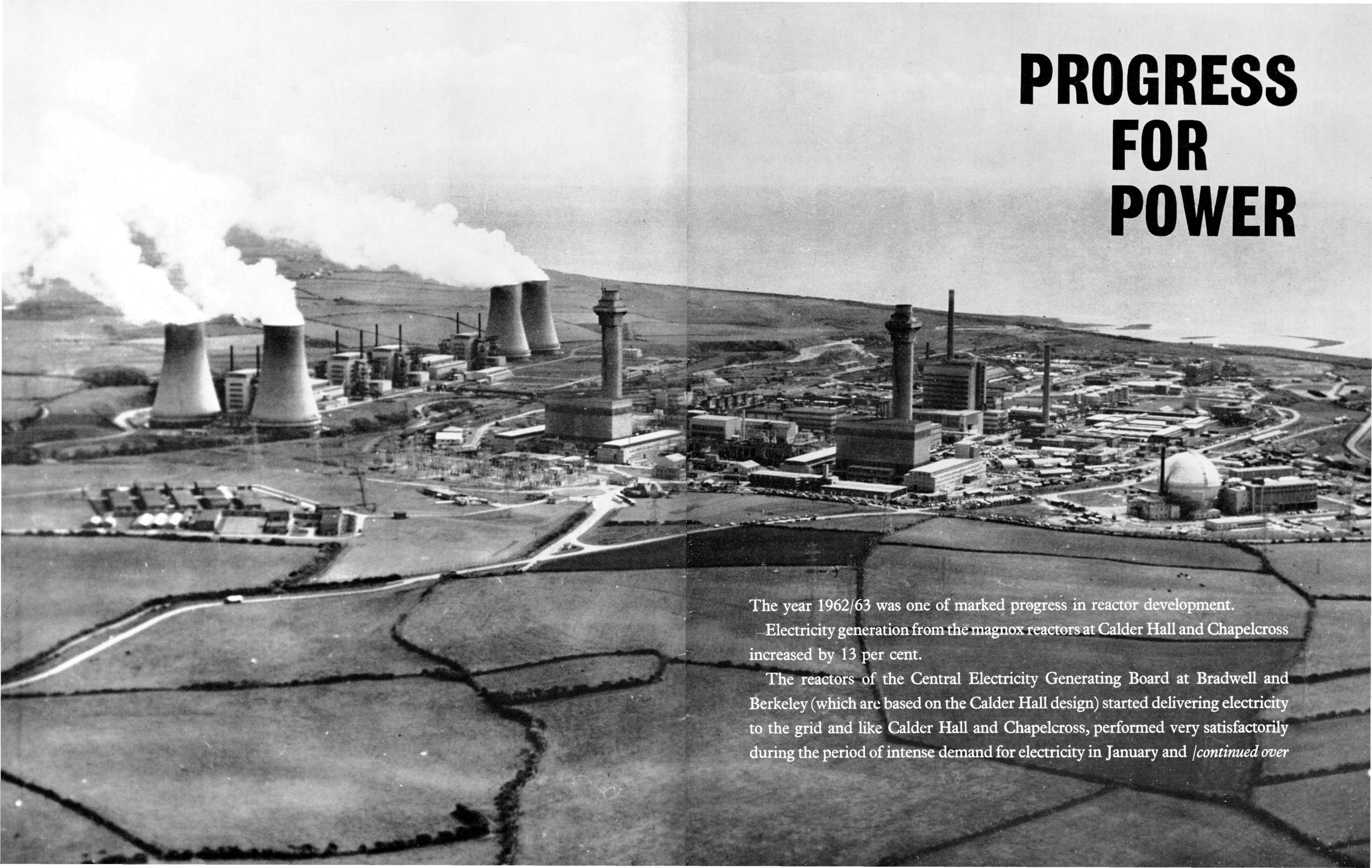
# ATOM 1963

An illustrated summary of the Ninth Annual Report from 1st April 1962 to 31st March 1963

United Kingdom Atomic Energy Authority

Price 2/6



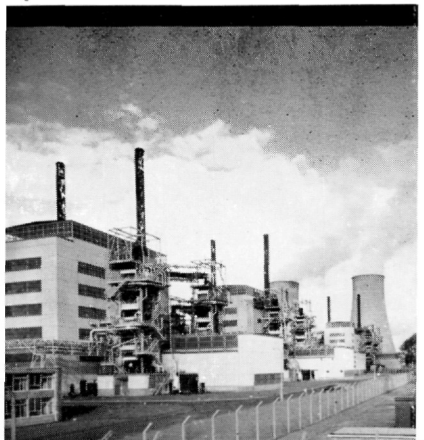
# PROGRESS FOR POWER

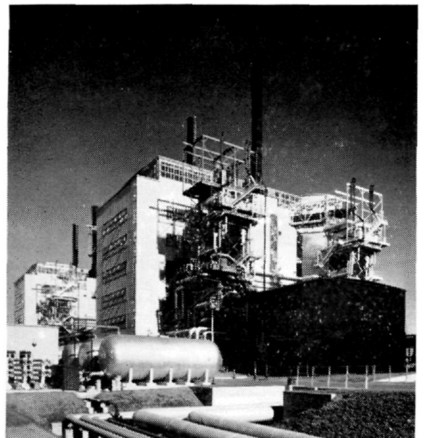
The year 1962/63 was one of marked progress in reactor development.

Electricity generation from the magnox reactors at Calder Hall and Chapelcross increased by 13 per cent.

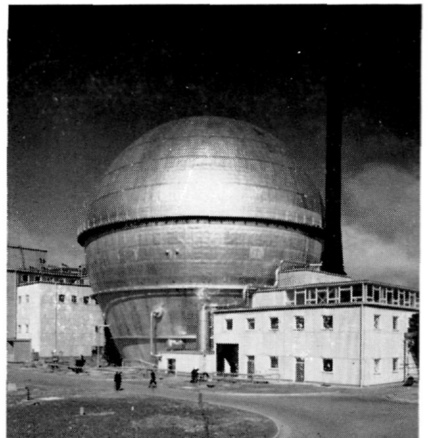
The reactors of the Central Electricity Generating Board at Bradwell and Berkeley (which are based on the Calder Hall design) started delivering electricity to the grid and like Calder Hall and Chapelcross, performed very satisfactorily during the period of intense demand for electricity in January and */continued over*

# Power Reactors: To-day and To-morrow

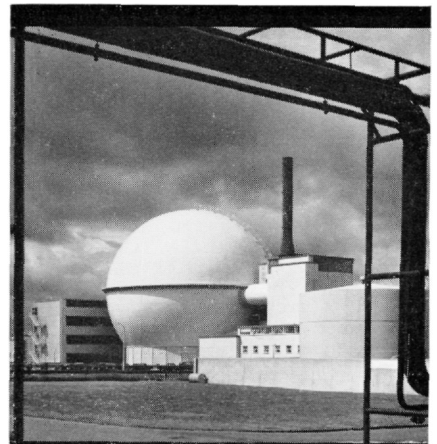




GAS-COOLED GRAPHITE-MODERATED REACTOR



ADVANCED GAS-COOLED REACTOR



FAST REACTOR

STEAM-GENERATING HEAVY-WATER REACTOR

HIGH-TEMPERATURE GAS-COOLED REACTOR

CALDER HALL
1956

CHAPELCROSS
1958

WINDSCALE
1962

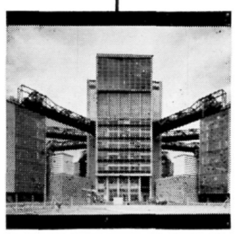
DOUNREAY
1959

WINFRITH
1967

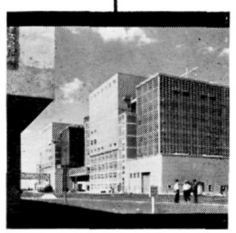
WINFRITH
1964
*Project of the O.E.C.D. European Nuclear Energy Agency in which U.K. is a partner.*

UNITED KINGDOM

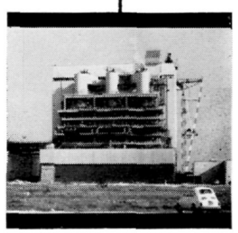
OVERSEAS



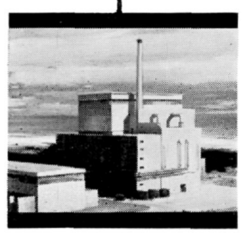
BERKELEY (C·E·G·B)
1962



BRADWELL (C·E·G·B)
1962



LATINA, ITALY
1963



TOKAI MURA, JAPAN
1965

**Hinkley Point "A" (Central Electricity Generating Board) 1963**
**Hunterston (South of Scotland Electricity Board) 1964**
**Trawsfynydd (Central Electricity Generating Board) 1964**
**Dungeness (Central Electricity Generating Board) 1964**
**Sizewell (Central Electricity Generating Board) 1965**
**Oldbury-on-Severn (Central Electricity Generating Board) 1966**
***Wylfa "A" (Central Electricity Generating Board) 1968**
**Order not yet placed and subject to modification.*



February, 1963. The Latina nuclear power station in Italy, designed by The Nuclear Power Group and supplied with natural uranium fuel elements made at Springfields by the Production Group of the Authority, became the first full-scale nuclear power station on the continent of Europe to go into operation.

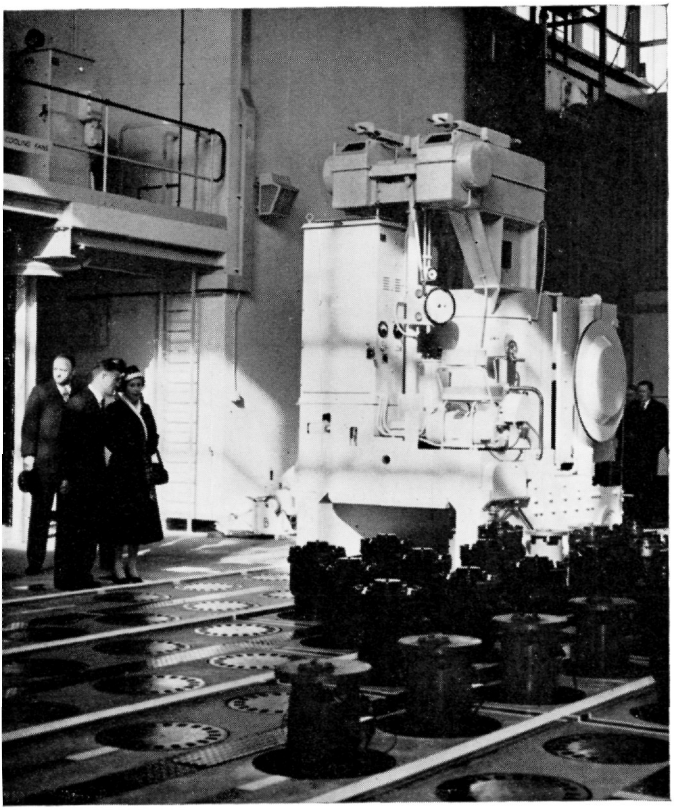
The advanced gas-cooled reactor at Windscale operated for the first time on 9th August, reached its full design output of 100 Megawatts (heat) in January and began electricity generation at 28 Megawatts (electrical) on 26th February; by 31st March 20.4 million kilowatt hours had been supplied to the national grid.

The Dounreay fast reactor reached 30 Megawatts (heat) on 7th August, 1962; electricity generation at 3 Megawatts (electrical) (rising later to 6 MW(E) ) began on 14th October and by 31st March 2.5 million kilowatt-hours had been generated of which 10 per cent had been exported to the grid.

On 20th February it was announced that Government authority had been received to proceed with the building of a prototype steam generating heavy-water reactor (S.G.H.W.) of some 100 MW(E) at Winfrith. This reactor will be designed to study the S.G.H.W. system experimentally and to prove its performance as an economic power-producing system.

The "Dragon" agreement of the European Nuclear Energy Agency—to which the United Kingdom is a signatory—was extended from April, 1964, to March, 1967. The object of this programme is to provide signatories with information leading to the design of an economic high-temperature reactor.

# CALDER HALL: PROMISE FOR THE FUTURE



*Calder Hall—now maintaining* 92 *per cent of full output capacity throughout the year—was opened by H.M. the Queen in* 1956.

The eight Calder and Chapelcross reactors have achieved standards of reliability which promise well for the future of nuclear power.

These reactors, being an early design, cannot be refuelled during operation; nevertheless, the stations maintained an output of electricity over the whole year equal to 92 per cent of full output capacity. If the shut-down time for refuelling is excluded, the stations maintained full output for 97 per cent of the time.

The operation of the stations permits full output during the winter months. During the past winter special efforts were made to achieve maximum generation during the daytime on weekdays to correspond with maximum load requirements on the electricity system.

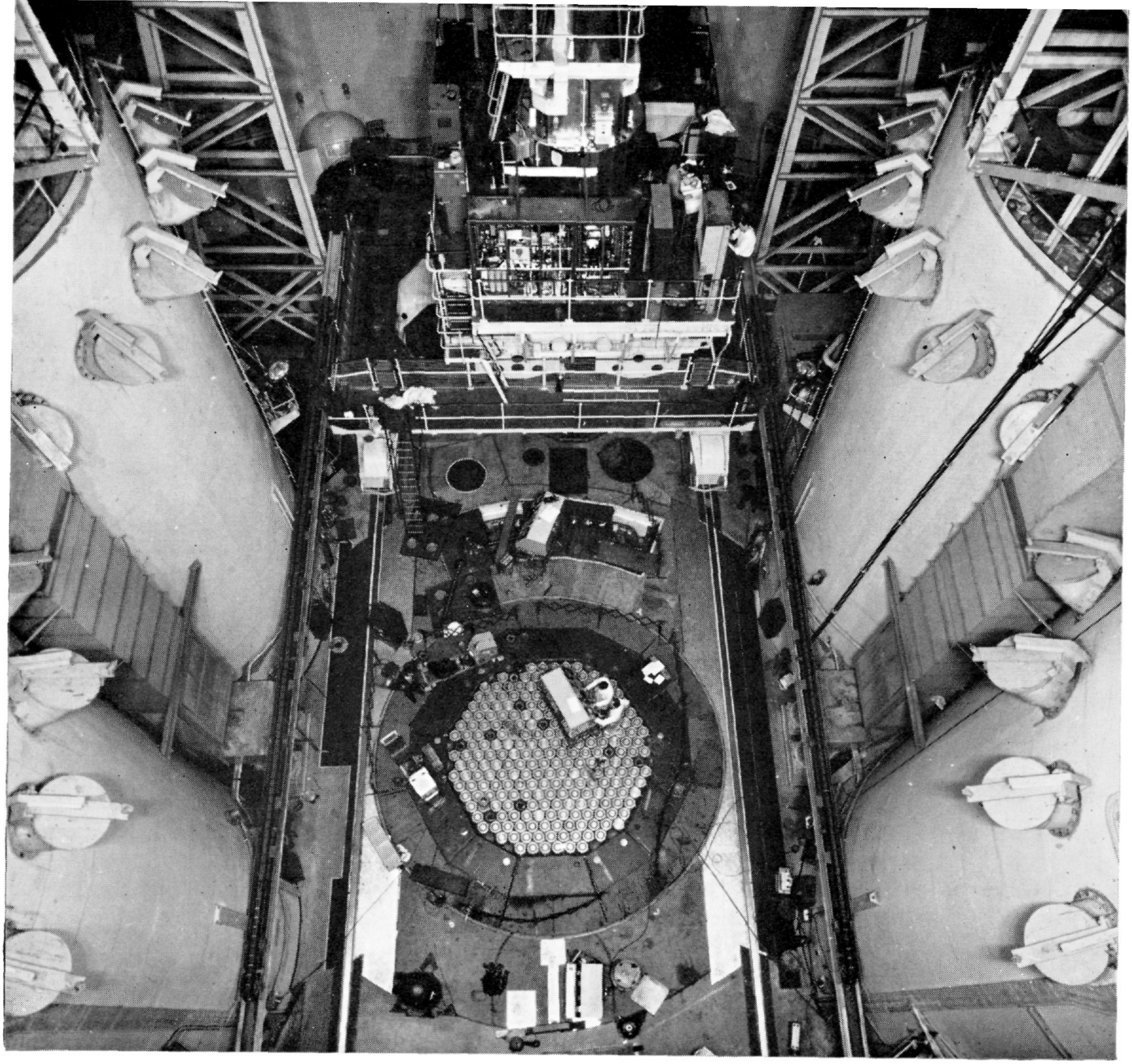
For the four months November to February inclusive this was achieved with all eight Calder and Chapelcross reactors with the exception of a single reactor which was off load for a period of three hours. During the year the Calder and Chapelcross reactors exported 2,700 million units of electricity to the national grid, an increase of 13 per cent over the previous year.

Reduction in defence requirements for plutonium will have a significant effect on the operation of the Calder and Chapelcross reactors, with the emphasis being transferred progressively to electricity rather than plutonium production. This will result in a reduction in the consumption of uranium and a consequent reduction in the time required for refuelling. These changes, together with certain alterations in the operating limits of the reactors and with the reblading of the turbines at Calder to deal with the greater volume of steam now available, are resulting in a significant increase in electrical output.

In addition to the generation of electricity, the Calder reactors have supplied all the steam needed for the Windscale factory for space heating and for the operation of the main chemical plant. As a result the whole of the Windscale factory now uses electricity and steam provided by the Calder reactors and is independent of all other forms of fuel.

## Consultancy: at home and abroad

The Authority act as consultants to the Central Electricity Generating Board on their nuclear power stations currently under construction in England and Wales and to the South of Scotland Electricity Board in respect of Hunterston. They supply a similar service to Agip Nucleare and to the Japan Atomic Power Company in connection with the construction by British industry of the nuclear power stations at Latina and Tokai Mura respectively.



*A bird's-eye view of the Advanced Gas-Cooled Reactor at Windscale.*

# REACTOR DEVELOPMENT

The current deployment of effort between reactor projects is shown below in percentages of qualified scientists and engineers in the Reactor, Research and Weapons Groups engaged on these projects.

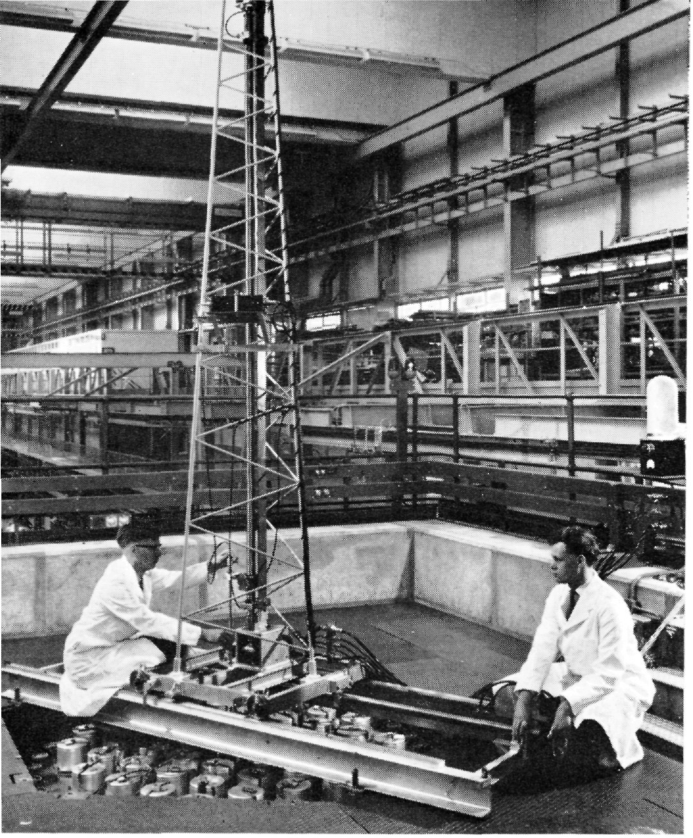
| System | Percentages |
|---|---|
| Advanced Gas-Cooled Reactor | 23 |
| Steam-generating Heavy Water Reactor | 15 |
| Fast Reactor | 36 |
| Civil Marine Propulsion Reactors | 13 |
| High Temperature Gas-Cooled Reactor* | 13 |

* Staff seconded to or supporting the European Nuclear Energy Agency high temperature reactor project Dragon.

**Advanced Gas-Cooled Reactor**

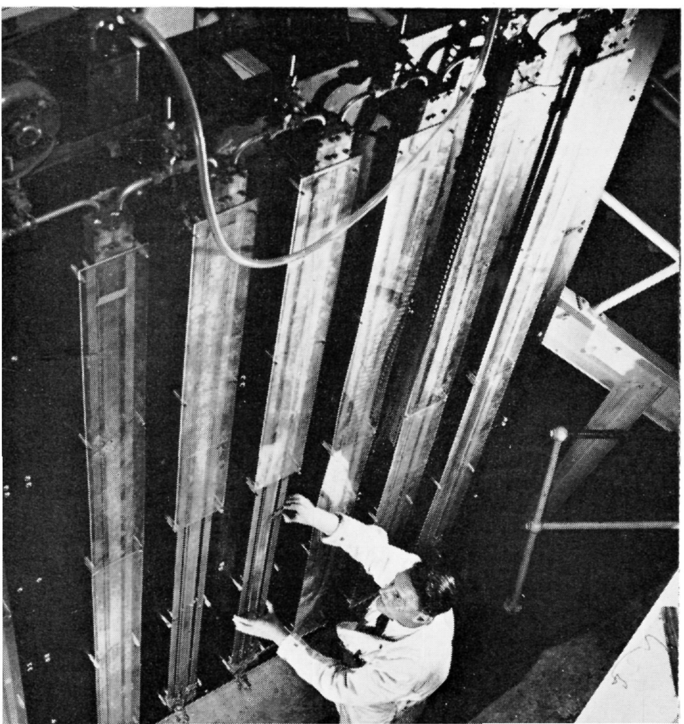
With the commissioning of the Windscale reactor, development of the Advanced Gas-Cooled Reactor technology has reached the demonstration stage. Studies of large A.G.R. power stations based upon the Windscale A.G.R. have continued.

There is more experimental information now than when the main fuel charge for the Windscale A.G.R. was designed and this has been incorporated in these design studies. The basic fuel arrangement is unchanged but improvements in the design have led to higher thermal efficiency, lower enrichment



*This assembly at Winfrith is used to study design problems in a steam-generating heavy-water reactor.*

*Measuring gas-pressure in A.G.R. In eight months A.G.R. supplied* 20,400,000 *kilowatt hours to the grid.*



and lower costs. The steam conditions will match those required for the most modern turbine sets. Experimental fuels incorporating these advances are now being irradiated in the Windscale A.G.R.

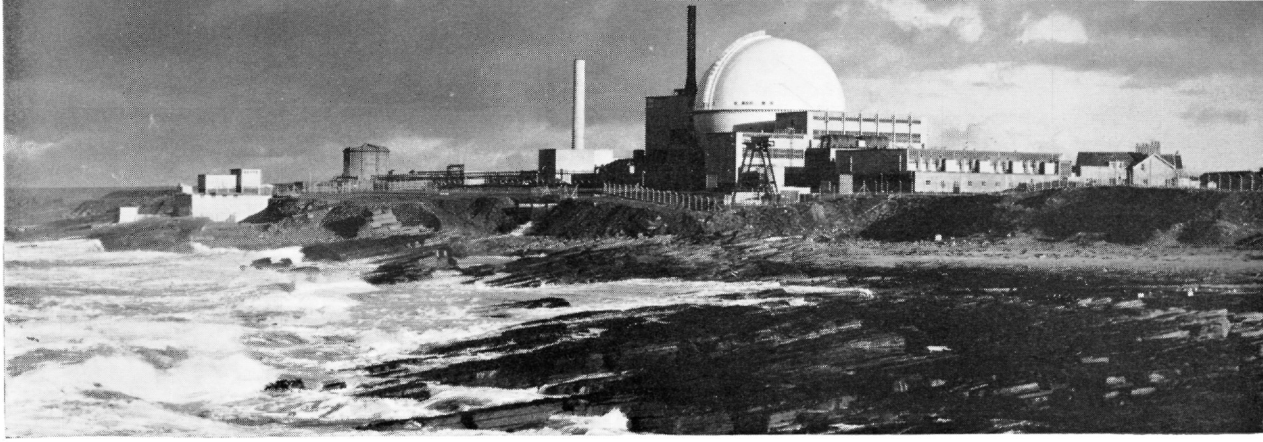
Reactor sizes of 1,000 MW(E) or greater are feasible, and these larger outputs would show marked savings in both capital costs per kilowatt and generating costs.

Apart from this development work, one of the immediate objectives in the Windscale A.G.R. programme is to establish the useful life for both fuel and plant. Present estimates necessarily are based upon information from small scale experiments but these will be checked against reactor experience during the first year of operation.

Arrangements have been made for experiments with a small number of highly irradiated fuel elements from the A.G.R. from which it will be possible to predict changes in power distribution and the kinetic behaviour of large A.G.R. power reactors after long irradiation.

Attention has been given to the longer term possibility of using uncanned uranium oxide or carbide dispersed in a refractory moderator as fuel elements in a future A.G.R. Low enrichment fuel of this type would be designed to retain fission products over a long irradiation and to withstand the thermal and mechanical stresses inherent in the reactor environment. Use of such a fuel would permit the fuel and coolant temperatures to be raised substantially. Two fuels have been selected for exploratory work, uranium dioxide dispersed in beryllia and uranium carbide in silicon carbide. Good progress has been made on the manufacture of specimens on a laboratory scale; irradiation tests will begin this year.

In order to predict long term effects of irradiation on graphite in a power reactor, accelerated tests on sample graphites in materials testing reactors have continued. Advances have been made in understanding graphite dimensional changes under irradiation and the present theory can explain all the experimental data so far obtained on several different graphites. Irradiation dose in experimental graphite specimens at reactor temperatures as yet corresponds to only about seven years life in a large civil A.G.R. Nevertheless, the success of the theory in interpreting results from low temperature experiments in which the damage is comparable with that expected in an A.G.R. has strengthened confidence that the dimensional changes in graphite at high irradiation doses and at A.G.R. temperatures will be well within acceptable limits.



*The Dounreay fast reactor is first in the world to supply electricity for public use.*

Further investigation of oxidation of the graphite moderator by the carbon dioxide coolant has shown that the effectiveness of carbon monoxide in protecting the graphite from attack depends on the presence of other substances in minor concentrations. An important aim of the early experimental work with the Windscale A.G.R. has been to determine the coolant mixture to give the best protection for the moderator.

Further studies of large A.G.R. power station designs have confirmed the generating and capital cost estimates made a year ago.

A marked trend in recent assessments has been to larger sizes facilitated by the use of concrete pressure vessels. Later stations in a substantial installation programme could well include reactors generating 1,000 MW(E).

This increased size, together with design improvements, could lead to a capital cost per kW 10 to 20 per cent below the £80/kW previously quoted. With overheads spread over a programme of 6,000 MW(E) at 75 per cent load factor with a station life of 20 years and an interest rate of 6 per cent the generating cost might fall in the later reactors below 0.40d per unit allowing for the improvements expected in fuel costs. With a 25 year life and 85 per cent load factor the generating cost might fall to 0.35d. per unit.

**Steam Generating Heavy Water Reactor**

Construction has started at Winfrith of a prototype steam generating heavy water moderated reactor (S.G.H.W.). The reactor is of pressure tube design with an output of 100 MW(E).

It is moderated partly by heavy water contained in the calandria, and partly by boiling light water coolant in the 112 pressure tubes which form the fuel element channels and which supply steam directly to the turbine. In order to demonstrate the feasibility of superheating, eight of the pressure tubes are being designed so that some of the steam from the boiling channels can be repassed through the reactor and superheated to 540°C. Fuel elements consist of a slightly enriched uranium dioxide clad in zirconium alloy for the boiling channels and in stainless steel for the superheat channels.

Measurements of critical size, power distribution and nuclear reaction rates on a range of S.G.H.W. reactor core designs have been carried out in the zero energy reactor DIMPLE and in sub-critical assemblies at Winfrith.

An experimental chemistry programme to establish conditions in which the cheaper and more easily fabricated ferritic steels can be used in place of stainless steels in water reactor circuits has begun. Effort on the development of suitable zirconium alloys has been increased; a number of trial pressure tubes are now being examined.

**Fast Reactor**

Final preparations for running the Dounreay Fast Reactor at power were completed in July, 1962, and a power level of 30 MW(H) was achieved on 7th August. This power level has been maintained over the remainder of the year apart from the shutdowns necessary to remove fuel for examination.

The reactor has continued to prove very stable in operation and easy to control. In October, electricity was supplied to the national grid. Although electricity generation is only a by-product of the experimental work, the reactor was able, during the operating periods, to supply the needs of the establishment and to export a surplus.

Since the most important function of the D.F.R. is to test advanced fuels under approximately correct conditions of temperature and rating it is desirable that the reactor should attain maximum power output and endurance from the uranium/molybdenum alloy fuel elements. This fuel has been improved during the year using experience of its behaviour at higher burn-ups obtained from more highly enriched test elements.

Production has begun of a fuel charge to a modified design which will enable the reactor power to be raised to about 50 MW(H).

A design study completed during the year for a 500 MW(E) fast reactor power station has established the features which need to be proven in a prototype fast reactor (P.F.R.)

Such a prototype must have fuel and engineering components on a scale which permits confident extrapolation to a civil power station.

Its engineering design will differ from that of the D.F.R. in having fewer circuits and larger heat exchangers, large mechanical pumps instead of small electro-magnetic pumps and single-well sodium steam boilers; the use of a concrete containment vessel is under consideration. No decision has yet been made regarding the siting of a prototype.

The zero-energy reactor ZEBRA began operating at Winfrith on 19th December. The fuel elements of this reactor are designed so that simulated fast reactor cores of differing composition may be studied. The early work is on cores fuelled with uranium-235 but cores containing plutonium fuelled regions will be studied later.

The development of manufacturing processes for fast reactor fuel has been made the responsibility of a team at Aldermaston.

### High-Temperature Gas-Cooled Reactor

Following the extension of the term of the Dragon agreement (to 31st March, 1967) all the Authority effort on the development of the high temperature gas-cooled reactor is now in support of the Organisation for Economic Co-operation and Development project (sited at Winfrith).

The Dragon reactor experiment is now at an advanced stage of construction and fuel-loading is expected to take place early in 1964.

The broad object of the extended programme is to provide the twelve European countries participating in the project with information leading to the design of an economic, land-based high temperature reactor. The extension of the agreement will permit a reasonable period of operation of the reactor experiment by the joint team.

*The physics of large fast reactors are studied in the ZEBRA reactor (Winfrith).*



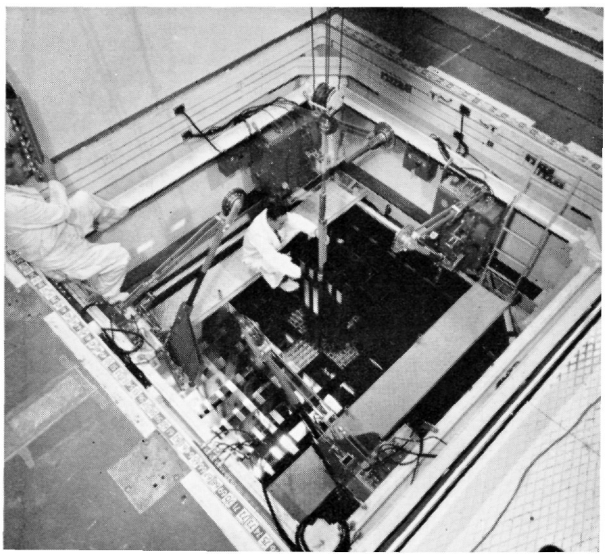
## Collaboration with Industry

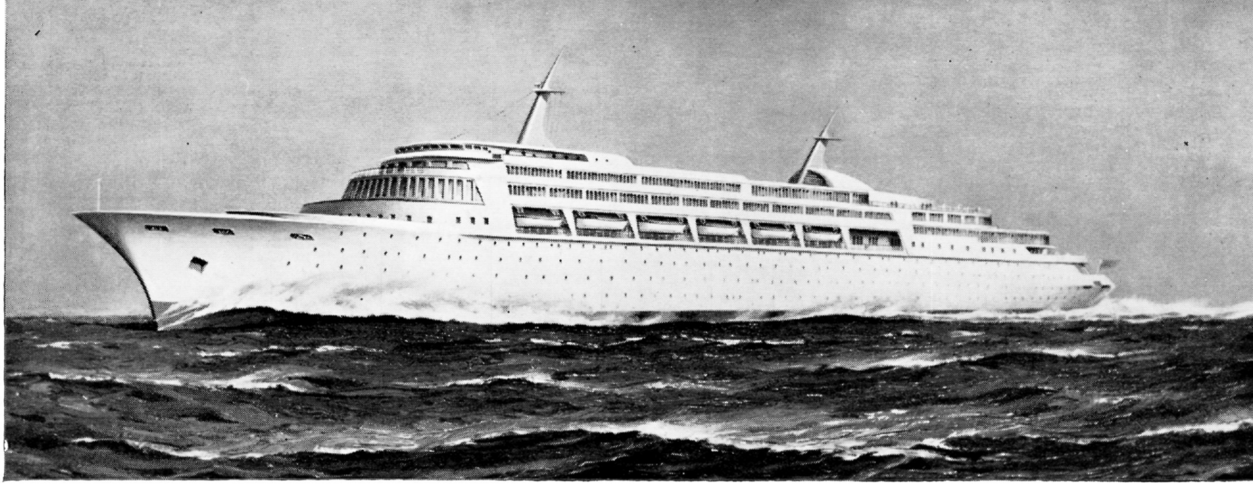
The close collaboration between the Authority and the British Consortia of companies engaged in constructing nuclear power stations at home and overseas has been maintained. In addition to the continued development of the gas-cooled reactor this collaboration also covered the development of several more advanced systems.

New collaboration agreements were signed with the Consortia in connection with the fast reactor and with water reactors. The agreement in connection with the steam generating heavy-water-moderated reactor was extended to 31st March, 1963, and a new and more comprehensive agreement will be negotiated to take account of government approval for construction of a prototype. It is intended that these advanced reactor systems will eventually, as with the gas-cooled system, be exploited commercially by the Consortia by means of licences granted by the Authority.

This collaboration between the Consortia and the Authority has for some time been guided and furthered by a Reactor Policy Committee. During the year, this Committee has been reconstituted to include representatives of the electricity generating boards and its rôle is now to consider policy matters in full partnership.

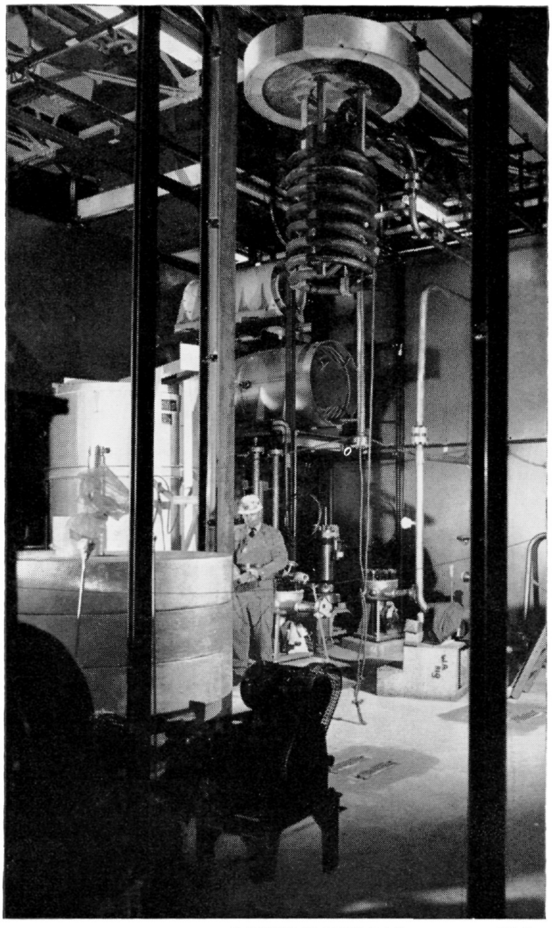
The organisations represented on the Committee are: the Atomic Energy Authority; the Central Electricity Generating Board; the South of Scotland Electricity Board; the Atomic Power Projects of English Electric, Babcock and Wilcox Ltd and Taylor Woodrow Construction Ltd; the Nuclear Power Group; and the United Power Corporation.





*Proposed design for a nuclear passenger liner.*

# REACTORS FOR SHIPS



*A VULCAIN high-pressure high-temperature loop being erected at the Reactor Engineering Laboratories, Risley.*

The prime object of the U.K. nuclear marine programme is to search for a suitable reactor which is economically attractive to a wide range of shipping.

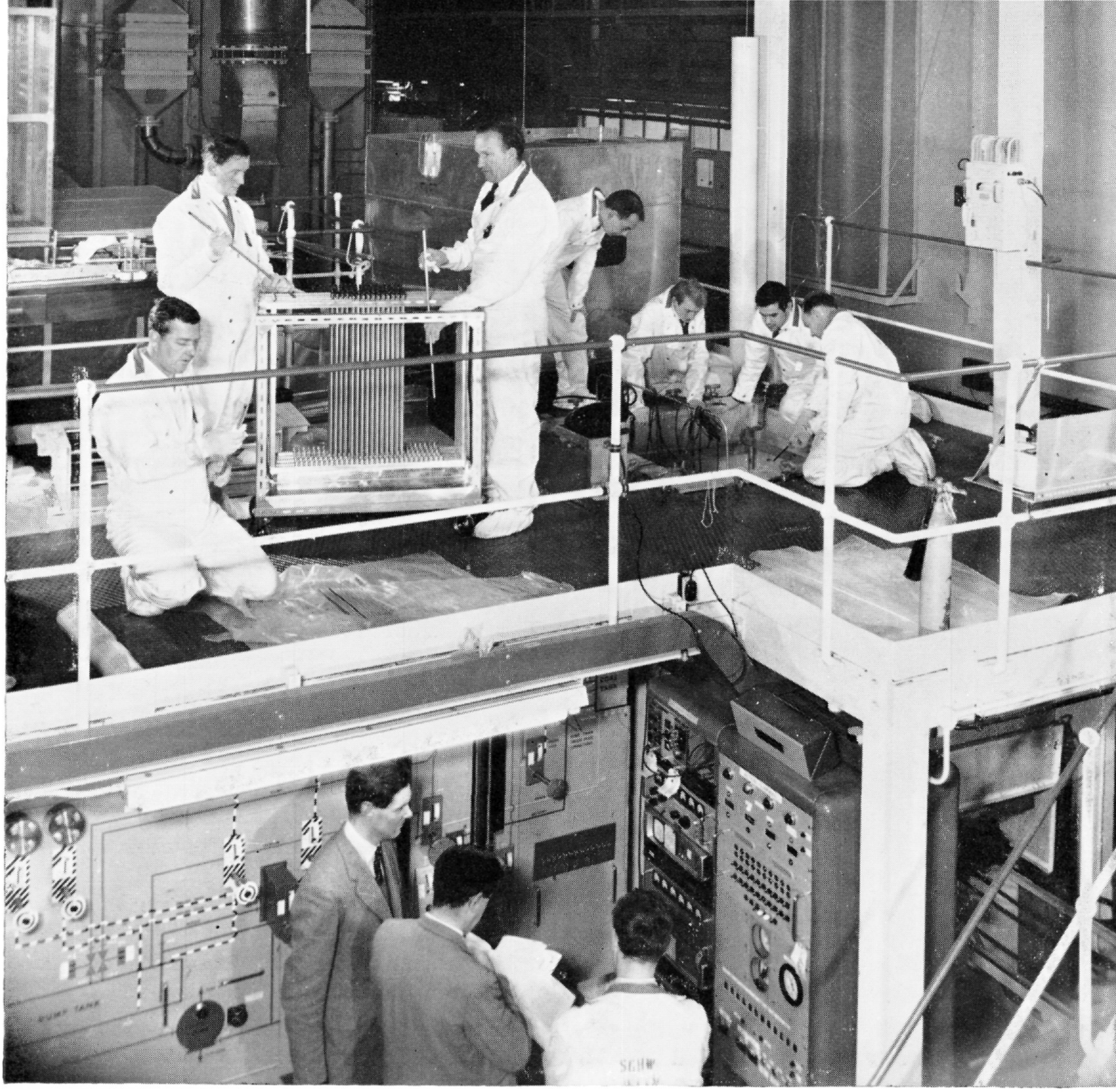
The programme of design and development work announced by Her Majesty's Government in November, 1961 is being implemented by a joint British Shipbuilding Research Association/Authority project team. This team comprises nuclear design engineers and scientists from the Authority with some attachments from the nuclear industry, together with a team of experienced marine engineers and naval architects seconded from the marine engineering industry.

The latter have a special responsibility for studying the design and operational problems arising from the installation of a nuclear reactor in a merchant ship and for studying the detailed design and special requirements of the propulsion machinery and auxiliary equipment.

Outline designs of several classes of merchant ships have been prepared, which take account of the effects of a nuclear installation on the design and construction of the hull, machinery and electrical equipment.

During 1962, the Working Group on marine reactor research which reports to the Minister for Science and the Minister of Transport, set up a Technical Advisory Panel to assess and make recommendations to the working group on six designs of ship reactor which had been studied during the first phase of the programme.

On 11th February, Her Majesty's Government announced that discussions would be held with the



*Winfrith's exponential assembly, HELEN I, is used to study marine systems.*

shipping and ship-building industries on the construction, ownership and operation of nuclear-powered ships with the expectation of taking a decision towards the end of 1963 on the construction of a prototype ship, provided that the results of the present research programme continued to be satisfactory.

The Working Group on marine reactor research consists of representatives of the Ministry of Transport (which provides the Chairman), the Authority, the Office of the Minister for Science, the Admiralty, the British Shipbuilding Research Association, Lloyd's Register of Shipping, the General Council of British Shipping, the Victoria University of Manchester and the Department of Scientific and Industrial Research.

The Technical Advisory Panel, under the chairmanship of Professor J. Diamond, of the Victoria University of Manchester, has members from the Authority, Lloyd's Register of Shipping, the British Shipbuilding Research Association and the Admiralty.

**VULCAIN and I.B.R.**

The recommendation of the Panel, which was transmitted by the Chairman of the Working Group and accepted by Ministers in November, was that future development be concentrated on the two reactors VULCAIN and the Integral Boiling Reactor (IBR).

These are both integral designs in which the major components are housed in the reactor vessel.

In comparison with earlier designs of marine reactors the size, weights and capital cost are expected to be significantly reduced; external pipes, valves and heat exchangers are eliminated and a smaller amount of shielding material is required. The reactor can be assembled and tested under clean workshop conditions before installation in a ship and can be removed and replaced by a freshly fuelled unit at the end of core life.

The VULCAIN reactor, which is being designed and developed jointly by the Authority and a consortium of Belgian firms (Syndicat Vulcain) under an agreement signed in Brussels in May, 1962, is essentially a pressurised water design using a mixture of heavy and light water as primary coolant and moderator. Steam is generated in the light water secondary circuit by means of a heat exchanger. Circulating pumps, shut-off rod mechanism and heat exchangers are all contained within the pressure vessel. Access to the pressure vessel head is permitted when the reactor is shut down, and the pump can be replaced in the event of mechanical failure. Both pumps and individual heat exchanger tube banks can be isolated by shut-off valves and the reactor can continue in operation in an emergency at reduced power.

In the I.B.R. design the fuel elements are contained in a series/parallel arrangement of fuel tubes of zirconium alloy through which light water is circulated at high pressure; the secondary coolant, from which steam is generated, surrounds the fuel tube assemblies. Steam/water separators are provided in the head of the vessel, the steam passing to the turbine and the water recirculating through the reactor.

In both designs, the heat exchangers are inside the reactor pressure vessel close to the fuel elements and the steam formed will contain radioactive nitrogen-16, which will pass into the main engines. The half life of nitrogen-16 is very short and the level of induced activity would not be high enough to interfere with normal maintenance. Existing evidence on the design and operation of land based reactors where the coolant water is similarly irradiated shows that the level of activity in the steam circuit has not interfered with operation and maintenance.

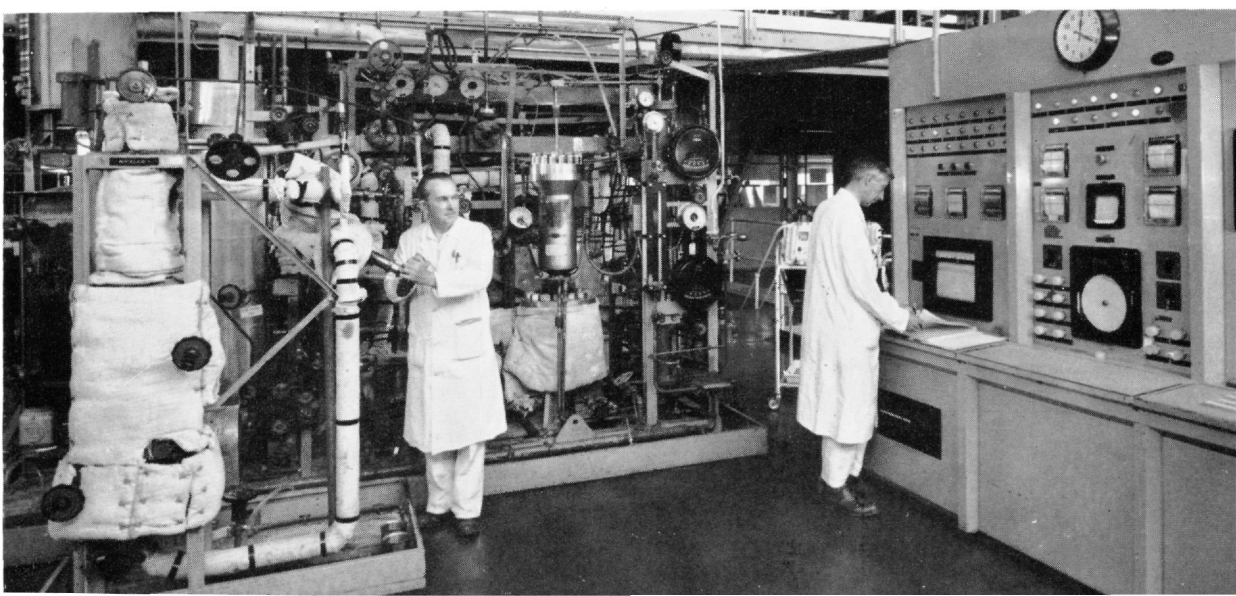
The present phase of the programme also includes intensive design and manufacturing development work to evaluate the reliability and assess the cost of the major reactor components.

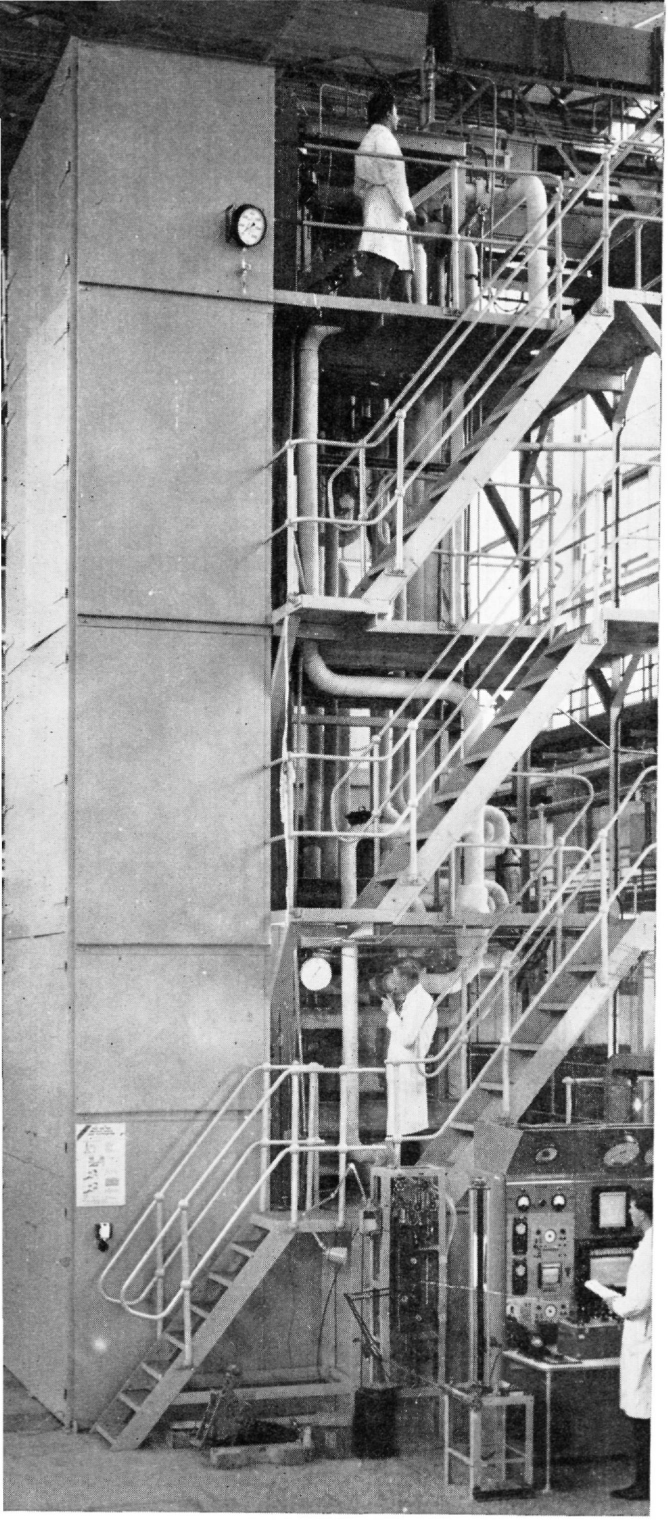
Many of the more conventional problems associated with the propulsion machinery and auxiliary equipment are being examined by the marine team in association with marine engineering and shipbuilding firms to ensure adequate standards of performance for the nuclear ship.

**Reactor Physics**

Reactor physics work in support of VULCAIN is being carried out in HELEN I and HELEN III at Winfrith (the various HELEN assemblies are sub-critical experimental facilities which provide essential data on the physics of water-moderated systems). HELEN III uses neutrons from the NESTOR reactor.

*Corrosion studies at Harwell provide information of value to designers of water reactors.*





*Heat transfer experiments for S.G.H.W. and marine Reactors are conducted on this "one megawatt rig" at Winfrith.*

Arrangements are in hand to extend these measurements to a VULCAIN type core using a zero energy facility under construction at the Belgian Centre d'Etude de l'Energie Nucleaire (C.E.N.) establishment at Mol. This will be followed by irradiation of a representative core in the pressurised water power reactor BR.3 at Mol. The Authority will manufacture half of the fuel charge for the experiment in B.R.3. Engineering development of components of the circuit pumps, instrumentation and control equipment has started and contracts to develop the necessary manufacturing techniques for the vessel and internals are being placed with industry.

The reactor physics of I.B.R. will be studied in HELEN II and HELEN V which are being commissioned at Winfrith. The Winfrith reactor DIMPLE will be used to study I.B.R. core arrangements under operational conditions. Work on core materials for I.B.R., such as the zirconium alloy fuel-tubes, is in hand together with an irradiation programme for the pressure-vessel steel.

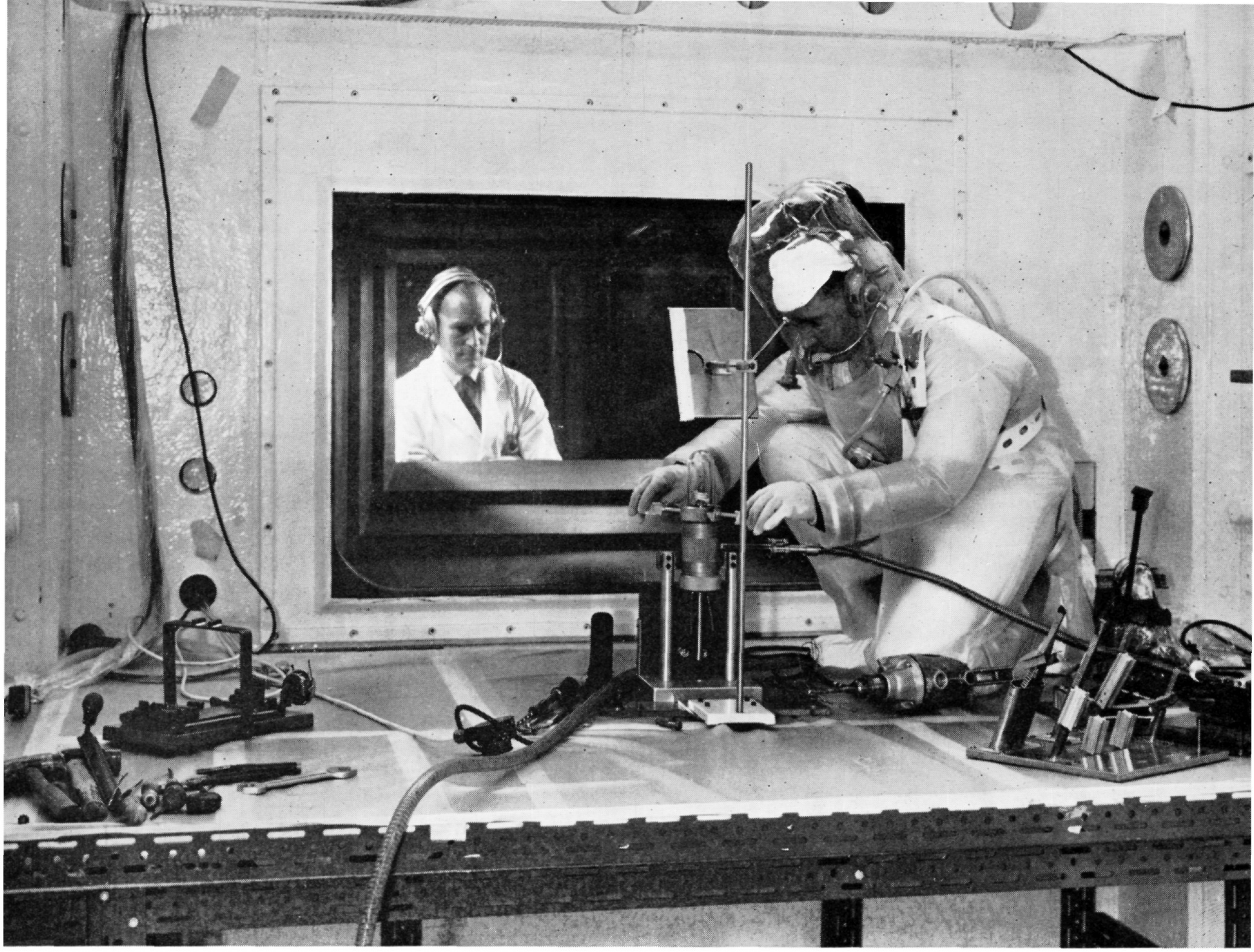
**Economics**

Present cost estimates are preliminary and involve some extrapolation; an important part of the current phase of the work is to obtain firmer cost estimates from a practical development programme in collaboration with shipbuilders and the marine engineering industry.

If present forecasts are confirmed, there are good prospects that the capital cost will fall within the target of £0.5M—£0.75M for a series of 20,000 shaft horsepower reactor units. This achievement would be dependent on the savings to be expected from series production of the complete reactors. The cost of the earlier reactors, particularly the first, would of course be greater.

Fuel costs depend essentially on achieving long burn-up. If the present oxide fuels are successfully developed and average irradiations of 20,000 Megawatt-days per tonne of uranium can be reached, VULCAIN and I.B.R. fuel costs will approach 0.2d/shaft-horsepower per hour. For ships of high utilisation and high power (e.g. 20,000 shaft horsepower and above) these figures show near parity with conventional steam-turbine ships.

The operation of nuclear ships will need shore installations for refuelling and servicing the reactors. The costs of these are taken into account in calculating the operating costs.



*The effects of radiation on materials is studied at Harwell. A mechanic in protective clothing is shown adjusting equipment.*

# HOW REACTORS BEHAVE

Apart from their work on specific reactor systems (such as A.G.R., the Fast Reactor, etc.) the Authority undertake more general research common to several reactor systems.

The greater part of this research is divided roughly equally between the Research and Reactor Groups and the Weapons Group also contributes. It includes reactor physics; the assessment of reactor types; the development of instruments; and the provision of information on the properties of materials relevant to reactor development generally.

### Nuclear Data

Detailed and reliable nuclear data are essential for reactor physics calculations. The United Kingdom, other European countries, Canada and the United States of America are co-operating in a major programme to obtain these data.

Work on "nuclear cross-sections" for neutrons is going forward at Harwell and also at the Atomic Weapons Research Establishment. These cross-sections, which are measures of the probabilities that various reactions between neutrons and the nuclei of atoms will take place, are required for many different nuclear species over a wide range of neutron energies.

### Theoretical Methods

The precision and detail with which reactor behaviour can be forecast have been much improved

*FIFI (Fine Flux Investigations Facility) is used at Windscale to study fuel for A.G.R. and other reactors.*

*Samples of highly radioactive material being loaded into Harwell's GLEEP reactor. GLEEP started work in* 1947.

by the increased accuracy of the nuclear data and by better understanding of the physics of reactors, combined with the advent of large, high-speed computers.

Development of these methods of calculation, and comparison with experiment, has continued in the Reactor Group. The methods developed are being applied to an analysis of the results of experiments in HERO (Windscale).

Refined theoretical methods have been applied to the Calder Hall reactors and give results which agree excellently with experiment. Similarly comparisons between theory and experiment have been extremely encouraging for plutonium-fuelled reactors, boron control rods, and water-moderated reactors.

Assessments of the comparative performance of different systems can thus be made with greater certainty than hitherto.

**Plutonium**

One subject of research is the possibility of using plutonium as an alternative to uranium-235 for enriching the fuel in thermal reactors, for example in the advanced gas-cooled reactor, the steam-generating heavy-water reactor and marine reactors.

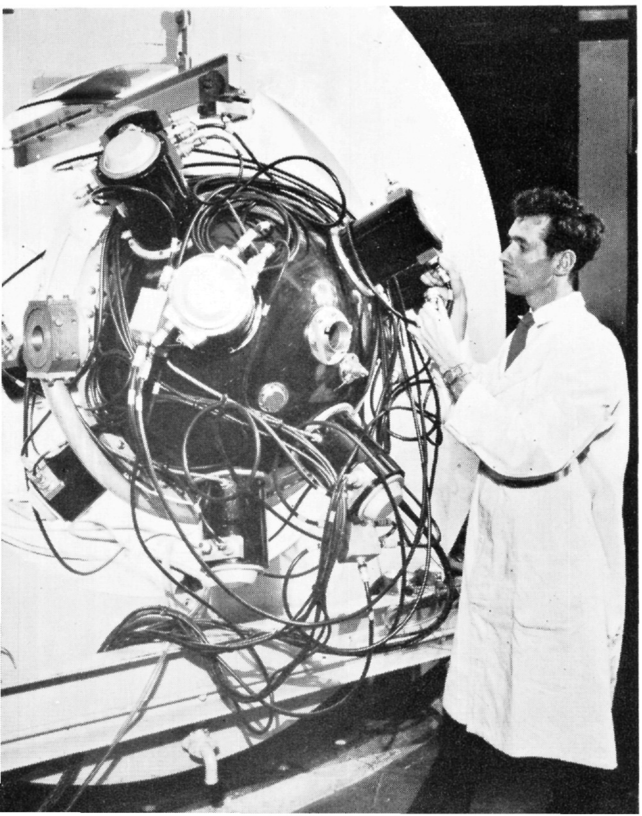
The main uncertainties in this application are the concentration of plutonium required to reach given irradiation levels, the behaviour of plutonium-bearing fuels under irradiation and the cost of manufacturing fuel elements. The heated zero-energy reactor ZENITH at Winfrith has been modified to allow the use of plutonium-bearing fuels and experiments are being made to determine the effect of plutonium in graphite-moderated reactors at higher temperatures and at higher concentrations of plutonium than have been investigated so far at Winfrith and Windscale. Arrangements have been made to prepare plutonium-bearing fuel elements at different enrichments for an extended programme of experimental physics and for irradiation in the Windscale A.G.R.

**Heat Transfer**

At Winfrith heat transfer in reactors is being studied in boiling water systems, particularly in the situation called "burn-out" (when a film of steam is formed on the fuel element which interferes with the removal of heat from the hot surface). Experimental evidence is being collected which will enable conditions leading to burn-out to be predicted in the clusters of fuel-elements used in boiling-water reactors. Work is being done at Harwell on heat transfer in systems employing drier steam; this work covers both burn-out and the hydrodynamics of the coolant flow.

Experiments on the effect of regularly roughening (by the attachment of wires or by other means) a surface used to transfer heat to a gas indicated that the heat transfer is improved markedly without a disproportionate increase in skin friction. Measurements on a heated cluster of Windscale A.G.R. fuel elements have confirmed that roughening the stainless-steel can does give the predicted improvement in heat transfer. To extend the experiments a loop is being commissioned at Windscale for investigating the effect of roughened surfaces on heat transfer in liquids.

A study of the feasibility of dust cooling is under way at Winfrith. By loading a gas such as carbon dioxide with fine particles (e.g. graphite) the heat transport and heat transfer can be considerably improved; the coolant combines the high-temperature properties of a gas with the heat-transfer properties of a liquid. Initial assessments and simple experiments on heat transfer have shown that the method might lead to savings in both capital and running costs but a great deal of work would be necessary to develop the technology to the stage at which it could be applied to a reactor.



*Aldermaston's liquid scintillation counter provides precision measurement of the average number of neutrons emitted per nuclear fission.*

**Reactor Control**

The higher rating and rapid dynamic response of advanced reactors mean that they require improved systems for their control.

The tight coupling between steam output from boilers and power from the reactor makes it necessary to consider the whole plant, reactor and boiler and generator, as an entity in order to determine requirements for control. The problems involved are being studied at Winfrith. The procedure is to establish mathematical models of the dynamic behaviour of each item of the plant and to use this information in studies of a control system under normal and fault conditions. Much use is made of the largest analogue and digital computers and substantial progress has been made in developing control theory.

The requirement for complete safety without unnecessary shutdowns due to faults in the safety equipment itself has led to the development of systems in which extreme reliability of individual units is combined with the use of units in sets of three or more, so arranged that failures would have to occur in a majority simultaneously (usually two out of three) before the reactor was shut down (sometimes called the method of redundancy). In addition, by self-monitoring and other methods, failures in units are indicated, without causing a reactor shut-down, so that they can be remedied.

These techniques of redundancy and self-monitoring are highly developed for electronic instruments and are now being extended to the servo-mechanisms used in automatic control systems with considerable improvement in performance.

**Shielding Research**

A "biological shield" has to be built round a reactor to protect the operating staff by reducing radiation to permissible levels. In a nuclear power station the "shield" would usually be of concrete, seven or eight feet thick.

Substantial savings could be made in the capital cost of nuclear power plants if it were possible to design biological shields to closer limits and thus reduce their weight; for marine reactors too it is important to reduce the weight of shielding. Research is aimed at improving the theory underlying shielding calculations and providing the information needed for such calculations.

## Fuel Materials

Major research programmes are aimed at obtaining, for fuels in use now or likely to be used in the near future, the information needed in order to be able to fabricate these fuels efficiently and use them economically in reactors. For these purposes it is necessary to know their chemical stability, compatibility with canning and other materials, and stability under irradiation.

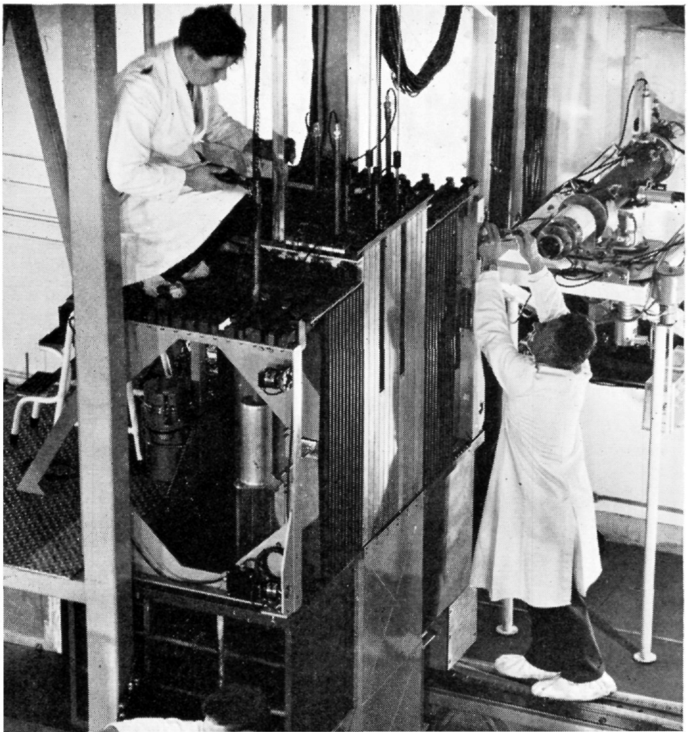
The fuel used in the magnox stations is uranium metal which, at higher temperatures, swells during irradiation owing to the formation of gaseous fission products. Swelling is greatly reduced by adding small quantities of iron and aluminium to the uranium. Work at Harwell has suggested as an explanation that precipitates introduced by these impurities anchor the tiny bubbles of fission-product gases and thus prevent them from coalescing into larger bubbles.

Carbides are attractive alternatives to oxide fuels for both thermal and fast reactors because of their higher thermal conductivity and greater density of fissile atoms. Current investigations are aimed at determining the stability of these materials under irradiation. The feasibility of nitrides and sulphides as alternative materials for fast reactor fuels is also being investigated.

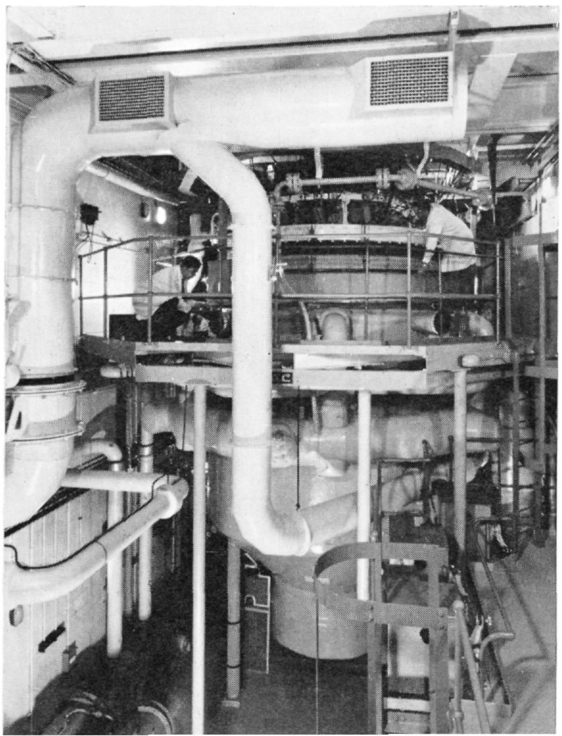
Progress has been made in producing a fuel by coating small spherical globules less than a millimetre across with ceramic materials that cannot be penetrated by fission products even at high temperature. Silicon carbide has been found to be very effective for this purpose and tests are being made to establish its radiation stability.

Novel forms of graphite, for use in fuel elements capable of retaining fission products, are being produced in an experimental plant at Harwell. Most of this work is supported by the "Dragon" Project (Organisation for Economic Co-operation and Development).

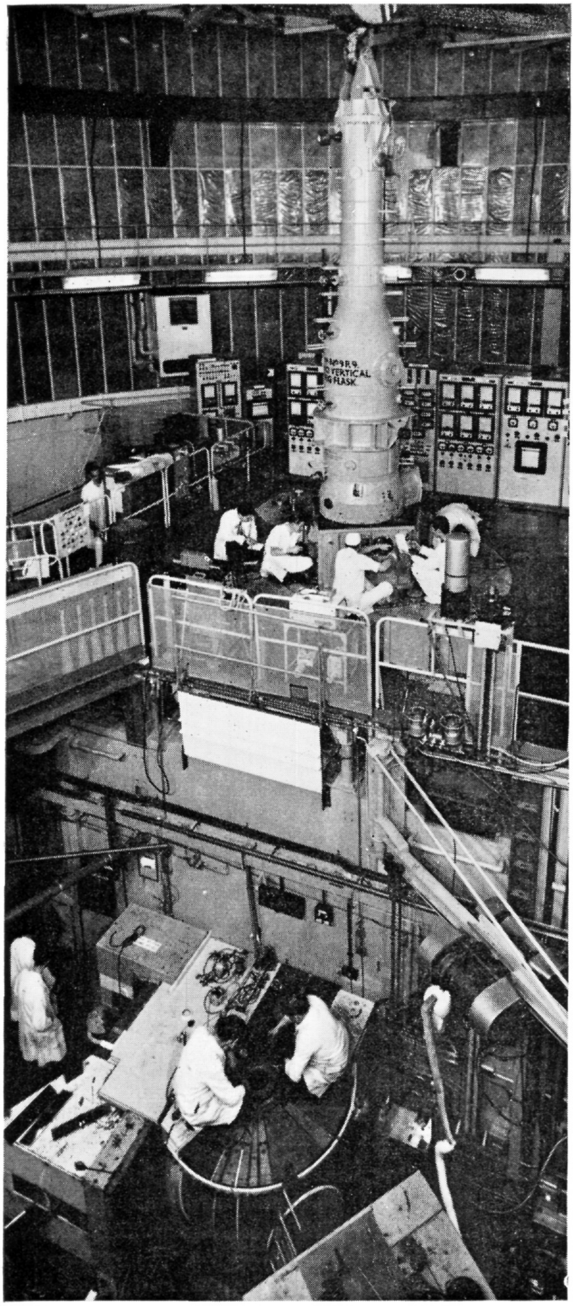
*VERA, a new low-power reactor at Aldermaston provides data for fast reactors.*



*The physics of high temperature gas-cooled systems are studied in the ZENITH reactor (Winfrith).*



# BASIC RESEARCH




*The PLUTO reactor at Harwell is used for irradiation experiments which involve large rigs and loops.*

The aim of the Authority's programme of basic research is partly to provide fundamental scientific knowledge for future developments of atomic energy, and partly to supply the scientific understanding needed to solve problems arising during the rapid development of the present programme.

Much specialised equipment is required, such as high-flux research reactors, "hot" laboratories, the neutron booster at Harwell, and many specialised techniques. Consequently much of the basic research supporting nuclear technology must be carried out in the Authority's laboratories rather than in universities. Where appropriate there is close collaboration with university and other laboratories both in the U.K. and overseas.

A large part of the general and applied research programme is concerned with the interaction of neutrons and other radiations with matter on both the nuclear and atomic scale. Nuclear interactions govern the physics of reactors. Atomic interactions produce gross effects in bulk matter which are particularly important in fuel.

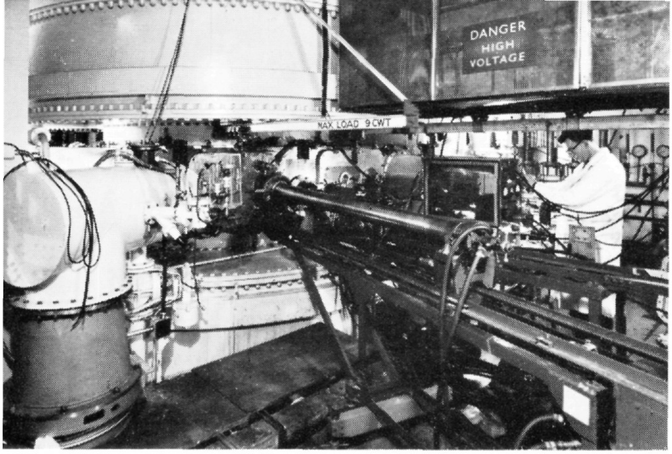
### New Cyclotron

A new variable-energy cyclotron is being built at Harwell for general studies on the physical and chemical effects of radiation. The machine will provide beams of protons, deuterons, helium ions and heavier particles over a range of energies and at much higher currents than those at present available. Information on effects following high doses of radiation of controlled energy will therefore be obtainable relatively quickly.

### Physical metallurgy

Although ceramics are likely to be the dominant fuels of the future, metallic fuels will be important for some years to come and other metals will always be used in reactor engineering. Research therefore continues on the physical metallurgy of uranium, plutonium, and other metals of technical interest.

Materials that maintain superconducting properties under high magnetic fields have several potentially important applications in the atomic energy field. The metallurgy programme therefore includes research on new alloys known to exhibit such properties with the aim of understanding the superconducting processes.




*Harwell's synchro-cyclotron accelerates protons to very high speeds in a spiral path.*

*Direct conversion is an alternative to conventional electricity generation. An experimental diode under test at Harwell.*

**Nuclear physics**

The Authority's programme of basic research in nuclear physics is aimed at deepening and making more reliable the theories of nuclear structure and reactions.

This work is mainly in the field of low-energy nuclear physics for which Harwell is uniquely equipped. During the past year the extremely short and sharply-defined pulses of deuterons from the new accelerator IBIS have been used, in the time-of-flight method, to determine with high precision the energies of neutrons from nuclear reactions, thus opening what is virtually a new field of study.

Further steps have been taken to make some of the specialised facilities at Aldermaston available for work of a non-defence character. The main areas of the Nuclear Research Division, including the light-water-moderated HERALD reactor and the 3 MeV, 6 MeV and 12 MeV Van de Graaff accelerators, were separated from the main site in January, 1963, and declared an unclassified area, so that the facilities could be made available to research workers from British and American universities. About a quarter of the facilities of the HERALD reactor are now available for university work, financed through a grant from the National Institute for Research in Nuclear Science. A programme of work under these arrangements is already well under way.

A number of research students from Oxford University are integrated into the Atomic Weapons Research Establishment teams working on the accelerators and it is hoped that the use of these machines by university workers will increase.

**Analytical chemistry**

In large areas of research progress can be made only if accurate and reliable analytical methods are available and throughout the Authority a considerable effort is devoted to analytical chemistry.

In the Research Group, the main part of the programme is directed to development and application of methods of analysis for investigations in such fields as solid state physics, nuclear physics, fall-out surveys in health physics, metallurgy and, of course, general chemistry and chemical engineering research. There are also a number of long range investigations into new techniques involving radiochemical, mass spectrometric, pelarographic and other methods.

At Aldermaston a new mass spectrometer of high sensitivity has been commissioned and will be used for the determination of isotopic ratios in solid samples of less than $10^{-9}$g in weight.

**Instrumentation**

A necessity in all laboratories and plants is the provision of instruments to measure a wide variety of physical quantities over a great range of values. Most of these instruments are available commercially but the Authority also undertake research to develop special instruments to meet their particular needs.

Nuclear instruments, like nuclear materials, have often to contend with the presence of radiation, which may have long-term effects on performance; these effects on, for example, thermocouples, are under investigation.

### Electronics

An extensive programme of research is undertaken in electronics. This work influences, and is influenced by, work in many other fields.

The detection and measurement of nuclear particles and radiations depend almost entirely on electronic methods; so too do the analysis of the measurements and the control and instrumentation of the particle accelerators and reactors used in making the measurements.

Much of the electronic equipment required is available commercially and the electronics programme at Harwell is aimed at discovering, or exploiting, and developing new techniques and materials in order to improve methods for dealing with existing problems or to anticipate problems of the future.

To cite an example, methods have been developed for recording on magnetic tape the counts from a combination of radiation detectors associated with an experiment using a particle accelerator and subsequently analysing and correlating the recorded information at high speed on a large multichannel analyser, which can thus serve several concurrent experiments.

By developing high-speed temporary stores using electrostatic storage tubes and ferrite cores it has been possible to increase the number of counts recorded per pulse of the accelerator and thus greatly to improve the utilisation of these expensive machines.

### Direct conversion

The Authority have a small programme of exploratory work at Harwell on methods for converting heat energy directly to electrical energy. Close contact is maintained with the Central Electricity Generating Board to ensure that this work does not duplicate that of the Board in this field.

One investigation is concerned with the application to nuclear reactors of the magnetohydrodynamic (M.H.D.) method of conversion. In this method a gas is heated to a high temperature, partly ionised, and passed through a magnetic field, where positive and negative ions are separated enabling electricity to be drawn off. To obtain interaction between a thermally ionised molecular gas, of the sort given off by fossil fuels, and the magnetic field the temperature would have to be about 2,500°C. This temperature is much beyond the range of a gas-cooled reactor, but it appears possible that an inert gas (such as would be used in a high temperature gas-cooled reactor) may, by seeding it with small amounts of metallic caesium or potassium and employing non-equilibrium ionisation, be made to interact at lower temperatures around 1,000 or 1,200°C. This possibility is being investigated.

In another method a nuclear fuel element is used as the cathode of a thermionic diode and is heated by fission; direct current can then be extracted from the anode. A successful experiment has been made during the year with two diodes in the PLUTO reactor having cathodes made of uranium-carbide/zirconium-carbide; caesium vapour was used to neutralise the space charge.

Attention is also being given to the design of direct conversion equipment for small power sources which depend on the energy generated by radioisotopes. Such sources have potential uses in space vehicles, navigational beacons, repeaters for undersea cables, remote weather stations, etc. The Authority would be able to supply as much radiostrontium as is likely to be required for this purpose if the need arose.

# Inventions

Valuable know-how and patents arise from the Authority's research and development work. To protect their inventions the Authority apply for patents, in all suitable cases, both in the U.K. and overseas. In continuance of their policy of exploiting their inventions, licences have been negotiated with industrial and other organisations both in the U.K. and in a number of overseas countries. The number and commercial importance of such licence agreements are increasing.

The Authority's inventions used by industry cover a wide range. Important licences negotiated during the year include those relating to a mobile linear accelerator, galvanic cells for oxygen measurement and automatic neutron diffractometer equipment.

The Authority have also sold a high temperature reactor reference design study to the Organisation for Economic Co-operation and Development Dragon project.

Other licence agreements negotiated during the year included chemical, electrical and electronic equipment; ionisation chambers; mechanical equipment; monitors; power units and regulators; radiation detectors; ratemeters and reactor instruments; and scintillators.

# FUSION

At the present stage, progress towards the release of useful power from fusion reactions is impeded by difficulties in heating a plasma (a hot ionised gas) and in holding it together for times long enough for sufficient fusion reactions to take place. These difficulties have called for a deeper understanding of the state of matter called "the plasma state".

The only way of holding a hot plasma together considered to be practicable at present is by means of magnetic field, and the difficulties have arisen because the plasma escapes from the magnetic "cages" in so many different ways. Even now, after several years of research, there is no certainty that all the possible methods of escape have been discovered, while those which are identified have not yet been mastered.

The Culham Laboratory programme remains concerned with stability studies on a wide range of plasma containment systems.

Most of these systems take the form of either pinch configurations or magnetic traps. In the former, the confining magnetic field is generated by an electric current passing through the plasma; in the latter, the confining magnetic fields are almost entirely produced by currents flowing in external conductors.

### Pinch Systems

In pinch experiments, a column of plasma carrying an electric current experiences a radial compression (or pinching) as a result of the interaction between the plasma and the magnetic field associated with this current, and is heated by the same current by means of Ohmic losses in the plasma column. Pinch experiments can be in linear or toroidal form, and the Culham programme includes both types.

ZETA remains the main toroidal pinch experiment, and during the year it has been modified to get a faster rise of current in the discharge,

*A plasma experiment in which a current flows along a central rod in the discharge tube and back through the gas.*

and a longer time of steady current. Experimental work has restarted, and further studies are being made on the mechanism of the plasma losses.

The largest linear pinch experiment (TIBER), which came into operation during the year, has tube dimensions comparable with those of ZETA, and is being used to study plasma behaviour with a rate of current rise 100 times that in ZETA.

### Inverse Pinch

In the "inverse pinch" systems, the plasma current returns along a central conducting rod, and the plasma cylinder is sandwiched between the field from this conductor, and another field applied outside the tube. In both "pinch" and "inverse pinch" systems, instabilities due to interchange between the plasma and the magnetic field are reduced by "shear", by which is meant a change in direction in the magnetic field with increasing distance from the centre of the plasma volume. The inverse pinch experiments, have, however, shown new forms of instability due to the finite resistivity of the plasma, and theoretical studies predict this kind of instability in three distinct modes. New inverse pinch experiments have been started to extend studies of these instabilities and ways of overcoming them.

### Shock Heated Pinch

By shock heating plasma, high ion temperatures and high densities can be produced simultaneously, and the plasma can be taken quickly through those intermediate temperatures where radiation losses and resistivity instabilities are troublesome. A shock heated pinch device (Tarantula) has been constructed on the Culham site, but it is not yet fully commissioned.

### Magnetic Mirrors

Mirror systems allow a separation of the arrangements for plasma heating and for containment. They are inherently leaky, though the leaks are not always serious. Hot plasma can be obtained in these traps by injecting neutral particles, charged particles, or plasma. In "Phoenix", neutral hydrogen atoms are injected and ionised inside the trap, and good plasma densities have been achieved. A larger apparatus is now being built on the Culham site. In another experiment, hydrogen ions are injected into the trap where they can be held for a time by space-modulated magnetic fields. The third experiment uses plasma guns to fire blobs of plasma into the trap, for which complex forms of mirror fields will be used in attempts to get greater stability.

### Fast Compression

Plasma already in a trap can be compressed and heated by suddenly increasing the surrounding field strength. In the cusp experiment, a cusp-shaped field is used which increases in strength in all directions away from the plasma, and therefore gives theoretical stability. In practice, there are leakage difficulties, and although good plasma densities have been achieved, the temperature is too low. A new preheating system has been developed using conical thetatrons as plasma guns. The thetatron itself is also used as a confinement system; it compresses and heats the plasma by suddenly increasing the surrounding field strength. It has produced plasmas of high density and temperatures, but it suffers from an instability caused by rotation and splitting of the hot plasma. A new and more powerful thetatron (or theta pinch) experiment is under construction on the Culham site.

### Basic Plasma Studies

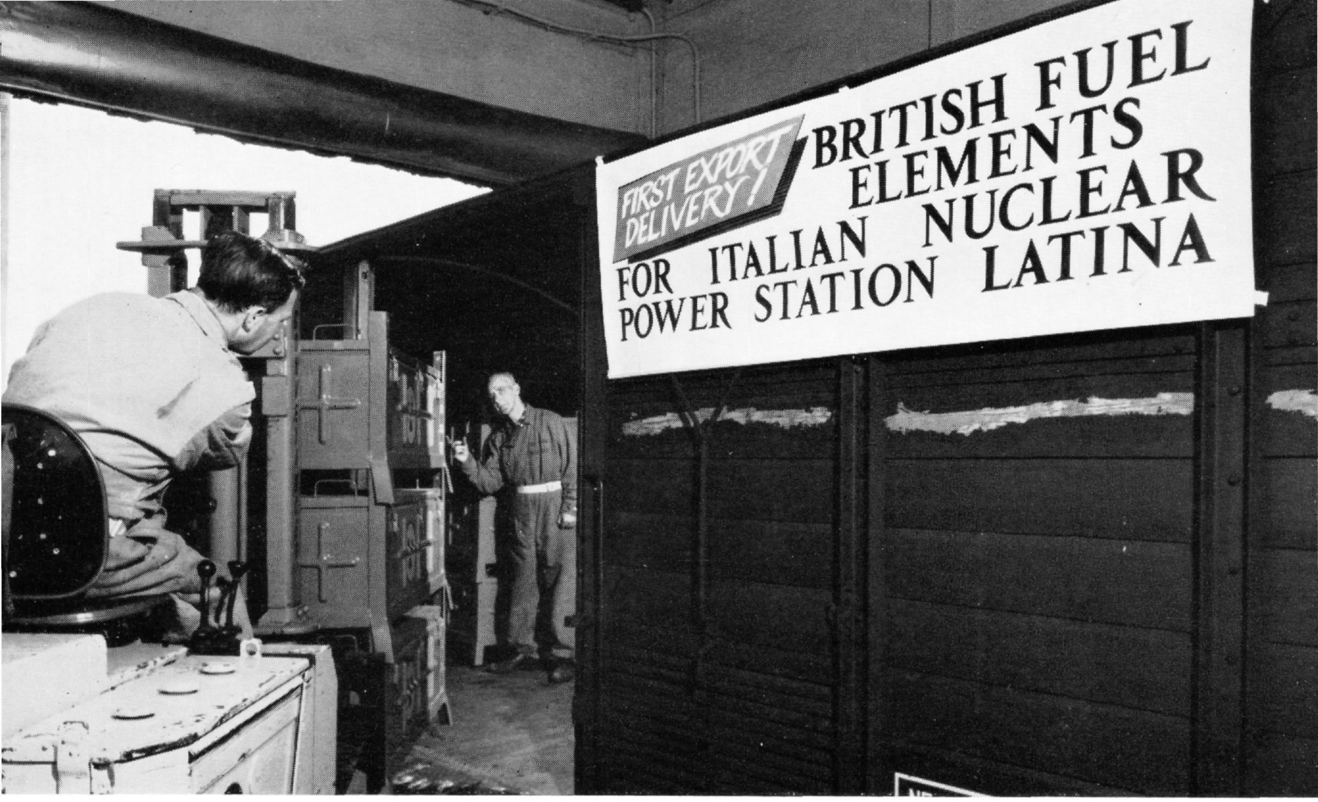
Fundamental studies of plasma are essential in the understanding of confinement systems and their instabilities. Many of the basic studies at Culham are concerned with wave motions in plasma, and are not linked to any particular kind of confinement system.

### Space Research

Most of the matter in the universe is in the plasma state, and in some parts it is in a condition of direct interest to Culham's plasma research. One of these regions is in the solar corona, which Culham is preparing to study as part of the Royal Society's space programme. Vacuum ultra-violet spectrographs on specially stabilised mountings have been developed for use in Skylark rockets during the coming year.

### The Culham Site

During 1964 the Laboratory, as at present planned, should be finished, and all the Authority plasma physics and fusion research staff should have moved, together with their apparatus, to the Culham site.




*The Springfields factory supplied 26,300 fuel elements for the Calder Hall-type nuclear power station at Latina in Italy.*

# FUEL PRODUCTION

The Authority's principal industrial activity has continued to be the manufacture and sale of magnox fuel elements for the United Kingdom electricity generating boards, for the Italian nuclear power station at Latina, and for their own reactors.

In addition to the contracts concluded between the Authority and the U.K. electricity generating boards for the supply of fuel elements and for the repurchase of the irradiated fuel arising from the reactors at Bradwell, Berkeley and Hunterston, Letters of Intent have been obtained from the C.E.G.B., in connection with the purchase of fuel elements for the Hinkley Point, Trawsfynydd, Dungeness, Sizewell and Oldbury power stations.

Agreement has been reached with the Japan Atomic Power Company on the basis of a contract for the supply by the Authority of hollow fuel elements for the company's nuclear power station, at present under construction at Tokai Mura by the General Electric Company Limited and a consortium of Japanese companies. The reactor is due to start up at the end of 1964 or the beginning of 1965 and the initial fuel loading is scheduled for delivery during 1964.

Most of the 400 tonnes of fuel to be supplied under the Authority's contract with S.I.M.E.A. was delivered to the Latina nuclear power station during the year.

The sale to the French of about 45 kilograms of plutonium in the form of oxide, for use in their experimental fast reactor, "Rapsodie," was negotiated through the Euratom Supply Agency under the U.K/Euratom Agreement of 1959.

The Authority supplied enriched uranium fuel for a number of research reactors overseas, as follows:

| *Location* | *Reactor* | *Type* |
|---|---|---|
| Riso, Denmark | DR3 | Material Testing Reactor (PLUTO type) |
| Lucas Heights, Australia | HIFAR | Material Testing Reactor (DIDO type) |
| Julich, West Germany | DIDO | Material Testing Reactor |
| Julich, West Germany | MERLIN | Research Reactor |

Seventy-five irradiated fuel assemblies from the Danish DR.3 reactor were returned without incident to the Authority's reprocessing plant at Dounreay. This operation was the first of its kind using a scheduled shipping service.

Steps have been taken to advertise to industry and to other potential users the properties of depleted uranium, i.e. uranium in which the content of the fissile isotope 235 has been reduced below the natural level of 0.7 per cent. The Authority have available large stocks of this heavy metal which can be used for the manufacture of radiation shields, balance weights and ceramic pigments. It is also valuable as a flux-flattener in thermal reactors and for a variety of other purposes.

**Springfields**

Requirements for civil natural uranium fuel elements are rising rapidly at the present time.

During 1962/63 the Springfields factory manufactured the initial charge for the Hinkley Point reactors and replacement fuel for the Bradwell and Berkeley reactors of the C.E.G.B. The factory also completed the export order for 26,300 fuel elements for the nuclear power station at Latina in Italy—the first export of fuel to any large civil nuclear power station.

Arrangements are being made for post-irradiation examination of the fuel discharged from the C.E.G.B. reactors, with the object of further improving the design of magnox fuel elements. The fuel at present in the Bradwell and Berkeley reactors has so far shown the high integrity which was expected on the basis of experience with the Calder Hall reactors.

In addition to the main function of the factory—the producing of fuel elements for the civil nuclear power programme—considerable work has been carried out to fulfil the requirements of the Authority's reactor development programme.

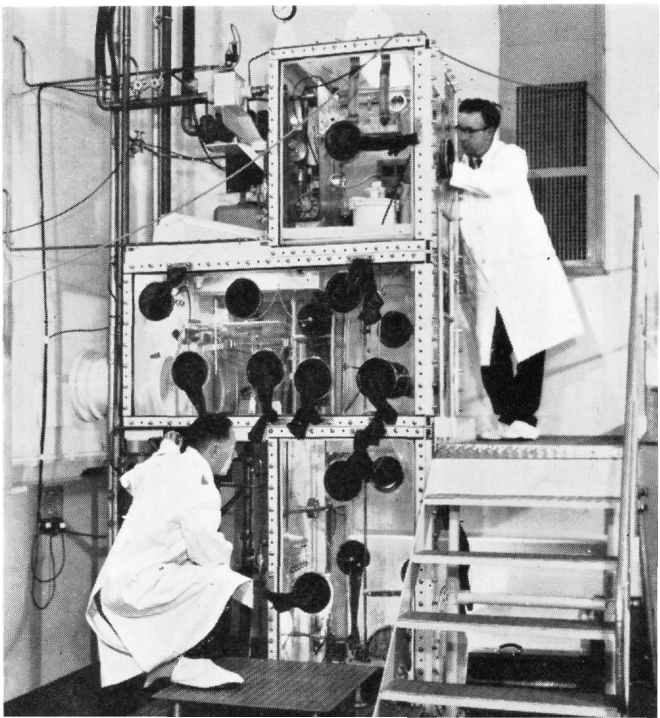
The fuel for the Windscale advanced gas-cooled reactor, which was manufactured at Springfields, consists of uranium oxide pellets enriched in uranium-235 and contained in stainless steel tubes. Not a single defect came to light during the year in the 35,000 elements loaded in the first charge of the reactor. The factory is also undertaking an increasing volume of work for other users in the whole range of uranium materials and nuclear fuel.

The efficiency of the various steps in the manufacturing process has continued to rise, thus giving improved utilisation of raw materials and component parts. Progressive improvement of inspection techniques, together with increases in productivity of the labour force, have enabled the downward trend in fuel element prices to be maintained.

**Capenhurst**

During the first part of the year the Capenhurst factory was working at full capacity and the efforts to improve further the efficiency of the plant continued to yield satisfactory results. Compared with operations a year before, the factory was meeting the same production schedules but with the consumption of electrical power reduced by 5 per cent. and with a reduction of 6 per cent. in the operating labour force.

Changes in the requirements for uranium-235 for defence purposes necessitated a reduction in output from July, 1962; production for defence purposes ceased during the year. The demand for enriched uranium for civil purposes is at present comparatively small and there was no alternative to the progressive closure of part of the plant. This operation was completed early in 1963 leaving only part of the factory producing enriched uranium for civil purposes. This rundown has necessitated a substantial reduction in manpower involving staff



*A small-scale fuel element line for a Prototype Fast Reactor has been set up at Aldermaston.*

redeployment and some redundancy. Some 50 per cent. of the employees who will be made surplus have however already found alternative employment inside or outside the Authority.

In the longer term it is probable that substantial quantities of enriched uranium will be required for the civil nuclear power programme. Development work to improve further the efficiency of the diffusion plant is therefore being continued.

### Windscale

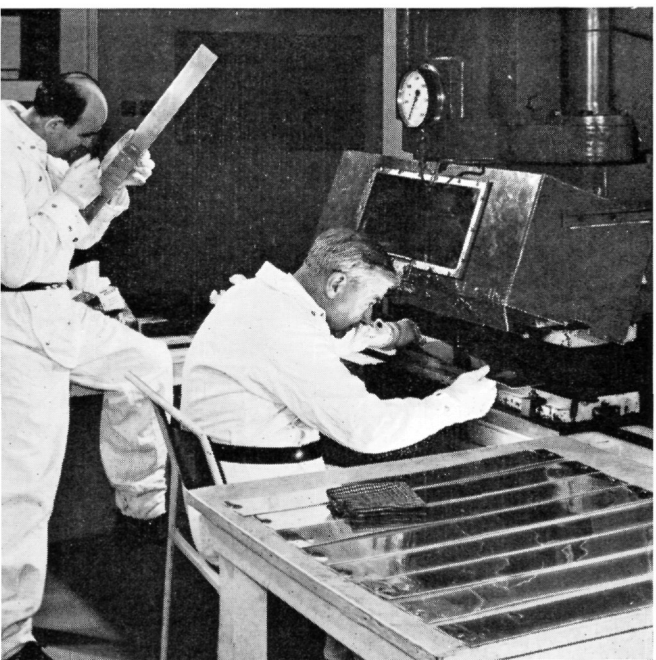
A new finishing plant has been commissioned at Windscale for the production of plutonium metal. The design of the plant takes into account not only the larger throughput which will be necessary as civil power stations are commissioned, but also the different isotopic content of plutonium derived from fuel elements which have undergone extended periods of irradiation. This necessitates full shielding of the plant, and the extensive use of remote handling gear. The plant incorporates many major improvements resulting from operational experience on the earlier plant.

The primary separation plant continued to operate very satisfactorily after eleven years of use and construction of the new separation plant is nearing completion.

### Dounreay

The manufacture of highly enriched fuel elements for materials testing reactors is carried out at the Dounreay chemical plant as is the reprocessing of irradiated highly enriched fuel. The plants for this purpose continued to operate satisfactorily during the year and have adequate capacity to meet all requirements.

*Fuel plates for materials testing reactors being inspected after manufacture at Dounreay.*



Detailed modifications to the reprocessing units have resulted in improvements in operation and increased the capacity of the plant.

### Development Work

Development and testing of magnox fuel elements continued with the objective of providing highly reliable long-life fuel elements for the civil nuclear power programme.

The endurance of fuel elements has always been one of the major factors in predictions relating to civil nuclear power stations and it is most reassuring at the present time to have substantial numbers of fuel channels at irradiations exceeding 3,000 megawatt-days of heat per tonne, which is the target which has been set for the civil nuclear power programme.

Fuel similar to that loaded into the Berkeley reactors of the C.E.G.B. has been irradiated in the Chapelcross reactors to an average irradiation of 3,500 MWd(H)/t without any significant sign of deterioration; the irradiation is continuing. Fuel elements of the Calder type, which have many features in common with the Bradwell fuel elements, have achieved similar irradiation levels.

Trials of hollow fuel elements aimed at proving the fuel design for the station under construction at Tokai Mura in Japan are proceeding satisfactorily.

Significant progress has been made during the year with a new design approach to the fin configuration of fuel element cans, further to improve stability and endurance.

Development work is being undertaken at the Springfields factory to evolve improved methods of manufacturing reactor grade uranium oxide and cheaper methods of producing sintered uranium oxide pellets for incorporation in advanced gas-cooled reactor fuel elements.

Good progress has been made with development of the gas centrifuge as a possible alternative to gaseous diffusion for preparation of enriched uranium. Experimental centrifuges have operated satisfactorily in the laboratory but it is too early yet to assess the long term economic prospects of the process. The development work is being done in close liaison with similar work sponsored by U.S.A.E.C. in America.

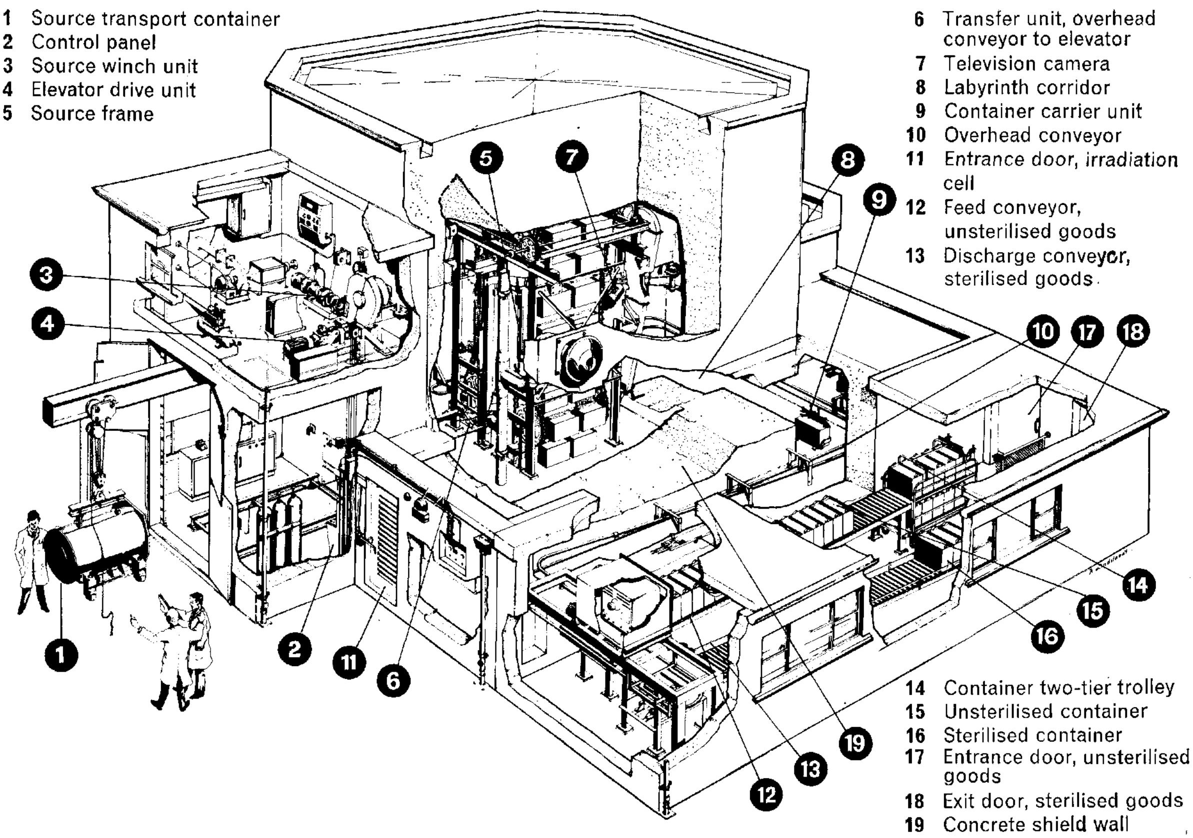
# ISOTOPES: A NEW TOOL FOR INDUSTRY


*Isotopes from Amersham being unloaded at Hanover airport. More than* 50 *per cent of the sales are exports.*

The Wantage Research Laboratory is concerned with the application of relatively small amounts of radioisotopes to industrial and research problems and with the use of massive sources of radiation for industrial processing. The programme is aimed at the development of new techniques and at extending the use of established methods.

Nucleonic thickness, density, and level gauges are firmly established in process control and suitable gauges are available commercially. Work is now concentrated on the non-destructive measurement of particular properties of materials, such as coating thickness and elemental composition.

Among the problems under investigation are the determination of the ash content of coal, using X-ray backscattering, and the determination of copper, lead and tin in minerals by X-ray fluorescence. In all those applications radioisotope




**IRRADIATION PLANT FOR STERILISATION OF SURGICAL SUTURES**

*Drawing reproduced by permission of Nuclear Chemical Plant Ltd.*

sources of X-rays (bremsstrahlung) are used in place of X-ray tubes to provide cheap, reliable and compact equipment.

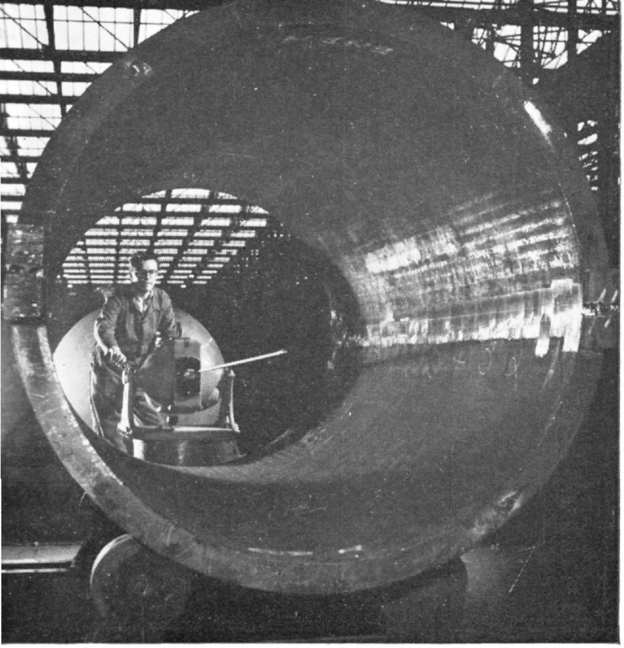
The radioactivation analysis team, which exists to tackle specialised problems received from industrial concerns, has in the past used the Harwell reactors for irradiation. A 14 MeV neutron generator is now also being used to widen the range of problems which can be solved by this technique. Present emphasis is on industrial problems and close collaboration with commercial firms is maintained.

The use of radioactive tracers for measuring water flow in large conduits has been further developed to a stage at which it is an important method of testing pump efficiencies, particularly in the cooling systems of power stations. With the increasing interest in the use and conservation of water in the United Kingdom it is important to develop tracer methods to supplement existing methods of measurement. Tracer methods similar to those used to measure the flow in large conduits have been used to check *in situ* the calibration of measuring weirs with which the flow of rivers is recorded. Tracers have also been used to measure the movement of subterranean water.

### Package Irradiation

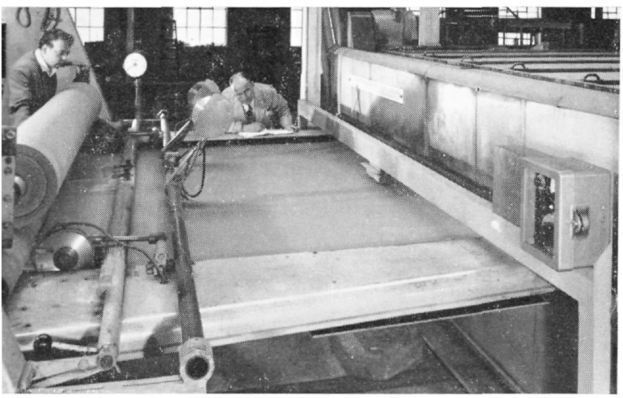
The package irradiation plant at Wantage, with an increased source strength of 320,000 curies, continues to be used to capacity by industrial firms to demonstrate the commercial feasibility of gamma radiation for sterilising medical equipment and pharmaceuticals. The throughput of 90,000 packages was double that of the previous year.

The use of cobalt-60 as a source of gamma radiation for industrial processes is increasing. Three British manufacturers have licences to use Authority patents and information for designing and constructing industrial gamma irradiation



*Gamma-ray photography of a welded seam in 3-inch steel.*
Photograph at the works of G. A. Harvey & Co. (London) Ltd.

*A beta thickness-gauge controls the thickness of cloth as it is manufactured.*
Courtesy of the Derby & Midland Warp Knitting Co. Ltd.



plants. Two commercially owned plants were built and commissioned during the year for sterilising plastic hypodermic syringes and surgical sutures.

Research is being carried out into the use of radiation for the treatment of food; encouraging results have been obtained during the year in the use of gamma radiation for eliminating from food certain micro-organisms harmful to public health. In the food programme particular emphasis is being placed on animal feeding studies designed to evaluate the process with regard to the safety of irradiated food for human consumption.

In the field of applied radiation chemistry work is being done on such topics as the modification of textile fibres and the vulcanisation of rubber; the radiolysis of glucose is being studied in support of the programme aimed at establishing the feasibility of using radiation to sterilise clinical solutions intended for intravenous injections.

### Radiochemical Centre

Sales of radioactive products from the Radiochemical Centre at Amersham in 1962/63 amounted to £1,473,000, an increase of 7 per cent. over the previous year. The general pattern of distribution changed very little, with rather more than 50 per cent. of the sales going abroad. The number of consignments increased to 46,000.

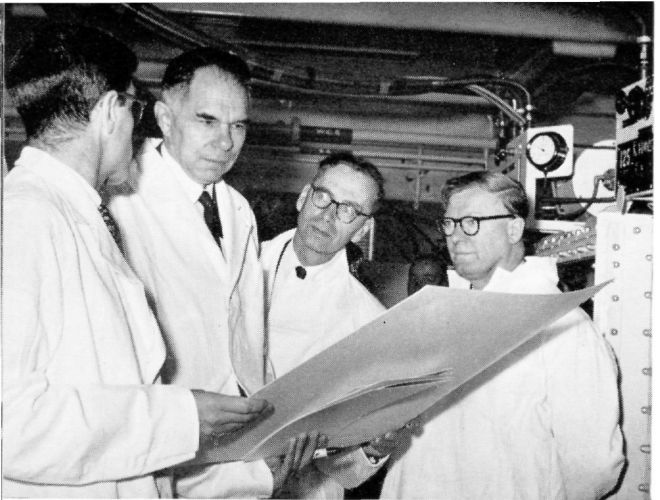
The demand for carbon-14 compounds from Amersham continued to increase steadily. Substantial progress was made during the year in developing new labelled compounds of this isotope, particularly those of immediate interest in connection with problems of medical biochemistry, to meet the growing interest in the quantitative study of uptake and turnover of nutritional factors such as vitamin B12 and folic acid in human patients.

The experience of those engaged in academic and medical tracer investigation has now shown that tritium is generally useful in addition to carbon-14 and not as a replacement for it. Very often the tritium is used for a preliminary investigation, and the demand for a tritium labelled compound is followed by one for the same compound with carbon-14. The number of different tritiated compounds prepared at Amersham has been increased to 165 and the demand doubled during the year. As with carbon-14, new compounds include many of special medical interest, including penicillin.

### Iodine-131

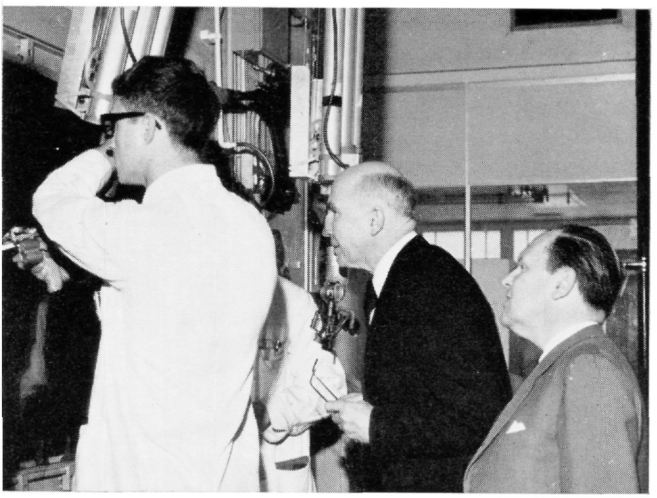
Compounds of iodine-131 are of considerable interest in medical diagnosis but their use has been restricted by the difficulty of preparing them cheaply, as they have had to be made to special order. Improved methods developed at Amersham for synthesising these compounds have now made it possible for them to be made routinely and to be supplied at short notice. Medical users have been taking advantage of this improved supply.

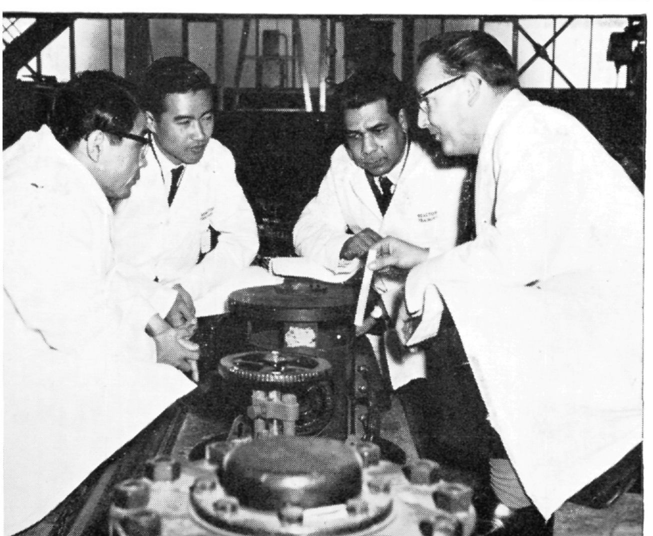
**A SURVEY** during the year showed that the Authority were consigning radioactive materials at the annual rate of about 102,000 packages. There was no incident involving any radioactive hazard to the public or to employees of transport undertakings from this traffic.



*Dr. Glenn Seaborg, Chairman of the U.S. Atomic Energy Commission, visits Harwell with Sir William Penney.*

*Sir Roger Makins, Chairman of the Authority (centre) with Admiral Quihillalt, of the Argentine A.E.C., at Amersham.*





*Students from Japan and Pakistan at the Reactor Operations School, Calder Hall.*

# CO-OPERATION WITH OTHER COUNTRIES

The Authority's policy in the field of international relations continued to have three principal aspects:

(*a*) exchanges of scientific information and personnel in unclassified fields with other countries and international organisations;

(*b*) special exchanges in certain limited areas (particularly where classified or commercially valuable information is involved);

(*c*) supporting the promotion of British nuclear exports (for example, by provision of consultancy services and attendance of Authority members and staff at international conferences and trade meetings).

Sir William Penney continued to serve as U.K. representative on the Scientific Advisory Committee of the Secretary General of the United Nations, and members of the Authority's staff attended a number of meetings convened by the various specialised agencies of the United Nations Organisation.

The Authority have continued to support the work of the International Atomic Energy Agency. Over 100 Authority scientists, engineers and technicians participated in Agency conferences, symposia and panels held during the year and served on consultancy and technical assistance missions to the developing countries.

## Europe

Her Majesty's Government, in the context of the negotiations for United Kingdom entry into the European communities, formally applied for membership of Euratom on 5th March, 1962. In the latter half of the year, negotiations with the Six and the Euratom Commission, were opened in Brussels by a delegation on which the Authority were represented. Considerable progress had been made, particularly on research and development questions, before the negotiations were brought to an end by the suspension of the Common Market talks on 29th January.

After this suspension, discussions in the framework of the U.K./Euratom Agreement of 1959, which had been in abeyance during the period of negotiation for U.K. entry into Euratom, were resumed at a meeting of the high level technical Joint Working Group in London on 7th March. A further meeting of the U.K./Euratom Continuing Committee is to be held in May, 1963.

An agreement was signed with the Swiss Nationale Gesellschaft zur Foerderung der Industriellen Atomtechnik under which, in addition to exchanging nuclear information on agreed subjects, the Authority will provide consultancy services in respect of the experimental heavy-water-moderated, gas-cooled reactor project at Lucens.

## The Commonwealth

The annual review meeting on collaboration between the Authority and Atomic Energy of Canada, Ltd., was held in London in November.

Arrangements for extended collaboration between the Authority and the Australian Atomic Energy Commission have been implemented through information exchanges and visits.

Dr. Usmani, Chairman of the Pakistan Atomic Energy Commission, visited the United Kingdom in June and October and discussed with the Chairman of the Authority the assistance which the Authority might provide to Pakistan's plans for research and power reactors. One service already commissioned from the Authority by Pakistan is the provision of advice on the new laboratories to be constructed for the Institute of Nuclear Science and Technology at Rawalpindi.

The Authority have continued to maintain close contact with the Indian Department of Atomic Energy. Dr. Bhabha, Secretary of the Department, visited the United Kingdom in June. Arrangements have been made for the Authority to lease to the Department fuel elements for the second charge for the research reactor Apsara built to U.K. designs at Trombay.

## U.S.A.

Close contact between the Authority and the United States Atomic Energy Commission has continued over a wide range of research and development work.

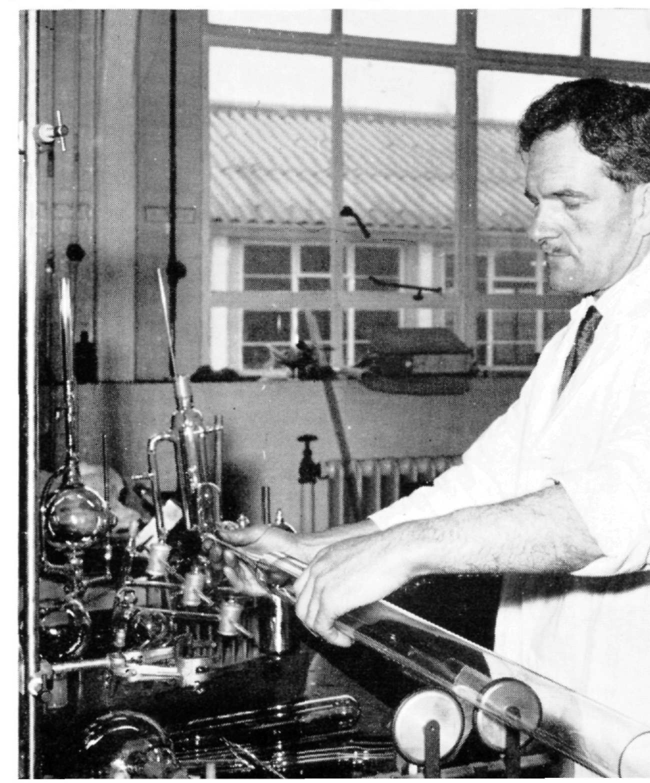
Visiting teams from America came for discussion with Authority representatives on heat transfer work, waste treatment and disposal, nuclear fuel reprocessing, uranium ceramics and fast reactor work. Authority teams went to the U.S.A. for meetings on plutonium fabrication and chemical reprocessing problems, research reactor fuel elements and graphite characteristics and behaviour. In addition, numerous individual visits in both directions took place for discussions and to enable scientists and engineers to see new plant and equipment.

## U.S.S.R.

The year saw the completion of the programme of exchange visits between the U.K. and U.S.S.R. which was agreed when the collaboration agreement between the Authority and the State Committee of the Council of Ministers for the Utilisation of Atomic Energy was signed in 1961. Two Authority teams concerned with solid state physics and with plasma physics and controlled thermonuclear research went to the U.S.S.R., and Soviet teams interested in fast reactors and in nuclear physics and high energy physics visited the U.K. During a visit to the Soviet Union by the Chairman of the Authority in October discussions were held which led to a further programme covering a second series of visits being agreed.

Contact between the Authority and almost all the other countries having nuclear energy programmes and organisation has been maintained by the exchange of reports and visits.

*Mr. J. Overend, a Harwell glassblower, is working for a year at the Lahore Atomic Energy Centre.*



# BOARD MEMBERSHIP

Membership of the Atomic Energy Authority as at 1st April, 1963, was:

*Chairman*

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

*Deputy Chairman*

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

*Full-time Members*

Sir William Cook, C.B., F.R.S.
(Member for Reactors)

Sir Alan Hitchman, K.C.B.
(Member for Finance and Administration)

Air Chief Marshal Sir Claude B. R. Pelly, G.B.E., K.C.B., M.C.
(Member for Weapons Research and Development)

*Part-time Members*

Sir John Cockcroft, O.M., K.C.B., C.B.E., F.R.S.
Professor A. H. Cottrell, F.R.S.
Lord Geddes of Epsom, C.B.E.
Mr. R. M. Geddes, O.B.E.
Mr. C. F. Kearton, O.B.E., F.R.S.
Sir Leonard Owen, C.B.E.
Mr. S. J. Pears, F.C.A.

*Secretary*

Mr. D. E. H. Peirson

The Minister for Science re-appointed Sir John Cockcroft as a part-time Member of the Authority for the five-year period 1st August, 1962 to 31st July, 1967; Mr. S. J. Pears as a part-time Member for the three-year period 1st May, 1963, to 30th April, 1966.

The appointment of Sir James Chadwick as a part-time Member expired on 20th August, 1962; that of Lord Citrine on 31st December, 1962.

The Minister appointed as part-time Members Professor A. H. Cottrell (1st September, 1962, to 31st August, 1967) and Lord Geddes of Epsom (1st January, 1963, to 31st December, 1966).

The Minister extended the appointment of Sir William Cook as a full-time Member of the Authority for a period of five years from 17th February, 1963.

# AUTHORITY ESTABLISHMENTS

**Aldermaston:**
**The Atomic Weapons Research Establishment**
Headquarters of the Weapons Group. Development of nuclear warheads, together with supporting research. Nuclear research and certain development work in aid of the Authority's civil nuclear energy programme.

**Amersham: Radiochemical Centre**
The production and marketing of radioisotopes.

**Blacknest, near Aldermaston**
Centre for seismological research.

**Bracknell Factory, Berkshire**
An outstation of A.E.R.E. which provides additional workshop capacity, especially for machining of graphite, and at which electronic equipment is manufactured on a small scale.

**Capenhurst Works, Cheshire**
Development work on uranium enrichment processes and operation of the gaseous diffusion plant for the supply of enriched uranium.

**Chapelcross Works, Dumfriesshire**
Reactor operations, including the supply of electricity to the national grid and plutonium production; experimental fuel irradiation and radiological research. There is also a training service for reactor operators.

**Chatham**
Part of the Analytical Chemistry Branch of Chemistry Division A.E.R.E.

**Culcheth, Warrington:**
**Reactor Materials Laboratories**
Investigation of physical and chemical properties of reactor and fuel element materials.

**Culham Laboratory, Abingdon, Berkshire**
The laboratory is being developed as a major centre for research into plasma physics and controlled thermonuclear fusion.

**Dounreay Experimental Reactor Establishment, Caithness**
Site of the Dounreay fast reactor. An experimental

reactor establishment engaged on fast reactor development including the fabrication, irradiation and reprocessing of fast reactor fuel. Provides a comprehensive irradiation service using the Dounreay materials testing reactor, and reprocesses M.T.R. fuels for United Kingdom and overseas operators. The establishment also provides site services for the Admiralty submarine reactor project.

**Foulness, Essex**

Laboratory experiments and field trials in aid of weapons development. Studies of materials and structures under stress loading for civil defence, military and reactor safety purposes.

**Harwell: Atomic Energy Research Establishment**

The largest establishment of the Research Group. The Group's responsibility is to do long-term research into the non-military problems of atomic energy. Work at Harwell is concerned mainly with materials, their basic properties (including nuclear properties) and the effects upon them of radiation. Besides basic research in many branches of physics, chemistry and metallurgy, work is done on electronics, health physics, and chemical engineering. The Establishment has three materials testing reactors, three low-energy reactors, several particle accelerators, and specialised laboratories for experiments with radioactive materials at all levels of activity up to kilocuries.

**London Office**

Headquarters of the United Kingdom Atomic Energy Authority. Co-ordination with the Groups of policy decisions and of the Authority's relations with government departments and other organisations in the U.K. and overseas. In addition, certain of the Authority's financial and administrative services are centred in the London Office.

**Orfordness, Suffolk**

Development and application of environmental testing in the weapons field.

**Oxford Office**

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

**Risley, Warrington, Lancs.**

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

**Springfields Works and Laboratory: Salwick, Preston**

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

**Tadley, Basingstoke, Hants.**

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

**Wantage Research Laboratory, Berkshire**

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

**Windscale and Calder Works and Laboratory: Sellafield, Cumberland**

Operation of production reactors, including the supply of electricity to the national grid, plutonium production, and a training service for reactor operators. Also the operation of chemical plants for the separation of plutonium, uranium, and fission products from irradiated fuels. The Reactor Development Laboratory is engaged on the development programme for the advanced gas-cooled reactor and on A.G.R. physics, using HERO. Other work done by the laboratory covers irradiation testing, including A.G.R. fuel elements, post-irradiation examination and heat transfer studies.

**Winfrith, Dorset: Atomic Energy Establishment**

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

**Woolwich: Royal Arsenal**

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

**Woolwich Common**

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

# INFORMATION SERVICES

*Visitors to the Authority stand at the Milan International Fair watch a demonstration of remote handling.*

*Recording a Japanese commentary for an Authority film to be shown at a reactor conference in Tokyo.*

## Libraries

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

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

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

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

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

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

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

All available reports are listed in the Authority's monthly list of Publications available to the Public, which is obtainable from the Librarian at Harwell.


*Sir John Cockcroft explains a reactor model during an Authority exhibition in Norwich.*

Annual cumulations can be purchased from H.M.S.O. bookshops or agents.

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

**Publications**

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

**Films**

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

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

"Power from Plutonium"
"Chemistry for the Nuclear Age"
"Harwell"
"Fuel for Nuclear Power"
"Explaining the Atom"
"Britain's Nuclear Power Programme"
"Nuclear Power Reactors"
"Steel for Nuclear Power"
"R. & D." (Research and Development)
"Industrial Uses of Radioisotopes"
"Dounreay Symposium"
"Winfrith Pipeline"
"Operation Undersea"
"Metals of the Nuclear Age"
"Criticality"
"How a Thermal Reactor Works"

**Photographs**

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

**Information Centre**

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

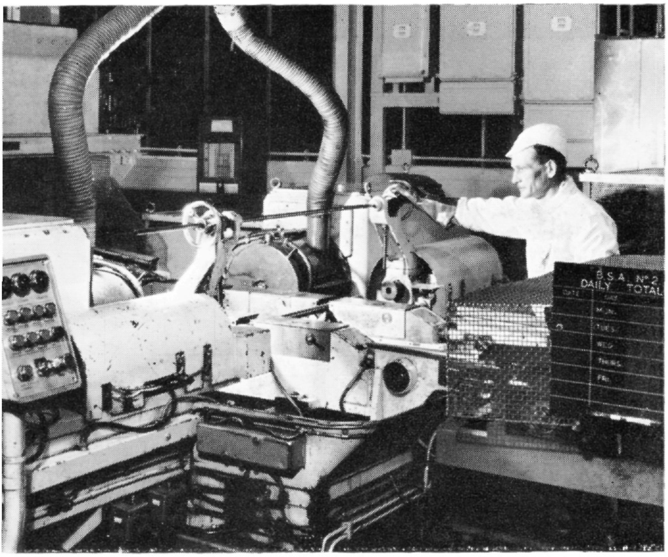
# THE AUTHORITY'S REACTORS AS AT 31st MARCH, 1963

| | | NAME | LOCATION | DATE OF START-UP | PEAK NEUTRON FLUX THERMAL $N/CM^2$ SEC. | MAXIMUM HEAT OUTPUT | MODERATOR | COOLANT | FUEL | PURPOSE |
|---|---|---|---|---|---|---|---|---|---|---|
| **RESEARCH AND EXPERIMENTAL REACTORS** | 1 | GLEEP | Harwell | 1947 | $1.5 \times 10^9$ | 3 kW | Graphite | Air | Natural uranium | Routine testing of the quality of graphite and uranium; research with oscillator; biological irradiations. |
| | 2 | BEPO | Harwell | 1948 | $2 \times 10^{12}$ | 6 MW | Graphite | Air | Natural uranium | Studies of nuclear reactor materials; isotope production; neutron physics; radiation chemistry. |
| | 3 | LIDO | Harwell | 1956 | $10^{12}$ | 100 kW | Light water | Light water | Enriched uranium-aluminium alloy | Thermal reactor studies including shielding and neutron spectra measurements. |
| | 4 | DIDO | Harwell | 1956 | $2 \times 10^{14}$ | 15 MW | Heavy water | Heavy water | Highly enriched uranium-aluminium alloy | Studies of nuclear reactor materials; isotope production; neutron physics; radiation chemistry. |
| | 5 | PLUTO | Harwell | 1957 | $2 \times 10^{14}$ | 15 MW | Heavy water | Heavy water | Highly enriched uranium-aluminium alloy | Studies of nuclear reactor materials; isotope production; neutron and solid state physics; radiation chemistry. |
| | 6 | D.M.T.R. | Dounreay | 1958 | $1.6\text{-}1.7 \times 10^{14}$ | 12-13 MW | Heavy water | Heavy water | Highly enriched uranium-aluminium alloy | Studies on nuclear reactor materials. |
| | 7 | HORACE | Aldermaston | 1958 | about $10^8$ | 10 Watts | Light water | Light water | Uranium-235 | To obtain basic nuclear information for HERALD. |
| | 8 | FAST REACTOR | Dounreay | 1959 | — | 60 MW | None | Sodium-potassium alloy | Enriched uranium; plutonium | Development of fast-reactor technology (reactor physics, fuel elements and coolant handling). |
| | 9 | ZENITH | Winfrith | 1959 | $2 \times 10^8$ | 100 Watts | Graphite | Nitrogen used as heating gas | Enriched uranium; plutonium | Reactor physics investigations for advanced graphite-moderated reactors. |
| | 10 | NERO | Winfrith | 1960 | $3 \times 10^8$ | 100 Watts | Graphite | None | Highly enriched uranium-aluminium alloy | Pile oscillator studies. |
| | 11 | HERALD | Aldermaston | 1960 | $5 \times 10^{13}$ | 5 MW | Light water | Light water | Highly enriched uranium-aluminium alloy | Studies in neutron physics, radio-chemistry and nuclear reactor materials, including work with universities. |
| | 12 | VERA | Aldermaston | 1961 | — | 100 Watts | None | None | Highly enriched uranium or plutonium | Experimental studies of fast reactor systems. |
| | 13 | NESTOR | Winfrith | 1961 | $10^{11}$ | 10 kW | Light water | Light water | Highly enriched uranium-aluminium alloy | Source of neutrons for sub-critical assemblies giving thermal fluxes of $10^8$ in the assemblies. |
| | 14 | DIMPLE | Winfrith | 1962 | $3 \times 10^8$ | Less than 100 Watts | Light water, heavy water, organic liquid or mixtures | None | Uranium or plutonium | Testing a wide range of lattices at uniform temperatures up to about 80°C. |
| | 15 | HERO | Windscale | 1962 | $3 \times 10^8$ | A few Watts | Graphite | Carbon dioxide used as heating gas | Enriched uranium oxide | Reactor physics studies for the advanced gas-cooled reactor system. |
| | 16 | DAPHNE | Harwell | 1962 | $1.5 \times 10^9$ | 100 Watts | Heavy water | Heavy water | Highly enriched uranium-aluminium alloy | Can simulate DIDO or PLUTO, to provide basic physics information in support of these reactors. |
| | 17 | A.G.R. | Windscale | 1962 | $1.6 \times 10^{13}$ | 100 MW (28 MW(E) net) | Graphite | Carbon dioxide | Enriched uranium oxide | To study the advanced gas-cooled power reactor system and to test fuel elements for the system. |
| | 18 | ZEBRA | Winfrith | 1962 | — | 100 Watts | None | None | Uranium-235; plutonium | A flexible system intended primarily to investigate the physics of large, fast reactors. |
| | 19 | HECTOR | Winfrith | 1963 | $3 \times 10^8$ | 100 Watts | Graphite | Carbon dioxide used as heating gas | Permanent fuel: highly enriched uranium-aluminium alloy. Central core: variable | Oscillator reactor; reactivity measurements on materials and fuel elements. |
| **REACTOR PLANNED** | 20 | S.G.H.W. | Winfrith | 1967 | — | 275 MW (heat) excluding super heat 100 MW(E) gross | Heavy water | Light water | Enriched Uranium oxide | To study the reliability, safe operation and economics of this type of reactor. |
| **POWER PLUTONIUM PRODUCING REACTORS (IN PRODUCTION)** | 21-24 | Calder 2 stations "A" and "B" (4 reactors) | Calderbridge | Station "A" 1956 Station "B" 1958 | — | 230 MW (heat) per reactor (44 MW(E) including steam) | Graphite | Carbon dioxide | Natural uranium | Power and plutonium production; experimental work in aid of the U.K. nuclear power programme. Output quoted includes 9 MW(E) equivalent of steam supplied to the Windscale site services. |
| | 25-28 | Chapelcross (4 reactors) | Annan | 1958 (1st reactor) 1959 (reactors 2, 3 and 4) | — | 230 MW (heat) per reactor (45 MW(E)) | Graphite | Carbon dioxide | Natural uranium | Power and plutonium production; experimental work in aid of the U.K. nuclear power programme. |

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

# REVIEW OF THE YEAR

## 1st April 1962 to 31st March 1963



*Machining bars of uranium at the Authority's fuel element factory at Springfields, Lancashire. In Harwell's Metallurgy Division a scientist adjusts a single crystal of uranium oxide in a diffractometer.*

The advanced gas-cooled reactor at Windscale operated for the first time on 9th August, 1962; reached its full design output of 100 MW(H) in January, 1963; and began electricity generation at 28 MW(E) on 26th February.

The Dounreay fast reactor reached 30 MW(H) on 7th August; electricity generation at 3 MW(E)—rising later to 6 MW(E)—began on 14th October.

The zero-energy fast reactor ZEBRA at Winfrith started operating on 19th December. The zero-energy research reactors DIMPLE and HECTOR at Winfrith started operation on 18th June, 1962, and 10th March, 1963, respectively.

On 20th February it was announced that Government Authority had been received to proceed with the building of a prototype steam-generating heavy-water reactor (S.G.H.W.) of some 100 MW(E) at Winfrith. The Local Authority's formal planning permission was received on 19th March and preparatory work on the site has begun.

During the year, work in the merchant marine field was concentrated on two possible reactor systems, VULCAIN and the integral boiling reactor. On 11th February Her Majesty's Government announced that discussions would be held with the shipping and shipbuilding industries on the construction, ownership and operation of nuclear powered ships with the expectation of taking a decision towards the end of 1963 on the construction of a prototype ship, provided that the results of the present research programme continued to be satisfactory meanwhile.

Progress was not confined to the reactor field. During the year, the world's first two cobalt-60 industrial irradiation plants designed specifically for sterilisation of medical products commenced continuous operation. These plants—one at Slough and one at Edinburgh—were built under licence from the Authority following large-scale experiments at the Wantage Research Laboratory.

Expenditure in 1962/63 on the Authority's programme of civil research and development was £48 million of which £35 million was current expenditure and £13 million was on capital facilities. The number of graduate or professional engineers or scientists employed on the programme at 31st March was 2,825 of whom 200 were doing work for other bodies on repayment. The following table shows the deployment of resources in terms of current expenditure and qualified staff on the various parts of the programme.

| | £m. Current Expenditure | | Qualified Scientists and Engineers* | |
|---|---|---|---|---|
| | 1961/2 | 1962/3 | 31.3.62 | 31.3.63 |
| Reactor Development Programme and Reactor Systems Research | 25 | 26 | 1760 | 1880 |
| General Research | 5 | 5 | 520 | 470 |
| Plasma Physics and Fusion Research | 2 | 3 | 170 | 190 |
| Isotopes Research | 1 | 1 | 90 | 85 |

* The staff numbers include qualified staff engaged upon supporting scientific, engineering and administrative services in establishments carrying out the programme.

The Authority's commercial activities increased markedly over the previous year. Sales of fuel elements are expanding as more nuclear power stations are commissioned by the Central Electricity Generating Board and an increased income from licensing is attributable to the greater industrial use that is now being made of the Authority's extensive and varied range of inventions. Close collaboration on numerous aspects of nuclear power was maintained with the Consortia and with other British industrial organisations. The wider application of established radioisotope techniques and the development of new uses for them is reflected in increased sales achieved by the Radiochemical Centre, both to United Kingdom and overseas customers.

Proceeds of sales are shown in the table below:

£'000

| | Reactor Fuel | | Graphite | Isotopes | Other Sales | Total |
|---|---|---|---|---|---|---|
| | Power | Research | | | | |
| 1960/61 | 10,224 | 645 | 4,940 | 1,300 | 206 | 17,315 |
| 1961/62 | 9,377 | 246 | 2,843 | 1,400 | 202 | 14,068 |
| 1962/63 | 22,210 | 295 | 3,000 | 1,473 | 308 | 27,286 |

An additional £7,497,000 was received for the sale of electricity and £565,000 for consultancy services, royalties and other receipts.

The Authority's programme of fissile material production and of research and development of nuclear warheads continued during the year as authorised by Her Majesty's Government and the Authority have continued their work on the establishment of methods for the detection and identification of nuclear explosions underground. In the framework of the weapons collaboration with the U.S.A., a British nuclear device was tested at the A.E.C.'s Nevada test site on 7th December, 1962.

It became clear during the year that government requirements for enriched uranium for defence would soon be nearly satisfied; and a decision was therefore taken to reduce the output of the diffusion plant at Capenhurst to a minimum level necessary to keep the plant in production. This necessitated a substantial reduction of manpower at the factory, to be effected by the end of 1963.

On the international front the principal activity during the year was the negotiation concerning United Kingdom membership of the European Atomic Energy Community (Euratom). This negotiation was brought to an end as a consequence of the breaking off of the Common Market negotiations at the end of January. The Authority further strengthened and extended other international contacts, both bilateral and multi-lateral, during the year. Negotiations for the extension of the Dragon agreement to 31st March, 1967, were successfully concluded.

## ATOMIC ACRONYMS

A number of new words have been formed by the acrostic method of using the initial letters of other words (e.g. "cabal" and "radar"). Several Atomic Energy Authority reactors and other experimental facilities have been named in this way. Some examples are listed below.

| | |
|---|---|
| **BEPO** | **B**ritish **E**xperimental **P**ile **O**peration |
| **DAPHNE** | **D**ido **A**nd **P**luto **H**andmaiden for **N**uclear **E**xperiments |
| **DIDO** | Reactor moderated by Deuterium Oxide, i.e. $D_2O$ or DDO |
| **DIMPLE** | **D**euterium **M**oderated **P**ile **L**ow **E**nergy |
| **GLEEP** | **G**raphite **L**ow **E**nergy **E**xperimental **P**ile |
| **HECTOR** | **H**eated **E**xperimental **C**arbon **T**hermal **O**scillator **R**eactor |
| **HELEN** | **H**ydrogenous **E**xponential **L**iquid **E**xperime**N**t |
| **HERALD** | **H**ighly **E**nriched **R**eactor **AL**Dermaston |
| **HERMES** | **H**eavy **E**lement and **R**adioactive **M**aterial **E**lectromagnetic **S**eparator |
| **HERO** | **H**ot **E**xperimental **R**eactor of **O** (Zero) power |
| **HORACE** | **$H_2O$ R**eactor **A**ldermaston **C**ritical **E**xperiment |
| **IBIS** | **I**ntense **B**unched **I**on **S**ource |
| **NERO** | **N**a (Chemical symbol for Sodium) **E**xperimental **R**eactor of **O** (Zero) power |
| **NESTOR** | **N**eutron **S**ource **T**hermal **R**eactor |
| **PHOENIX** | **P**lasma **H**eating **O**btained by **E**nergetic **N**eutral **I**njection **EX**periment |
| **PLUTO** | **P**lutonium **L**oop **T**esting **R**eact**O**r |
| **SCORPIO** | **S**ub-critical **C**arbon-m**O**derated **R**eactor Assembly for **P**lutonium **I**nvestigati**O**ns |
| **VERA** | **V**ersatile **E**xperimental **R**eactor **A**ssembly |
| **ZEBRA** | **Z**ero **E**nergy **B**reeder **R**eactor **A**ssembly |
| **ZENITH** | **Z**ero **E**nergy **NI**trogen Heated **TH**ermal Reactor |
| **ZETA** | **Z**ero **E**nergy **T**hermonuclear **A**pparatus |

*Front Cover: Radiochemistry. Glove-box experiment at Harwell.*
*Back Cover: Reactor design studies. Heavy-water assembly at Winfrith.*

*Designed by Ronald Terry.* *Printed by Kent Paper Co. Ltd., London and Ashford Kent.* AVAILABLE FROM H.M.S.O. 2/6 NET.