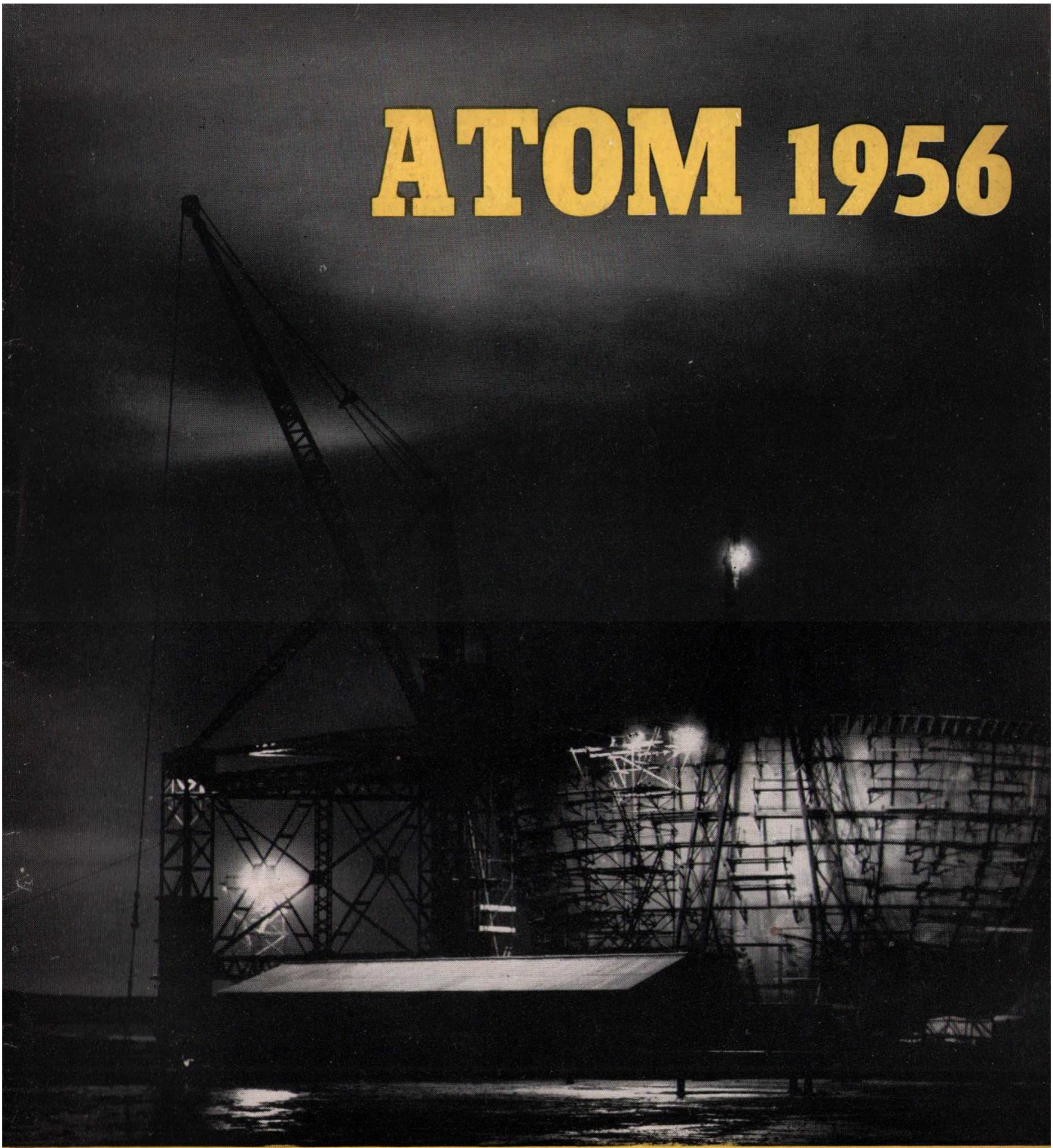
# ATOM 1956



*An illustrated summary of the Second Annual Report of the*

**UNITED KINGDOM ATOMIC ENERGY AUTHORITY**

**1st April 1955 to 31st March 1956**

Price 1s. 6d. net

Mr. Dag Hammarskjold, Secretary of the United Nations, inspecting models of Harwell reactors at the United Kingdom Exhibition held concurrently with the Geneva Conference. Left to right: Dr. Walter Whitman, Organising Secretary of the Conference; Mr. Hammarskjold; Sir John Cockcroft, Director of the Atomic Energy Research Establishment, Harwell; Sir Edwin Plowden, Chairman of the United Kingdom Atomic Energy Authority; and Mr. Mathew Gordon of United Nations.

# Geneva - August 1955

Increasing interest in the civil applications of atomic energy has coincided with a considerable release—by the atomic powers—of information which has hitherto been secret.

These two factors ensured the success of the *First International Conference on the Peaceful Uses of Atomic Energy* which was held by the United Nations at Geneva from 8th to 20th August, 1955. One of the largest scientific gatherings ever organised, it was attended by 1,400 representatives from 73 countries. More than 1,000 scientific papers were prepared for the conference. Eighty of these were contributed by the United Kingdom.

Sir John Cockcroft, leader of the United Kingdom delegation, has said: "The Conference has been more successful than we had dared to hope from such a large gathering. It has brought together East and West after a long period of separation in the physical sciences. It has been a meeting ground for friends from all parts of the world. It has enabled us to discuss how best we can help other countries and has done a great deal to re-establish the normal pattern of communication in the scientific world."

Front Cover :

Fast breeder reactor under construction at Dounreay in the north of Scotland.

# ATOM 1956

"An illustrated summary of the second annual report of the United Kingdom Atomic Energy Authority—1st April, 1955 to 31st March, 1956"

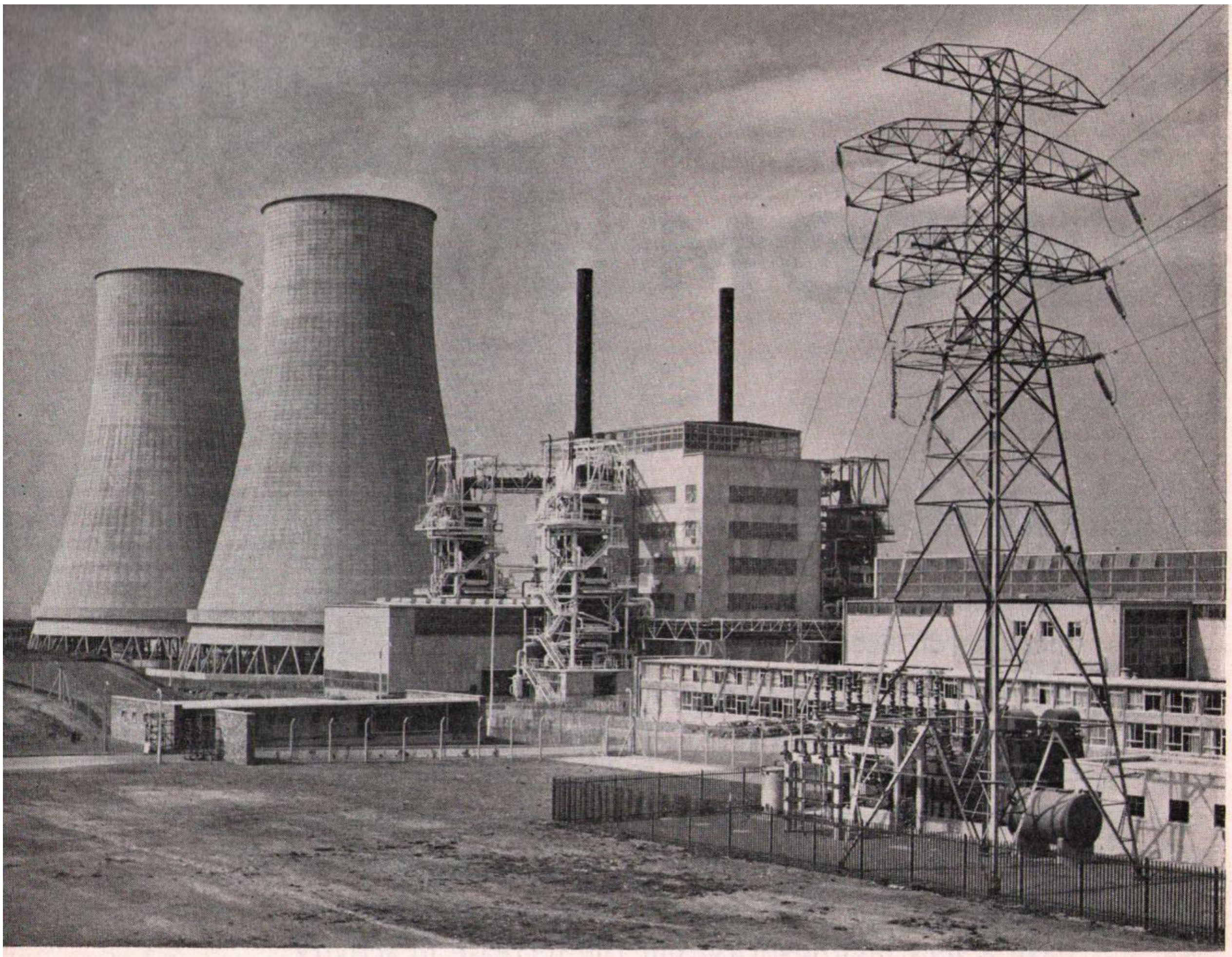
## Introduction

The dominant feature of the year has been the great increase of interest and activity, both in this country and overseas, in the development of atomic energy as a source of power for peaceful purposes.

This has not entailed any reduction in the Atomic Energy Authority's activities on the defence side. The nuclear weapons programme, and particularly the development of thermonuclear weapons, continues to have a very high priority, but the increase in activity on the civil side is a new feature of national and international affairs.

A year ago, nuclear power appeared, for most countries, to be a possibility in the remote and indefinite future.

Now it is a matter not of conjecture but of dates and comparative costs.



Calder Hall.

# CALDER HALL
## Britain's First Atomic Power Station

Britain's first atomic power station—at Calder Hall in Cumberland—is to be opened by Her Majesty the Queen on October 17th, 1956.

Early in 1956 progress had reached a stage when it was possible to decide that the station would be operating with sufficient reliability by October to supply electricity to the National Grid of the Central Electricity Authority. The ultimate output to the Grid will be about 65,000 kilowatts (1 kilowatt = 1,000 watts).

The Calder Hall station has two reactors (or piles), each consisting of a large cylindrical block of graphite pierced by a multitude of vertical channels containing rods of natural uranium fuel. Heat, generated in the reactor by splitting some of the atoms in the fuel, is carried away by carbon dioxide gas circulated under pressure through the channels. The hot gas passes from the reactor to "heat-exchangers" or boilers where the heat turns water to steam which is superheated and led away to a turbine house in the normal way. Here it will drive four fairly conventional 23,000 kilowatt turbo-alternator sets, two to each reactor.

The heat output of the reactors is controlled by means of sliding boron steel rods which have the property of removing from circulation the atomic particles responsible for splitting the uranium atoms. If the rods are slid further into the reactor more particles are absorbed, fewer atoms split and the heat output reduced. Conversely, by withdrawing the rods the heat output can be raised.

Among the tasks completed during the year was the lifting into position of the eight heat-exchangers, each of which weighs 200 tons.

A station of the Calder Hall type produces plutonium as well as electricity and in June, 1955, it was decided that more plutonium was needed for the military programme. To allow this to be done while interfering as little as possible with

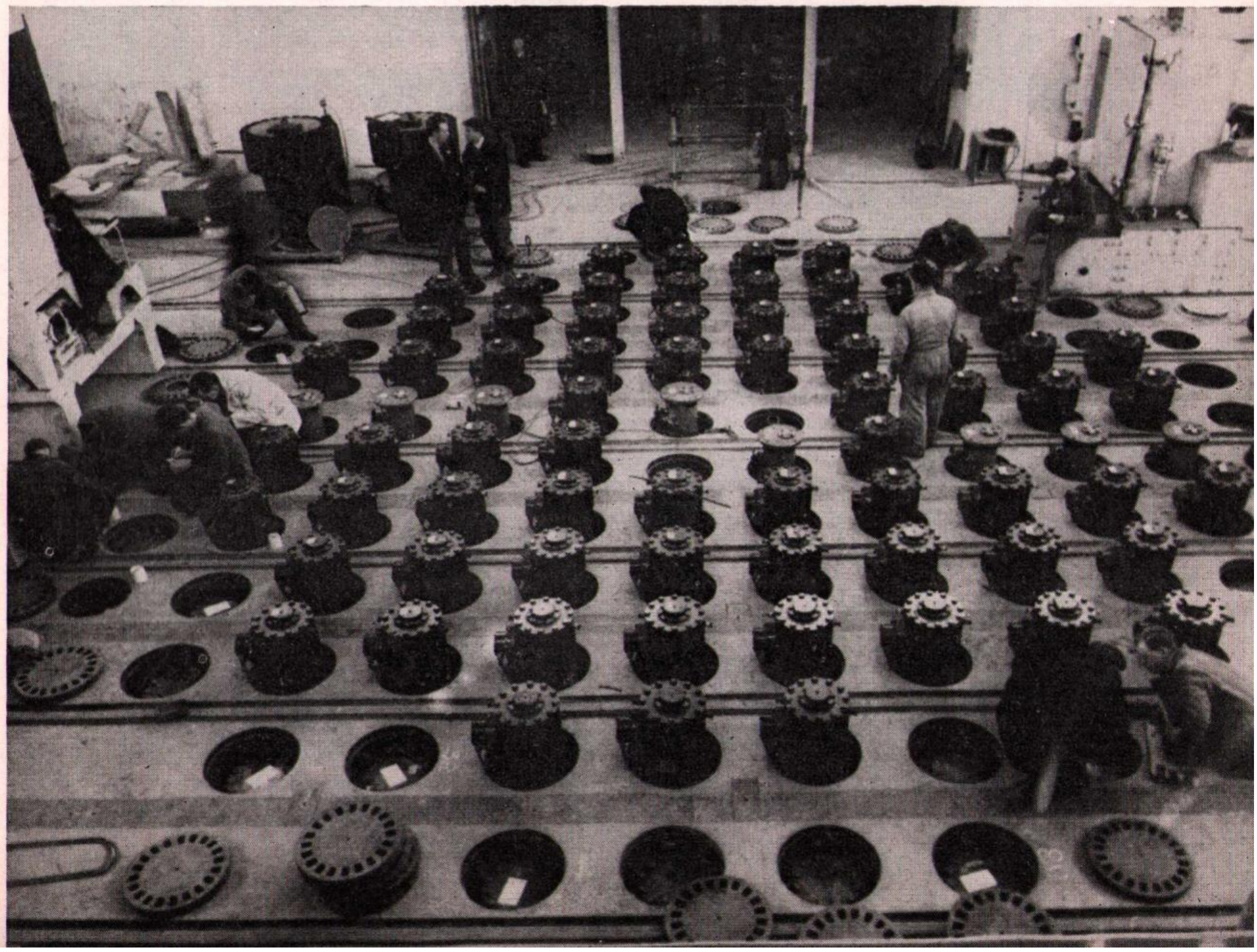
(*a*) the civil programme for nuclear power stations and

(*b*) the Authority's pioneer work on new types of reactors

it was decided to build three new units of the Calder Hall type. One of these will be alongside the first Calder Hall station and two more are being built at Chapel Cross near Annan, Dumfriesshire.

The first reactors to be built by private industry for the Electricity Authorities under the Government's 10-year "Programme of Nuclear Power" (see pages 6-7) will be based on the Calder Hall design.

Preparing one of the Calder Hall reactors for the insertion of uranium rods.



# The Nuclear Power Programme

In February, 1955, Her Majesty's Government announced a 10-year "Programme of Nuclear Power". The plan envisages the building of twelve nuclear power stations by private industry for the Electricity Authorities. These stations should provide 1½-2 million kilowatts by 1965.

The first stations under the plan will be improved versions of the Calder Hall graphite-moderated gas-cooled reactor.

The Authority have been studying alternative reactor systems which might be used in the later stations (see *Research*, pages 16-17).

If all goes well the total nuclear power station capacity installed by 1975 should be about 10 to 15 million kilowatts.

## Industry and the Programme

During the year great progress has been made on the scheme of collaboration with the four groups of industrial firms who are to submit tenders to the Central Electricity Authority in October of this year for the building of the first two stations in the 10-year programme. The four groups referred to are each led by one of the heavy electrical plant manufacturers, namely:

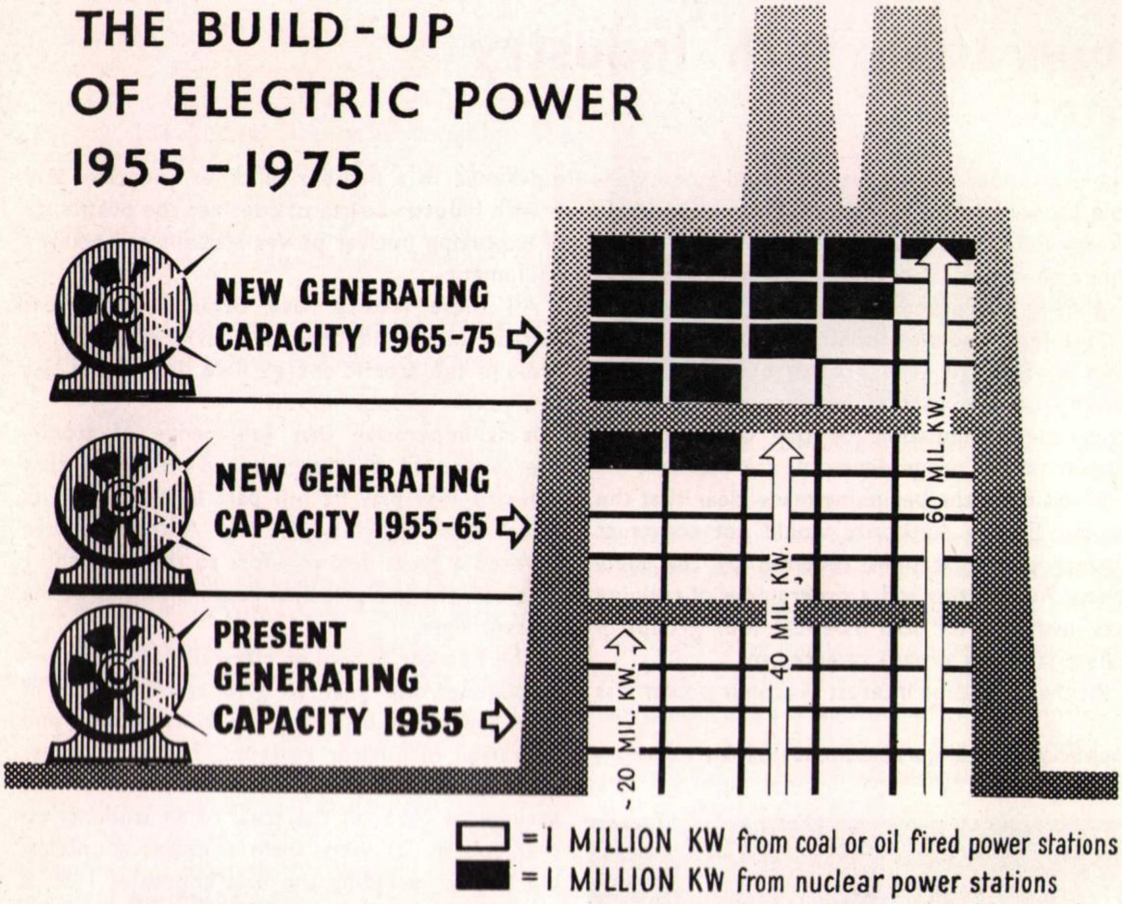
Associated Electrical Industries;
The General Electric Company;
The English Electric Company;
C. A. Parsons.

A year ago senior members of the four teams had attended courses at the Harwell Reactor School. This was followed by a comprehensive and detailed course of instruction in the establishments of the Authority's Industrial Group. During this course they were able to see the operation of the Authority's reactor installations, to examine the construction work in progress at Calder Hall and to participate in discussions in design offices and development laboratories. Following this a more specialised course was arranged for the "section leaders" of the design teams.

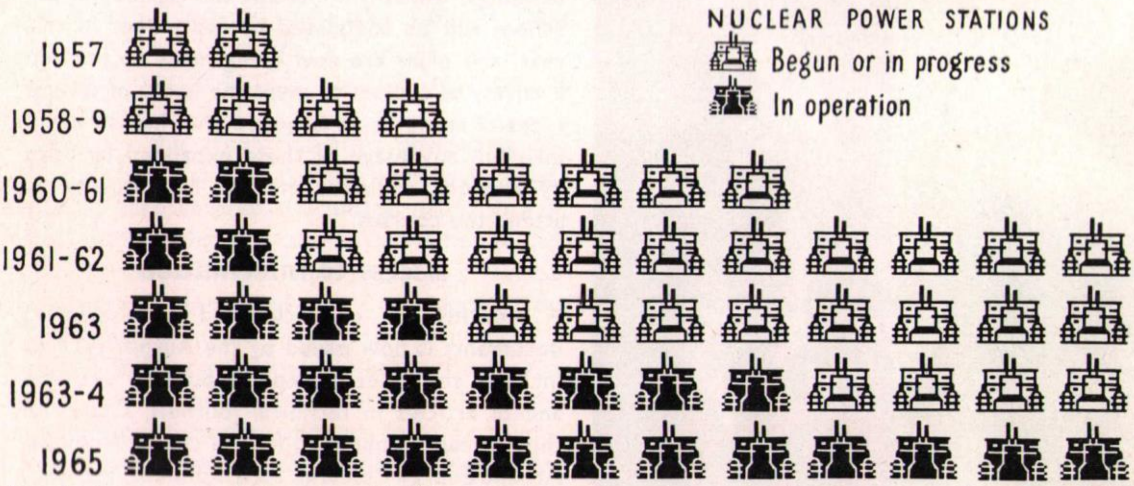
With a nucleus of trained staff the four groups set up design organisations and began preliminary design work. A Nuclear Power Collaboration Committee was also set up with representatives of the four groups from industry and of the Atomic Energy Authority which meets every two months. It has been attended since its beginning by members of the Central Electricity Authority and more recently by representatives of the South of Scotland Electricity Board.

The efforts of the design teams give every promise that the first "programme" stations will represent a substantial advance on Calder Hall.

# THE BUILD-UP OF ELECTRIC POWER 1955 - 1975




# Britain's Programme of Nuclear Power




This chart represents *only* the proposed *building* of nuclear power stations for the *10-year programme*. It does *not* show stations that would be begun but not yet completed by 1965

# Co-operation with Industry

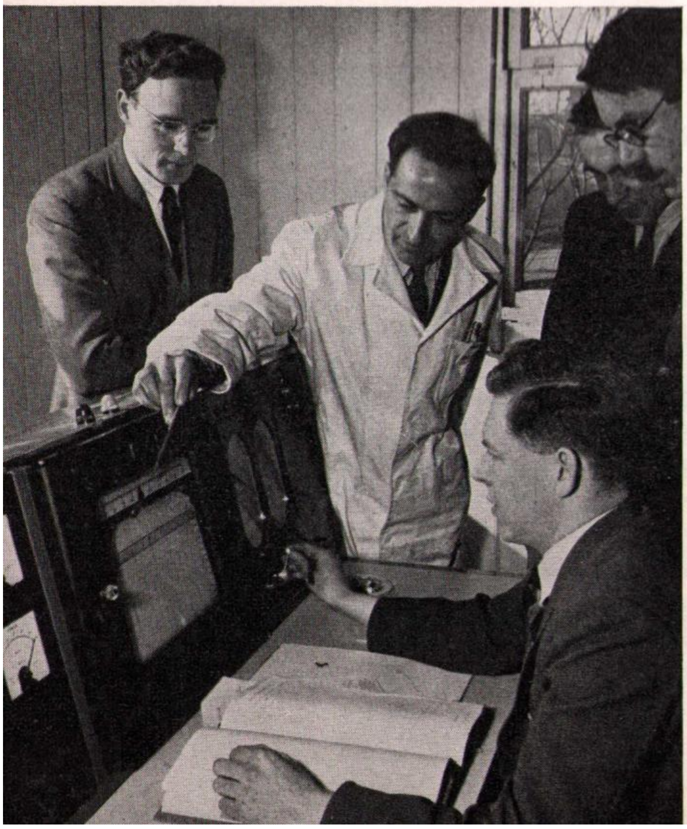
The year under review has witnessed a considerable increase in industrial activity in the atomic energy field. For a number of years the United Kingdom atomic energy programme was exclusively a Government operation.

This remained the situation until little more than a year ago. The growth of interest and activity on the part of industry can be dated from the formulation of the Government's nuclear power programme.

It was from the beginning made clear that the Atomic Energy Authority would not construct nuclear power stations required by the Electricity Authorities and a programme of training was instituted for staff from the four groups of industrial firms already referred to.

At the same time interest in atomic power was quickened in a number of other countries and British industry began to consider the possibility of exporting nuclear power stations or ancillary equipment.

Explaining a pile control simulator to industrial students—Reactor School, Harwell.



All these factors have occasioned a great increase in the independent activity of industrial firms in the atomic energy field during the last twelve or eighteen months.

It is imperative that knowledge of atomic energy should be disseminated in order that industry may play its full part in exploiting its commercial applications. The Authority have devoted a great deal of effort to this, regarding it as one of their principal responsibilities at the present time.

The Reactor School at Harwell has continued throughout the year to give training to staff from industrial firms on the construction and operation of nuclear reactors. The first course open to overseas students was held in the autumn of 1955; of the total of 49 students on that course, 21 were from overseas countries. Up to and including the first course of 1956, a total of 199 full-time and 100 part-time students have passed through the Reactor School. New buildings, which will increase the capacity of the School will be completed by September of this year, and plans are now being made to provide a variety of courses to meet the needs of several types of students. It is hoped that industry will take full advantage of these expanded facilities by allowing sufficient men of high quality to attend the courses.

## Access to Information

A monthly list of unclassified (non-security) documents is now issued by the Authority. This includes the titles of reports publicly available and of articles in technical journals. Copies of this list can be obtained free of charge from the Atomic Energy Research Establishment, Harwell.

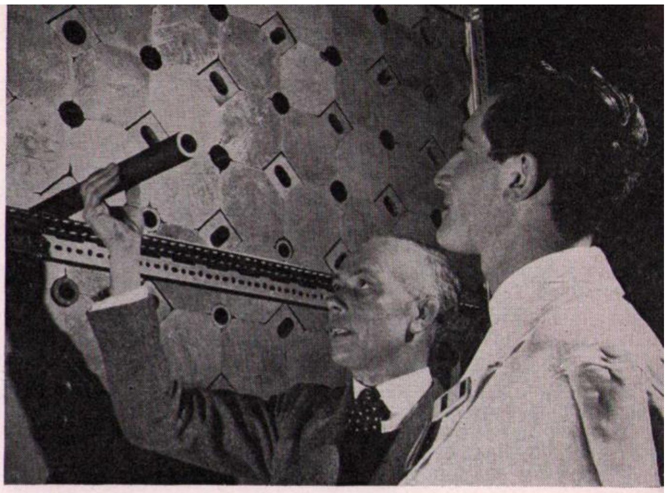
Copies of the unclassified documents listed are supplied to the following libraries: The Science Museum Library, London; Sheffield Central Library; The Central Library, Birmingham; The Mitchell Library, Glasgow; The Central Library, Liverpool; The Central Library, Manchester; The Central Library, Newcastle. In addition some of the documents are on sale through H.M. Stationery Office.

Classified (secret and confidential) information cannot be made freely available. However, firms working in the atomic energy field cannot be fully effective unless they have access to all the relevant information and the Authority are prepared to enter into "access agreements" on condition that (*a*) the Authority secure a financial return for information and patents built up at considerable expense to the taxpayer and (*b*) particular firms do not at this early stage of development obtain exclusive rights in particular basic reactor systems—this would be unfair to industry as a whole.

Access may take the form of receiving reports; of visiting the Authority's establishments; or—more rarely—of attaching staff to the Authority. Over 100 scientists and engineers from British firms were attached to the Authority's establishments in April of this year.

The growth of industrial participation was illustrated in February by the announcement of Associated Electrical Industries Ltd. of their intention to construct a "swimming pool" research reactor at their research laboratory at Aldermaston Court.

Besides the groups of firms developing the Calder Hall type of reactor, two new major groups have entered the nuclear field. Vickers Ltd., Rolls Royce Ltd. and Foster Wheeler Ltd. have formed a new company—Vickers Nuclear Engineering Ltd.—and are considering the application of nuclear energy to marine propulsion. The Hawker-Siddeley Nuclear Power Co. Ltd. have taken as their initial study liquid-metal fuelled reactor systems covering a wide range of applications. The British Shipbuilding Research Association, by agreement with the Authority, have a team at Harwell studying the feasibility of reactor designs for marine propulsion.



Reactor School Harwell—demonstrating the methods for slowing down fast neutrons.

## The Export of Reactors

The export of nuclear reactors, whether for research or power production, will be the responsibility of industry and not of the Authority.

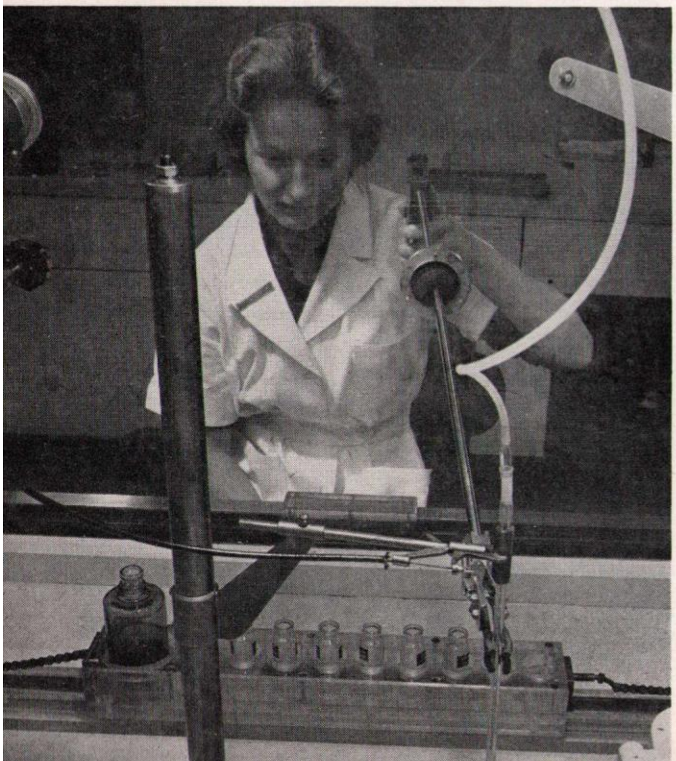
It will, however, be for the Authority to provide the necessary fuel and they expect to be able to provide natural uranium to match whatever volume of export business may be secured in the foreseeable future. Enriched fuel is in short supply but part of the annual output has been set aside for export orders which may be placed with British industry for reactors requiring this type of fuel.

It is hardly to be expected that exports of nuclear reactors will reach a large volume over the next few years. The first reactors built for the Electricity Authorities may be the first in the world to produce Electricity on a commercial basis. It is reasonable to expect that orders from overseas will follow rather than precede the achievement of nuclear power on a competitive basis in this country.

The heavy electrical plant manufacturers are not however neglecting any opportunity to develop interest in foreign markets and the Authority, in conjunction with the Board of Trade, are in touch with manufacturers on this subject.


Radioisotopes arriving at Tokio Airport. They were carried in the wing tip of the aircraft.

Dispensing Beta ray active isotopes at Amersham.



# Isotopes

A radioactive isotope is a material whose atoms are their own "radio station". Its presence can be detected by "signals" which register on photographic film or electronic instruments.

Isotopes have many uses in medicine, chemistry and biology and their application to industrial processes is making a significant contribution to productivity.

Sales of radioactive isotopes from the Radiochemical Centre at Amersham and the Isotope Division at Harwell have grown steadily during the year. The total value of isotope sales was nearly £500,000 and more than half this figure is represented by exports to over 50 countries.

Many new applications of radioactive isotopes have been studied during the past year. They have been used, for example, to investigate the pollution of beaches by sewage and to detect leaks in water mains and oil pipelines. With a neutron source, a new technique has been evolved for mapping the rock strata in oil well bore holes.

There is a continuing demand for training in the handling of isotopes. During the past year 167 students attended the ordinary course at the Isotope School (Harwell) and 104 attended special courses. An increased use of Harwell's Industrial Advisory Service has resulted from training given at the School to students from industry.

## Irradiation

Radioactive by-products from reactors have a great potential value in industry.

For example, rubbers and plastics can be treated by radiation to withstand higher temperatures than untreated products. Work on the sterilization of drugs has shown that antibiotics which would be destroyed by heat sterilization can be freed from bacteriological contamination.

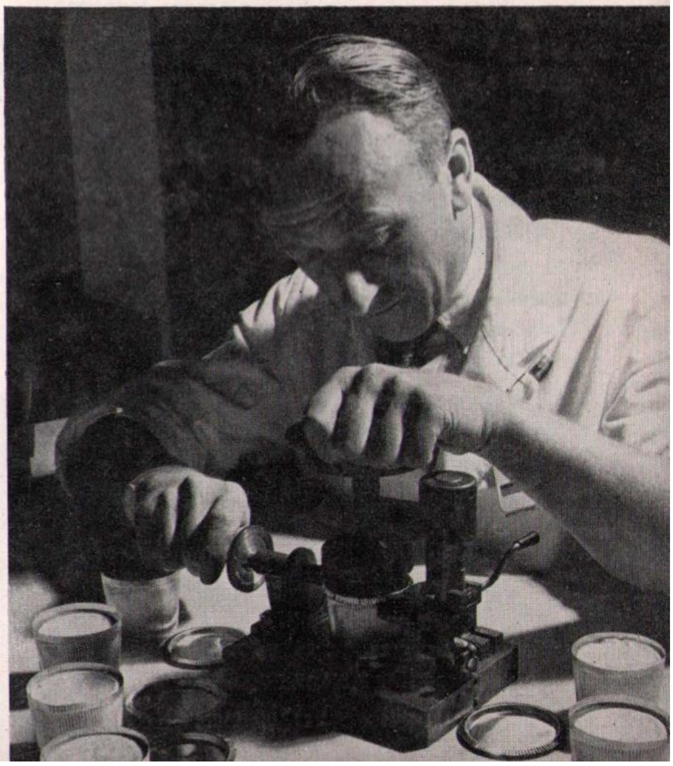
To increase existing facilities for this type of research, arrangements are being made at Harwell for the Technological Irradiation Group to have the use of spent fuel rods from the reactors Dido and Pluto. These fuel elements should provide a radiation source equivalent to about 1 ton of radium.

One of the by-products from the reactors—Cobalt-60—can be used for loading into machines for the treatment of cancer. A dozen British hospitals and several others in Europe are using cobalt in this way.

Further uses for irradiation are being actively explored by the Technological Irradiation Group of the Isotope Division—in close collaboration with industry. To extend this work arrangements are in hand to move most of the Group and other sections of the Isotope Division to Grove, about nine miles from Harwell.

Treating a patient by injecting a radioisotope.

Sealing sulphur into tubs before irradiation in a pile at Harwell.



# Twenty-One Reactors– in operation under construction or planned

The United Kingdom Atomic Energy Authority have nine nuclear reactors in operation. Three more are to be completed and put into service this year, and the construction of nine others is under way. These 21 are represented by the 12 types shown.

Conspicuous progress has been made during the year on the "fast fission breeder" reactor at Dounreay in the North of Scotland. In this reactor, of an advanced type, it is expected that for every fissile atom consumed in the "core" more than one fertile atom in the "blanket" will be transformed into fuel. So the amount of fresh fuel "bred" will exceed that consumed.

Work has been completed at Dounreay on the lower half of the steel sphere intended eventually to enclose the reactor proper. This lower half, a bowl 70 feet high and 140 feet across, is larger than the dome of St. Pauls. The next stage in the construction is the building of the 80 ft. diameter reactor vault inside the open bowl to contain the reactor core, the fertile blanket and the reflector to surround the core. Outside these the primary heat-exchangers will be installed and when these are finished the upper half of the bowl will be erected and the reactor totally enclosed.

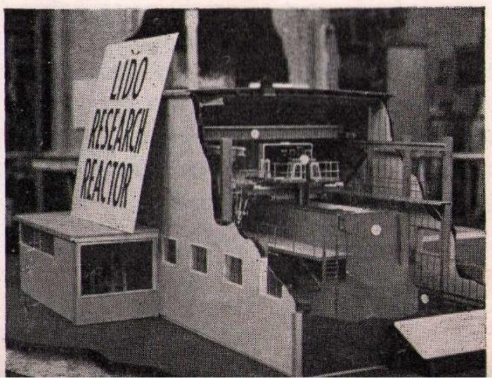
To extract the huge heat output efficiently, a liquid metal will be circulated through the reactor core and the primary heat-exchangers. From the latter the heat will be carried out of the protecting sphere by a secondary liquid-metal circuit and transferred to water and converted into steam in secondary heat-exchangers.

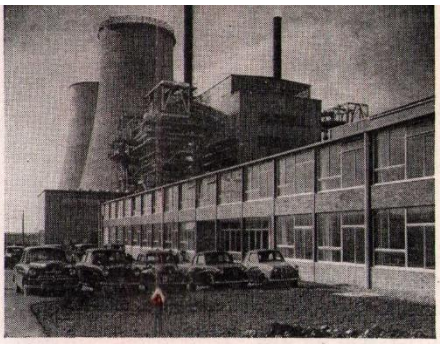
Dounreay will be equipped with medium power generating machinery and it should be operating for experimental purposes (including plutonium breeding studies) by 1959.

**1. WINDSCALE** (Cumberland) two thickly shielded plutonium production reactors operating since 1950. Each consists of an octagonal prism of graphite, pierced by a large number of horizontal channels in which are laid rows of uranium rods. Every rod is sealed in a finned, tightly fitting aluminium can and the heat produced in the nuclear reactor is removed by atmospheric pressure air.

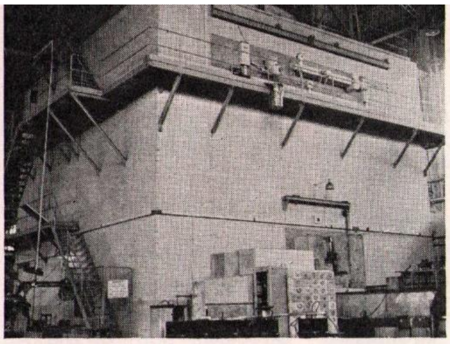
**5. ZEPHYR** (Harwell). Zero Energy Fast Fission Reactor. The first "fast" research reactor to be built in Britain ; it began working in 1954. Its core fuelled with plutonium, is a cylinder 6 ins. dia. by 6 ins. long. Fast reactors such as Zephyr can produce as a by-product more fuel than they burn.

**9. LIDO** (Harwell). A "swimming pool type" reactor for shielding studies to be brought up to criticality by September, 1956. In Lido, enriched uranium fuel is suspended in a large tank filled with the ordinary water used as moderator and coolant. The picture shows a model of the reactor.

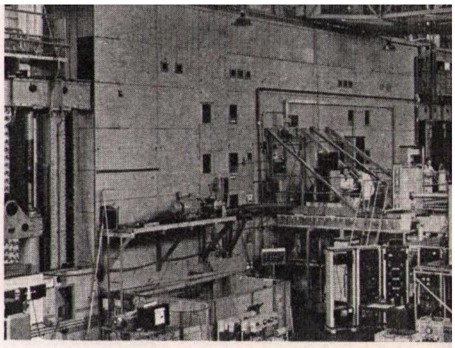




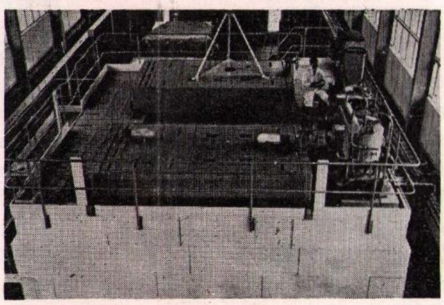
**2. CALDER HALL** (Cumberland) power reactor is to operate in October, 1956. In the complete station there are two graphite moderated reactors, cooled by carbon dioxide under pressure, and contained in mild steel pressure vessels 40 ft. in diameter and 60 ft. high housed in thick concrete biological shields. Outside these stand the huge cylindrical heat-exchangers, four to each reactor.



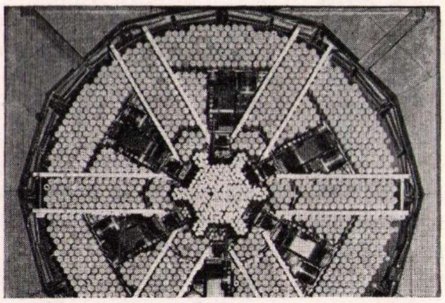
**3. GLEEP** (Harwell) Graphite Low Energy Experimental Pile. This graphite moderated air-cooled reactor has been in continuous use since 1947 for general experimental purposes. Its maximum operating power is limited to 100 kilowatts (it normally runs at much less) and it contains 505 tons of graphite, 12 tons of uranium metal and 21 tons of uranium oxide.



**4. BEPO** (Harwell). British Experimental Pile in continuous use since 1948. Another graphite moderated air-cooled reactor used primarily experimentally but also for making isotopes. Its power is limited to 6,500 kilowatts (dissipated as heat in the cooling air), its core consists of 850 tons of graphite and the full uranium metal load is 40 tons.



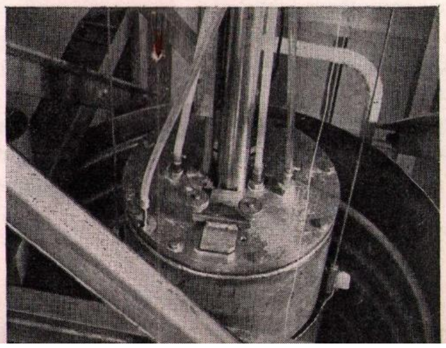
**6. DIMPLE** (Harwell). Deuterium Moderated Pile Low Energy. The first heavy water moderated reactor to be completed (1954) in the United Kingdom. Its extreme simplicity (canned uranium rods—heavy water tank—graphite reflector), and low power make Dimple a highly flexible research tool.



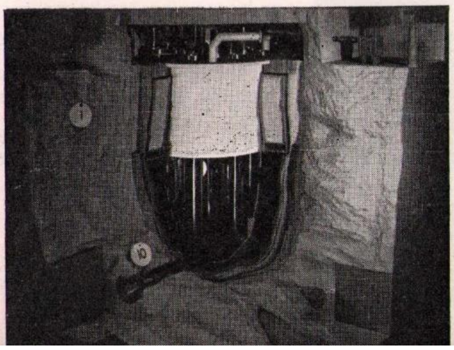
**7. ZEUS** (Harwell). Zero Energy Uranium System. This 100-watt research reactor began working in 1955. It is an uncooled fast reactor with a large highly enriched uranium core (the same size as the Dounreay reactor core) and a natural uranium blanket for breeding studies.

**8. DIDO** (Harwell). This 10,000 kilowatt high flux materials testing reactor should be worked up to full power by Christmas. Another heavy water moderated-aluminium tank reactor, it will have the highest neutron flux in Western Europe and be used for research and tests on fuel systems.

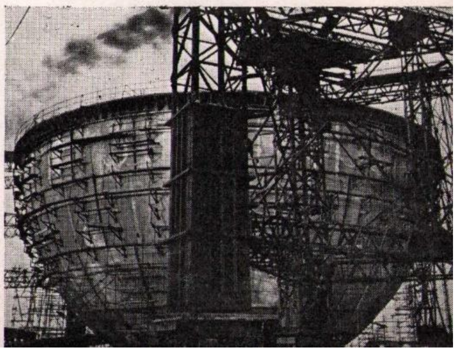
**10. ZETR** (Harwell). Zero Energy Thermal Reactor. This zero energy thermal system began operation in 1955 and is used in studies on nuclear fuels in solution for Stage III of the Authority's reactor programme. Both natural and artificial isotopes of uranium are used.



**11. PLUTO** (Harwell). A 10,000 kilowatt enriched uranium fuelled high flux materials testing reactor (to be duplicated at Dounreay) of the same basic design as DIDO. Its six test loops (available early in 1958) will provide pilot models of the essentials of future reactor systems. Photo shows model.



**12. DOUNREAY** (Caithness). A "fast breeder" liquid-metal cooled reactor (scheduled for 1958) to use highly enriched uranium or plutonium as fuel with uranium-238 or thorium in the breeder blanket. More fissile material should appear in the blanket than is consumed in the core.



# Uranium Supplies

Uranium, which is the necessary starting point of both military and civil atomic energy programmes, has throughout the year attracted more attention than almost any other metal.

The main reason for this has been the spate of new discoveries, most of them on the North American continent. These discoveries have been so extensive that they have removed the danger of a worldwide shortage. The Authority have continued planning ahead to match their growing requirements with greater production, particularly from Commonwealth sources. But as the world supply position grows easier, more attention has to be paid to the relative cost of production from new deposits. There is now no question of paying almost any price for uranium.

The forecast made in September, 1954, by the Director of the Raw Materials Division of the United States Atomic Energy Commission that the acceptable price for uranium contained in a high-grade concentrate might become about $10 (71 shillings sterling) a pound has already received some confirmation.

Using a geiger counter to detect radioactive minerals.

For their current uranium imports the Authority have continued to depend on contracts placed by the Combined Development Agency on behalf both of the Authority and of the United States Atomic Energy Commission, but during the year under review the first contracts have been signed for the delivery of uranium direct to the United Kingdom—as distinct from contracts for supplies through the C.D.A.

In March the Authority signed a contract to buy for a number of years uranium concentrates from the Mary Kathleen Mine in Queensland, Australia, and they have also undertaken to buy a considerable tonnage from the South Alligator region of the Northern Territory of Australia if and when uranium concentrates are produced from this region at a minimum guaranteed price.

The Authority have also taken steps to foster interest in uranium prospecting in the Central African Federation, which is geologically promising although no rich strike has yet been made. The Authority—in conjunction with the Geological Survey and Museum—has opened an office in Salisbury, Southern Rhodesia, to advise and encourage local prospectors.

The efficiency of uranium prospecting depends on the efficiency and sensitivity of the electronic instruments used. In collaboration with the Geological Survey, with mining houses, individual prospectors and the electronics industry, the Electronics Division at Harwell continues to develop prospecting instruments of the most advanced type. Its products include portable geiger and scintillation counters for prospectors, air-borne and car-borne survey equipment, and instruments for use in mines and in treatment plants. Close liaison is maintained with the Scientific Instrument Manufacturers' Association and constant attention given to the development and manufacture of instruments with appeal for export markets.

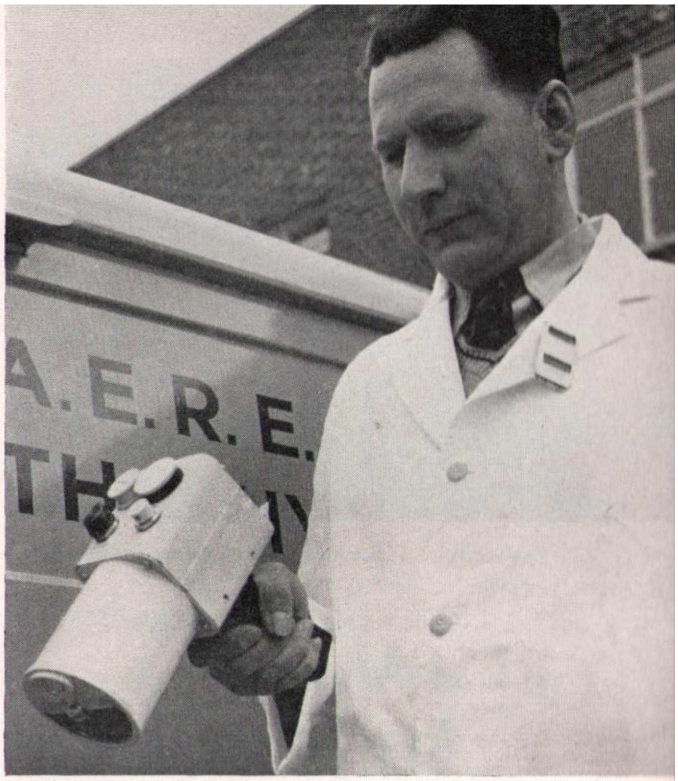
# Safety and Health

The type of reactor which is planned for the first power stations is of inherently safe design. As it uses dilute fuel *a nuclear explosion is impossible in any circumstances* and it is difficult to conceive of any circumstances which would cause the release of any appreciable fraction of the radioactivity.

However, it is recognised that there is at present only a relatively short experience of the working of nuclear reactors and that—even though the design is inherently safe—it must be demonstrated, over a period of years, that the nuclear power stations are not dangerous in operation. Accordingly the first stations will be built away from heavily built-up areas.

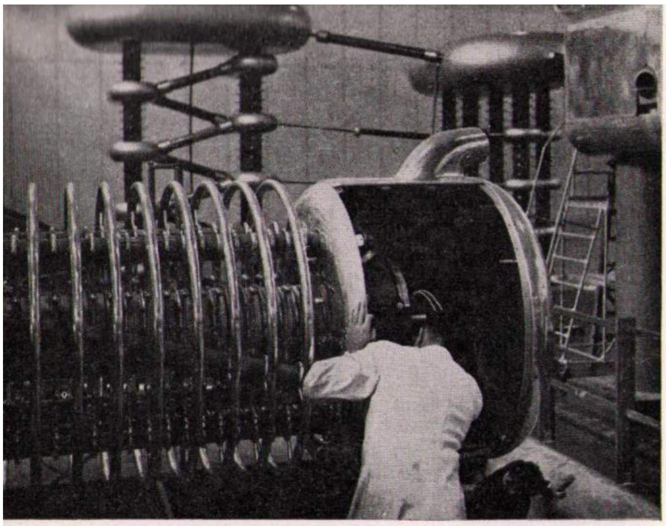
The Authority have set up a panel of their own specialists together with representatives of the electricity undertakings to consider the problems of reactor siting. This panel has studied the sites proposed by C.E.A. for the first two stations at Berkeley, Gloucestershire, and Bradwell, Essex, and in the light of the panel's recommendations the Authority have advised C.E.A. that in the Authority's opinion these sites are appropriate to the type of reactor to be built there. The panel has also examined proposals by the South of Scotland Electricity Board for sites for a third station.

The need to take unusual precautions against radioactivity helps to keep employees of the Authority safety-conscious. This, coupled with the careful design of plant and equipment, has resulted in a low incidence of industrial accidents. The lost-time frequency rates for the year ended September, 1955, were 1.01 per 100,000 man-hours for the Industrial Group; 0.42 for the Weapons Group; and 0.95 for the Research Group. These figures compare well with those for the chemical industry; in fact, employment in the Authority is safer than in most comparable industries. In particular the dangers of radioactivity are well controlled, so that the chance of employees being injured from this cause is exceedingly small. In the period under review there was no case of occupational toxicity illness or death; nor was there a single fatal accident.



Health Protection at Harwell—a portable geiger counter used for checking radioactivity.

A great deal of work is being applied to the problems of waste disposal to ensure that members of the general public are fully protected from possible exposure to radioactive materials. Part of the waste material has to be stored permanently, but some of it is in the form of very dilute solutions and these can be safely discharged into rivers or the sea, sometimes after preliminary purification. Whenever substantial quantities of radioactive wastes are dispersed into the environment, detailed studies are made of all the possible complications. At Windscale, these studies have lasted many years and have included measurements of the radioactivity in fish, in seaweed, in sea bed and in shore sand.



The 500,000 Electron volt proton injector at Harwell.

# RESEARCH – key to the future

Although atomic power stations of the Calder Hall type are already being built and others are in prospect, these represent only the first milestone on Britain's road to nuclear power.

To map the way ahead there is an immense research and development programme designed to make this type of station more efficient and to determine the shape of reactors that will be built ten, twenty or even thirty years from now.

The purpose of such a programme is to devise reactors that will make more economic use of the various atomic fuels and thus produce electricity at a lower cost than that prophesied for the first commercial nuclear power stations (three-fifths of a penny a unit).

A large part of current research is concentrated on three of the main constituents in reactor design: THE FUEL, THE MODERATOR, THE COOLANT.

The *fuels* of the atomic age (corresponding to the coal, oil or wood burnt in ordinary fires) are uranium or plutonium. Atomic fuels can release immense amounts of energy compared with the fuels that mankind has used in the past. Although this has not yet been achieved in practice, *one pound of uranium*—if the nuclei of all its atoms were split—would produce as much energy as 3,000,000 *pounds of coal*.

The *moderator* is a substance used with the fuel to slow down the neutrons so that more "fissions" or splittings will take place. Possible moderators are ordinary water, "heavy" water, the metal beryllium or carbon. In the Calder Hall reactor, carbon is used in the form of graphite (which is made from coke and pitch).

The *coolant* is used to carry the heat away so that it can be used, e.g. to turn water to steam. Possible coolants are air and other gases, water and certain liquid metals. At Calder Hall a gas (carbon dioxide) is used.

## Current Activities

The year under review has included the following work on what are termed Stage I, II and III reactors for the development of nuclear power:

*STAGE I*

The reactions between carbon-dioxide and graphite at temperatures envisaged for the Central Electricity Authority reactors has been studied.

*STAGE II*

Research work has been carried out for the development of a *pressurised water reactor* and a *sodium graphite reactor*. These would produce more heat for every pound of fuel than would a gas-cooled reactor. They would however need enriched fuel, i.e. fuel containing more fissile material than does natural uranium (one part in 140).

*Pressurised Water Reactor*. A number of "loops" (experimental circuits within a reactor) have been built to study the corrosion of carbon steels and stainless steels under conditions likely to occur in this type of reactor. One such loop is being installed in the N.R.X. reactor in Canada; one is in BEPO at Harwell; and another will be put in DIDO (also at Harwell). Fuel specimens using highly alloyed uranium and the more corrosion-resistant uranium oxide have been made up and investigated for damage by irradiation. The use of diphenyl and terphenyl as an alternative to water—as a moderator and coolant—is being investigated; if these could be used the pressure of the system would be much lower and corrosion problems might be less severe.

*Sodium-Graphite Reactor.* Investigations are in progress on a reactor using graphite as a moderator but with liquid sodium (a liquid metal) as a coolant. This would allow of higher temperatures and efficiency but lower pressure than the pressurised water system. One of its problems will be to prevent the liquid sodium penetrating the graphite.

If these studies show one of these reactors to be more economically favourable than the Stage I reactors, design work on a prototype will probably start at the end of this year. *Present information suggests that the choice will probably fall on the sodium-graphite system.*

*STAGE III*

Four other reactor systems are being investigated for Stage III of the programme. The objective of Stage III is to attain a much better use of fuel by "breeding".

(i) *Fast Reactors.* The experimental fast (non-moderated) reactor ZEPHYR, which has been in operation since the beginning of 1955, has indicated that—in the ideal conditions of a small uncooled system—the reactor can produce about twice as much fuel as it consumes. ZEUS, the zero-energy version of the Dounreay reactor, came into operation last December; it is being used to obtain final information for the design and operation of the Dounreay reactor.

(ii) *Aqueous Homogeneous Reactor.* The characteristic of this reactor is that the uranium fuel and the water moderator are mixed into a "soup". As in the fast reactor this would be surrounded by a "blanket" in which new fuel could be bred. The "blanket" is likely to be of thorium, from which uranium-233 would be bred. Very low fuel costs are the aim in this reactor.

(iii) *Liquid-Metal Fuelled Reactor.* Another alternative is a reactor using a graphite moderator and a liquid fuel consisting of enriched uranium dissolved in liquid bismuth.

(iv) *High-Temperature Gas-Cooled Reactor.* The achievement of high outlet temperatures (of the order of 750 degrees Centigrade) would make possible the use of gas turbines as a means of extracting energy from the system.

It is probable that one or two of the Stage III systems will be chosen in 1957/8 as the basis of a relatively low-powered reactor designed to test the general technology of the system and its possible application to the development of nuclear power stations with a 10,000 kilowatt output. These would be more suitable for export to many countries than the larger stations now being developed for the Electricity Authorities in the United Kingdom.

## Thermonuclear Reactions

In the reactors we have been discussing so far, the energy is obtained by splitting the nucleus of the heavy atoms. An alternative method of obtaining energy is to bring light nuclei together to form heavier ones.

Since 1948 the Atomic Energy Authority and its predecessors have supported a programme of research into the possibilities of obtaining economic power from controlled thermonuclear reactions. The occurrence of abundant fuel such as deuterium (heavy hydrogen) in the sea and lithium is a strong incentive to attain this objective.

To make a fusion reaction possible the nuclear fuel must be brought to a temperature in the region of 100,000,000 degrees Centrigade.

Two main problems must be solved: to bring a mixture of the light elements to this very high temperature and to maintain this temperature long enough for the energy released in nuclear fusion to be greater than that required to heat the fuel.

Many methods of heating a gas under conditions of good thermal insulation have been tested under laboratory conditions and extremely high temperatures have been measured.

The Authority's work is in the laboratory stage and many problems have to be solved before a practicable fusion reactor will be possible.

# International Relations

The steps taken during the past year to release from security restrictions virtually the whole of the basic information needed in a research and development programme for the peaceful applications of atomic energy have opened up a wide range of opportunities for the free flow of information between scientists of all countries. This flow of information has stimulated a remarkable increase in interest in nuclear energy in many countries. This was exemplified by the International Conference on the Peaceful Uses of Atomic Energy in Geneva in August, 1955; by the marked increase in the number of foreign requests for information and visits to the Authority's establishments; and by the increase in the invitations to the Authority's scientists to visit other countries.

Subject only to the unavoidable limits imposed by security the Authority have continued to co-operate with other countries under arrangements already concluded, and a number of new bilateral arrangements for co-operation have been made, notably with the United States, India, Belgium and the Netherlands.

It has become increasingly clear that the key to the enjoyment of the future of atomic energy is the possession of a nucleus of adequately trained staff. The initial training of such staff is one of the principal ways in which countries with advanced atomic energy projects can assist others. The Authority's Isotope School at Harwell was fully international in character from the outset, and during the past year the Harwell Reactor School began to run courses open to students from all over the world.

## International Agency

Considerable progress has been made towards the establishment of the International Atomic Energy Agency sponsored by the United Nations. The United Kingdom was one of the twelve countries appointing representatives to a Negotiating Group to adopt a revised draft for the Statute of the Agency. This will be submitted to a conference of interested members of the United Nations and the Specialised Agencies in New York next September.

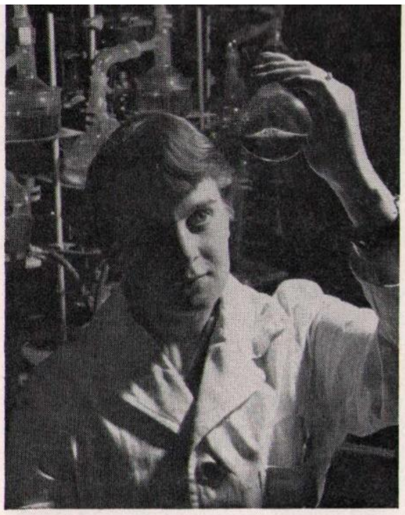
H.M. Government are giving assistance to the Baghdad Pact countries (Iraq, Pakistan, Iran and Turkey) in the setting up of a Training Centre in Baghdad for radioisotope techniques. They have also expressed their willingness to participate in measures to facilitate the training of students from the Colombo Plan countries (India, Pakistan, Ceylon, Burma, Thailand, South Viet-nam, Laos, Cambodia, the Philippines, Indonesia and Japan).

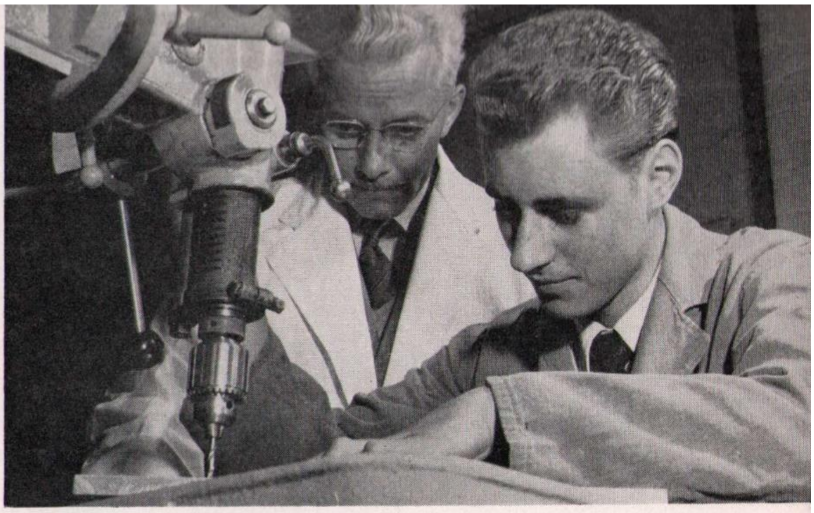
The O.E.E.C. countries have during the last year been considering a number of proposals for closer European co-operation in the atomic energy field and H.M. Government have stated their intention to co-operate as fully as possible. The "Messina" group of countries have been considering the possibility of establishing an organisation which would operate through pooled resources. They have nevertheless participated in the O.E.E.C. deliberations.

Staff of the Authority have continued their participation in the work of the European Council for Nuclear Research (C.E.R.N.) and the European Atomic Energy Society.

Countries with whom Britain has agreements or other forms of collaboration or with whom technical discussions have taken place include the following:

*Commonwealth:* Australia, Canada, India, Pakistan, South Africa. *Other Countries:* The United States of America, Argentine, Austria, Belgium, Brazil, Denmark, France, Iran, Iraq, Israel, Italy, Japan, Jugoslavia, The Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, Western Germany.





Laboratory worker at Springfields.

Craft apprentice receiving instruction at Harwell.

# Careers in Atomic Energy

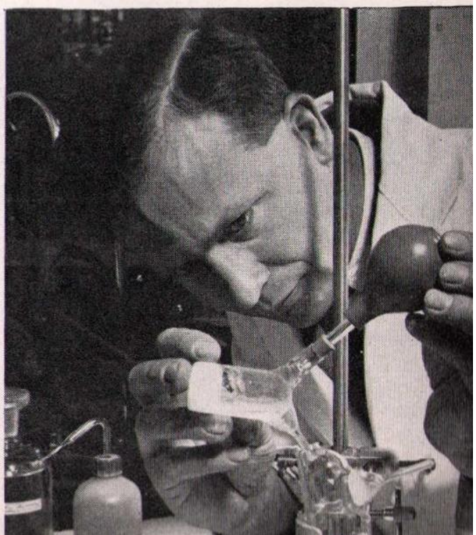
Although the staff employed by the Authority increased from 20,000 in April, 1955, to nearly 24,000 in March of this year, the acute shortage of scientists and technologists referred to in the first annual report remains a national problem. The expansion has therefore required a concentrated recruitment campaign which, although reasonably successful for middle and lower grades staff, has not yet solved the difficulty of filling the more senior and particularly engineering posts.

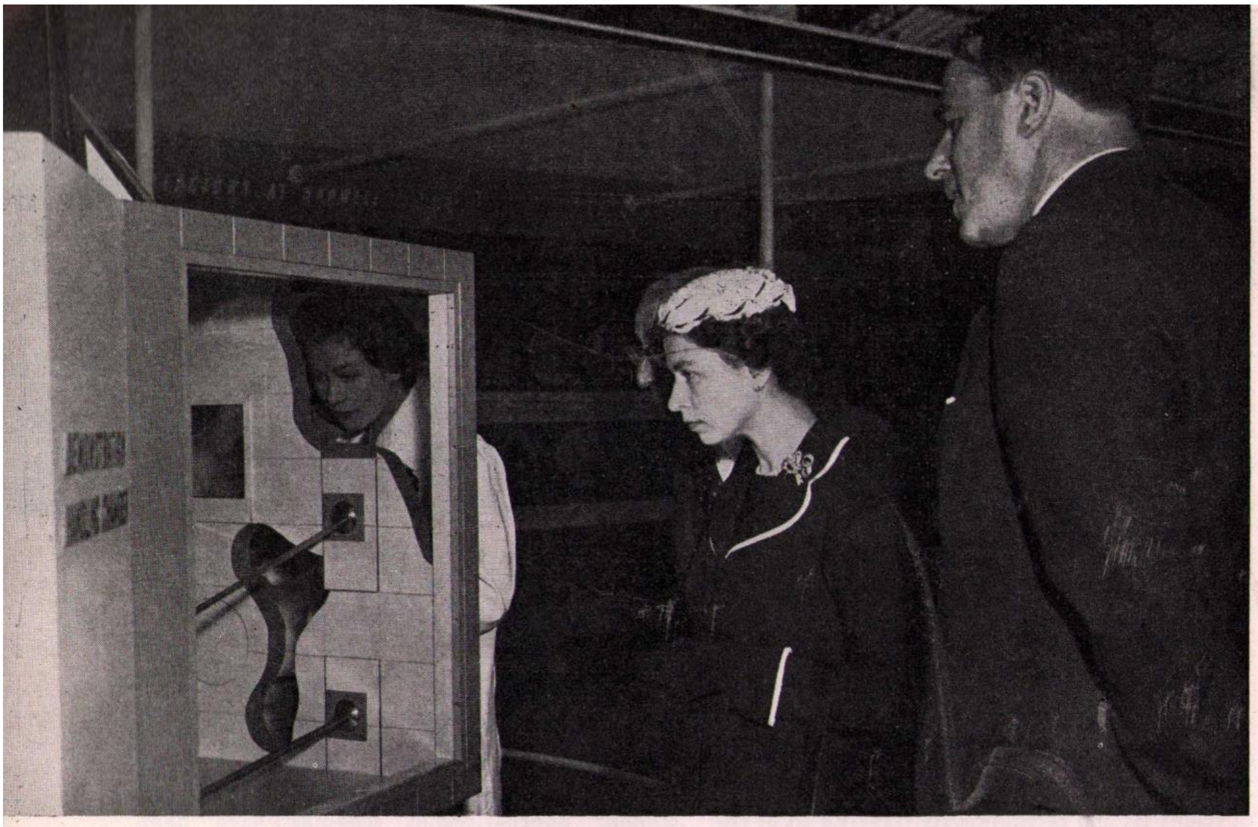
During 1955, bursaries were again awarded to members of the staff for full-time University education, "sandwich courses" were introduced experimentally and the scheme for post-graduate apprenticeship developed further. Craft and student apprenticeship schemes have been continued. In March, 1956, 357 craft and 69 student apprentices were in the Authority's service from whom five were selected for full-time degree or diploma courses.

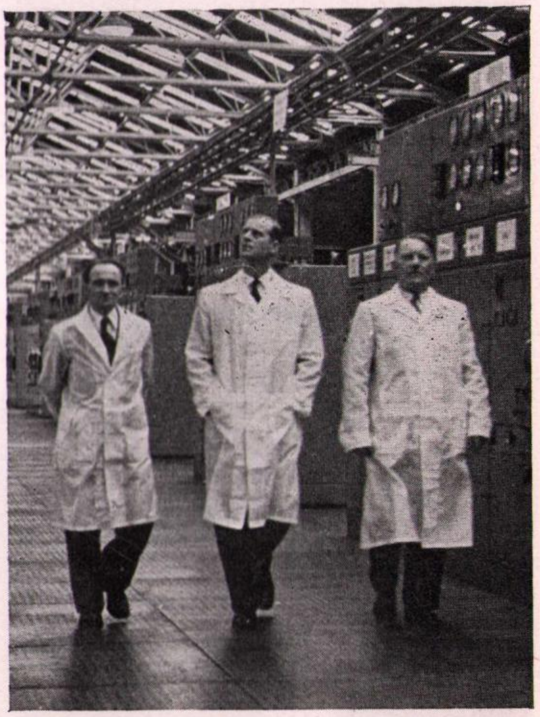
The Authority wish to record their gratitude to their staff for accepting efficiently the additional burdens imposed by expansions in organisation and in programmes.

Engineers at Calder Hall.

Chemist at Amersham.







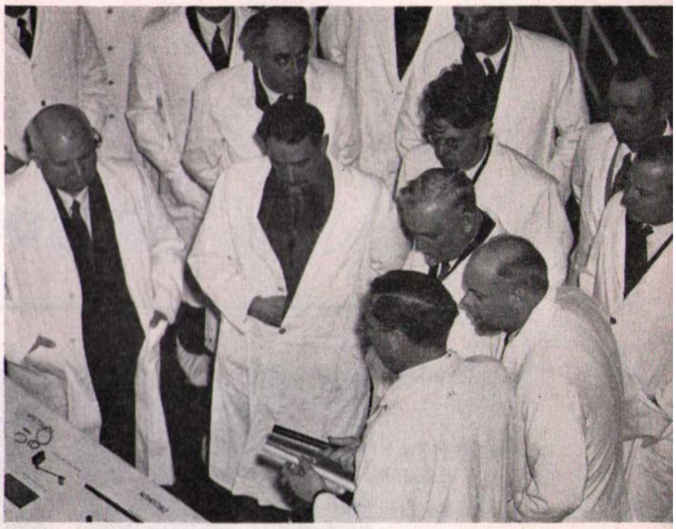
# Distinguished Visitors

A measure of the current interest in the British nuclear energy programme is the large number of visits paid to the Authority's establishments.

Her Majesty the Queen and H.R.H. the Duke of Edinburgh showed great interest in the Authority's exhibit at the British Industries Fair at Olympia. H.R.H. the Duke of Edinburgh paid visits to establishments of the Industrial Group and H.R.H. the Princess Margaret to Harwell and the Radiochemical Centre, Amersham. The Prime Minister, the Rt. Hon. Sir Anthony Eden, visited both Harwell and Aldermaston.

Visitors included not only scientists and industrialists from this country but representatives of foreign and Commonwealth countries. In all, during the year, there were visitors from 36 different countries. The highlight was the one-day air visit to Harwell arranged by the Authority for delegates of all nations participating in the Geneva Conference.

Representatives of the Authority were able to visit several atomic energy projects abroad. In implementation of the Civil Bilateral Agreement concluded in June 1955 with the U.S.A., several visits were paid to America, while in November a party of eight led by Dr. B. J. F. Schonland of Harwell paid a six-day visit to Russia.



OPPOSITE PAGE

*Top:* Her Majesty The Queen at the Authority's stand at B.I.F.

*Bottom Left:* H.R.H. The Princess Margaret at the Radio-chemical Centre, Amersham.

*Bottom right:* H.R.H. The Duke of Edinburgh visiting Calder Hall.

THIS PAGE

*Top:* The Prime Minister at Aldermaston.

*Centre:* Marshal Bulganin, Mr. Kruschev and a Russian delegation visit Harwell.

*Bottom:* Geneva delegates at Harwell.

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Lord President of the Council

ATOMIC ENERGY OFFICE

Sir EDWIN PLOWDEN,
K.C.B., K.B.E.

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