast Reactor, once it has come to full power, and a zero energy facility will be provided.

Good progress was made with the Dounreay Fast Reactor during 1959-60. Following the first stage in the commissioning, the charge of 120 tons of sodium and potassium alloy was prepared and charged into the primary and secondary heat

exchangers. The reactor was then made ready for operation after a very detailed testing programme had been carried out to ensure the reliability of every component. The reactor went critical in November, 1959, and was then run at low power (100 watts), but at high temperature, in order to test under operating conditions the reliability of the components and safety devices. Some trouble was experienced through formation of oxides in the coolant, and improvements were made to the oxide clean-up circuits. In general, experience during start-up confirmed the Authority's confidence in the potentialities of this reactor system.

During the initial stage of low power operation, the physics programme required for testing the control problems of fast reactor systems was started. At the conclusion of this initial low power stage, the reactor was shut down for the programmed modifications to the core, involving the fitting of an adaptor to part of the core, so that other, more advanced, types of fast reactor fuel elements can be tested.

Knowledge of this system has been further increased through cordial and helpful collaboration with the U.S.A.E.C. and with the Power Reactor Development Company of America. Information and visits have been exchanged under these agreements covering data on the Enrico Fermi, EBR II and Dounreay reactors, and associated zero energy work. Visits were also exchanged with the Russians, who are now operating a plutonium oxide fuel fast reactor experiment of 5 MW(Thermal).

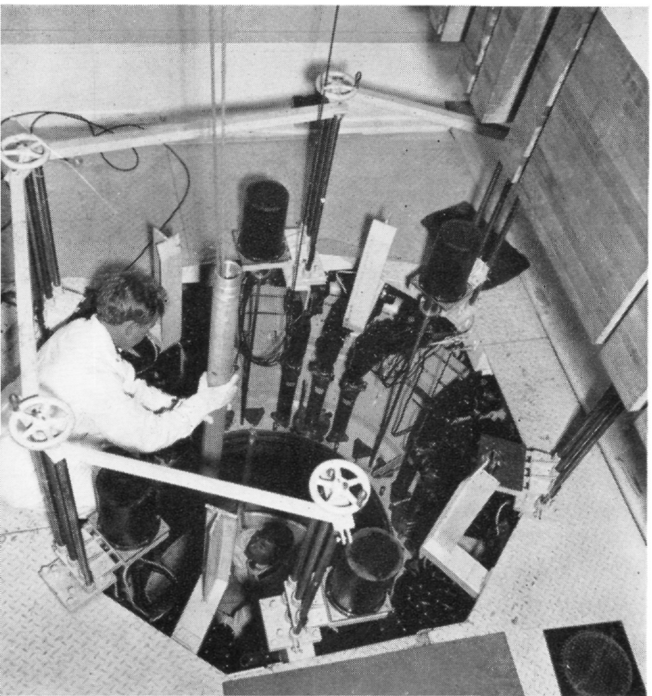
A start has been made on the study of some suitable fast reactor systems for civil power production, and the optimisation of the characteristics of such systems. These studies will pave the way for the investigation of the design of a prototype, on which effort will be increasingly devoted in 1960-61.

The Steam Generating Heavy Water Reactor

The use as coolant of steam instead of carbon dioxide in heavy water-moderated systems offers substantial advantages. During 1959-60, in the course of the design study of a steam cooled-heavy water (SCHW) reactor prototype, a further development of this concept has taken place; instead of generating the steam in external heat exchangers, it is now proposed that the water should be evaporated in the reactor core itself. This idea of a steam generating heavy water reactor (S.G.H.W.) offers savings on capital cost since the light water coolant in the core would contribute towards moderation and the investment of heavy water would be reduced; furthermore, there would be no need for external heat exchangers.

The immediate object of study is a reactor using water and steam coolant in pressure tubes inserted through a heavy water container, steam being separated outside the reactor before being returned for superheat. The combination of the two different moderators and the use of the boiling principle introduces novel problems in reactor physics and stability, and the performance cannot at present be predicted to the required accuracy. Preliminary physics experiments will be carried out in DIMPLE to assist in assessing the feasibility and performance of the system. Work has also proceeded on experimental investigations of heat transfer problems in water/steam systems and on a feasibility study of a possible prototype power reactor.

A decision on whether to proceed with the construction of an S.G.H.W. will depend upon the results of this further work which will be reviewed later this year, and upon the availability of both technical manpower and financial resources.



Submarines

The Authority have continued to give advice to the Admiralty on the safety aspects of the "Dreadnought" submarine, which is an American "Skipjack" pressurised-water reactor installed in a British hull. In addition facilities and accommodation have been provided at Dounreay, together with help in the establishment of the Admiralty's development and training organisation.

Merchant Ships

The Authority were represented on the Committee for the Application of Nuclear Power to Marine Purposes and its sub-committees which assessed proposals put forward to the Government by industry for a 65,000 ton commercial tanker. The Government subsequently invited certain firms to make more detailed proposals in the form of tenders to the Ministry of Transport. The Authority have undertaken to help in the assessment of these tenders when they are received. The two reactor systems for which tenders were invited were a boiling water reactor and an organic liquid moderated reactor.

The Authority have made design studies of possible marine reactor systems for the Committee and from this work have drawn the general conclusion that reactor systems on known techniques will not compete on an economic basis with conventional ship propulsion. Considerable improvements will be required before economic operation is likely.

The Authority are continuing studies of organic liquid cooling and boiling water systems, and the possibilities of steam generating and steam cooled heavy water systems for ships.

The core of the ZENITH reactor at Winfrith, Dorset. It is being used initially to obtain data for the "Dragon" project.

Sample of uranium concentrate from Australia being assayed in the Authority laboratories at Springfields.

FUEL FOR THE REACTORS

The manufacture of uranium cartridges for the Calder and Chapelcross reactors is now being carried out on the production lines of the new factory at Springfields. The new fuel element production lines have been designed to meet the requirements of the nuclear power programme and the Authority's reactors and will, when running at full capacity, be capable of an output of more than 300,000 uranium metal fuel elements per annum.

The manufacture of the first fuel charges for the civil power stations at Bradwell and Berkeley was about to start in March, 1960.

The C.E.G.B. and S.S.E.B. nuclear power stations have two nuclear reactors per site and each reactor requires between 250 and 400 tonnes of fuel for the initial charge. The value of these charges is of the order of £5m. and £8m. respectively. After commissioning, the annual rate of fuel replacement is expected to be between one fifth and one quarter of the initial charge.

Several thousand tonnes of natural uranium fuel will be supplied by the Authority during the next few years and much of the production planning and supply organisational work involved was undertaken during the year. A fuel element is a precision article. Although mass production methods of manufacture are necessary, each element must be subjected to individual treatment and rigorous inspection. There

Metallographic examination of specimen of beryllium—a possible canning material for nuclear fuels.

may be 100 or more fuel elements per tonne of fuel so that a typical reactor may contain over 30,000 individual uranium cartridges.

The failure in service of a fuel element leads to serious loss of reactor operating time and if undetected can provide a hazard to the continued operation of the reactor. It is, therefore, of vital importance to prove both the soundness of the fuel element design and of the production and inspection methods adopted. Very considerable effort has been devoted to commissioning the new production lines and improved inspection methods have been introduced.

Although research and development and out-of-pile proving trials can make a great contribution towards establishing the basic soundness of a design, only reactor proving trials on a statistically significant scale can finally prove both the design and the production and inspection methods. Because a very small number of failures is important, the proving trials must be carried out on a considerable scale to demonstrate the required degree of integrity: thus in the case of Calder and Chapelcross reactors the maximum number of failures that could, to date, be attributed to defective welds is of the order of 0.005 per cent. Consequently a new weld arrangement or manufacturing technique would need to demonstrate a comparable or better performance rate in proving trials.

Reactor proving trials on the final design of the fuel elements for Bradwell, Berkeley, Hinkley Point and Hunterston during the past year have involved the manufacture of large numbers of prototype fuel elements during the commissioning period in the new factory.

Power reactors are being constructed in Italy and in Japan by the Nuclear Power Group and by the General Electric Company Limited respectively. Construction contracts have been signed between these British companies and Societa Italiana Meridionale per l'Energia Atomic, in Italy, and the Japan Atomic Power Company. The Authority have negotiated heads of contract for the supply of fuel with both these organisations. The detailed fuel and reprocessing contracts, which still have to be negotiated, will necessarily be lengthy documents involving many matters not previously the subject of commercial agreement. The Italian station at Latina and the Japanese station at Tokai Mura are single reactor sites and will require about 290 and 200 tonnes of nuclear fuel respectively for the initial charges. The annual consumption of nuclear fuel of each station after commissioning will be about 65 and 50 tonnes respectively.

Fuel for Research Reactors

Enriched uranium fuel is manufactured by the Authority for their own materials testing and research reactors and also for other similar reactors both at home and overseas. During the year a fuel supply and reprocessing contract was signed with the Danish Atomic Energy Commission and their M.T.R. reactor at Risoe is now operating on fuel supplied by the Authority. The Authority also supply enriched fuel elements for the Hifar materials testing reactor operated by the Australian Atomic Energy Commission. Negotiations are proceeding for the supply and reprocessing by the Authority of research reactor fuel for two reactors under construction in Germany. Enriched fuel has been supplied by the Authority for research reactors manufactured in the United Kingdom.

Several United Kingdom universities have installed sub-critical assemblies for teaching purposes. Each assembly utilises about 5 tonnes of natural uranium supplied and fabricated by the Authority. Educational bodies are now becoming interested in reactors using enriched fuel and it is expected that the Authority will be called upon to supply two or three fuel charges, totalling about 10 kilos of uranium-235 during the next few years.

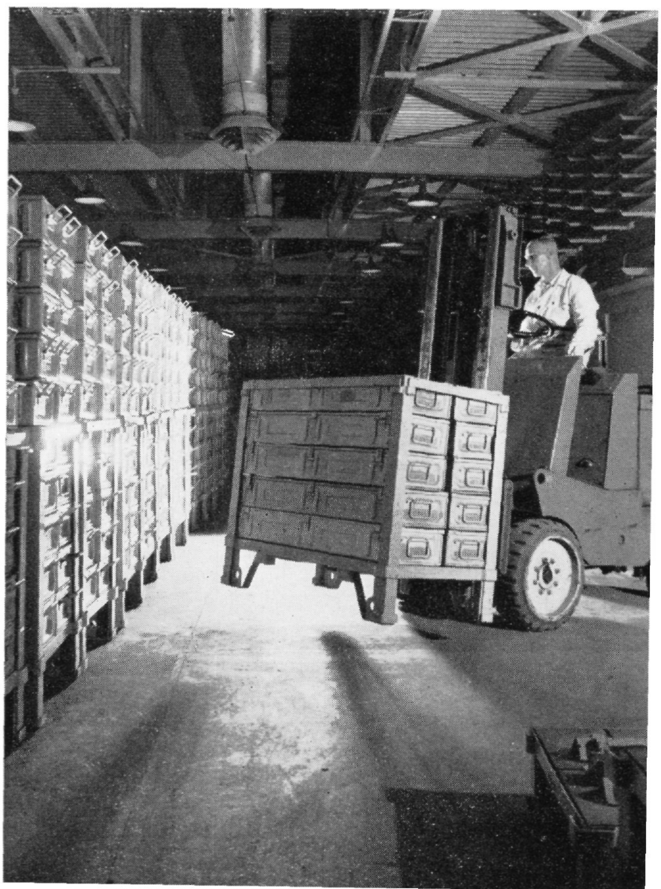
New types of nuclear fuel

New designs of nuclear fuel are being devised by the Authority and by industry. The feasibility and probable cost of manufacture need to be known before development of the particular reactor system can be pursued. Enquiries of this type are increasing and the Authority are examining a variety of fuel designs and are giving guidance on the economics of design from the manufacturing standpoint.

Negotiations are proceeding with various foreign organisations regarding the possible grant of licences by the Authority for the manufacture overseas of natural uranium fuel elements by the Springfields process.

Checking fuel elements at the Springfields plant, which has been expanded to meet the requirements of the power programme.

Fuel element store. At full capacity Springfields will have an annual output of 300,000 *elements.*



RESEARCH AND DEVELOPMENT

Nuclear Physics Research

Research in nuclear physics is undertaken to extend our knowledge of the structure of the nucleus and provide accurate measurements of the nuclear properties needed for reactor design. Detailed understanding of the arrangement of nucleons (i.e. protons and neutrons) within nuclei and of the nature of the extremely strong forces which hold a nucleus together is still imperfect.

An extensive programme of work with the synchrocyclotron at Harwell has been devoted to acquiring new data in the energy range 20 to 150 MeV. The study of interactions between nucleons and nuclei has been pursued at fairly low energies up to 12 MeV, using the 5 MeV Van de Graaff generator and the newly completed 12 MeV tandem electrostatic accelerator at Harwell. (A similar machine at Aldermaston has operated satisfactorily during the past year.)

A new accelerating machine came into operation at Harwell in November, 1959, when the Neutron Project Laboratory started work. This will provide intense bursts of neutrons which can be used, in the time of flight method, to make precise measurements of the neutron cross-sections for various nuclei over a wide range of energies. The machine incorporates a linear accelerator capable of accelerating electrons to 30 MeV; the energetic electrons strike a target of mercury and release gamma rays which in turn release neutrons from a uranium target. The intensity of the neutron pulse is increased some tenfold by using in this target a sub-critical assembly of enriched uranium.

The aim of experimental work being carried out at Aldermaston with the 6 MV and 3 MV electrostatic generators is to contribute to measurements of fast neutron scattering and capture cross-sections of the number of neutrons emitted in the fission of uranium and plutonium isotopes and other similar data—all of which can be used to predict the critical size, breeding ratio and other properties of a fast reactor.

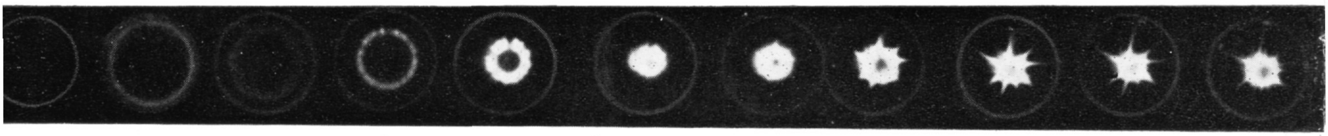
Flash-Radiography

Considerable progress has been achieved at Aldermaston in the provision of short duration radiographs of systems opaque to ordinary light and moving at high speed. Special low inductance Marx generators have been constructed giving a single voltage pulse of 1 MV or 2 MV with a duration of order 0.2 micro-seconds. They are believed to have appreciably better performance than any comparable generator for which published information is available. To work with these generators special X-ray tubes have also been developed, with both hot and cold cathodes.

Very High Speed Cameras

Very high speed cameras were originally developed at Aldermaston to record the growth of an atomic explosion during the first few millionths of a second. Today much improved designs are making important contributions to knowledge of pinched discharges in controlled thermonuclear reaction work, and A.W.R.E. cameras are used in this connection both at Harwell and at Aldermaston.

Two types of mechanical very high speed cameras are manufactured at Aldermaston. One, the streak camera, records along a length of film the size of a light source, which is varying with time,



0 0·24 0·48 0·72 0·96 1·20 1·44 1·68 1·92 2·16 2·40

High speed photographs of a gas discharge in which a rapidly rising axial magnetic field is used to compress deuterium gas (Thetatron experiment). The framing camera viewed the discharge axially. The time in millionths of a second is shewn below the photographs and each of the latter has an exposure time of one eight-millionth of a second. Photographs of this type give information of value to controlled thermonuclear research.

the other, the framing camera, produces individual pictures at intervals on a strip of film.

In the second of these the time between each picture is one seven-millionth of a second. Each picture is exposed for one ten-millionth of a second.

C.T.R.

The Harwell device, ZETA—used for research into Controlled Thermonuclear Reactions—is a ring-shaped apparatus in which deuterium gas is heated to high temperatures by passing through it a large pulse of current (up to 200,000 amperes). The result is a "pinched" discharge, since the electro-magnetic forces associated with the current cause the gas to be compressed inwards and so move away from the walls of the containing tube. Two similar but smaller devices—Sceptre III and Sceptre IV were built (with financial assistance from the Authority) at the laboratories of Associated Electrical Industries at Aldermaston Court.

Initial experiments on ZETA showed that there was an excessive loss of energy from the gas during the current pulse.

During the past year, the stored energy supply and the stabilizing magnetic field supply of ZETA were both increased by about six times. As a result, gas currents of up to 800,000 amperes were obtained. This made it possible to operate at considerably higher gas pressure. However, this increase in current has not led either to a substantial increase in the gas temperatures, nor in the energy containment time.

Theoretical studies have suggested that a necessary though perhaps not a sufficient condition for stability is that the current can be made to flow in a thin skin on the surface of the ionized gas. It is known that such a surface current is produced if the current is made to increase sufficiently rapidly at the beginning of the current pulse, but for technical reasons a sufficiently rapid rate of rise of current cannot be obtained with either ZETA or Sceptre. An experiment, known as I.C.S.E. (Intermediate Current Stability Experiment) is therefore being designed, in which the current will rise fast enough to produce a skin effect. I.C.S.E. will essentially be a large scale experiment in plasma physics.

The design of the experiment is now well advanced and orders have been placed for some of the main components.

The first building to be erected on the Authority's new C.T.R. site at Culham will be for I.C.S.E. and its associated facilities. Further buildings will follow to accommodate the remainder of the research and supporting services to be moved from A.E.R.E., Harwell, and A.W.R.E., Aldermaston. Within four or five years the new laboratories at Culham should approach their planned size of 1,000 total staff. These are scheduled for completion during 1961.

The Director of the new establishment will be Mr. J. B. Adams, now in charge of the Proton-Synchrotron Group at C.E.R.N., Geneva.

Research has continued at Aldermaston on various types of pinched discharge in hydrogen and deuterium gas at low pressure. A group at A.W.R.E., studying atomic collision processes, have obtained new results which, besides supplying the more accurate quantitative data required for C.T.R. work, provide new insight into the interactions between fast ions and atoms.

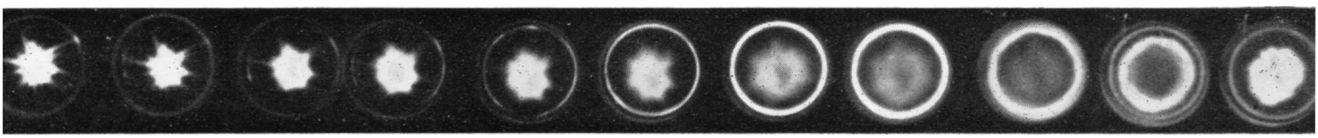
Research Reactors

GLEEP, Britain's first reactor (completed in 1947), has continued to be used extensively to check the nuclear quality of commercially produced graphite; it has also been used to measure the reactivity changes in irradiated fuel elements.

The swimming pool reactor LIDO is being used to test the effectiveness of various shielding materials and in the study of the neutron physics of reactor lattices. The team doing this work has been augmented recently by staff from the industrial firms engaged on the Power Programme.

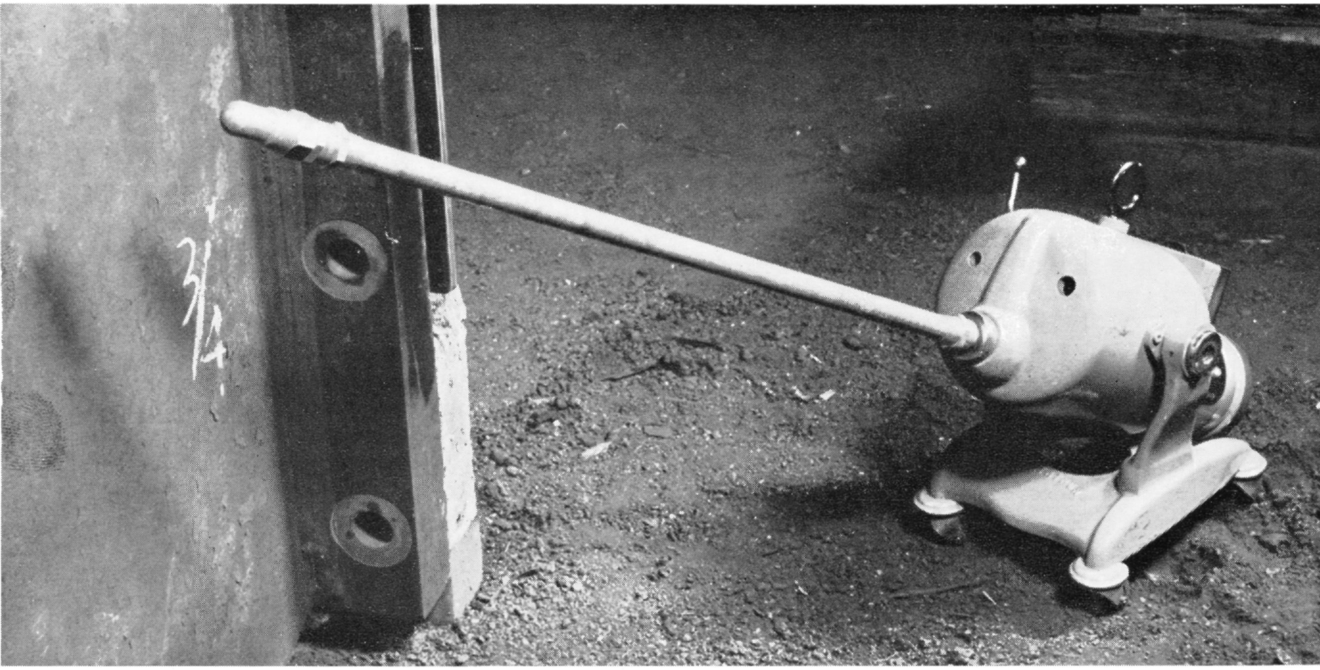
Irradiation work carried out in the Authority's three large materials testing reactors (DIDO, PLUTO, D.M.T.R.) has been increasing in significance. For example, these high flux reactors have played a very important role in accelerated tests of the behaviour of graphite and of small specimens of fuel and canning materials.

The light water moderated research reactor HERALD at Aldermaston started operation on 29th February, 1960.



2·65 2·89 3·13 3·38 3·62 3·86 4·13 4·40 4·67 4·94 5·20

RADIOISOTOPES



Radiographs. *Using a Caesium-137 source to examine a weld.*

The Authority sold through the Radiochemical Centre, Amersham, radioactive isotopes for civil purposes to a value of £1.1 million in 1959-60, an increase of 25 per cent over the previous year. Over half the sales (60 per cent) continued to be for export. Medical users took half of the total of 35,000 deliveries during the year. Fifteen per cent of deliveries (about one-quarter of the total sales value) went to industry and the remainder went to various research users.

Two new laboratories have been brought into commission at Amersham. One is for the synthesis of organic compounds labelled with Carbon-14 or with tritium, for which the demand has increased ten-fold in the past ten years. The other laboratory is for the manipulation of radium and related elements.

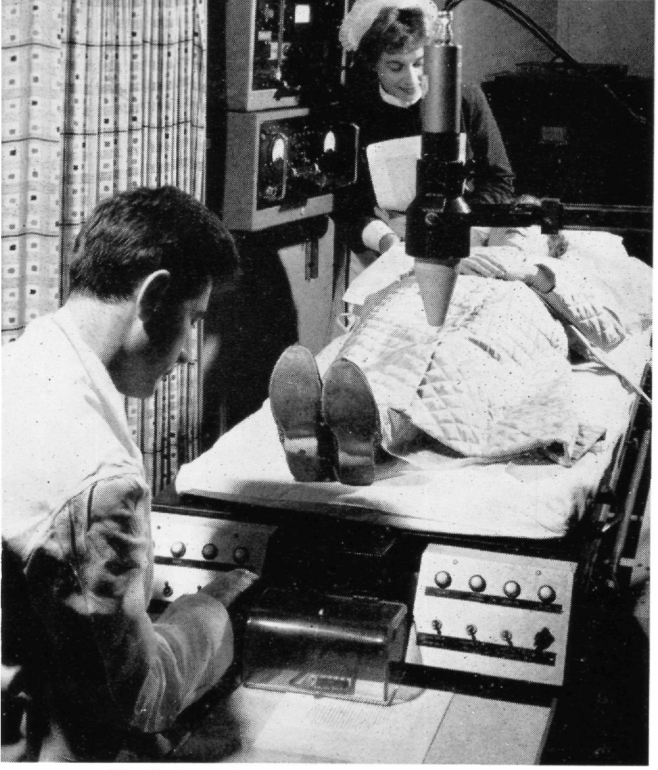
Two new catalogues ("Radioactive Chemicals" and "Radioactive Sources") were issued during the year. These include nearly 1,000 items which are in regular production. They cover the whole range of radioactive products offered for sale through the Radiochemical Centre—primary isotopes, labelled compounds and radiation sources. A new illustrated booklet is available describing the work of the Radiochemical Centre.*

Work has continued in the Wantage Research Laboratory on the application of radioisotopes, especially in industry. Thus the method of fluorescence spectroscopy, using radioactive sources, has been applied to measuring very thin surface coatings. Instruments based on this and a related technique have been used industrially to measure metal coatings about a ten-thousandth of a centimetre thick, and also the thickness of ink on paper.

Radioactive tracers continue to be applied in new ways. In the electro-plating industry, the modes of action of some additives commonly used to brighten and level the plated deposit have been elucidated for the first time with the help of tracers. The tracers were detected by micro-autoradiography, in which the active material is made to take a photograph of itself.

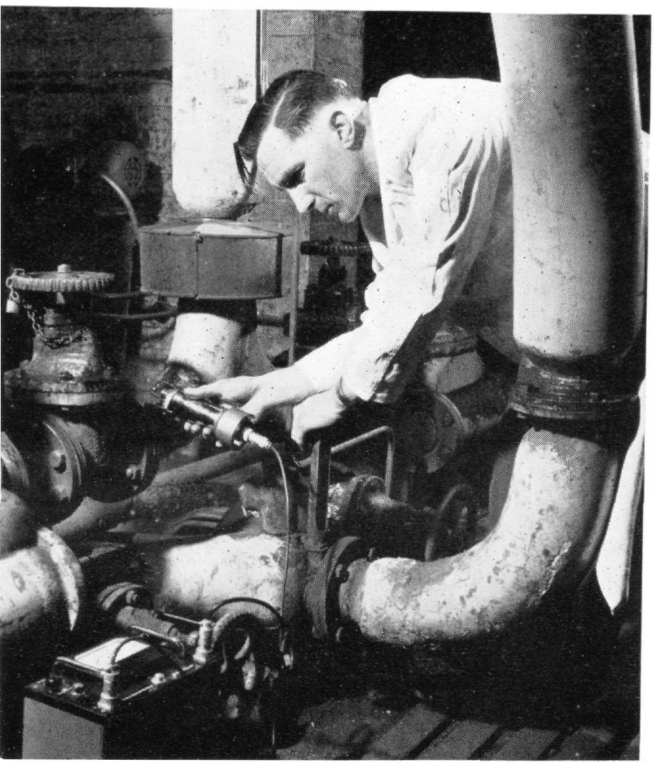
*"*The Radiochemical Centre*" H.M.S.O. 5/-

Checking Packages. *Isotopes can be used to check that packages on a production line are properly filled. Photograph shows a "package monitor" in use at a biscuit factory. It does not affect the food in any way.*



Medicine. *Isotopes can be used for diagnosis and therapy. The device shown can trace the distribution of radioactivity after an injection.*

Thickness Gauge measures pipework. *The thickness of a material can be found from the attenuation of radiation passing through it.*



In the development of fuel element cans for power reactors, tracers have been used to identify and locate constituents of the metal such as might lead to failure in operation. A method has also been devised for testing fuel element cans for incipient leaks, using krypton-85 gas as a tracer. By similar methods, leaks at a rate less than one ten-thousandth of a cubic centimetre in a year can be detected in small components such as transistors.

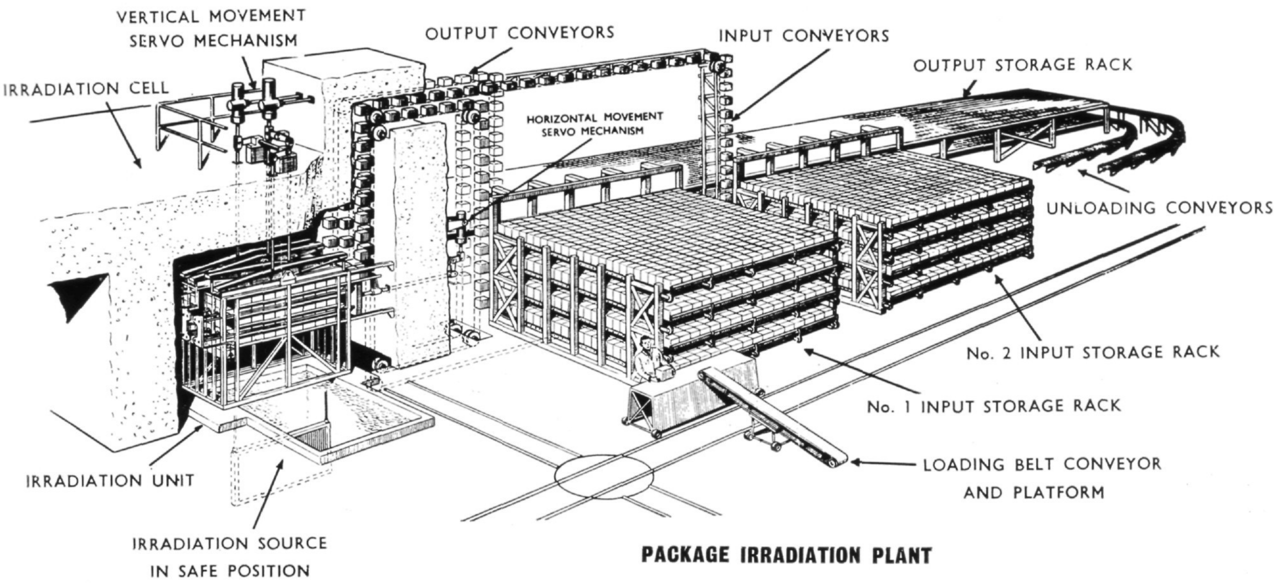
By tracer methods, the rate of flow of liquid in closed channels can now be measured with an error of less than one part in two hundred; this is an improvement in both accuracy and convenience over established methods. Measurements of this kind are important in commissioning hydro-electric generators.

Further work has been done at Wantage on the use of large sources of gamma-radiation for sterilisation and other applications.

One of these is the use of gamma ray sterilisation of disposable plastic hypodermic syringes and similar medical equipment; the advantages are that these cheap thermoplastic products can be thrown away after having been used once, at a cost no more than that of cleaning and re-sterilising ordinary types of syringe and other medical instruments. Gamma radiation is also ideal for sterilising rubber appliances which, like thermoplastics, are unable to stand high temperatures; the high penetration of this radiation permits sterilisation after the appliances have been packed in double sealed containers. For several months 10,000 catheters a week have been sterilised in an installation at Harwell in which spent fuel elements from DIDO and PLUTO are used as sources of radiation.

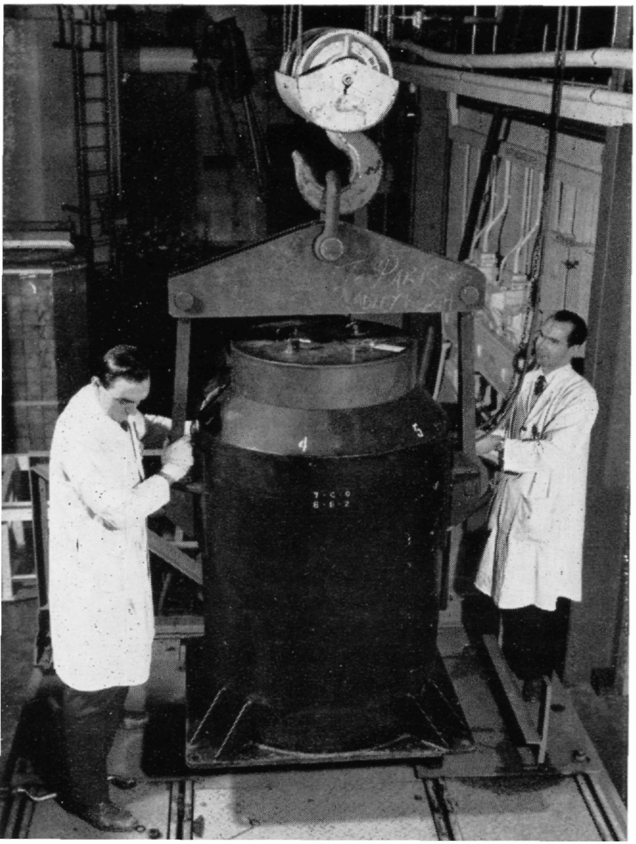
A pilot scale plant for irradiating packages of materials with gamma rays has been built at Wantage to use, at first, 120,000 curies of cobalt-60. Eighty per cent of the capacity of this plant is reserved for sterilisation by manufacturers of medical equipment, for clinical trials and for packaging and storage tests before full-scale production. The remainder of the capacity is taken up in the research and development programme of the Technological Irradiation Group.

The first industrial gamma-ray sterilisation unit in the world has been completed in Australia and 150,000 curies of cobalt-60, supplied by the Authority, have been installed. Further cobalt sources of up to 500,000 curies have been ordered for extensions to the plant.

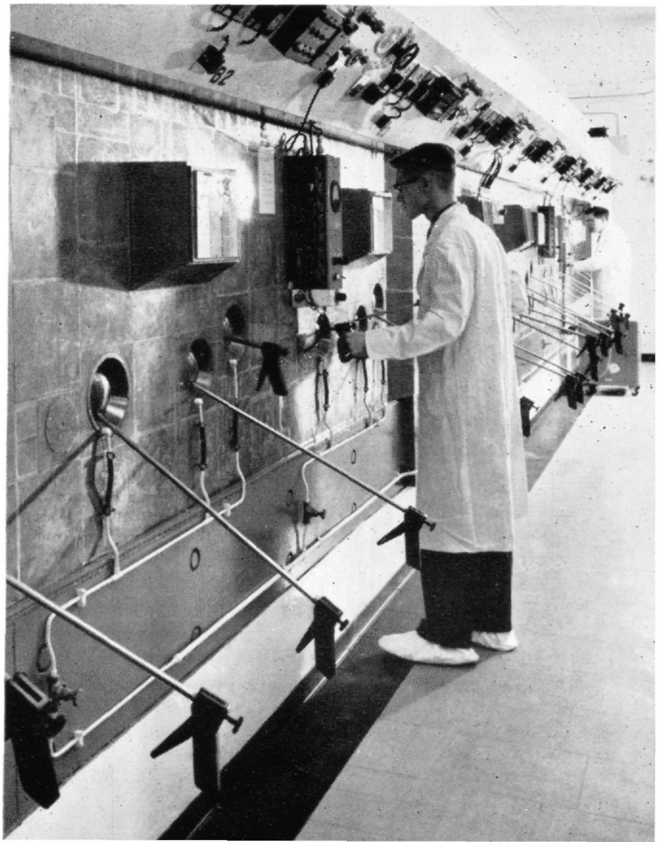


PACKAGE IRRADIATION PLANT

Eight-ton lead flask for transporting 150,000 *curies of cobalt*-60. *The Authority have supplied a source of this kind for industrial use in Australia.*



New chemistry laboratory at the Radiochemical Centre, Amersham, recently extended to meet increasing demands for isotopes.



TRAINING

Harwell Reactor School

Three Standard Courses were held during the year and co-operation with the Colleges of Advanced Technology at Birmingham, Bradford and Salford in connection with these Standard Courses was continued.

The second and third Control and Instrumentation of Reactors Course, each of two weeks' duration, were held. A second course was organised on behalf of O.E.E.C. for university staff from the O.E.E.C. countries.

To benefit from the accumulated experience at the Atomic Energy Establishment, the final three weeks of the Standard Course will in future be held at Warmwell, near Winfrith. The Control and Instrumentation of Reactors Course, and the second week of the Senior Technical Executives' Course, will be held in Bournemouth.

Calder Operation School

Seven Standard Courses were held during the year of which three were for overseas students. A special one-week course was held for senior technical executives. One hundred and sixty-four British and 53 overseas students attended courses during the year making a total of 406 students since the inception of the school in 1957.

During the year there was a heavy demand for training for the operating staff of the consortia, the C.E.G.B. and the S.S.E.B. The Production Group reactors at Calder and at Chapelcross, and the associated Calder Operation School, have become focal points for the training of nuclear technologists on an international scale.

C.E.G.B. Operating Staff

The training programme for C.E.G.B. nuclear power station operating staff continued during the year. The programme comprised a course at the Calder Reactor School and practical experience on the operation of the Calder reactors. Engineers from the C.E.G.B. staff are being incorporated in the operating team which will commission and operate the prototype advanced gas-cooled reactor now under construction at Windscale. It is envisaged that these engineers will remain attached to the Authority for three or four years.

Isotope School

The Isotope School, now at Wantage, gave a total of 14 courses during the year. These included several of the general isotope courses first given nine years ago, as well as the specialised courses on radiological protection, isotopes in medicine and auto-radiography, which have been available for two or three years. Innovations during 1959-60 included advanced courses for specialists on isotopes in radio-chemistry, in physics and measurement, in analytical chemistry and in radio-biochemistry, all of which represent further extensions of the policy of providing tailor-made courses to suit the particular need.

HEALTH AND SAFETY

From 1st July, 1959, a new Authority Health and Safety Branch, independent of the Groups, was established with the following responsibilities:—

(a) to advise the Authority on the formulation of their health and safety policy, and to disseminate this policy for application by Heads of Groups and Establishments;

(b) to apply this policy to the assessment and inspection of reactors and plants (including laboratories); and

(c) to provide the focal point from which the Authority's external relations in the health and safety field will be conducted.

The creation of this new branch does not alter the principle that all Authority staff are responsible through the normal management chain of command for the safety of operations under their control.

The health and safety aspects of the work at each Establishment remain the responsibility of local specialised organisations whose function is to advise the Head of the Establishment and to co-operate with the Authority Health and Safety Branch in the development of Authority policy and practices. These local organisations provide a suitable range of health and safety services and carry out appropriate investigations and research in the health and safety field.

Branch Organisation

The new Authority branch is divided into three divisions:—

Safeguards Division (Risley)

Responsible for:

(i) Assessing the safety of reactors and plants.
(ii) Associated technical studies.
(iii) Providing an inspection service.

Radiological Protection Division (Harwell)

Concerned with radiation and other hazards affecting Authority employees and the general public.

Administrative Division (London)

(i) Provides general services to the two technical Divisions.
(ii) Deals with the non-technical work of the Branch including liaison with Government Departments.

Protection of Staff

The maximum permissable levels adopted by the Authority are based on the advice of the Medical Research Council which, during the year, considered revised recommendations made by the International Commission on Radiological Protection. The principal changes were the replacement of the maximum permissible weekly dose by the introduction of a maximum permissible thirteen-week dose, and the introduction of a "dose for age" formula to control cumulative exposures. The Authority, on the advice of the Medical Research Council, had already adopted the thirteen-week period for control purposes.

During 1959 there were fourteen occasions when the maximum permissible exposure (3 rads* in thirteen weeks) was exceeded. This compared with twenty-five occasions in 1958 and fifty-four in 1957. In every case steps were taken to ensure that long-term dose limits were not exceeded. In some Establishments the individual doses are so low as to make the evaluation of aggregate dose difficult. In order to extend the measurement of doses to lower values, investigations are proceeding into the issue of films for measuring individual radiation doses for a longer period.

The Trade Union Side of the National Joint Industrial Council have congratulated the Authority on their "fine record" in the health and safety field, and have said that the Authority's safety policies are producing highly satisfactory results.

Protection of the Public

The main potential public health problems arising from the work of the Authority are associated with waste disposal and with the transport of radioactive materials.

The Authority have continued to work in the closest consultation with the Government Departments empowered under the Atomic Energy Authority Act, 1954, to authorise the discharge of radioactive waste, and have undertaken to act for two years as the agents of the Ministry of Housing and Local Government in the operation of the national disposal service proposed in the Radioactive Substances Bill.

In relation to transport of radioactive and other toxic materials, it has been the policy of the Authority to ensure, as far as possible, that the containers used are acceptable as a matter of routine for normal public transport. During the year there has been continuing consultation with Government Departments and the various transport authorities.

The Authority have also been associated with two working panels of the International Atomic Energy Agency which have been convened to prepare regulations for the safe transport of radioactive substances by air, land and sea.

Safeguards

The Authority have worked closely with the Ministry of Power to assist in the establishment of the Inspectorate of Nuclear Installations required under the Nuclear Installations (Licensing and Insurance) Act, 1959. The Authority will continue to advise on the technical aspects of the licensing of nuclear reactors and plants both during the interim period while the Inspectorate is being established and subsequently, though on a diminishing scale. Arrangements are being made by the Authority to train some of the Ministry's inspectors.

International Co-operation

The scale of activity in the international field has increased steadily during the year. The Authority have been able to contribute to a number of studies organised by the international bodies concerned, notably the International Atomic Energy Agency.

Veale Committee

A Committee set up, under the chairmanship of Sir Douglas Veale, to consider the training of radiological health and safety specialists, reported in April, 1960. Their report* is being studied by the Authority and the Government Departments concerned.

Methods of training at three levels were considered. At the top level there are postgraduate courses in the Universities of London and Birmingham, and Edinburgh University are planning a course to start in October, 1960. The Committee believe these courses will meet the need for 20-30 top-grade specialists a year.

Similar but less advanced courses at two or three colleges of technology are recommended and certificate courses (at a lower level again) at technical colleges.

To make the best use of specialists, the Committee recommend that a national radiological advisory service, with regional centres, should be set up under the Minister for Science. This service would be able to give advice to organisations (such as firms making use of radioisotopes) without full-time health and safety specialists of their own.

It would be available to give expert help in the case of an accident involving possible radioactivity hazards.

It would also provide such services as processing the film badges which are worn by all workers who may be exposed to radiation.

The report also recommends that all medical students should be given some knowledge of radiological health and safety in their undergraduate training, and that a course should be included in the curriculum for the Diploma in Public Health.

Short residential courses for managers, administrators, medical officers of health and other professional workers are also proposed, as well as books, films, articles, and radio and TV programmes for the information of the public.

*"Training in Radiological Health and Safety: Report of a Committee appointed by the United Kingdom Atomic Energy Authority." H.M.S.O. price 5/6d.

* A rad is a unit of absorbed dose of radiation.

Mr. Daigoro Yusukawa and Sir Roger Makins sign heads of contract for the supply of fuel to a nuclear power station which a British company is building in Japan.

A Japanese fuel inspection team visited Harwell in October, 1959.

INTERNATIONAL

International activity in the field of atomic energy continues to grow and the Authority have participated fully in this increased activity.

Overseas countries have shown an increasing awareness of the size of the effort needed to back a nuclear power programme and the long period of preparation necessary. This has led to numerous visits and enquiries concerning British-type power reactors.

International Organisations

The Authority have continued their support of the work of the International Atomic Energy Agency. They have released staff to take part in conferences, symposia and working parties, and to serve on missions sent to advise member countries. Authority staff contributed substantially to the Agency's Conference on Waste Disposal held at Monaco in November, 1959. Several senior scientists have been seconded to work as members of the Agency's staff.

Eighteen holders of I.A.E.A. Fellowships have now received training at Authority Schools or Establishments; six others are due to start training shortly. They have come from sixteen countries in Europe, Asia and South America.

Among the resolutions adopted at the third annual General Conference of the Agency in September, 1959, was one put forward by the U.K. recommending the Agency to press on urgently with its work on the preparation of manuals and codes of practice in the health and safety field.

The first meeting of the Board of Management for the Dragon Project (H.T.G.C.R.) of the European Nuclear Energy Agency was held at Winfrith on 1st June, 1959. Dr. Sigvard Eklund of Sweden was elected Chairman of the Board, and Mr. C. A. Rennie of the Authority's Research Group was appointed Chief Executive. During the year a team of scientists and engineers from the twelve European countries associated with the development of this joint project has been assembling at Winfrith, and the project is now well under way. Of the 128 professional staff engaged on the project at 31st March, 1960, 71 had been seconded from the Authority's staff and three from United Kingdom industry. Fifty-four came from overseas.

RELATIONS

The Authority, acting on behalf of the Dragon Board of Management, concluded an agreement for exchange of information concerning the Dragon reactor on the one hand and the similar reactor to be constructed in U.S.A. on the other.

The boiling water reactor at Halden in Norway, which is being operated jointly by certain member countries of the E.N.E.A., began working on 29th June, 1959. Two members of the Authority's staff have been working on the project for over a year. Dr. Schonland, Director of the Atomic Energy Research Establishment, was elected Chairman for 1960-61.

The Authority, although not a shareholder in the Eurochemic project of the E.N.E.A., have signed a Letter of Intent designed to serve as a frame-work for specific services to be rendered to the project by the Authority or British firms.

The Authority are represented on a new committee on nuclear reactor data which has been set up under E.N.E.A. auspices and with full United States and Canadian participation.

During the year action has been taken to implement the co-operation agreement between H.M. Government and the European Atomic Energy Community (Euratom) signed in February, 1959. The first meeting of the United Kingdom/Euratom Continuing Committee for Co-operation took place in London on 4th December, 1959. As a result of arrangements made at Joint Working Group meetings, a number of Euratom specialists have visited Authority establishments during the year; discussions have been held on methods of reactor planning and programming; and a joint symposium on fast reactors was held at Risley and Dounreay. Authority representatives took part in a Euratom Conference on corrosion in nuclear reactors.

The CENTO Institute of Nuclear Science (formerly the Bagdad Pact Nuclear Centre) was formally opened at Tehran on 23rd June, 1959. The Centre, which is under the direction of Mr. H. A. C. MacKay of the Authority's Research Group, has held two courses during the year; a general radioisotope course and a special agricultural course, for students from Iran, Pakistan and Turkey. The Authority have offered to accept free of charge a limited number of research workers from those three

Mr. R. F. Jackson explains the Harwell reactor DIDO to the Hon. John A. McCone, Chairman of the U.S. Atomic Energy Commission. The audience includes Sir William Penney (with glasses).

Calder Operation School. A reactor simulator is demonstrated to students from Germany and Peru.

Mr. T. A. J. Jaques of the U.K. (left) and Mr. B. Aarset of Norway work together on the "Dragon" reactor project at Winfrith.

Two students from Sweden and one from Spain discuss reactor graphite with the manager of the Calder Operation School.

countries at the Wantage Radiation Laboratory to investigate applications of radioisotopes.

Authority staff have continued to take part in the work of the European Atomic Energy Society and the European Organisation for Nuclear Research (C.E.R.N.). The C.E.R.N. synchrotron achieved its full design energy on 24th November, reflecting great credit on the team under the direction of Mr. J. B. Adams. Mr. Adams himself is returning to the Authority's Research Group to take charge of research into controlled thermonuclear reactions.

The Authority have continued to participate in the work of various United Nations bodies such as the Scientific Committee on the Effects of Radiation, the F.A.O., the I.L.O., the International Standards Organisation and the W.H.O.

The Commonwealth

At the annual conference between the Authority and Atomic Energy of Canada, Ltd., the wide programme of joint work already in hand was reviewed and provision made for closer collaboration on the development of heavy water reactor systems.

The Authority have agreed with the Australian Atomic Energy Commission to undertake a joint programme of research on beryllium irradiation problems. As part of these arrangements fuel element testing facilities will be made available to the Authority in the Commission's Hifar reactor at Lucas Heights.

There have been discussions between Members and staff of the Authority and representatives of the Indian Atomic Energy Commission concerning the possible construction of a nuclear power station under the next Indian Five Year Plan.

U.S.A.

An amendment to the 1958 Agreement between the United Kingdom and United States Governments for co-operation on the defence uses of atomic energy was signed in Washington in May, 1959 and came into force in July.

The Chairman of the United States Atomic Energy Commission, Mr. John A. McCone, came to the United Kingdom in October, 1959, and Lord Plowden visited Washington in the following month. During his visit agreement was reached with the Commission covering collaboration on the advanced gas-cooled reactor system. The existing close collaboration on fast reactor work was marked by the presence of American attached staff at the start-up of the Dounreay reactor in December.

Other Countries

An agreement between the Governments of the United Kingdom and Spain for co-operation in nuclear research and in the development of nuclear power was signed in January, 1960.

An agreement made in 1956 between the Authority and the Netherlands atomic energy organisation, the Reactor Centrum Nederland, for collaboration in certain fields of reactor development has been extended for a further three years.

Contracts covering the two British-type power stations, for which Letters of Intent had already been issued by the Japan Atomic Power Co. to the G.E.C./ Simon Carves Group of Companies and by the Italian organisation Agip Nucleare to the Nuclear Power Plant Co. have now been signed. Special arrangements have been made for training engineers from Agip Nucleare, including work at Calder Hall, in order that they may gain experience of the operation of gas-cooled power reactors.

Numerous discussions have taken place between representatives of the Japanese organisation and the Authority over the reactor designs submitted, and over health and safety considerations. Heads of Contracts for the supply of fuel elements for the Japanese reactor were signed during a visit by representatives of the Japan Atomic Power Co. to London in February.

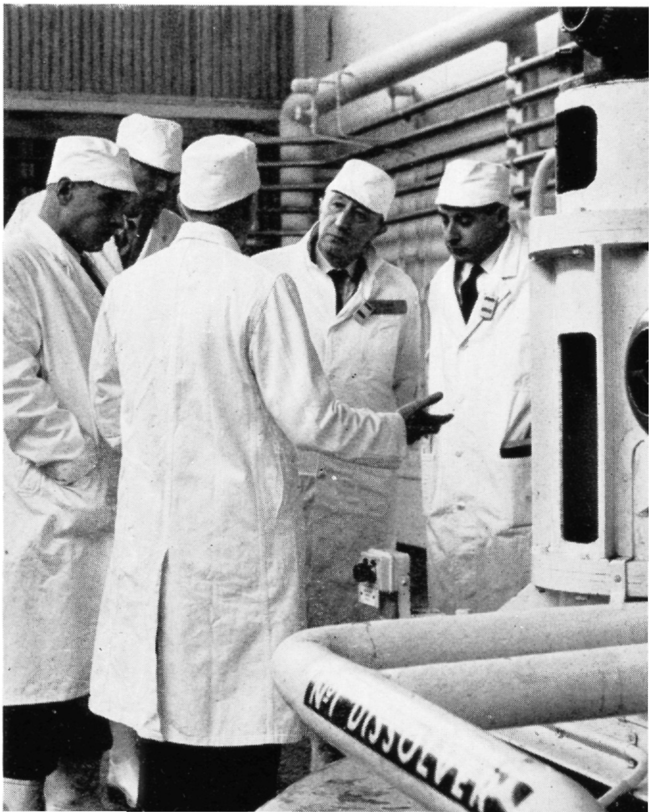
The Authority have been closely concerned with the arrangements made by Germany and Denmark for the installation of British research reactors. Danish and German engineers have been given special facilities to work at Harwell in order to obtain experience. The Danish reactor DR 3, manufactured in the United Kingdom on the basis of the Authority's PLUTO system, and for which fuel had been supplied by the Authority, started up in January, 1960. Authority specialists are advising on the early stages of its operations.

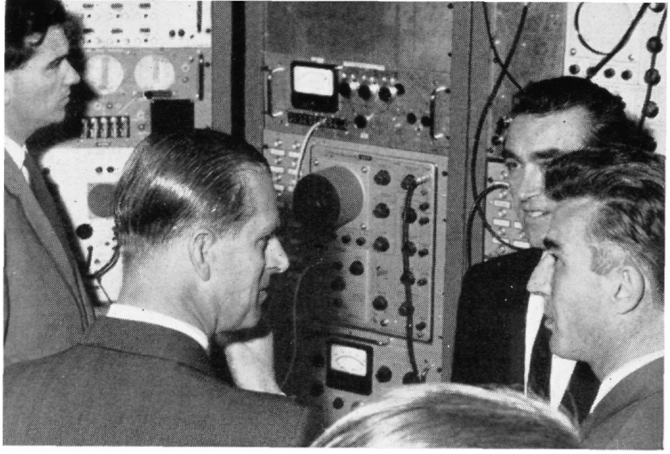
Exchanges with the French Commissariat a l'Energie Atomique have included visits in both directions. In one instance the teams were widened to include representatives of the power generating companies.

A fast reactor team from the Authority visited the U.S.S.R. in July to see the Russian fast reactor, and in return three Russians specialising in this field visited Dounreay and other Authority establishments in January, 1960.

Lord Hailsham, Minister for Science, met M. Hirsch, President of Euratom, during U.K.-Euratom discussions in London, December, 1959.

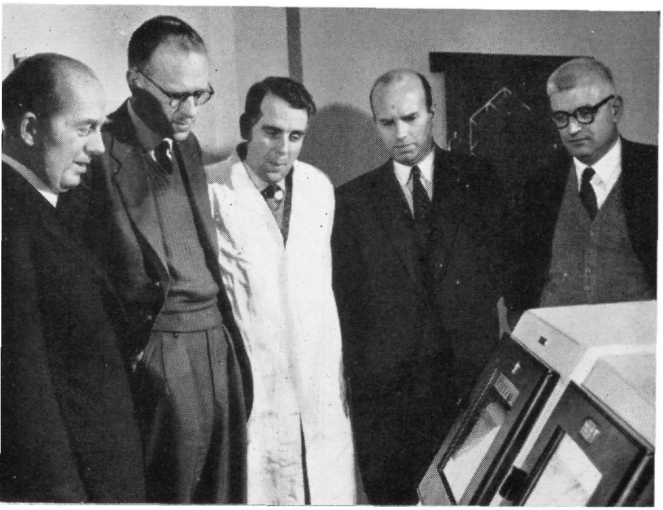
Journalists from Euratom countries visited British nuclear installations in July, 1959. *Some are seen here at the Springfields fuel element factory.*





C.E.R.N., Geneva. *Prince Philip meets Mr. J. B. Adams (extreme right), who is returning to U.K.A.E.A. as head of C.T.R. research.*

To study methods of detecting nuclear explosions, the Weapons Group fired conventional explosives underground. Picture shows preparation of a charge at Kit Hill Mine, Cornwall.



EVENTS OF THE YEAR

April 1 1959 to March 31 1960

During the year 1959-60 the Authority continued to devote a major effort in support of the civil power programme of the Central Electricity Generating and the South of Scotland Electricity Boards. Those major projects undertaken by the Authority primarily to support the defence programme were completed and all the main plants constructed for that purpose were operating successfully.

New uranium processing and fuel element fabrication facilities were completed during the year and at the end of the year the Authority were about to commence manufacture of the first fuel element charges for Bradwell and Berkeley. The last three Chapelcross reactors were brought up to full power, and the planned extension of capacity of the Capenhurst diffusion plant was completed. Production during the year, of both plutonium and uranium-235, was up to programme.

A large amount of development work was carried out in aid of the nuclear power stations at present under construction for the electricity generating boards. The construction of the advanced gas-cooled reactor prototype at Windscale proceeded according to programme. The Dounreay experimental fast reactor commenced operation on low power on 14th November, 1959, and the zero energy reactor, ZENITH, at Winfrith on 19th December.

A good start was made on the organisation, planning and initial construction of the high temperature gas-cooled reactor experiment at Winfrith in which the Authority are co-operating with eleven other European countries under the auspices of the O.E.E.C.

In addition the Authority continued to study the potentialities of other reactor systems.

Technical assistance was provided to the Admiralty in connection with submarine reactor develop-

Dounreay. *Sir William Cook (left) and senior colleagues in the control room of the fast reactor as it began operation (14th November, 1959).*

Italy. *Visitors to the A.E.A. exhibit at the Milan Samples Fair (April, 1959) hear an interpreter explain a working model of Calder Hall. An identical model was shown at the British Exhibition in New York.*

ment, and to the Admiralty also, and later the Ministry of Transport, in connection with studies of possible reactor systems for merchant ship propulsion.

The design of the new experimental facility I.C.S.E. (Intermediate Current Stability Experiment), together with other work on controlled thermonuclear reactions proceeded at Harwell, at the Atomic Weapons Research Extablishment, Aldermaston, and at the laboratories of Associated Electrical Industries at Aldermaston Court. In January, 1960 the Authority received planning permission for a new establishment to be built on the site of the former Royal Naval Air Station at Culham in Oxfordshire. Work on thermonuclear reactions is to be transferred from both Harwell and Aldermaston to this new establishment.

While development of weapons for various military applications continued, the Authority also provided technical assistance in connection with the Geneva discussions on nuclear test suspension, and, in this connection, undertook an experimental programme of underground firings of non-nuclear explosives in the United Kingdom.

There has been a world-wide change in the relationship between the supply of and the demand for uranium, and the Authority's commitments under long-term contracts are greater than their immediate requirements. Proposals were formulated to stretch out some deliveries of uranium over longer periods.

The reorganisation of the Authority's health and safety staff led to the establishment of a new Authority Health and Safety Branch. The Committee on Training in Health and Safety (the Veale Committee) completed its report in February, 1960. The Authority assisted in the establishment of the Inspectorate of Nuclear Installations required under the Nuclear Installations (Licensing and Insurance) Act, 1959.

Receipts from the Authority's commercial operations amounted to almost £20 million. Heads of Contract for the supply of fuel elements for the first Japanese nuclear power station were signed in London on 7th March, 1960.

Sales of radioisotopes increased by 25 per cent over the previous year.

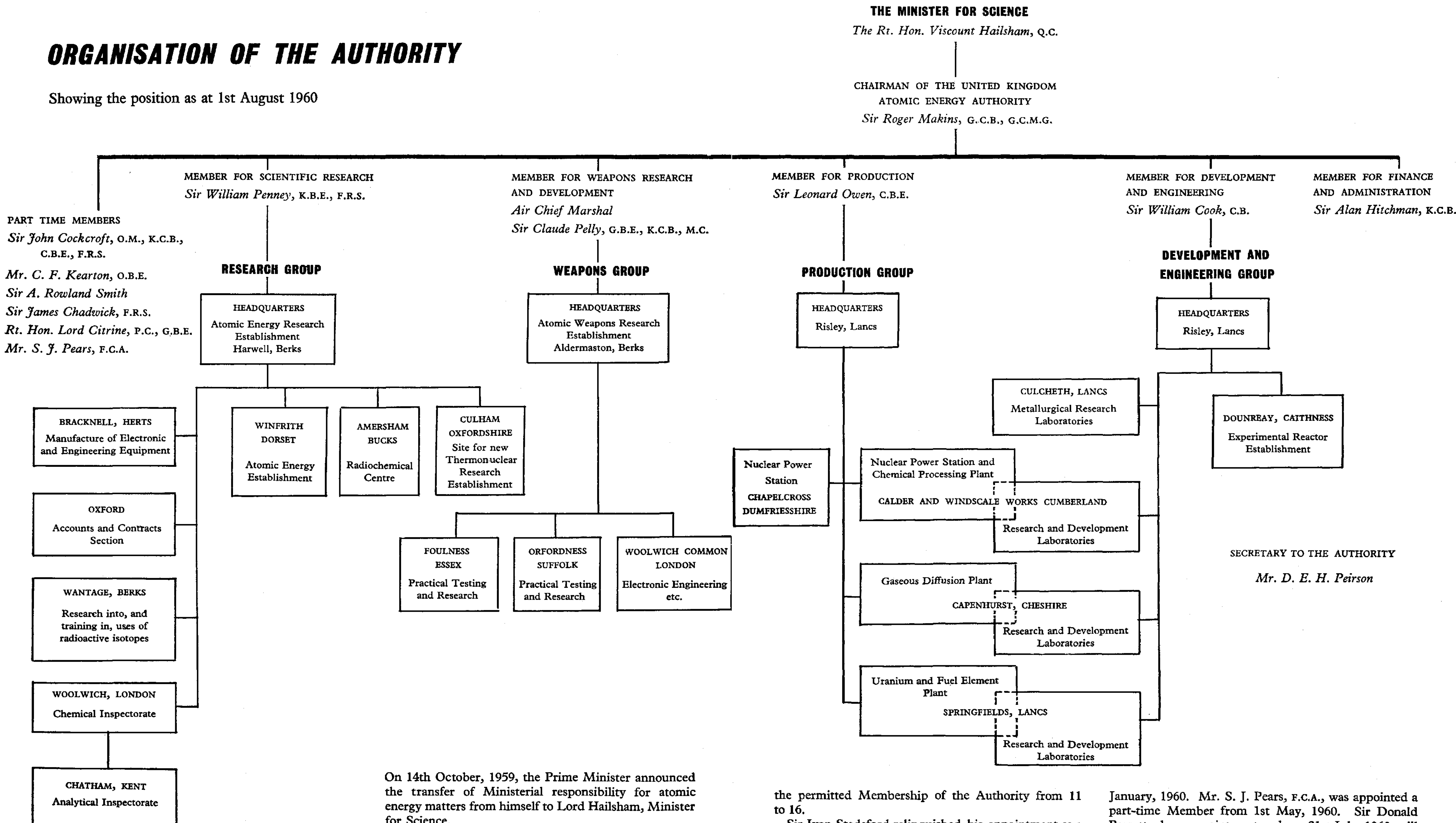
The Authority continued to collaborate with overseas atomic energy organisations. Co-operation between the United Kingdom and Euratom was set in hand in pursuance of the agreement of February, 1959. New inter-Governmental agreements were concluded during the year with the United States and with Spain.

The Authority's employees increased in number during the year from 35,260 to 38,500.

The Authority's Estimates for 1960-61 provide for a net expenditure of £93,293,000 compared with £92,433,010 for 1959-60.

ORGANISATION OF THE AUTHORITY

Showing the position as at 1st August 1960



On 14th October, 1959, the Prime Minister announced the transfer of Ministerial responsibility for atomic energy matters from himself to Lord Hailsham, Minister for Science.

Lord Plowden relinquished his appointment as Chairman of the Authority on 31st December, 1959. He was succeeded by Sir Roger Makins.

The Atomic Energy Authority Act, 1959, increased the permitted Membership of the Authority from 11 to 16.

Sir Ivan Stedeford relinquished his appointment as a part-time Member on 31st July, 1959. Sir Leonard Owen was appointed Member for Production and Sir Claude Pelly Member for Weapons Research and Development. Both appointments were effective from 1st January, 1960. Mr. S. J. Pears, F.C.A., was appointed a part-time Member from 1st May, 1960. Sir Donald Perrott whose appointment ends on 31st July, 1960, will be retiring from the Authority on that date. Sir Alan Hitchman, while retaining his former responsibilities for external relations and commercial policy, will also assume those exercised hitherto by Sir Donald Perrott.

THE AUTHORITY'S REACTORS AS AT 31st MARCH, 1960

	NAME	LOCATION	DATE OF START-UP	PEAK NEUTRON FLUX	MAXIMUM HEAT OUTPUT	MODERATOR	COOLANT	FUEL	PURPOSE
RESEARCH AND EXPERIMENTAL REACTORS	**1** GLEEP	Harwell	1947	3.7×10^{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	1.4×10^{14}	10 MW	Heavy water	Heavy water	Uranium 235	Nuclear reactor material studies, isotope production, neutron physics, radiation chemistry.
	6 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.
	7 D.M.T.R. (PLUTO type)	Dounreay	1958	1.4×10^{14}	10 MW	Heavy water	Heavy water	Uranium 235	Studies on nuclear reactor materials.
	8 HORACE	Aldermaston	1958	about 10^{8}	10 Watts	Light water	Light water	Uranium 235	To obtain basic nuclear information on HERALD.
	9 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).
	10 ZENITH	Winfrith	1959	10^{8} thermal n/cm² sec.	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 temperatures, 800° C in core, 400° C in reflector).
	11 HERALD	Aldermaston	1960	10^{14}	5 MW	Light water	Light water	Uranium 235	Neutron physics, radiochemical and nuclear reactor materials studies.
RESEARCH AND EXPERIMENTAL REACTORS UNDER CONSTRUCTION	**12** A.G.R.	Windscale	1961	2.5×10^{13} thermal n/cm² sec.	100 MW	Graphite	Carbon Dioxide	Enriched uranium oxide	To study the advanced gas-cooled power reactor system and to test fuel elements for the system.
	13 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.
RESEARCH AND EXPERIMENTAL REACTORS THE CONSTRUCTION OF WHICH HAS BEEN APPROVED	**14** NESTOR	Winfrith	Dec. 1960	10^{11} n/cm² sec.	10 kW	Light water	Light water	Enriched uranium-aluminium alloy	Source of neutrons for sub-critical assemblies.
	15 HECTOR	Winfrith	mid 1962	3×10^{8} n/cm² sec.	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.
PLUTONIUM/POWER PRODUCING REACTORS (IN PRODUCTION)	**16-19** Calder (2 stations) ("A" and "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.
	20-23 Chapelcross	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 was dismantled in June, 1958.: HAZEL was dismantled in September, 1958.: NERO was dismantled at Harwell and is to be re-erected at Winfrith in 1960.: NEPTUNE ceased operation in June, 1959.*

INFORMATION SERVICES

Libraries

The libraries of the *Atomic Energy Research Establishment, Harwell, Berkshire,* and of the *Development and Engineering 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, CharlesII 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"
- "Metals of the Nuclear Age"
- "R. & D." (Research and Development)

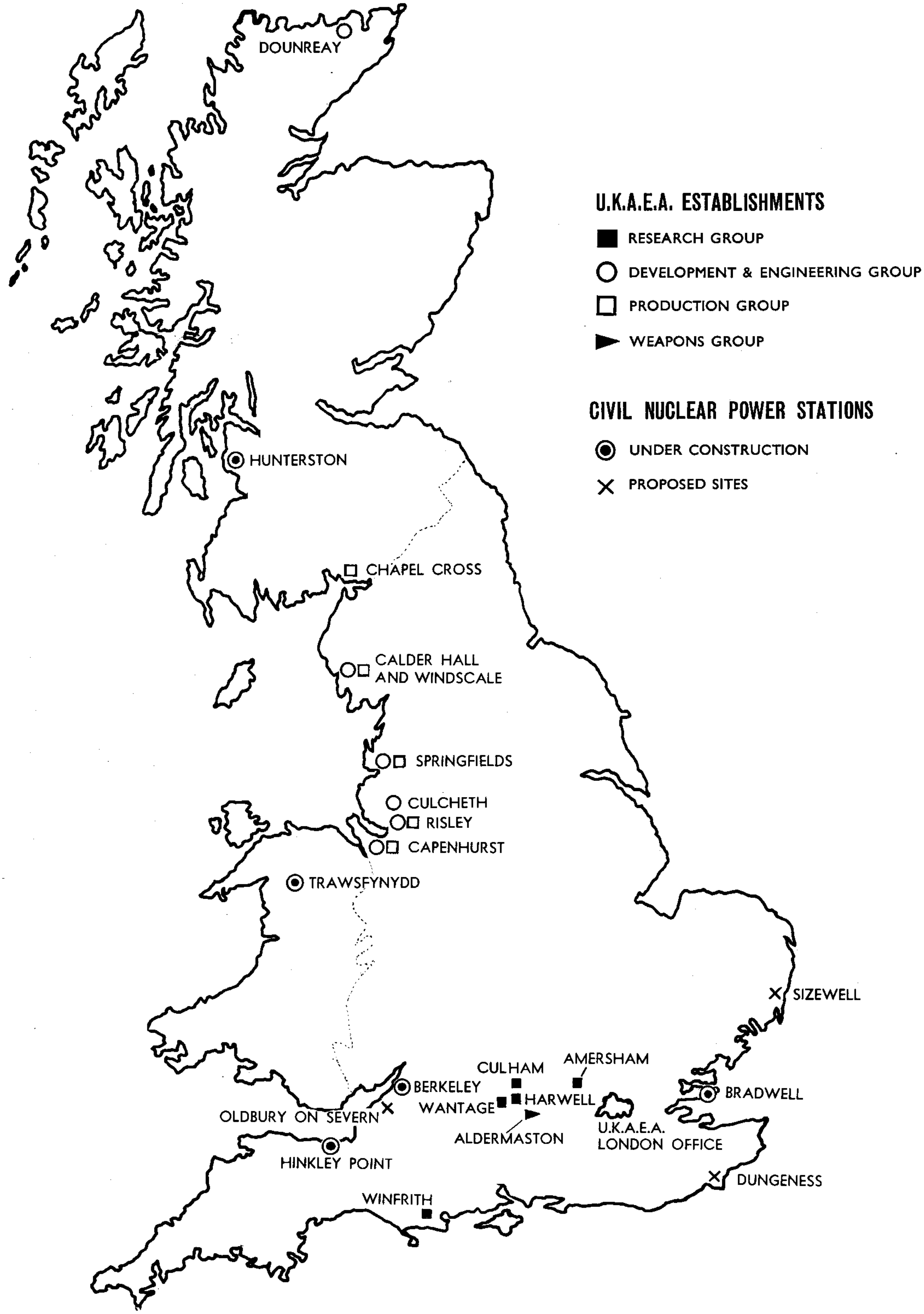
A full list is available on request from Public Relations Branch, U.K.A.E.A., 11 Charles II Street, London, S.W.1.

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 now comprises the recently opened *Isotope Information Bureau.*

Designed by Ronald Terry. Printed by The Vandyck Printers Ltd., Bristol and London

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



FRONT COVER: *Night view of Advanced Gas-cooled Reactor.*

BACK COVER: *Radioisotopes dispensed and ready for delivery from Amersham.*


AMERSHAM, ENGLAND
RADIOACTIVE