HARWELL

Handbook

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A brief guide to the

Atomic Energy Research Establishment
of the U.K.A.E.A.

and the

The Rutherford High Energy Laboratory
of the National Institute for Research
in Nuclear Science

Director A.E.R.E Dr. F. A. Vick, O.B.E.

Director Rutherford Laboratory, Dr. T. G. Pickavance

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The United Kingdom Atomic Energy Authority

History

During the war British work on atomic energy (which from 1943 to 1945 was amalgamated with that of the United States and Canada) was in the charge of the Department of Scientific and Industrial Research. Shortly after the war responsibility was transferred to the Ministry of Supply, which set up research and production organisations in the United Kingdom in 1946. The organisations were, initially, the Atomic Energy Research Establishment at Harwell, Berkshire, responsible for research into all aspects of atomic energy, and the Department of Atomic Energy Production with headquarters at Risley, in Lancashire, responsible for producing fissile material. Later, development of nuclear weapons began at a special unit in the Armament Research Establishment, Woolwich which subsequently formed the nucleus of the Atomic Weapons Research Establishment.

For the first few years these organisations were concerned mainly with building factories to make plutonium and enriched uranium for military purposes, and with doing the concomitant research. In the early 1950's however attention, especially on the research side, began to turn to the generation of electric power from nuclear energy. A study at Harwell of the feasibility of using natural uranium for power generation led to the design of a gas-cooled graphite-moderated power reactor and in 1953, on the basis of this work, the Risley organisation began to build Calder Hall, the dual-purpose, plutonium-producing and power-generating, plant which was the world's first industrial-scale nuclear power station.

The growing importance of the industrial applications of atomic energy, fore-shadowed by Calder Hall, and the need for an organisation more more nearly akin to that of a large industrial undertaking led the government in 1953 to conclude that responsibility should be transferred to a non-departmental organisation under general government supervision. The organisation ultimately set up, under an Act of 1954 (amended in 1959), was the United Kingdom Atomic Energy Authority, which came into being on July 19th 1954 and assumed responsibility for the atomic energy establishments and factories on the 1st August following.

Under the Act the responsible Minister (originally the Lord President of the Council, subsequently the Prime Minister, and now the Minister for Science) is charged with promoting and controlling the development of atomic energy and with the general supervision of the Authority. He

appoints Members of the Authority, and ensures that the proper degree of importance is given to the various applications of atomic energy; he may, after consultation with the Authority, give to it such directions as he thinks fit, but he does not intervene in the detailed conduct of its affairs. The Authority's powers in the field of atomic energy cover the production, use, and disposal of atomic energy and radioactive substances and all forms of research into these matters. In accordance with

Government decisions, the Authority's principal tasks are to fulfil the military programme for production of nuclear explosives and to assist in the fulfilment of the country's nuclear power programme. After these, the Authority's next tasks are to select and develop the most promising reactor systems to succeed the gas-cooled graphite-moderated systems of the first power stations, to do fundamental scientific research, and to produce radioisotopes and develop their applications.

Membership

Under the Act of 1954, as amended in 1959, the Authority consists of a Chairman and not less than seven or more than fifteen other members. The full-time members are:

Sir Roger Makins, G.C.B., G.C.M.G.	Chairman
Sir William Cook, C.B.	Member for Development and Engineering
Sir Alan Hitchman, K.C.B.	Member for Finance and Administration
Sir Leonard Owen, C.B.E.	Member for Production
Sir Claude Pelly, G.B.E., K.C.B., M.C.	Member for Weapons Research
Sir William Penney, K.B.E., F.R.S.	Member for Scientific Research

The part-time Members are:

Sir James Chadwick, F.R.S.

Rt. Hon. Lord Citrine, P.C., G.B.E.

Sir John Cockcroft, O.M., K.C.B., C.B.E., F.R.S.

Mr. A.R.M. Geddes, O.B.E.

Mr. C.F. Kearton, O.B.E.

Sir Rowland Smith

Mr. John Pears, F.C.A.

The Secretary of the Authority is Mr. D.E.H. Peirson

Organisation

The work of the Authority is shared by four Groups, a Health and Safety Branch, and a London Office which provides a central administrative, secretarial, and co-ordinating service. The executive head of each Group is the appropriate full-time Member.

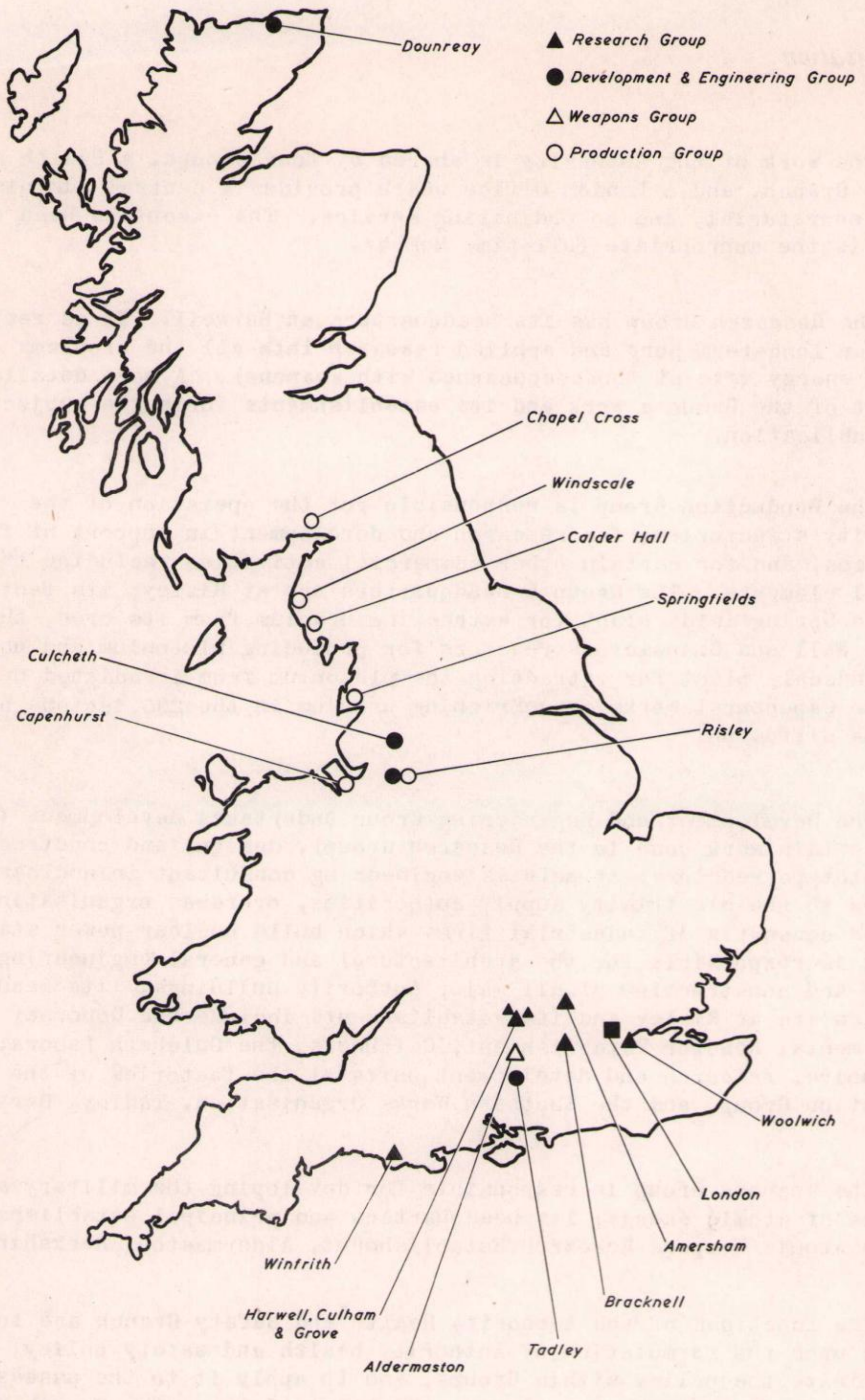
The Research Group has its headquarters at Harwell. It is responsible for long-term pure and applied research into all the problems of atomic energy (except those concerned with weapons). A more detailed account of the Group's work and its establishments forms the subject of this publication.

The Production Group is responsible for the operation of the Authority's factories, for research and development in support of factory processes, and for certain other commercial activities including the sale of fuel elements. The Group's headquarters are at Risley; its factories are the Springfields plant for extracting uranium from its ores, the Calder Hall and Chapelcross reactors for producing plutonium and power, the Windscale plant for extracting the plutonium from irradiated uranium, and the Capenhurst Works for enriching uranium in the 235 isotope by gaseous diffusion.

The Development and Engineering Group undertakes development (other than certain work done in the Research Group), design, and construction of prototype reactors; it acts as engineering consultant in nuclear power matters to the electricity supply authorities, overseas organisations, and the consortia of industrial firms which build nuclear power stations; and it is responsible for the architectural and general engineering design and construction of all major Authority buildings. Its headquarters are at Risley and its establishments include the Dounreay Experimental Reactor Establishment, Caithness, the Culcheth Laboratories, Lancashire, research and development units at the factories of the Production Group, and the Southern Works Organisation, Tadley, Berkshire.

The Weapons Group is responsible for developing the military applications of atomic energy; its headquarters and principal establishment is the Atomic Weapons Research Establishment, Aldermaston, Berkshire.

The functions of the Authority Health and Safety Branch are to advise upon the formulation of Authority health and safety policy, to disseminate the policy within Groups, and to apply it to the assessment and inspection of reactors, plants, and laboratories. The Branch also acts as a focal point for external relations, technical and political, in the health and safety field. The Radiation Protection Division of the Branch is situated at Harwell.

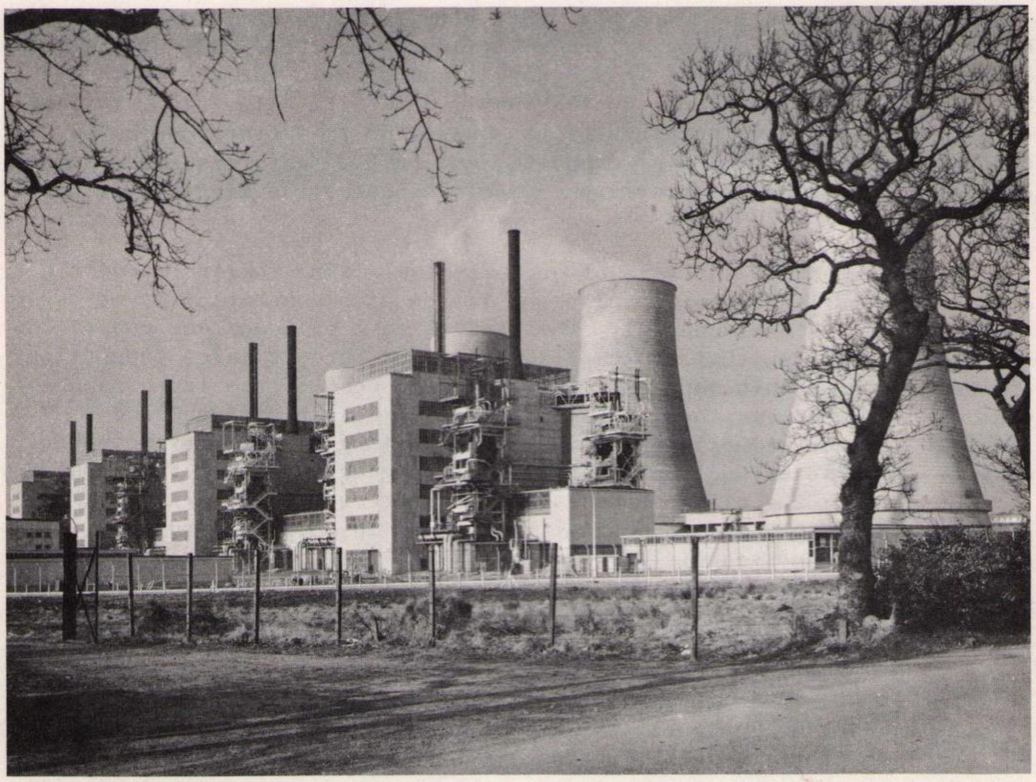


Establishments and Factories of the U. K. A. E. A.

The British Nuclear Power Programme

For over half a century the consumption of energy in the United Kingdom has doubled every ten years; this growth continues and in the years after the war there was anxiety about finding the fuel needed to meet the rapidly-growing annual increment in energy demand. During 1954 when Calder Hall was being built, the Government considered the difficulties, of expanding coal production and finding foreign exchange to buy oil, serious enough to warrant embarking on a programme of nuclear power stations to supplement fossil-fuelled plants. Although it was expected that in the long run nuclear power would be economically competitive with coal and oil power, at that time the primary aim was to develop an alternative fuel to coal and oil; the emphasis has since changed.

The programme, announced in February 1955, called for the construction of nuclear stations with a total installed capacity of 1500-2000



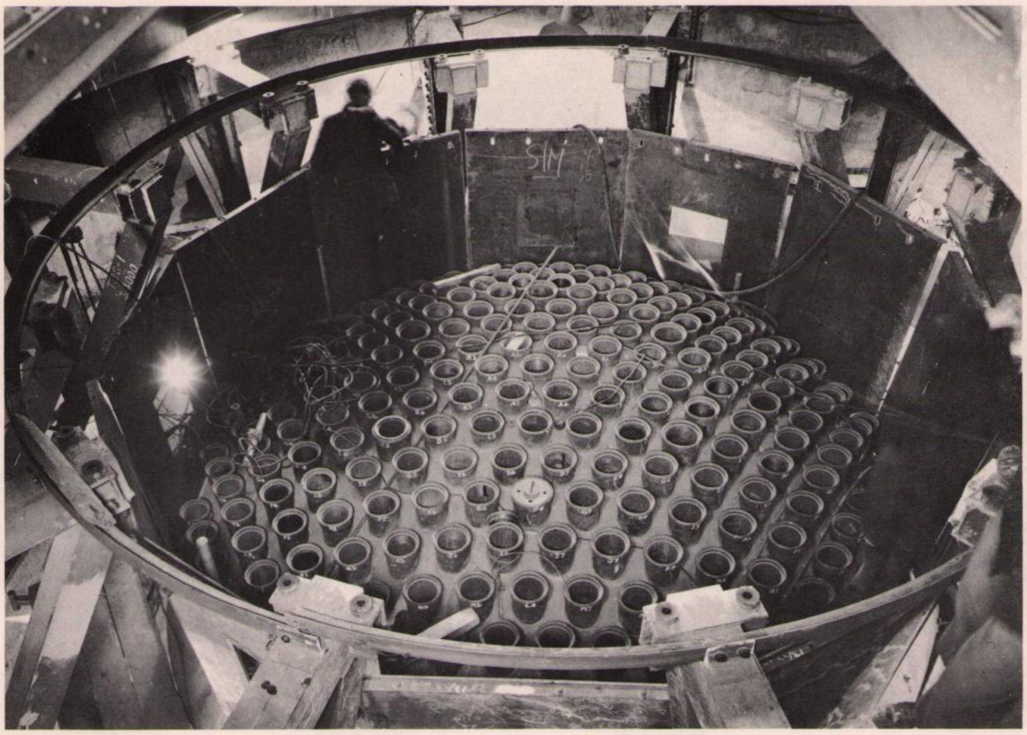
Reactors of the Authority's Chapelcross nuclear power station

MW(e) by 1965. The stations, like ordinary stations, would be owned and operated by the electricity authorities and would be built for those authorities by industry. The Atomic Energy Authority's part was to do the research and development for the programme and provide the basic design information, to manufacture fuel elements, and to process irradiated fuel. British industry organised itself into a limited number of consortia of large concerns with the appropriate experience - electrical engineering, steam plant engineering, construction etc - to undertake these very large works. This distribution of responsibility between publicly-owned and private industry remains unchanged in principle.

When tenders for the first stations of the programme were received at the end of 1956, they showed that it was practicable and economic to build plants with much greater capacity than had been expected when the programme was drawn up. This continuing technical development, allied to increasing concern over the fuel situation during the Suez crisis, led the government in March 1957 to expand the programme to 5,000-6,000 MW(e) installed capacity by the end of 1965. However, since then the fuel situation has improved greatly and in June 1960 the programme was slowed down to 5,000 MW(e) by 1968.

The first five stations now under construction, are: for the Central Electricity Generating Board, Bradwell (300 MW(e)), Berkeley (276 MW(e) Hinkley Point (500 MW(e)), Trawsfynnydd (500 MW(e)), for the South of Scotland Electricity Board, Hunterston (300 MW(e)). All these stations are based on improved versions of the Calder Hall reactor, cooled by carbon dioxide, moderated by graphite, and fuelled with natural uranium canned in magnox alloy (they are commonly known as the magnox reactors).

As an immediate shortage of ordinary fuel is no longer feared the emphasis in nuclear power development is now upon generation at costs competitive with coal and oil. The capital cost of a nuclear power station is high, so that the capital component forms a large proportion of the cost of a unit sent out. Although the cost of the large magnox stations is much less than that of the Calder Hall prototype, and although further reductions in cost are resulting from improvements in design, the cost of nuclear power is still higher than that from coal-fired stations; the differences have been increased by remarkable advances in design, and consequent reductions in cost, of ordinary stations in recent years. The prospective fall in the price of uranium will reduce the fuel component of power cost from nuclear stations but lower capital costs are essential for nuclear power to become competitive with fossil. The next major reduction will be achieved in the Advanced Gas-cooled Reactor (A.G.R.) now being developed by the Authority. In this the natural-uranium metal fuel of the magnox stations is replaced by uranium dioxide (slightly enriched in uranium-235) canned in beryllium or stainless steel; the coolant is carbon dioxide and the moderator graphite. Much higher gas temperature and heat rating of the fuel will be obtained, with the result that the size of the plant will be reduced and the steam conditions improved. A prototype is being built at Windscale, to come into operation in 1961, and it is hoped that the first commercial stations based on the design will begin operating in the mid-1960's. When operated on base load, nuclear power stations should become competitive with fossil-fuelled stations towards the end of the present decade.

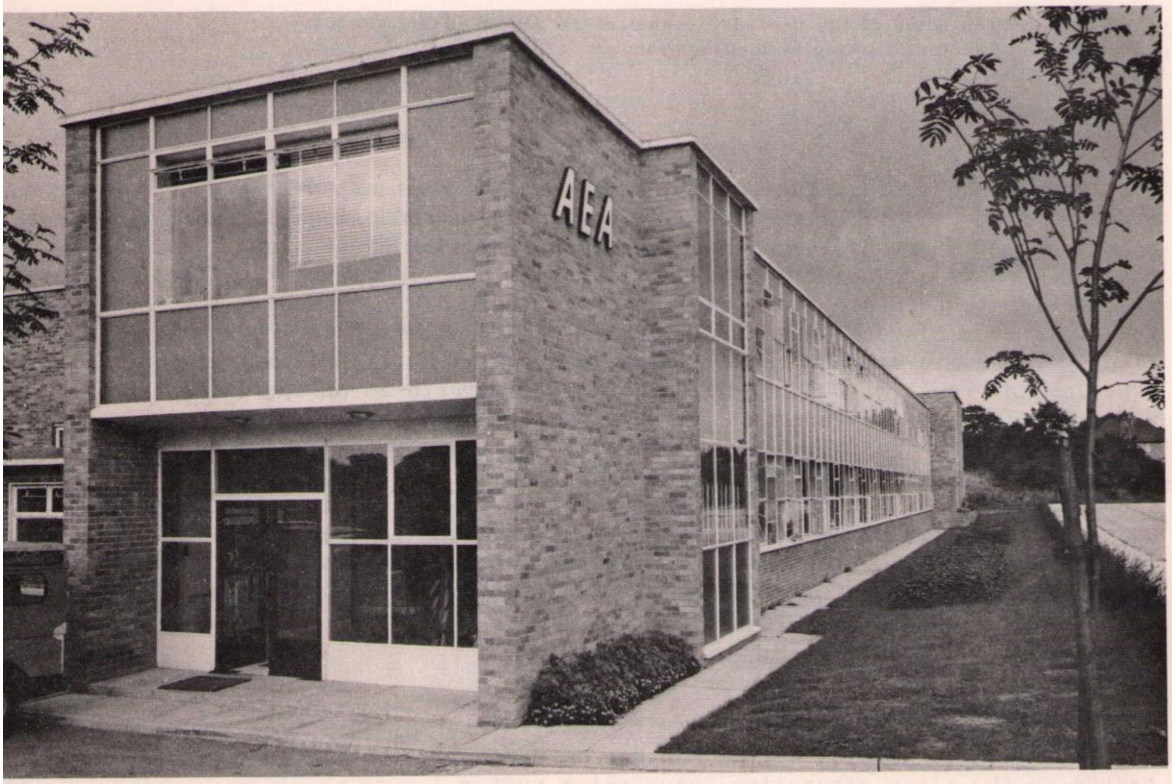


Top dome of the pressure vessel of the Advanced Gas-Cooled Reactor, showing re-fuelling branches

Beyond the A.G.R., further reductions in the cost of power are expected from reductions in capital costs and from reductions in fuel costs brought about by large increases in utilisation of uranium. Two reactor systems are being developed with these ends in view. The first is the high-temperature gas-cooled reactor (H.T.G.C.R.), in which the fuel will be a dispersion of fissile and fertile material in a ceramic, clad in a ceramic can and cooled by an inert gas such as helium. In the experimental reactor (DRAGON) being built at Winfrith in co-operation with the O.E.E.C. the ceramic will be graphite. Gas temperatures in the region 700-800°C are expected. Commercial versions of the system may be self-sustaining when operated in the uranium-233/thorium cycle. The second system under study is the fast breeder, working in the plutonium/uranium-238 cycle. A 60 MW(th) experimental reactor has been built at the Dounreay Experimental Reactor Establishment for studies of the system and of various types of fuel element. The fast system should be capable of breeding with a high gain factor.

The Authority is also studying thermal reactor systems that might be suitable as alternatives to the A.G.R.; at present attention is concentrated on the steam-generating heavy-water system.

Buildings of the Wantage Research Laboratory



The A. E. A. factory, Bracknell

The Research Group of the Atomic Energy Authority

The main responsibilities of the Research Group are to obtain the fundamental information, in all the physical sciences, necessary to further the use of atomic energy; to use this information to assess the feasibility, technical and economic, of new or different ways for developing nuclear power; and to increase the applications of radioisotopes in industry and produce the isotopes themselves.

The Executive Head of the Research Group is the Member for Scientific Research, who is responsible for policy governing the Authority's scientific programme and scientific manpower (other than on weapons). The headquarters of the Group, and its largest establishment, is the Atomic Energy Research Establishment (A.E.R.E.), Harwell, Berkshire, at which most of the basic research is done. The A.E.R.E. has three out-stations; the Wantage Research Laboratory, which houses the isotope work; the Woolwich and Chatham Analytical Laboratories; and the A.E.A. Factory at Bracknell.

The Atomic Energy Research Establishment from the Ridgeway

The second largest establishment is the Atomic Energy Establishment, (A.E.E.), Winfrith, Dorset, which is responsible for studies of power reactor systems. Isotope production and marketing is centred at the Radiochemical Centre (R.C.C.), Amersham, Buckinghamshire. At Culham, Oxfordshire, the building has begun of a new establishment, to be called the Culham Laboratory, which will do research into controlled thermonuclear reactions, plasma physics, and the study of nuclear fusion as a possible source of industrial power.

Within the policies laid down by the Authority the work of the Research Group is governed by the Research Group Management Board, membership of which is given on a later page.

Checking part of the accelerator of the neutron project

The Atomic Energy Research Establishment

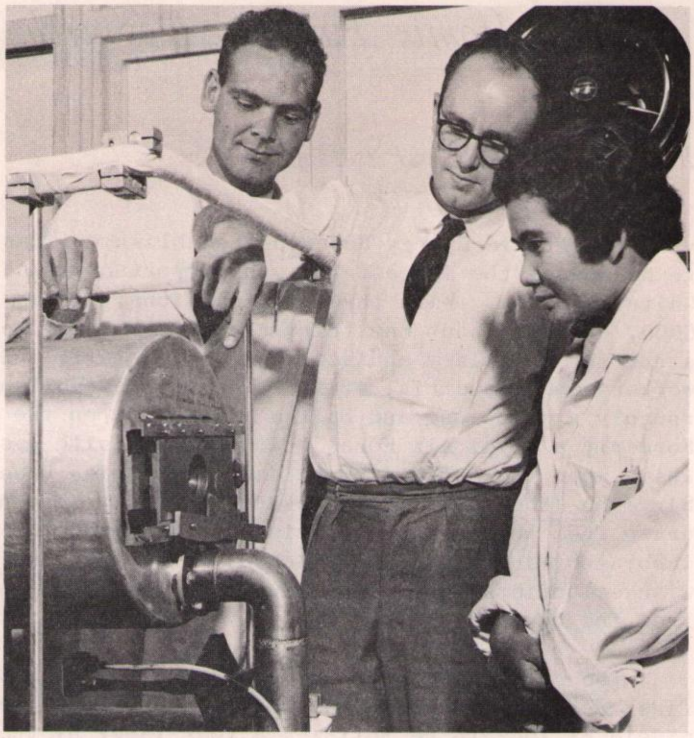
The Establishment and its History

The Atomic Energy Research Establishment has grown in fifteen years to be one of the largest and most important research laboratories in the United Kingdom. With three out-stations, it has a total staff of over 6000, of whom about one third are professional scientists or engineers, a quarter ancillary and administrative staff, and the remainder skilled workers and industrial staff. The main establishment occupies a site roughly a mile long and half a mile wide, on the Berkshire downs. Formerly a Royal Air Force station, this site was taken over in January 1946, when the establishment came into being under its first Director, Sir John (then Dr. J.D.) Cockcroft, F.R.S. The nucleus of the staff was drawn from the war-time atomic bomb team and the Chalk River research laboratory in Canada (of which Dr. Cockcroft had been director), together with scientists from other government laboratories, from industry, and from the universities.

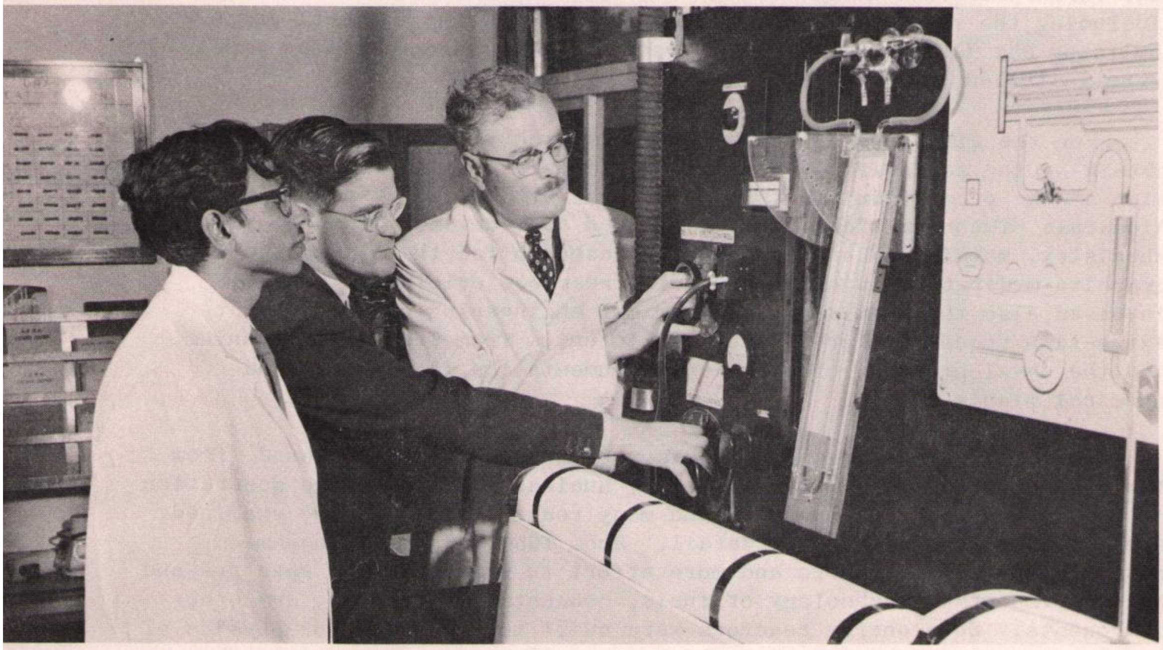
The construction of major pieces of equipment began at once. The first research reactor, the lower-power GLEEP, became critical in the middle of 1947 to be followed a year later by the 6,000 kW(th) BEPO; in 1948 also the 5MV electrostatic accelerator was completed and in 1949 the 180 MeV synchrocyclotron. All these machines were accommodated in the former aircraft hangars. Special laboratories also were built, including the radiochemical building 220 (1949), the chemical engineering building 351 (1952); an effluent treatment plant and discharge pipeline were installed in 1948.

For the first two or three years research was directed mainly to obtaining the scientific information needed for the design and construction of the production plants in the north of England, especially the Windscale plutonium plant. This involved nuclear and reactor physics, chemistry, metallurgy and engineering research for the air-cooled graphite-moderated plutonium-producing reactors originally used; it involved also the chemistry and chemical engineering of the solvent-extraction processes for separating plutonium from irradiated uranium, and the development of electronic instrumentation for reactor and chemical plants.

In spite of the urgency of this work however time was found, from the beginning, to think about applying nuclear fission to the generation of energy for peaceful purposes and many reactor schemes were examined, some of them in considerable detail. From 1950 onwards it became possible to turn over more and more effort to work on power reactors and the all-important technology of fuels, coolants, moderators, and other components. Zero energy reactors were built to study reactor physics of complete cores; these included the water-moderated DIMPLE, other thermal assemblies, and the fast reactors ZEPHYR and ZEUS. A swimming-pool



Students at the Isotope School examining a beta spectrometer



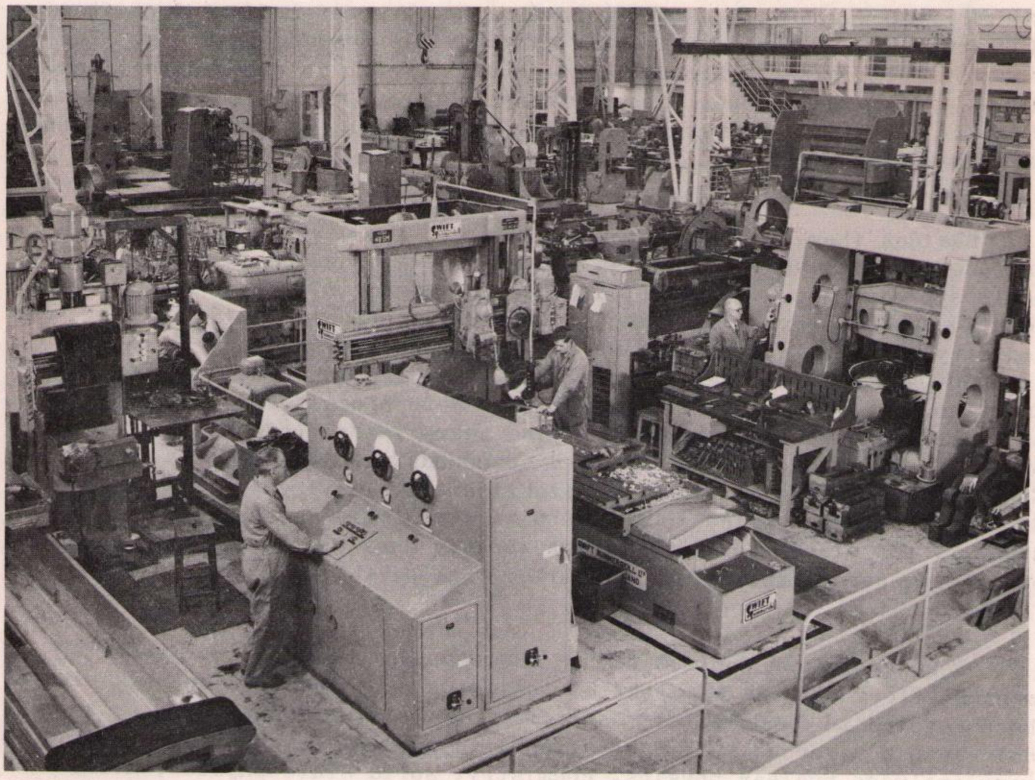
The air heat-transfer rig at the Reactor School reactor LIDO was built and two high-flux heavy-water-moderated reactors DIDO and PLUTO, regarded primarily as materials testing reactors. The need for still other reactors, coupled with growth in other directions, led to a decision to open a second Research Group establishment, now known as the Atomic Energy Establishment, Winfrith, to which the reactor development work has been transferred.

Besides these major programmes, Harwell has developed the production and use of radioisotopes. A few isotopes were produced in GLEEP but serious production began with, and has continued in, BEPO; production has been accompanied by a research and advisory service aimed at helping industry, in particular, to make the maximum use of the new technique. In 1950 Harwell took over responsibility for the Radiochemical Centre, Amersham, at which natural radioisotopes were processed and distributed and labelled compounds prepared. Nine years later production and distribution of all isotopes and labelled compounds were transferred to the Centre, which is now a separate establishment, leaving A.E.R.E. free to do research into applications and to forward their development in industry and elsewhere; this latter work is done at the newly-opened Wantage Research Laboratory, six miles from Harwell.

Research of an applied nature has occupied most of the Establishment's effort but, as a matter of policy, some twenty percent has always been devoted to fundamental research, for it is held that only by so doing can a vigorous spirit of scientific enquiry be kept alive. This work includes nuclear physics, chemistry, solid state physics, metallurgy, theoretical physics, and other branches. From it has come the growing programme of research on controlled thermonuclear reactions, now to be transferred to a new establishment at the neighbouring Culham site. Basic research has included also the study of particle accelerators and has led to the development of a 7 GeV proton synchrotron, now under construction for the Rutherford High Energy Laboratory of the National Institute for Research in Nuclear Science. This Institute, formed in 1957, is a co-operative enterprise between universities, the Authority, and other bodies, which is designed to make available to universities big machines and other installations which would be beyond their individual resources. One aspect of fundamental research with which A.E.R.E. has not concerned itself is the biological and medical side of atomic energy. By agreement, this has been the responsibility of the Medical Research Council who in 1947 set up a Radiobiological Research Unit at Harwell; this Unit has worked in close co-operation with the Establishment and has used some of its services and installations, notably GLEEP.

Organisation of A.E.R.E.

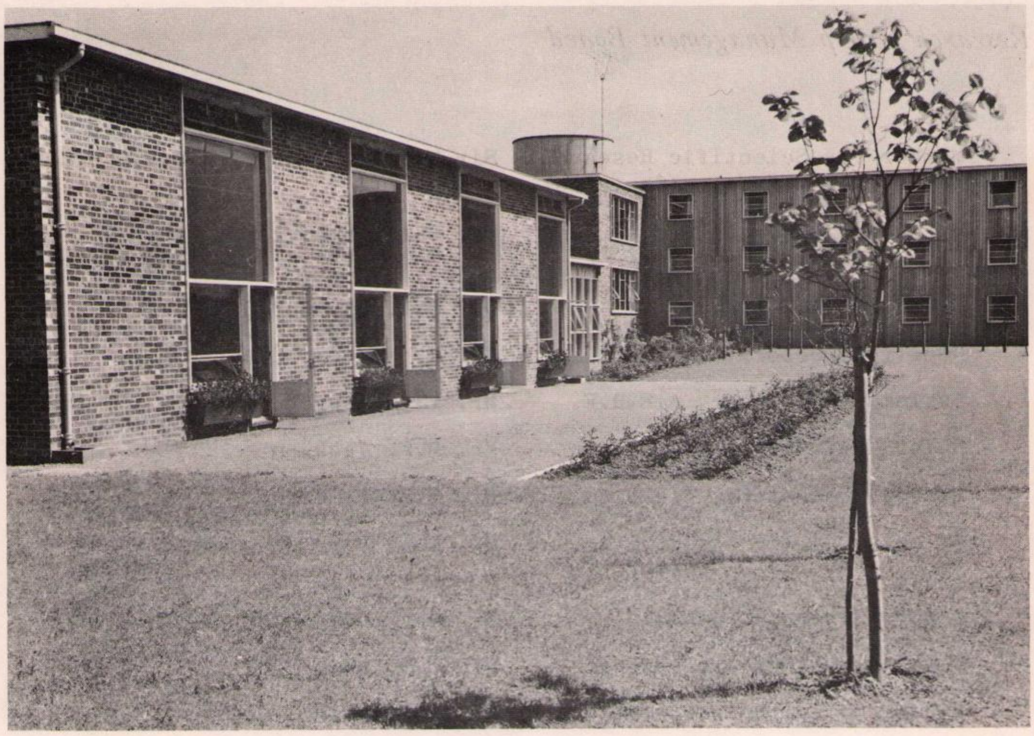
Flexibility is the keynote of the organisation at Harwell, flexibility to accommodate readily changes in emphasis in research, flexibility to allow adequate freedom in the scientific direction of each of the Establishment's many fields of enquiry. The Establishment



Part of the main workshops at A. E. R. E.

is organised in a number of scientific Divisions each responsible, broadly, for work in a particular field. Divisions vary in size, some of the larger ones having about 200 professional staff; each is led by a Division Head, a man of high standing in the scientific world. The divisions are sometimes likened to university departments under their professors but most of them are considerably bigger than their counterparts in the academic world, at least in the United Kingdom. Some of the Divisions also provide the essential services without which a large establishment cannot operate. The management board and senior staff of the Establishment are set out on the next page.

Engineering services in the Establishment include central design offices and workshops (both supplemented by local design offices and workshops) with additional capacity at the out-station at Bracknell; there are also maintenance and operating services and arrangements for treating radioactive waste of all kinds. The Engineering Division has an important apprentice training scheme. Scientific services include health physics, a central computing service, equipped with a high-speed electronic computer and punched card machinery for collating experimental data, a post-design service for electronic equipment, and a library and information service. There is a comprehensive medical service. The Establishment also runs training courses of many kinds, for suitably qualified persons from both inside and outside the Authority, in its Reactor School and Isotope School.



Rush Common Hostel, Abingdon

The reading room of the Library

Research Group Management Board

Member for Scientific Research (Chairman)	Sir William Penney, K.B.E., F.R.S.
Director, Research Group	Sir Basil Schonland, C.B.E., F.R.S.
Director, A.E.R.E.	Dr. F.A. Vick, O.B.E.
Deputy Director, A.E.R.E.	Dr. R. Spence, C.B., F.R.S.
Assistant Director, A.E.R.E.	Mr. L. Grainger
Chief Engineer, A.E.R.E.	Mr. R.F. Jackson
General Secretary, A.E.R.E.	Mr. T.B. Le Cren
Director, A.E.E. (Winfrith Heath)	Mr. D.W. Fry
Deputy Director, A.E.E.	Dr. J.V. Dunworth, C.B.E.
Director Culham Laboratory	Mr. J.B. Adams
London Office Representative	Mr. A.E. Drake, O.B.E.
Development and Engineering Group Representative	Mr. R.V. Moore, G.C.
Production Group Representative	Mr. J.C.C. Stewart, C.B.E.
Weapons Group Representative	Mr. E.F. Newley

Division Heads A.E.R.E.

Accelerator (until 1st January 1961)	Mr. L.B. Mullet
Chemistry	Dr. R. Spence, C.B., F.R.S.
Chemical Engineering	Mr. A.S. White
Controlled Thermonuclear Reactions	Mr. R.S. Pease (acting)
Electronics	Mr. E.H. Cooke-Yarborough
Chief Engineer	Mr. R.F. Jackson
Health Physics	Mr. N.G. Stewart

Isotope Research	Mr. B.S. Smith
Medical	Dr. Katharine Williams
Metallurgy	Dr. P. Murray
Nuclear Physics	Dr. E. Bretscher
Research Reactors	Mr. W.F. Wood
Solid State Physics	Dr. W.M. Lomer
Theoretical Physics	Dr. W.C. Marshall

Administration

General Secretary	Mr. T.B. Le Cren
Deputy General Secretary	Mr. P.J. Searby
Chief Finance and Accounts Officer	Mr. A.G. Coulbeck
Chief Personnel Officer	Mr. P.G. Oates
Industrial Collaboration Office	Dr. N.F. Goodway

Directorate

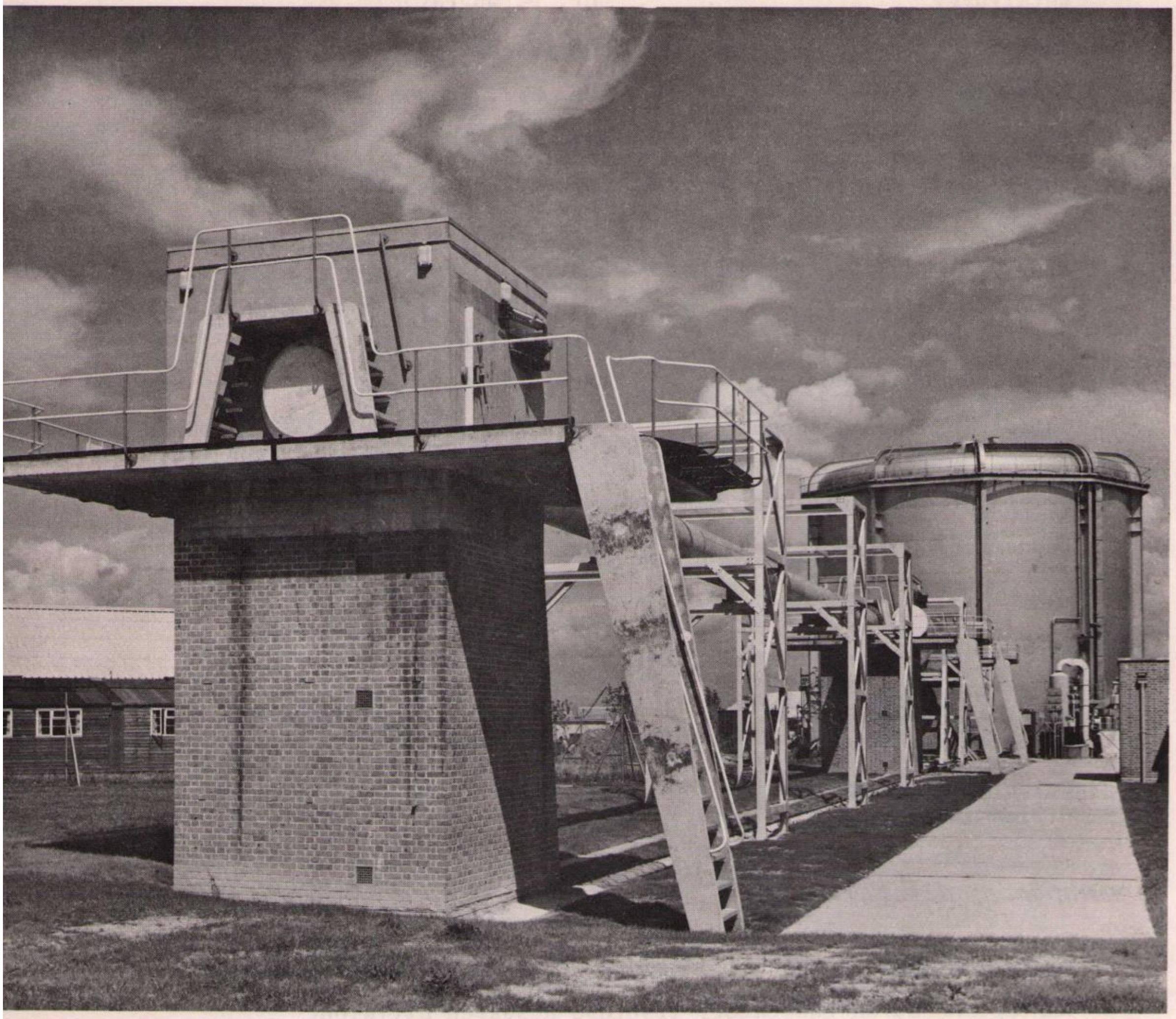
Overseas Collaboration Office (Directorate)	Mr. J.F. Jackson O.B.E.
Scientific Administration Office (Directorate)	Mr. R.M. Fishenden

Outstations of A.E.R.E.

A.E.A. Factory, Bracknell (Engineering and Electronics Divisions)

Wantage Research Laboratory (Isotope Research Division)

Woolwich and Chatham Analytical Laboratories (Chemistry Division)



Experimental end of the flight tube of the neutron spectrometer in DIDO; neutrons from the reactor are released into the tube in bursts by a rotating chopper and their flight timed electronically

The Work of the Establishment

The work of the Atomic Energy Research Establishment upon the manifold civil applications of atomic energy falls into a number of programmes of which the largest is in support of the development of power-producing fission reactors. With the formation of the Atomic Energy Establishment the work on complete reactor systems has been moved to Winfrith; A.E.R.E. tackles the many basic problems that still remain to be solved, especially in connection with the properties and behaviour of materials in reactors.

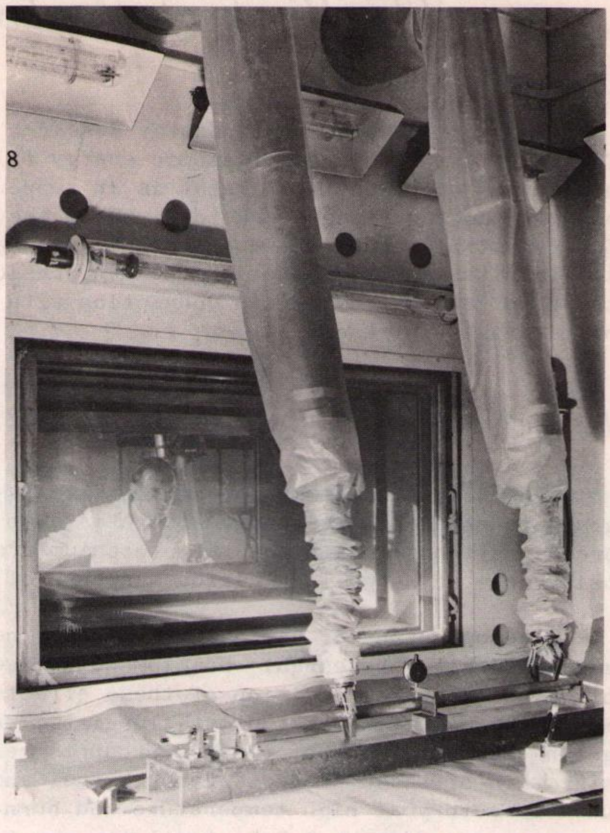
Work in Support of the Reactor Programme

The British nuclear power programme is based primarily on gas-cooled graphite-moderated reactors. There is also a strong interest in fast breeder systems working on the plutonium/uranium-238 cycle. Work is being done at Harwell on various aspects of these and of other systems.

The behaviour of various fuels under neutron irradiation has required a great deal of research. Uranium metal swells and distorts in a number of ways and the elucidation of these effects and their causes has been a major preoccupation of the metallurgists, whilst the chemists are investigating the chemistry of fission products released in the metal and the migration of these products through fuel and cans. Metal fuel however is unsatisfactory at high temperature and burn-up, consequently ceramic fuels are proposed for the A.G.R. and later reactors. Of the ceramics uranium dioxide has been shown by general irradiation tests to be stable and now detailed information is being sought in chemical studies of the rate and extent of fission product release and in metallurgical studies of the behaviour of complete fuel elements. The preparation and fabrication of uranium oxide and carbide, and the processing of irradiated ceramic fuels, are also being examined, together with alternatives to magnox for fuel element cans, in particular beryllium.

The very different fuels of the H.T.G.C. reactor, with their dispersion of fissile and fertile atoms in a graphite matrix and their impermeable graphite cans, have required investigation into methods of fabrication and into the behaviour under irradiation, and studies of the mechanism by which fission product atoms may be transported through graphite.

The probable development of fast reactors for burning plutonium has led to work on the metallurgy and chemistry of this element and on plutonium-bearing fuel elements. A wider choice of materials for both fuels and cans is possible for fast than for thermal reactors, because absorption cross-sections of all elements are much smaller for fast than for thermal neutrons. It is possible to contemplate the use of alloys of plutonium and uranium with a variety of metals as well as dispersions of ceramic plutonium compounds.



Measuring accurately the length and diameter of an irradiated fuel rod by remote manipulation (Building 459)

The properties of moderators and coolants, and their reactions upon one another, as well as upon fuel and canning materials, are being studied. The storage of energy in graphite as a result of neutron bombardment has been investigated in graphite samples irradiated in DIDO and PLUTO at rates corresponding to 5-10 times those that would be encountered in power reactors; the information obtained has greatly increased confidence in predictions of behaviour in power stations. Reactions between graphite and carbon dioxide coolant, which have been the subject of study for some years, are now being examined at the higher temperatures that will be encountered in the A.G.R. This branch of radiation chemistry has been extended to other gaseous coolants and to the stability of certain organic compounds which might be used as moderators or coolants, or both, in other reactor systems.

The nuclear design of modern reactors involves complex calculations performed on high speed computers. To take the fullest advantage of the flexibility afforded by these machines, it is necessary to have accurate nuclear data determined at frequent intervals throughout a wide range of neutron energies. It is important also to understand, better than is at present possible, the details of the scattering processes by which fast neutrons reach thermal energies and of the distribution of neutrons throughout the energy range. These measurements are made by the nuclear physicists using a variety of techniques, especially the time-of-flight method.

Isotope production: loading cans of material for irradiation in BEPO

The foregoing indicates the need at an Establishment of this kind for research reactors such as BEPO, LIDO, DIDO, and PLUTO, and other large experimental installations, including 'hot' caves for handling large radioactive specimens, smaller shielded enclosures in which detailed metallurgical measurements can be made, radio-chemical laboratories, and particle accelerators used as sources of neutrons.

Isotope Programme

Since 1947, when the first small quantities were produced in Gleep, the United Kingdom's production of radio-isotopes has grown until, in the year ending April, 1960 over a million pounds worth were sold, 60% of them to overseas buyers. The marketing side of this programme is in the hands of the Radio-chemical Centre. Research into, and development of, new applications of these materials is done by A.E.R.E. at the Wantage Research Laboratory, which houses the Isotope Research Division and the Isotope School.

The advisory service for industry, run by the Isotope Research Division, involves everything up to and including feasibility studies and experimental investigations at a works or on a site. As the result of the past work of this service radioisotopes are used at factories in thickness gauges and other control devices in many different processes, from strip steel rolling to filling packets of pills, and are applied to

Glove box for handling alpha-active material

industrial investigations in such varied ways as radioautographical studies of metal-plating, the use of tracers for gas and liquid flow investigations, and studies of coastal erosion and the movement of silt and mud in estuaries.

Medical applications are invariably developed by doctors and medical research workers but Harwell has contributed by developing special forms of radioactive material to suit particular applications; thus, recent work in this field has included development of colloidal compounds for irradiation in certain body cavities.

The nuclear power programme will make very large quantities of radioactive material obtainable, either directly by irradiating cobalt in reactors to yield cobalt-60 or indirectly by separating fission products such as caesium-137 from irradiated fuel elements. The question, can large sources of these isotopes be used profitably in industry, has been studied for some years by the Technological Irradiation Group of the Isotope Research Division. The possibilities include sterilization by irradiation which has the advantage that it does not involve raising the temperature of the material to be treated; it might be applied to the preservation of food, to the extermination of pests in stored products, and to the large-scale sterilization of surgical appliances and medical products. The first two of these are the subject of continuing investigations and the last has already been shown to be practicable and quantities of such items as catheters, hypodermic syringes etc. are being sterilized in the DIDO cooling pond at Harwell. Other applications include polymerisation and halogenation, which give possibilities for improvements in plastics and in various industrial chemical processes.

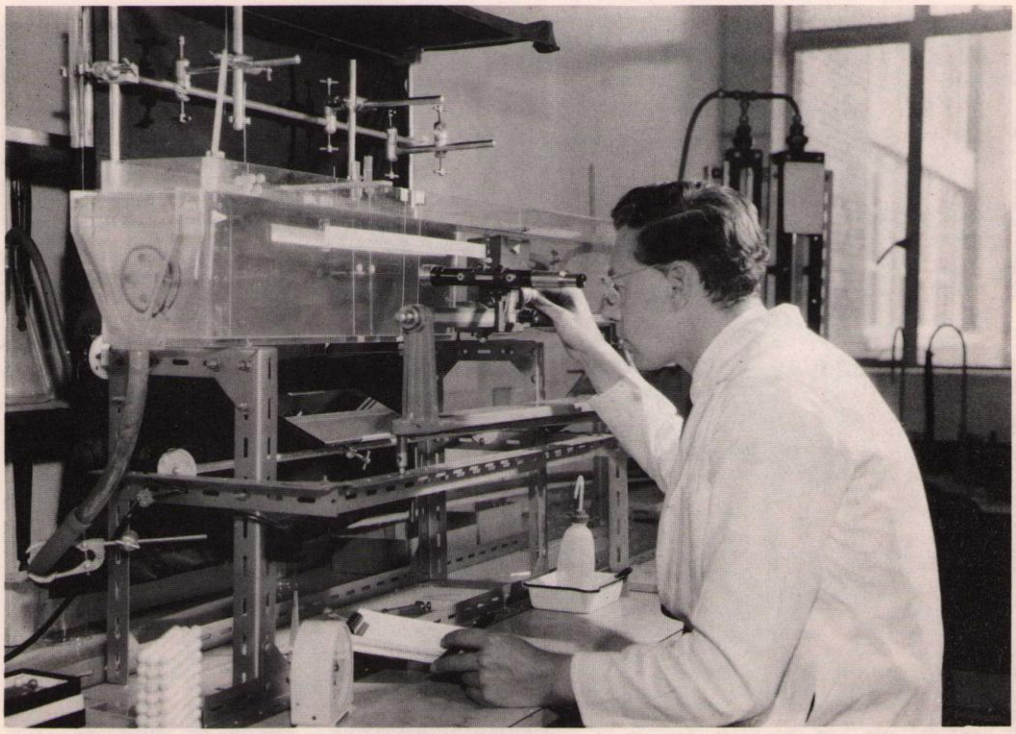
Radiation can produce mutation of genes in biological material, and the application of this fact to agriculture is being studied with the aim of crossing otherwise incompatible strains and hence developing improved plants for agricultural purposes.

Besides the DIDO pond at Harwell, the irradiation sources available at Wantage include cobalt-60 cells, a linear accelerator, and a recently commissioned package irradiation plant (with cobalt-60 sources) which is designed as a versatile pilot plant to give experience in continuous irradiation of commercial packages of material.

Fundamental Research

The importance attached to fundamental research at Harwell has already been stressed. For this work there are available the research reactors, providing strong fluxes of neutrons at all energies, the accelerators, and the neutron project, which furnishes an intense pulsed source of neutrons. There are also specialised laboratories for experiments with materials of all activities up to thousands of curies.

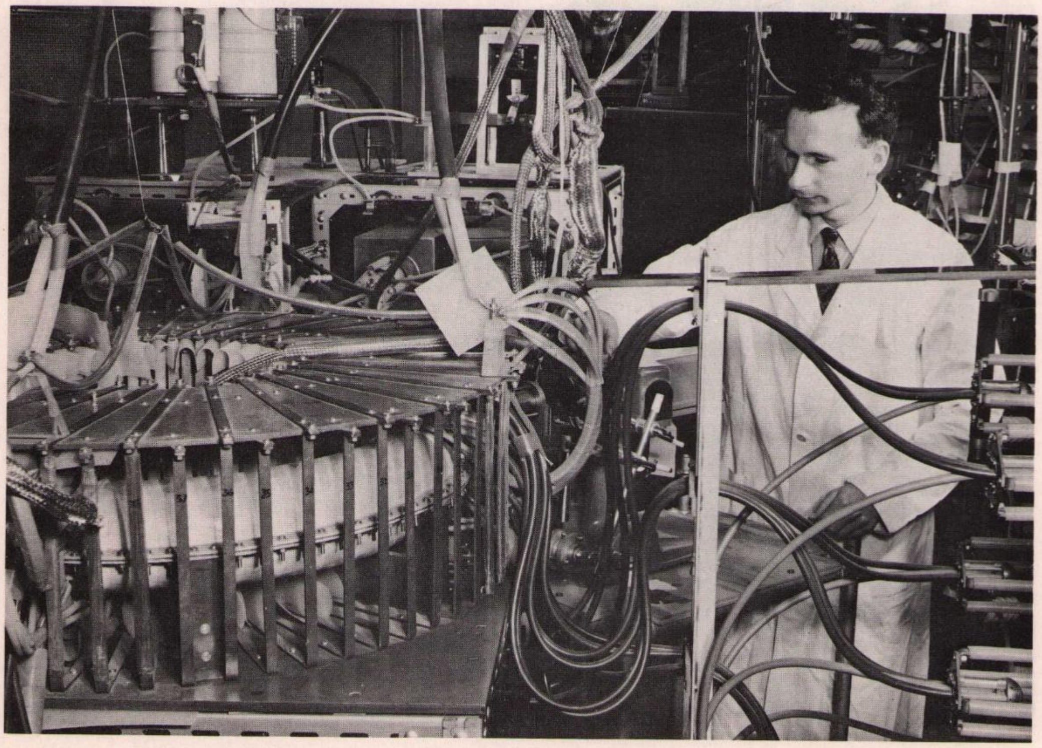
Research into the development and design of particle accelerators has for some years been in the hands of the Accelerator Division, which was responsible for the design of the recently completed 12 MV tandem electrostatic generator and the 50 MeV proton linear accelerator; the latter is one of the tools of the Rutherford High Energy Laboratory. The Division played a major part in the design of the 7 GeV proton synchrotron, Nimrod, now being built for the Laboratory. On 1st January 1960 however work on accelerators, and most of the staff of the Division, will be transferred to the Rutherford Laboratory.



Chemical engineering research: measurement of drag forces in a hydraulic tank

In the Nuclear Physics Division, research is done on interactions between nucleons and between nucleons and nuclei, in particular on changes in polarization after scattering of nucleons. Another group of nuclear physics experiments, important alike for fundamental and for technical advance, is concerned with measurement of neutron cross-sections and other nuclear parameters over a wide range of energies, using the time-of-flight method.

Another important line of fundamental research has been in solid-state physics. In the Metallurgy Division studies have been made of the effects of irradiation on the properties of solids, which have led to a study of the effects of crystal defects on these properties. The electronic structure of metals, which is closely connected with their alloying behaviour, is being investigated by such varied techniques as nuclear magnetic resonance, magnetic susceptibility measurements, and determinations of specific heats at temperatures near the absolute zero. Neutron beams are being used to study the nature of magnetism, to investigate atomic vibrations, and to locate atomic positions, for which purposes they supplement the more usual x-ray methods. Theoretical Physics Division works on the theory of the solid state, with a strong emphasis on quantum mechanical methods. In September 1960 a Solid State Physics Division was formed, taking staff from each of the Divisions just mentioned, to do much of the work on the behaviour of solids in general including among other things, the research into the physical properties of metals, alloys, and magnetic materials and the use of neutrons beams for crystal physics. The basic and applied studies of the effects of radiation on materials of decisive importance to reactor technology will remain under the control of existing divisions, particularly the Metallurgy Division.



'Spider', a small toroidal discharge tube for investigating shock heating produced in a plasma by a rapidly-rising current pulse

Basic research in the Chemistry Division is concerned especially with the chemistry of heavy elements, notably the new synthetic elements beyond uranium, and with problems in radio-chemistry and radiation-chemistry; allied to this work are studies of the chemistry of the fission fragments and the chemical effects produced by them. A large amount of research is done in new analytical techniques, including improved polarographic methods and radioactivation analysis, and in the physical chemistry of ion exchange and electro-deionization. Another group of studies is concerned with the structure and reactions of the oxides of uranium and plutonium, which are of increasing technical importance.

Controlled Thermonuclear Research

One of the most exciting possibilities in atomic energy is that of producing electric power from the fusion of light nuclei, probably isotopes of hydrogen; if this could be achieved it would mean virtually unlimited energy for the world. The only practicable way of bringing about such fusion appears to be to heat a gas to temperatures of about 100,000,000°C. At these temperatures the gas is fully ionised - its atoms are completely dissociated into nuclei and electrons; its behaviour is then so different from that of solids, liquids, and gases at ordinary temperatures, that it is regarded as a fourth state of matter and given the name plasma.

The key work of the C.T.R. Division is in the field of plasma physics, the study of the behaviour of ionised gases in the presence of magnetic fields. The latter aspect is important because these intensely hot materials can in practice be confined only by making use of the restricting action of magnetic fields upon the motion of charged particles. Methods of heating and confining plasma, and the stability of various configurations of confined plasma, are being investigated. Most of this work is being done on the 'pinched' discharge in which a plasma is both heated and confined by the passage through it of a very large electric current; confinement results from the interaction of the current with the magnetic field which it produces. A major effort is being devoted to the development of techniques for obtaining as complete a picture as possible of the physical conditions existing in the plasma i.e. for determining the variation in space and time of such properties as the temperature, density, electric and magnetic fields, resistivity, impurity content, and degree of ionisation.

The largest pinch device so far built is ZETA, described later in this booklet. Studies with ZETA have shown that, although the current channel in the gas is 'pinched' away from the walls of the ring-shaped tube in which it is heated, there is an excessive loss of energy to the tube walls during the current pulse. The exact mechanism by which this energy is being lost is not fully understood but there is evidence to suggest that energetic particles are being continually lost to the walls. The main object of the present experimental programme is to build up a complete picture of the important physical processes in the ZETA discharge and to find the reasons for the loss of energy and particles.

Parallel with this work small-scale equipment is being used to study more specific aspects of plasma physics such for example as the propagation of magneto-hydrodynamic waves in plasma, the stability in various modifications of pinch geometry, and plasma confinement in different configurations of magnetic field. Experiments are also being made on the injection and trapping of energetic particles as a means of building up high temperature plasma.

Although many problems in fusion research may be solved by small or medium-scale experiments, some can be attacked only by large, and hence costly, experimental assemblies. The new Culham Laboratory will provide flexible accommodation for all types of experiment.

Health Physics

Exposure to penetrating radiation and to some radioactive isotopes is detrimental to health unless the exposure is limited to low values which are laid down in internationally-agreed standards. To ensure that radiation levels are normally kept well below these figures, both inside and outside the Establishment, the Health Physics Division operates a comprehensive monitoring service over a considerable area around Harwell as well as within its buildings. The Division is consulted at an early stage in the design of laboratories and in the planning of experiments, to ensure that all possible protection is provided.

The work on day-to-day protection and control is supported by a longer term programme of research designed to supplement and verify the data used in formulating maximum permissible levels of exposure, to investigate the dosimetry of high energy particles particularly neutrons, to improve the economics of radiation protection, and to study the consequences of a large accidental release of radioactive material.


An experiment at tracer level to study the release of particulates and gaseous fission products from hot uranium in a stream of coolant gas

Electronics

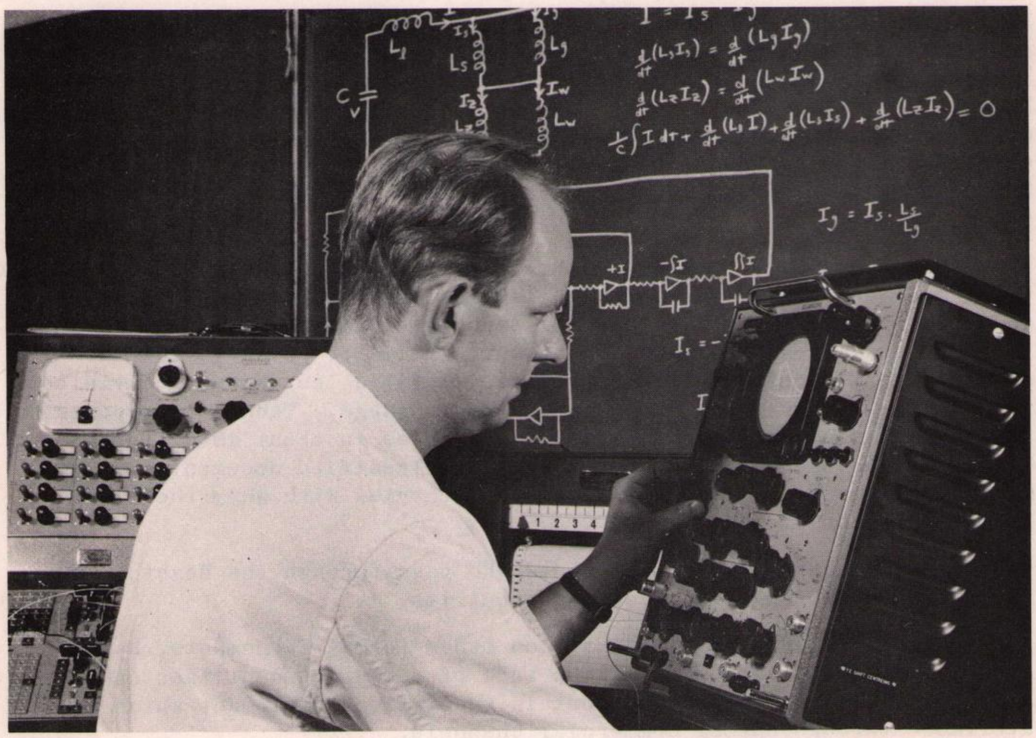
Radiation monitoring is but one of the many operations in nuclear science that require electronic equipment of specialized design. All research involving radioactive materials depends upon electronic instruments, as does the control of reactors and the experimental study of their behaviour. Experiments using high-energy particle accelerators are capable of providing information at so great a rate that only by using electronic methods for recording and analysing the data can the machines be employed economically. Much of the equipment needed can be supplied by industry, which has collaborated closely with Harwell from the earliest days, when the apparatus had to be developed and made at the Establishment, but specialised equipment of many different types is often wanted by the laboratories.

These demands are met by a programme of electronic development in the Electronics Division, which has the task of studying and developing electronic techniques likely to be of value to Harwell research and of applying these techniques effectively. Among current work are applications of transistors and of special magnetic materials and the development of circuits for working with millimicrosecond pulses. Research is also done into the reliability of electronic equipment and means of improving it.

Publication: Library and Information Service

The results of work at Harwell are published in two ways, first through the normal medium of scientific and technical journals, and second in the form of unclassified (i.e. non-confidential) reports. These reports are available to the public through certain libraries designated as depositories by the Authority. Most unclassified reports are also on sale through Her Majesty's Stationery Office; those that are not may be bought in microcopy form from Micro Methods Ltd., East Ardsley, Wakefield, Yorkshire. Paper copies of current reports may be bought as they are issued against a running account with the Authority; subscribers may obtain all reports as issued or only those in one or more subject categories, but not individual reports.

A list of reports and translations published by the Authority, and of articles in periodicals by Authority staff, is issued each month by the Library at Harwell ("U.K.A.E.A. List of Publications available to the Public") and may be obtained free from the Librarian. The list is cumu-



Analogue computing techniques being used to analyse electrical circuits and to study plasma behaviour in thermonuclear apparatus lated annually and the cumulations are sold through H.M.S.O. Other information about Authority publications is given in a "Guide to U.K.A.E.A. Documents", available free from the Public Relations Branch, U.K.A.E.A., London Office.

Special bibliographies on selected subjects are prepared from time to time by the Information Office at Harwell, and within the limits of available effort, the office will compile other bibliographies in answer to requests from industry, universities, and other research institutions.

The A.E.R.E. library holds a comprehensive stock of atomic energy literature, and material that cannot be obtained elsewhere may be borrowed by other libraries through the normal library channels; material cannot be lent to individual enquirers.

Overseas Collaboration

From its formation the Authority has been concerned with relations with overseas bodies, both private and official, national and international. It inherited a close and largely informal pattern of collaboration with Canada; there was also collaboration with the U.S.A. within the limits set by the McMahon Act of 1946. In 1954 amendments to American legislation made possible a closer degree of collaboration and during 1955 the United Kingdom concluded formal collaborative agreements in the civil and defence fields with the U.S.A. Since then the number of such agreements has increased until in 1960 there were more than 15 countries with which the Authority maintained formal relations.

Apart from collaboration with individual countries under bilateral agreements, the Authority also participates in the activities of many international organisations, including the International Atomic Energy Agency, several of the specialised Agencies of the United Nations Organisation, the International Committee on Radiological Protection, Organisation Europeenne pour la Recherche Nucleaire (C.E.R.N.), the European Nuclear Energy Agency, Euratom, and the Central Treaty Organisation (CENTO).

Agreements are concluded by Her Majesty's Government. The Authority plays the leading part in the detailed implementation of the agreements and usually Harwell is the focus of exchanges of information in the field of basic research and development. Media of exchange include delegations to conferences and symposia, invited lecturers, and visitors to and from Harwell; the number of these is large. Technical reports are regularly exchanged with foreign libraries in about 40 different countries and under certain circumstances classified documents may be made available to official projects in countries with whom there are formal agreements.

About a quarter of the students who pass through the Reactor and Isotope Schools come from overseas countries.

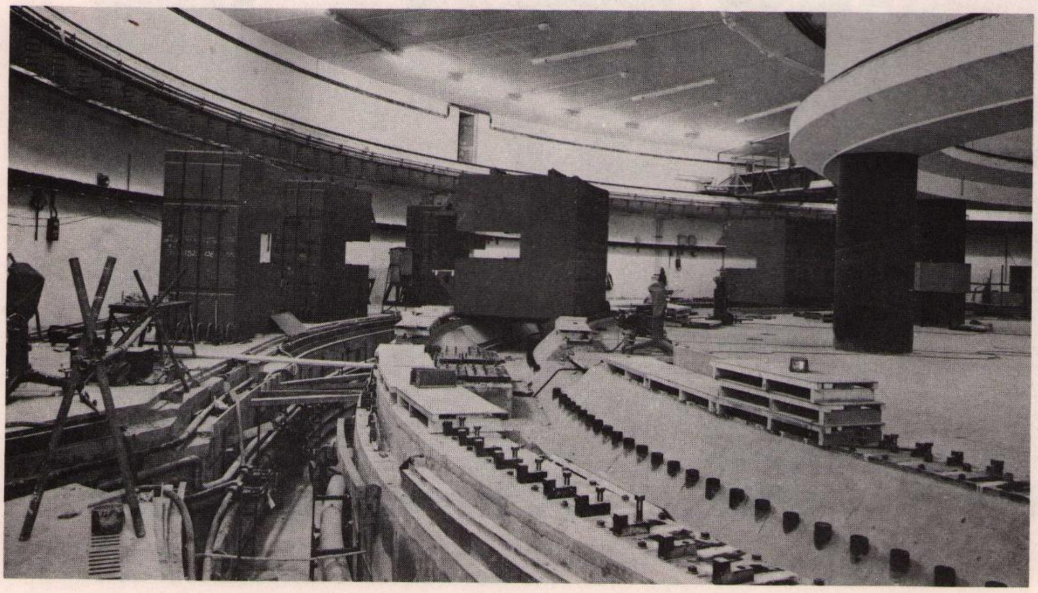
Under the terms of bilateral and other formal agreements, Harwell also acts as retail agents for the sale of research quantities of special nuclear materials and certain specialised equipment which is not available through normal commercial channels.

The Rutherford High Energy Laboratory of the National Institute for Research in Nuclear Science

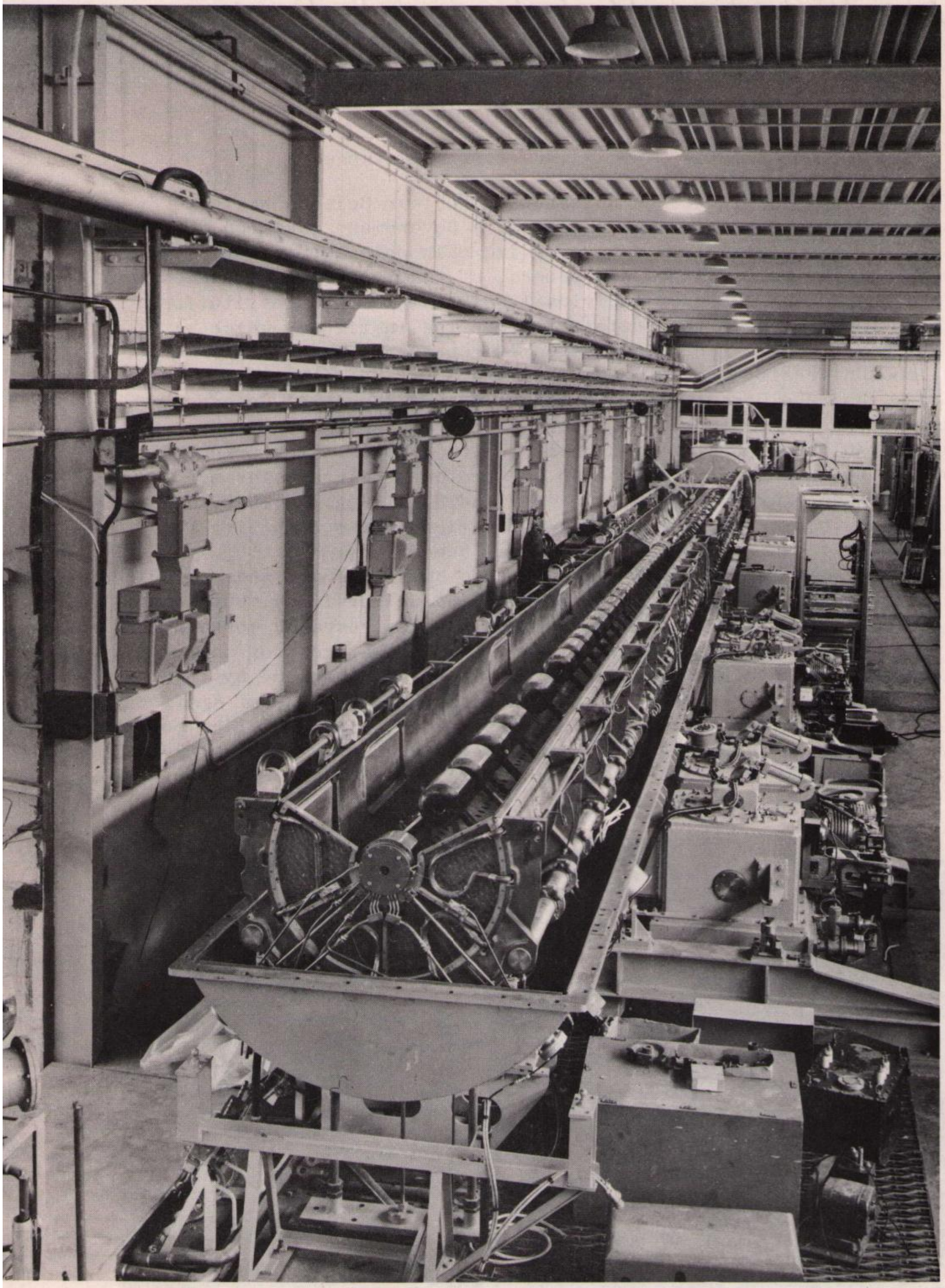
Director Dr. T.G. Pickavance

The National Institute for Research in Nuclear Science was constituted in March 1957 as a consequence of a Government decision to set up an establishment which would have as its main object the provision, for common use by universities and others, of facilities and equipment which are beyond the scope of individual universities and institutions carrying out research in the nuclear field. The Institute, which was given its Royal Charter in 1958, has on it representatives of the universities, the University Grants Committee, the Royal Society, the U.K.A.E.A., and the Department of Scientific and Industrial Research. The Institute's first laboratory, the Rutherford High Energy Laboratory, has been established on a site adjacent to the A.E.R.E. The principal machines of the Laboratory are the 50 MeV proton linear accelerator, which was handed over to the Institute by the U.K.A.E.A. in 1959, and the 7 GeV proton synchrotron, now under construction by the Authority for the Institute, to which the name Nimrod has been given.

The general policy is that the Institute shall operate these machines for visiting teams of research workers from the universities, but the Institute's staff will include some nuclear-physics research workers on fixed-term contracts. Originally it was intended that most of the operation, maintenance, and machine development would be done by the Authority as a service; however it now appears that the size of staff required for Nimrod, when it comes into operation in 1962, will be such that these functions could be better undertaken by the Institute itself. The first university visitors are already at work carrying out experiments on the proton linear accelerator.



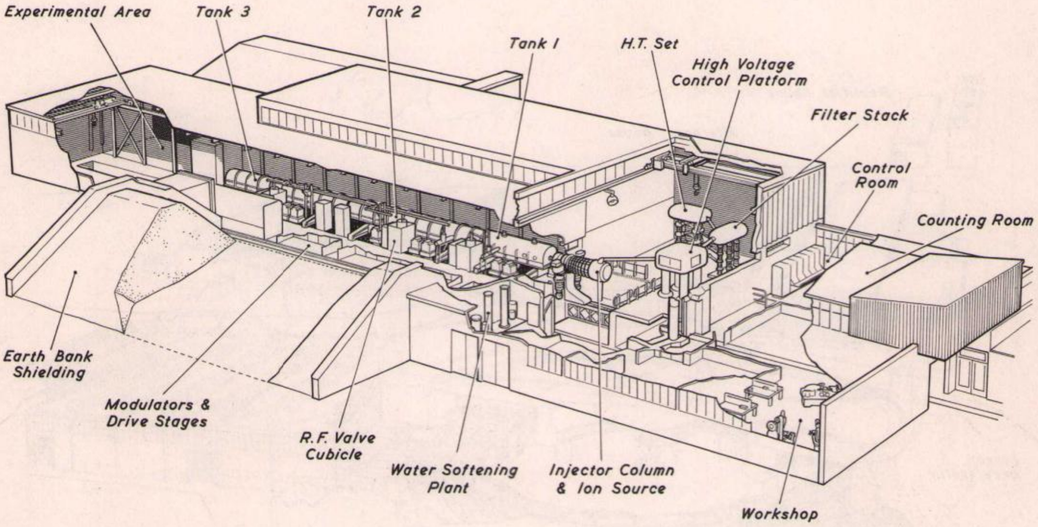
Sectors of the 140ft. diameter magnet of NIMROD being placed on their circular foundations



Tank III of the 50 MeV proton linear accelerator; the cover has been removed to expose the drift tubes

The Proton Linear Accelerator

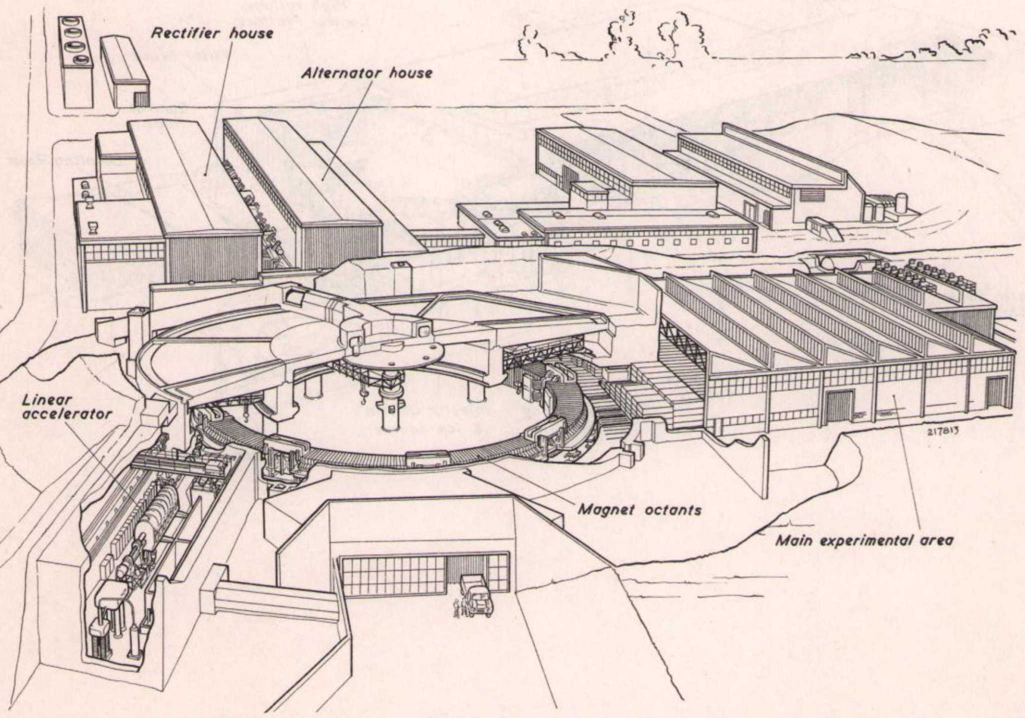
The first accelerator of the Rutherford High Energy Laboratory, to become operational was the proton linear accelerator, designed and built for the Institute by the Authority. The machine consists of three cylindrical resonant cavities in which pulses of protons, injected at 500 keV from a Cockcroft-Walton accelerator, are accelerated successively to energies of 10, 30, and 50 MeV. Each resonant structure is contained in an evacuated tank, the total length of the three tanks being some 100 ft. Emergent pulses of protons pass through a shielding concrete wall into the experimental area, where a bending magnet will be installed to deflect the beam in any one of five directions, to five different experimental assemblies. It is expected that in full operation the mean proton current will approach 5 microamperes (3×10^{13} protons sec^{-1}) whilst during the pulse the peak value will be a hundred times this; the pulse length is 200 microseconds and the repetition rate 50 pulses a second.



Nimrod

The name NIMROD ("A mighty one in the earth". Genesis 10. 8-12) has been given to the 7 GeV proton synchrotron which is being built under the direction of the Authority for the National Institute for Research in Nuclear Science. The machine consists of a ring-shaped magnet 150 ft in diameter, weighing 7,000 tons, between whose poles is placed a toroidal evacuated chamber; a pulse of protons, given an initial acceleration to 15 MeV in a linear accelerator, is injected into this chamber and the protons are forced by the magnetic field into a circular path, in which they receive an acceleration from a radio-frequency electric field once in each revolution. When the pulse has reached its maximum energy it is extracted from the vacuum chamber and allowed to pass into experimental apparatus. During the acceleration the magnetic field strength and the frequency of the electric accelerating field have both to be increased steadily and rapidly to confine the proton orbits to the magnet ring, and in such a manner as to maintain the delicately balanced stability in the motion of the protons. The whole machine is housed in a semi-underground circular building of reinforced concrete 200 ft in diameter, with 6 ft concrete roof upon which a 20 ft layer of earth is placed for additional shielding.

The machine is designed to produce 10^{12} protons per pulse at a repetition rate of 28 pulses a minute; this is equivalent to about 1/16 of a micro-ampere. NIMROD should be completed in 1962.

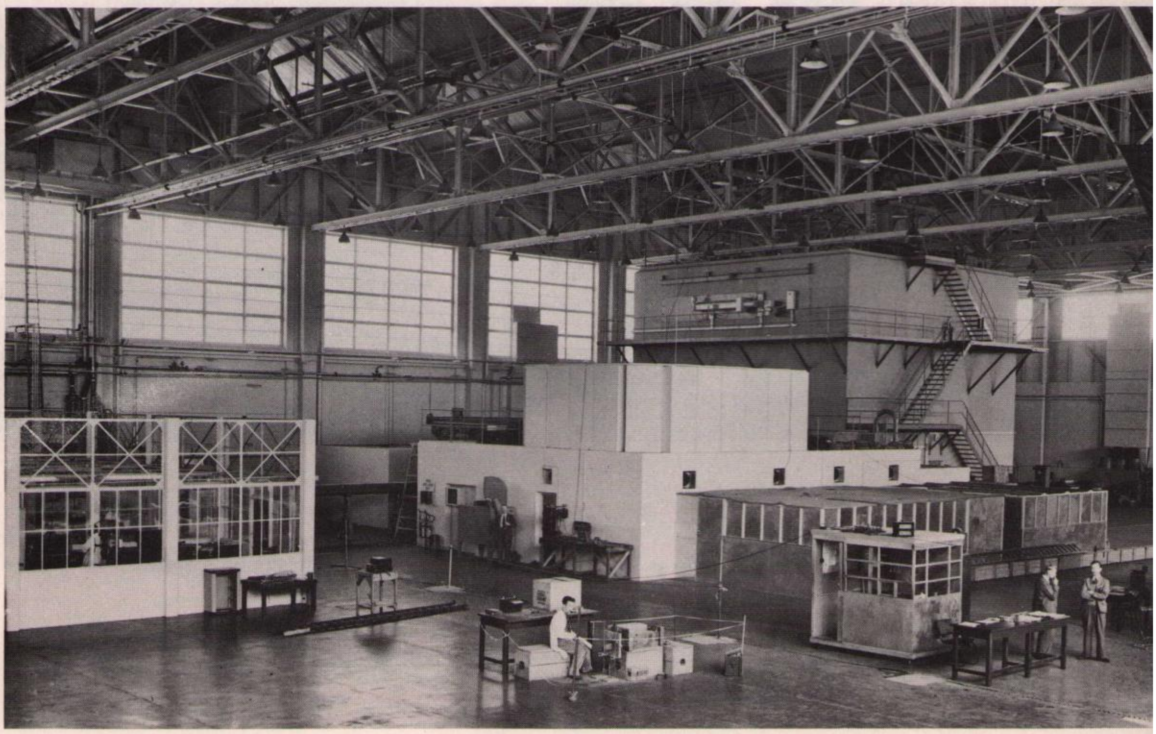


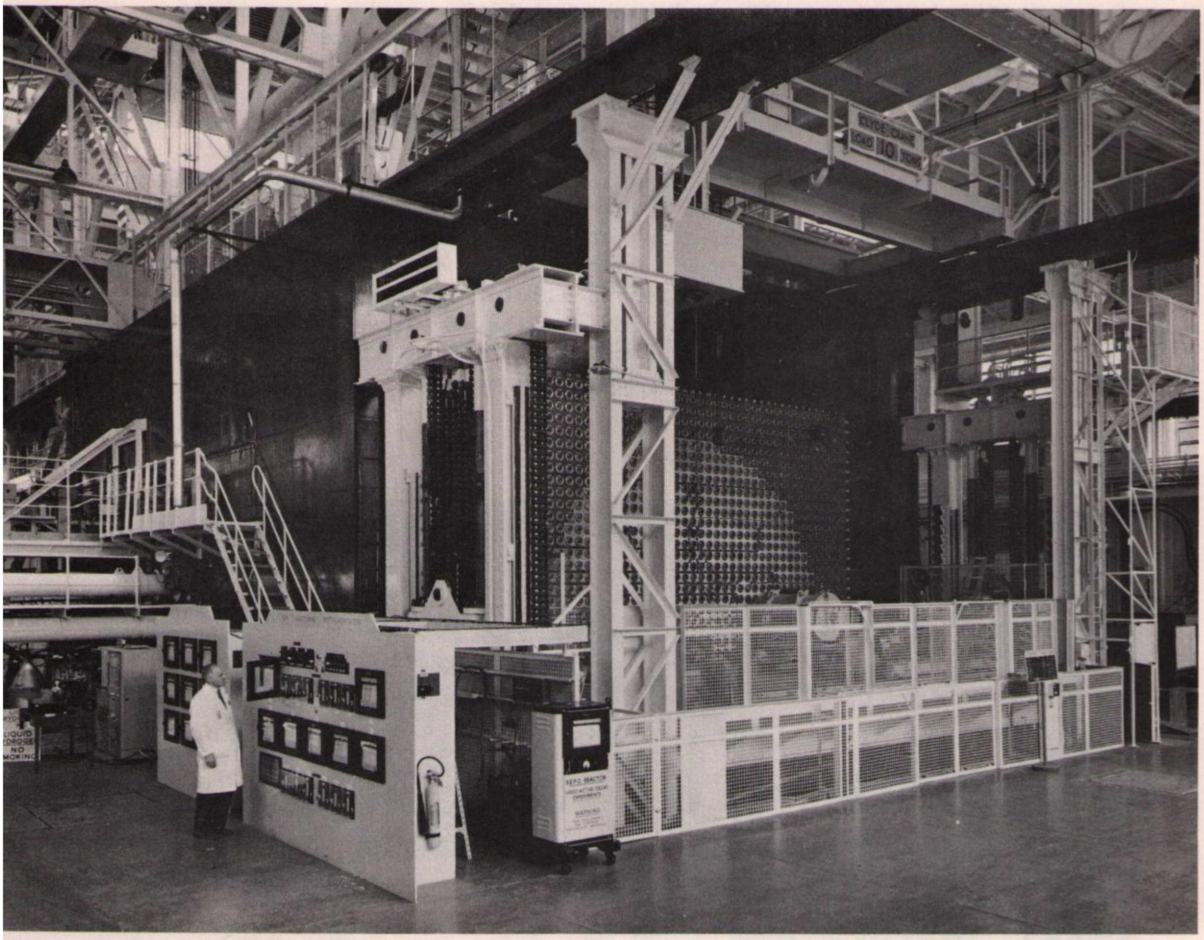
Notes on Installations and Laboratories at A.E.R.E.

Contents

GLEEP Reactor

The first nuclear reactor to be built in the United Kingdom, GLEEP (Graphite Low Energy Experimental Pile) was designed and constructed by a team of scientists and engineers working at Chalk River and Harwell between 1945 and 1947; it diverged in August 1947. GLEEP is graphite moderated and is cooled by circulating air. Originally the fuel was natural uranium metal, uncanned but aluminium sprayed, and uranium dioxide pellets canned in aluminium; in 1960 the reactor was completely overhauled, modernised, and refuelled with natural uranium metal canned in aluminium. Using a small fan to increase air circulation the pile has been run at 100 kW(th) but the normal rating is 3 kW at which the average thermal neutron flux is 5×10^8 neutrons cm^{-2} sec^{-1}. GLEEP's primary purpose is the measurement of cross-sections for pile neutrons and the quality testing of fuel and moderators by the reactor modulation method; it is equipped with a reactor oscillator for small samples and a 'danger-coefficient' train capable of oscillating large samples in the core. It has also been used continuously, ever since it was completed, for fast neutron irradiations of biological samples.



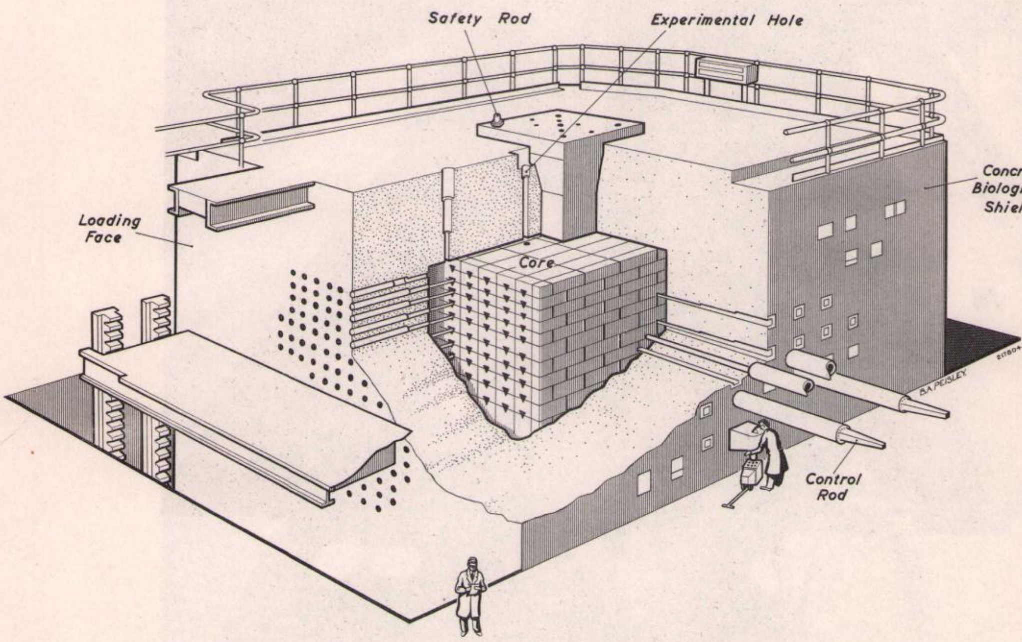


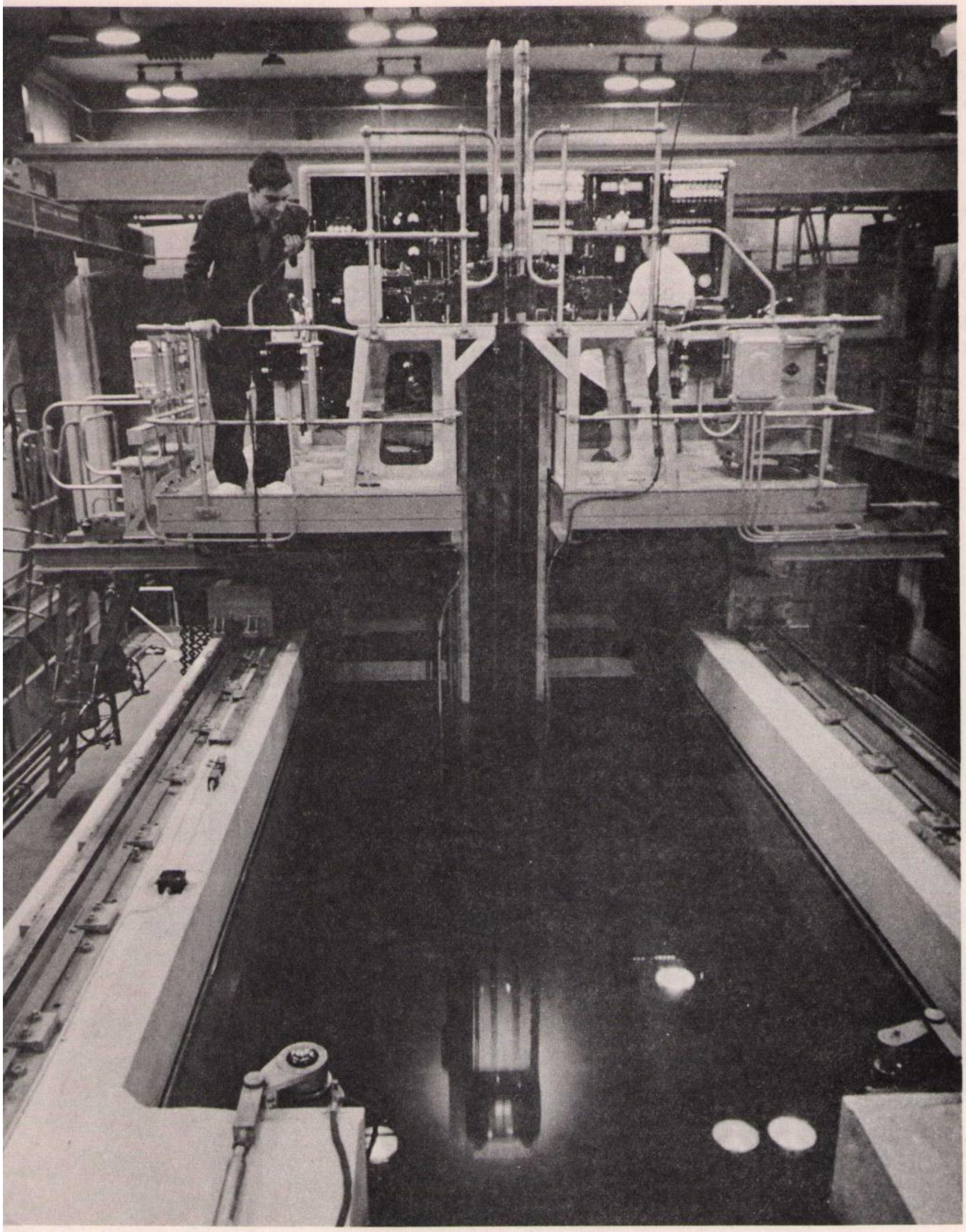
Control and discharge faces of BEPO   Control rods move in the horizontal tubes at the left

Bepo Reactor

BEPO, the British Experimental Pile, was built by the Risley organisation to Harwell specifications; it first diverged in July 1948. It is graphite moderated and fuelled with natural uranium, though recently a few elements containing slightly enriched uranium have been added; cooling is by forced draught of air. The reactor power is 6,500 kW(th) and the average thermal neutron flux is 5.6×10^{11} neutrons cm^{-2} sec^{-1}. The reactor is used primarily for the production of radio-isotopes, general irradiations, loop experiments, and as a source of neutrons for nuclear measurements; it is equipped with pneumatic tubes for short-period irradiations. BEPO has an exceptionally large number of experimental holes - more than sixty are constantly in use - and the reactor continues to be an invaluable experimental tool.

About 1,000 kW of the heat output of the pile is transferred to water in a heat exchanger and used to warm buildings.

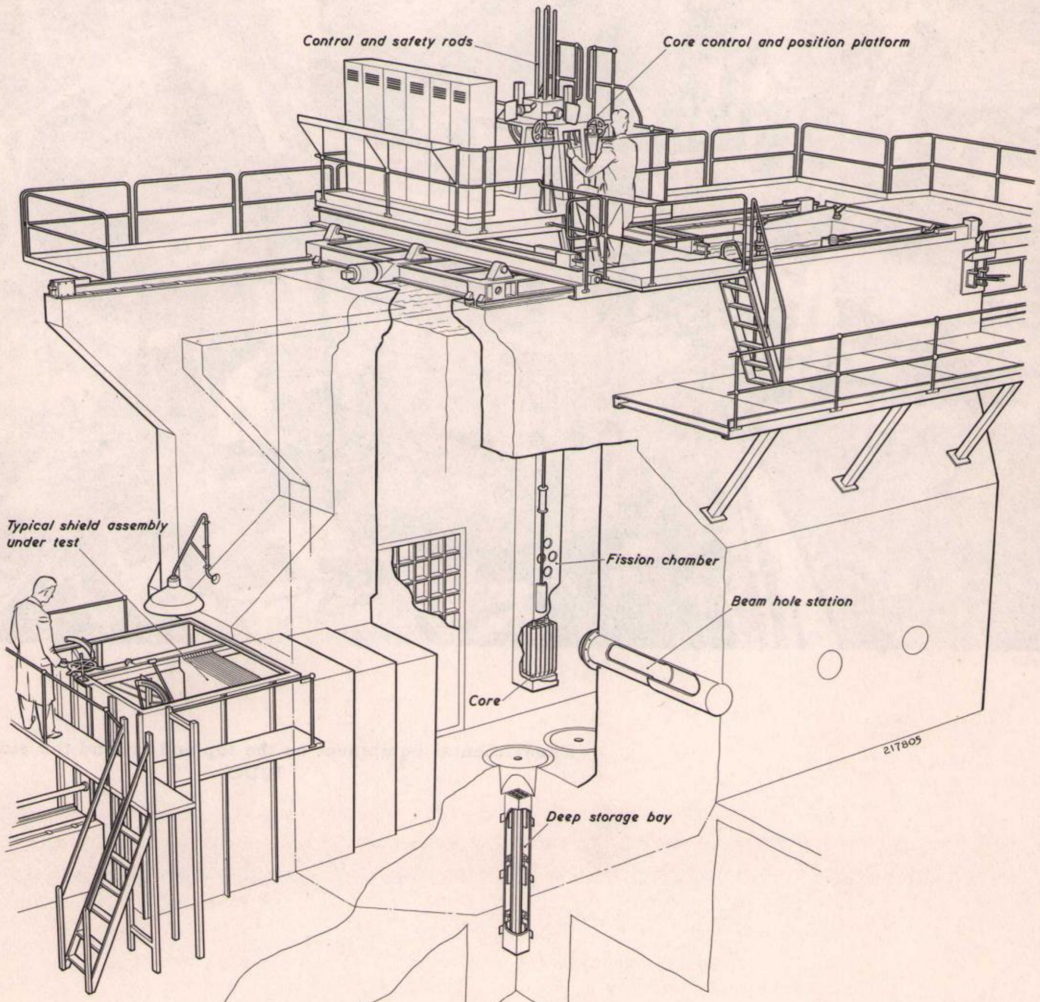


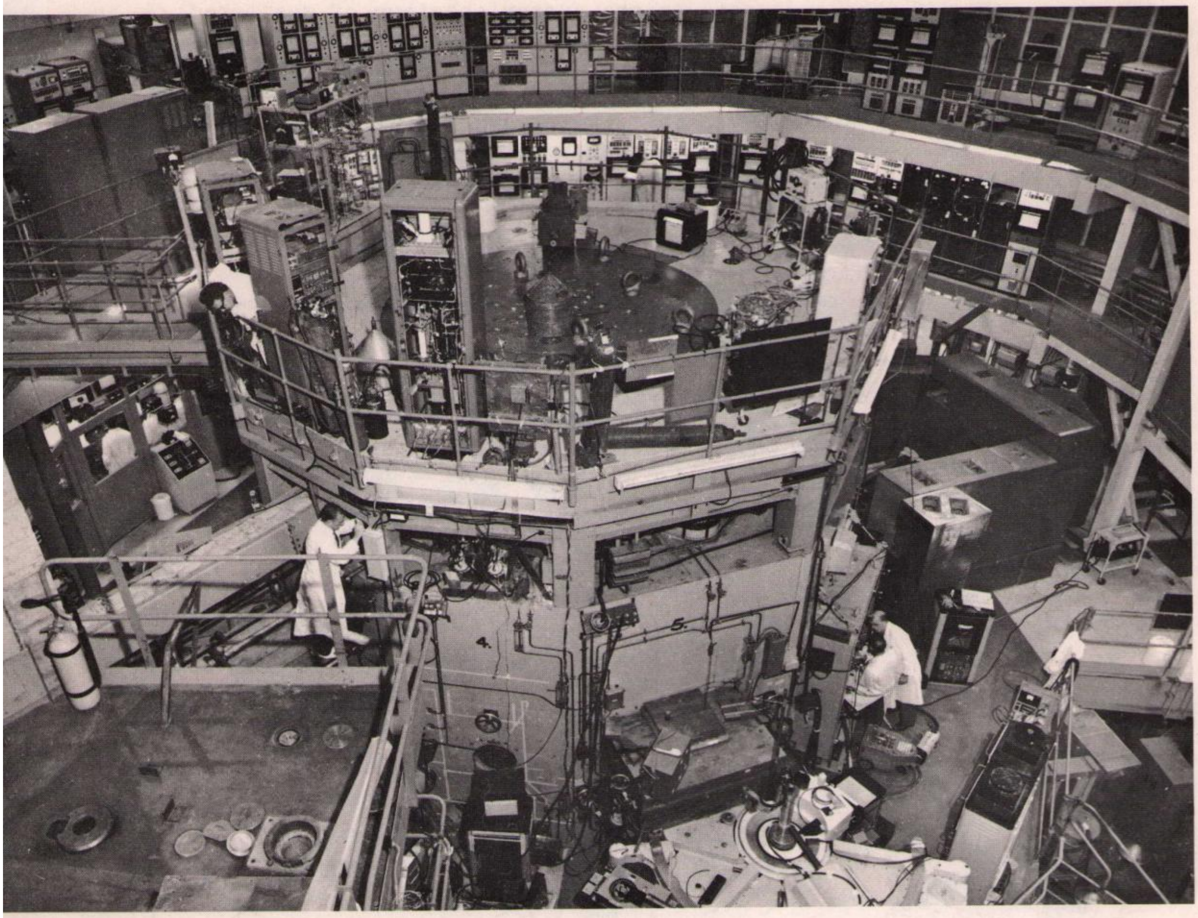


LIDO. The glow around the submerged core is from Cerenkov radiation released by the passage of fast electrons through water

Lido Reactor

LIDO is a 100 kW(th) swimming pool reactor, commissioned in September 1956 and intended mainly for research into shielding, particularly the development of light-weight shields; it is also used as a neutron source for measurements on the energy spectrum of scattered neutrons in various lattices and moderators. The reactor is moderated and cooled by light water contained in a rectangular tank, 28ft long, 8ft wide, and 24ft deep, in which the small core assembly is suspended; the fuel is uranium enriched to 46% uranium-235 and alloyed with aluminium. The average thermal neutron flux is 6×10^{11} neutrons cm^{-2} sec^{-1}.





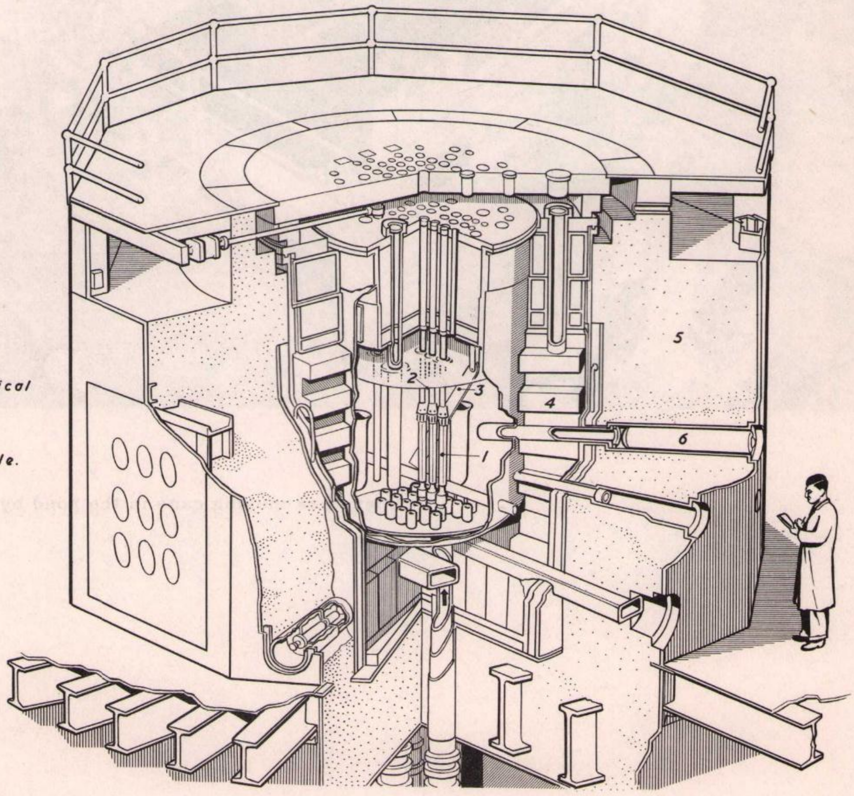
Experimental equipment on the top and around the sides of DIDO

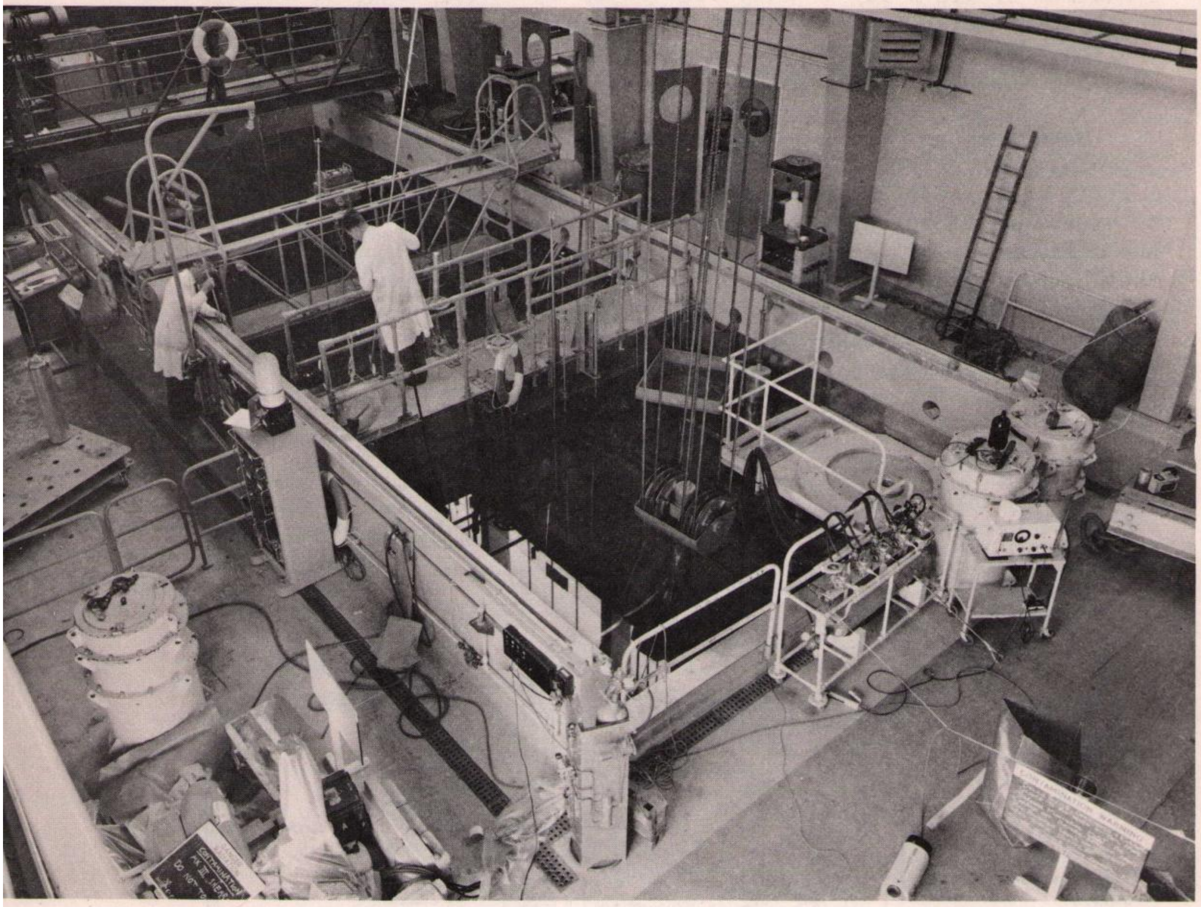
Dido and Pluto Reactors

There are two high-flux reactors at Harwell, DIDO (which went critical in November 1956) and PLUTO (critical November 1957). Both are moderated and cooled with heavy water and fuelled with uranium-aluminium alloy enriched to 80% uranium-235; nominal power is 10,000 kW(th) and the average thermal neutron flux is 7.7×10^{13} neutrons cm^{-2} sec^{-1}, with a maximum of 1.6×10^{14}. Heat removed by the heavy water is transferred to ordinary water in heat exchangers and discharged to atmosphere in cooling towers. Each reactor is built inside a steel containment building which is maintained at a pressure slightly below atmospheric.

Both reactors are intended principally for irradiation experiments, especially on materials for reactors, and nuclear physics experiments; certain radioisotopes are also produced in them. DIDO has a total of 59 experimental holes of varying sizes in which fluxes from 10^{10} up to the maximum may be obtained. PLUTO has only 18 experimental holes but they are generally larger and are capable of accommodating loops and large collimators. Special fuel elements are available, for use in either reactor, in which a large increase in damaging fast neutron flux is obtained by placing the experiment to be irradiated in the middle of the fuel element.

1. Fuel Element.
2. Heavy Water.
3. Control Arm.
4. Graphite.
5. Concrete Biological Shield.
6. Experimental Hole.



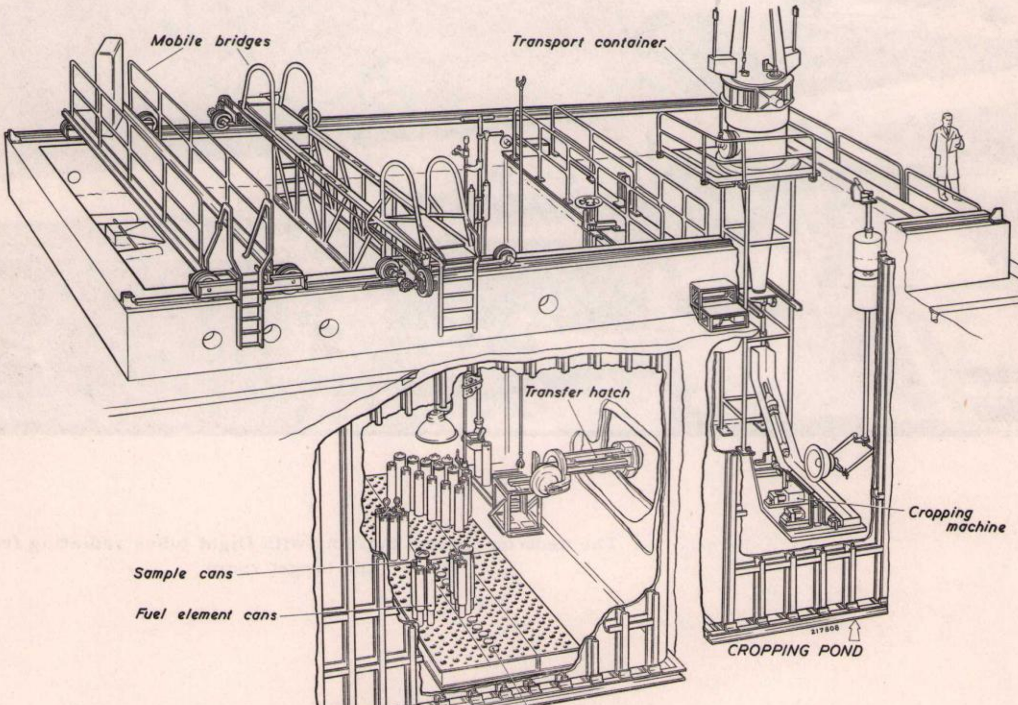


Operators moving cans in the pond by means of long tongs

Fuel-element Cooling Pond Building 466

Before chemical treatment, spent fuel elements removed from the reactors DIDO and PLUTO are stored under water for some weeks to allow the radioactivity of fission products to decay. During this time the gamma radiation emitted in this decay can be used for irradiations for research or pilot-scale industrial trials; the concentration of fission products is high and gamma-ray dose rates up to 5 megarads an hour may be obtained.

The pond used for this 'cooling' process is designed to simplify irradiations. It is divided into two sections. In the first, the top and bottom parts of the fuel elements (which contain no active material) are chopped off. The cropped elements are then moved to the second, main, section of the pond; here they are put into containers and the filled containers are stored at the bottom of the pond in a regular square lattice of known geometry, in which they are fixed by locating pins. Samples of materials to be irradiated are enclosed in watertight cyclinders which are placed among the fuel element containers in positions calculated to give the required dose rate, which is checked by measurement at frequent intervals. Sometimes it is necessary to move the cylinders, or the samples within them, during irradiation to ensure uniformity of dose.

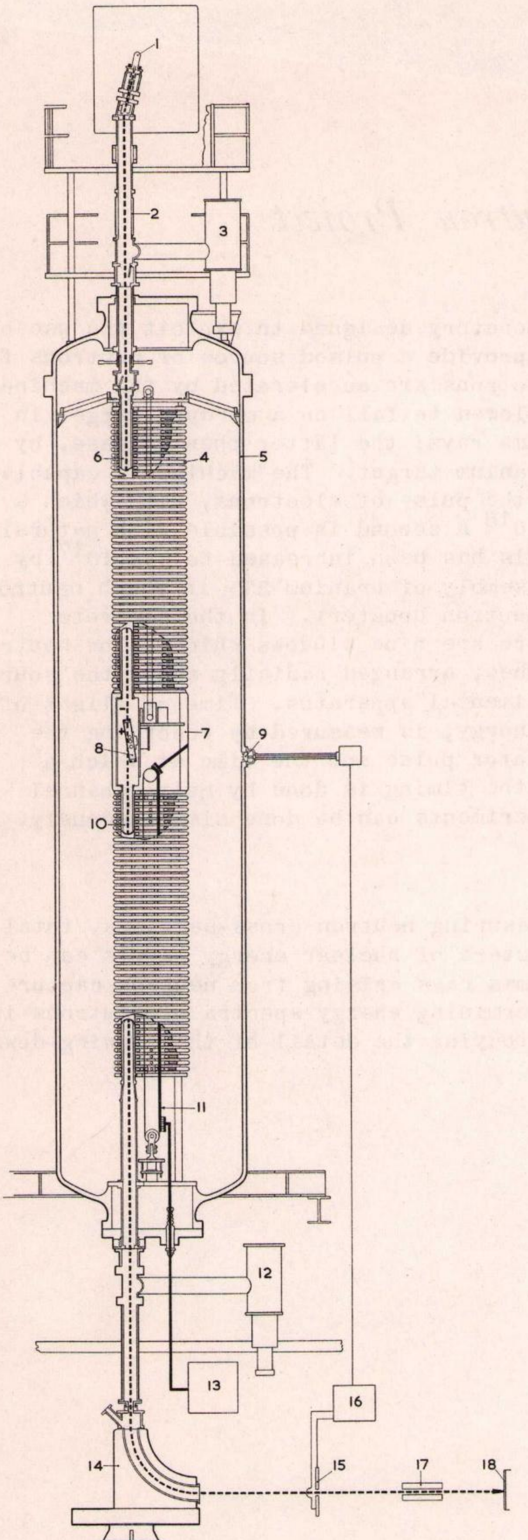


The neutron project building with flight tubes radiating from the target room

The Neutron Project

The neutron project is a laboratory designed to exploit the use of a linear electron accelerator to provide a pulsed source of neutrons for time-of-flight measurements. Electrons are accelerated by the machine to an energy of 30 MeV and are allowed to fall on a mercury target in which they generate bursts of gamma rays; the latter then release, by photo-fission, neutrons from a uranium target. The machine is capable of giving a current of 400 mA in the pulse of electrons, with which a rate of neutron emission of 2×10^{16} a second is possible with natural uranium in the target; however this has been increased to 3×10^{17} by using as target a sub-critical assembly of uranium-235 in which neutron multiplication takes place (the neutron booster). In the concrete shield surrounding the target there are nine windows which allow neutrons to enter nine evacuated flight tubes, arranged radially about the source, down which they pass to the experimental apparatus. Time of flight of neutrons down the tubes, and so energy, is measured by recording the time interval between the accelerator pulse and the time at which a neutron arrives at the detector; the timing is done by multi-channel analysers. A large number of experiments can be done simultaneously.

The apparatus is used for measuring neutron cross-sections, total and partial, from which the parameters of nuclear energy levels can be deduced, and for studying hard gamma rays arising from neutron capture. The method is also applied to determining energy spectra of neutrons in various reactor lattices and to studying the detail of the slowing-down process.

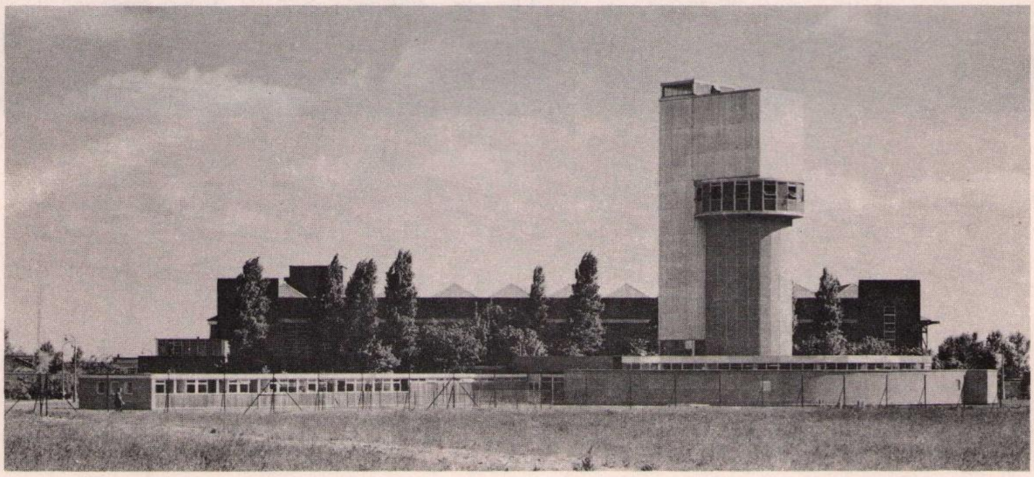


1. Ion Source
2. Injector
3. Pump
4. Insulated Equipotential Plates
5. Pressure Vessel
6. Upper Accelerator Tube
7. Electrode
8. Stripper
9. Corona Probe
10. Lower Accelerator Tube
11. Belt Charging System
12. Pump
13. 100 kV Voltage Supply
14. Analysing Magnet
15. Slit
16. Slit Amplifier
17. Lens
18. Target

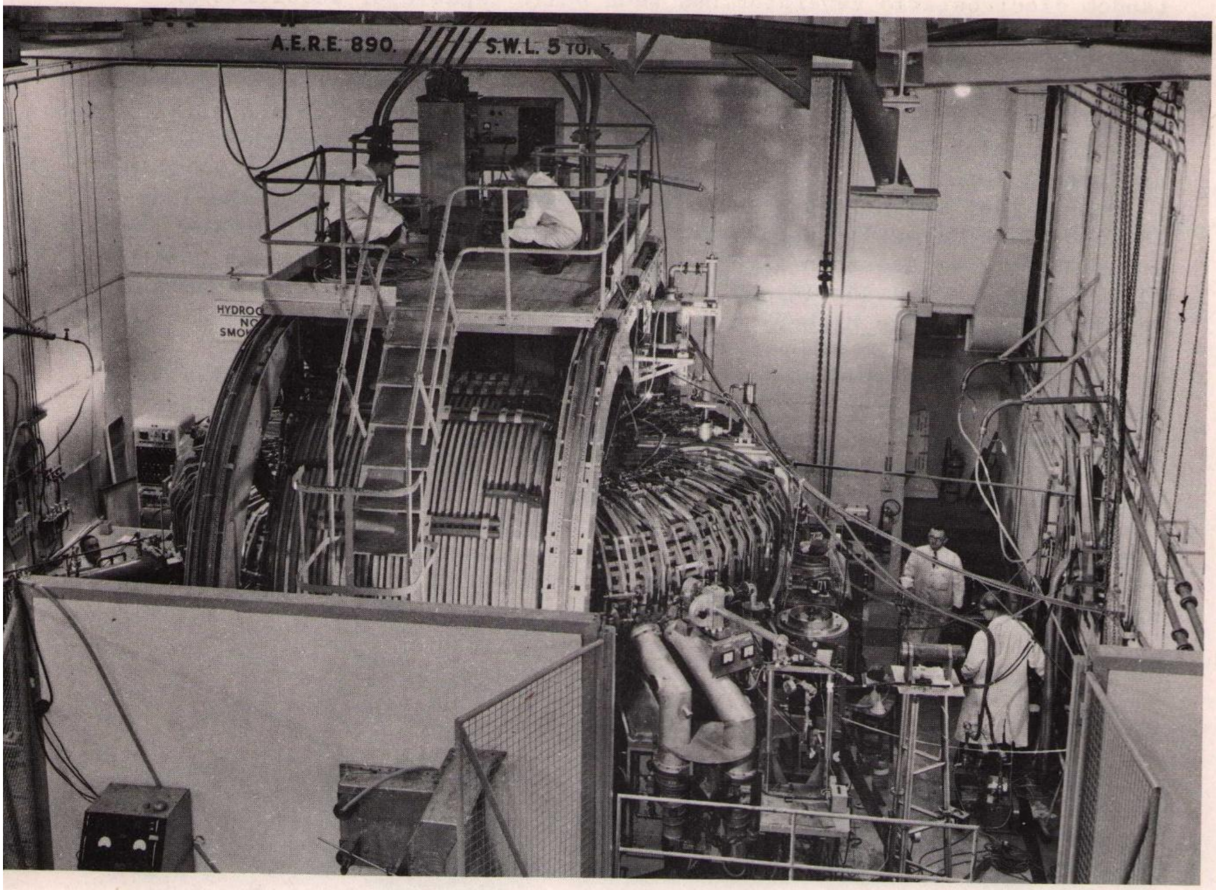
The Tandem Electrostatic Generator

To extend to the highest mass numbers the range of nuclides upon which precision measurements of nuclear energy levels can be made, a tandem electrostatic generator has been built capable of accelerating protons and deuterons to energies up to 12 MeV. The acceleration is achieved by using, in effect, two 6 MV electrostatic generators in tandem. Negative ions are formed by passing positive ions through gases in which they pick up extra electrons and are accelerated to a central electrode which is at 6 MV positive potential; in this electrode they are turned into positive ions by passing them through a stripper (a thin film or a gas) which removes electrons because the velocity of the ions is much higher than it was at the time of electron attachment in the ion source; they are then given a second acceleration by the same potential. Thus a total acceleration equivalent to 12 MV is obtained without generating a voltage higher than 6 MV.

The Harwell machine (which was developed jointly with A.W.R.E.) is arranged vertically, with the ion source at the top; below it are the first accelerating tube, the central high voltage electrode and stripper, and the second accelerating tube. The central electrode is maintained at 6 MV positive with respect to earth by a Van de Graaff belt mechanism. The beam of particles emerging at the bottom is turned through a right angle by a magnet which can be rotated so as to direct the beam to any one of a number of experiments set up in the semi-circular experimental area at the bottom of the machine.

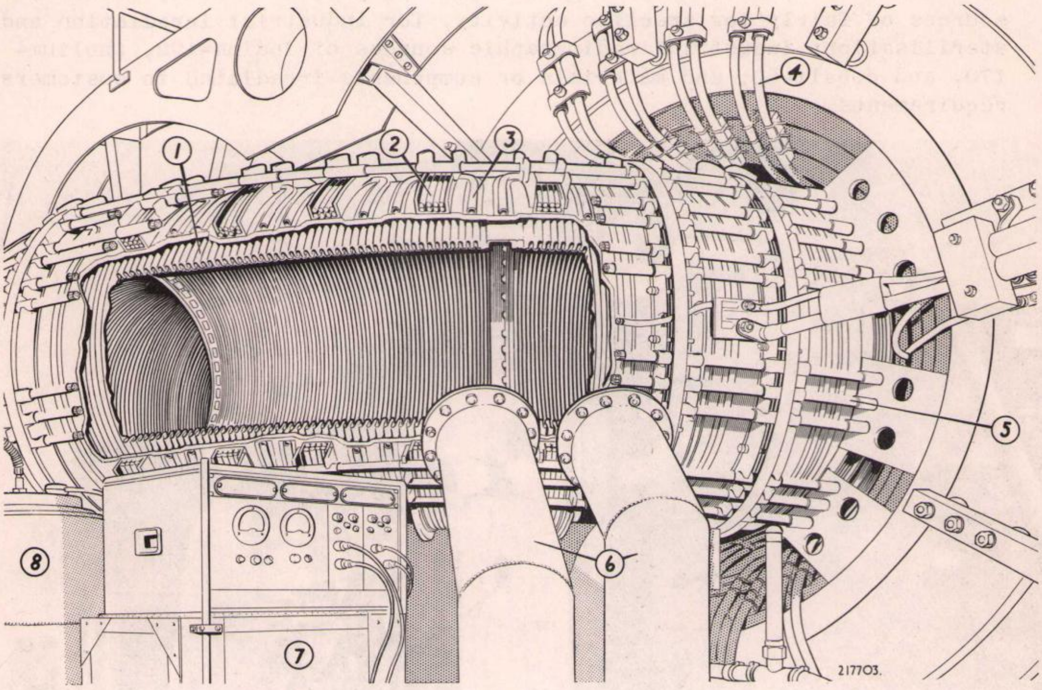


The tandem electrostatic accelerator building


A.E.R.E. 890.
S.W.L. 5

Zeta

Much of the work on forming, containing, and heating plasma - which is the essence of controlled-thermonuclear research - has been done with ZETA (Zero-Energy Thermonuclear Assembly), an apparatus in which deuterium gas is heated to high temperature in a toroidal discharge tube. The gas, initially weakly ionised, forms the single secondary turn of a transformer: a charge from a large capacitor bank is discharged into the primary of the transformer and induces a large pulse of current in the gas, heating it to temperatures in the region of a million degrees and causing it to become a plasma. The magnetic field set up by the current compresses the plasma, moving it away from the walls of the tube in the characteristic "pinched" discharge. A smaller, axial, magnetic field, produced by coils wound round the toroid, reduces instabilities in the discharge, especially a tendency to wriggle about and touch the walls of the tube.



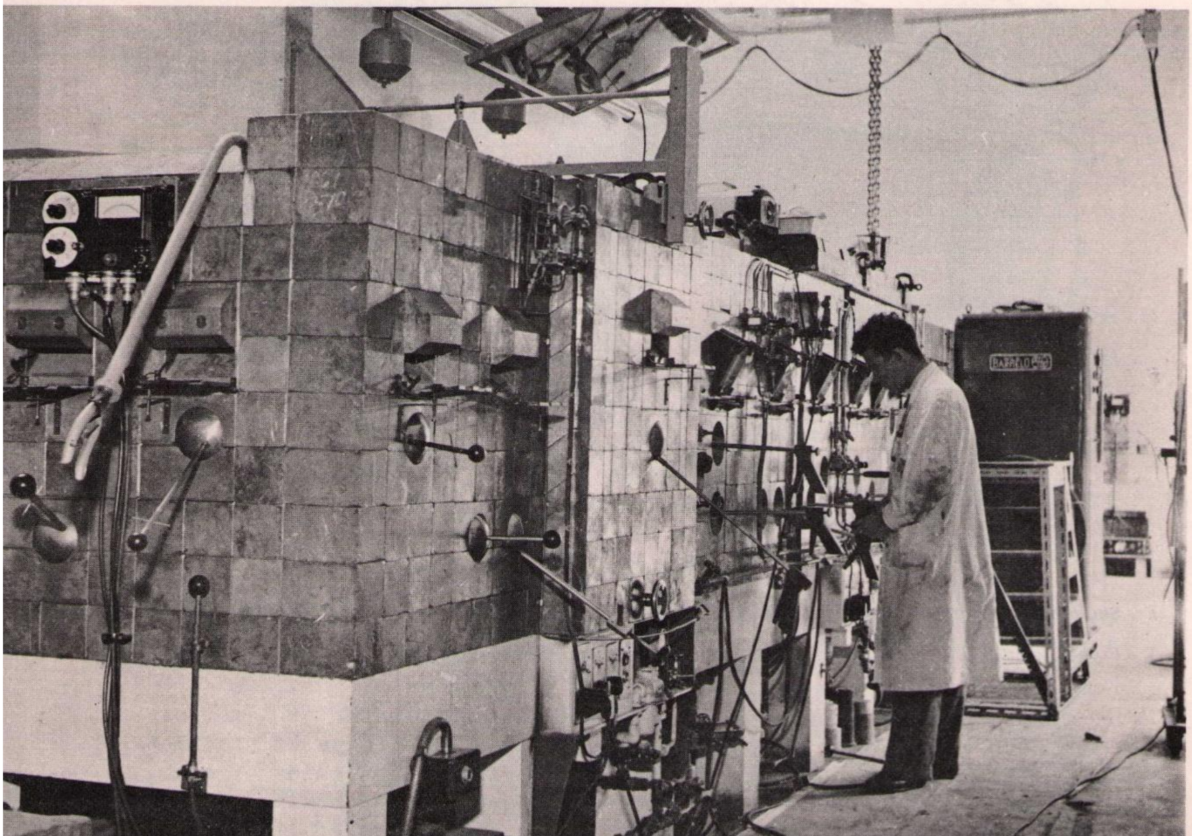
1. Section of corrugated liner. 2. Axial field windings. 3. Water cooling pipes. 4. Bias windings. 5. Pulse windings. 6. 6" pump manifold. 7. Refrigerator. 8. Cold trap.

The toroid has a bore of 1 metre and a mean diameter of 3 metres; it has been fitted with a continuous corrugated liner made of stainless steel. The capacitor bank is capable of storing 3 megajoules of energy, which enables gas currents up to 800,000 amperes to be obtained. Elucidation of the physical phenomena in the plasma and of its instabilities requires the use of a wide variety of diagnostic methods, including optical and microwave spectroscopy and various kinds of probes.

The Isotope Production Unit, Building 10.23

Situated close to BEPO, a major source of radioisotopes, the Isotope Production Unit is an outpost at Harwell of the Radiochemical Centre. In it are handled all the radioactive materials which can be used in the form in which they come from the reactor; those that require processing of any kind are sent straight to the Centre. The work of the Unit consists in removing the material from the container in which it was irradiated, measuring its activity, and then putting it into another can for storage or despatch to a customer. To protect operators from radiation the work is performed by remote control in lead-walled handling cells. The cells are assembled round a storage block in which up to 50,000 curies of radio-cobalt (cobalt-60) can be stored.

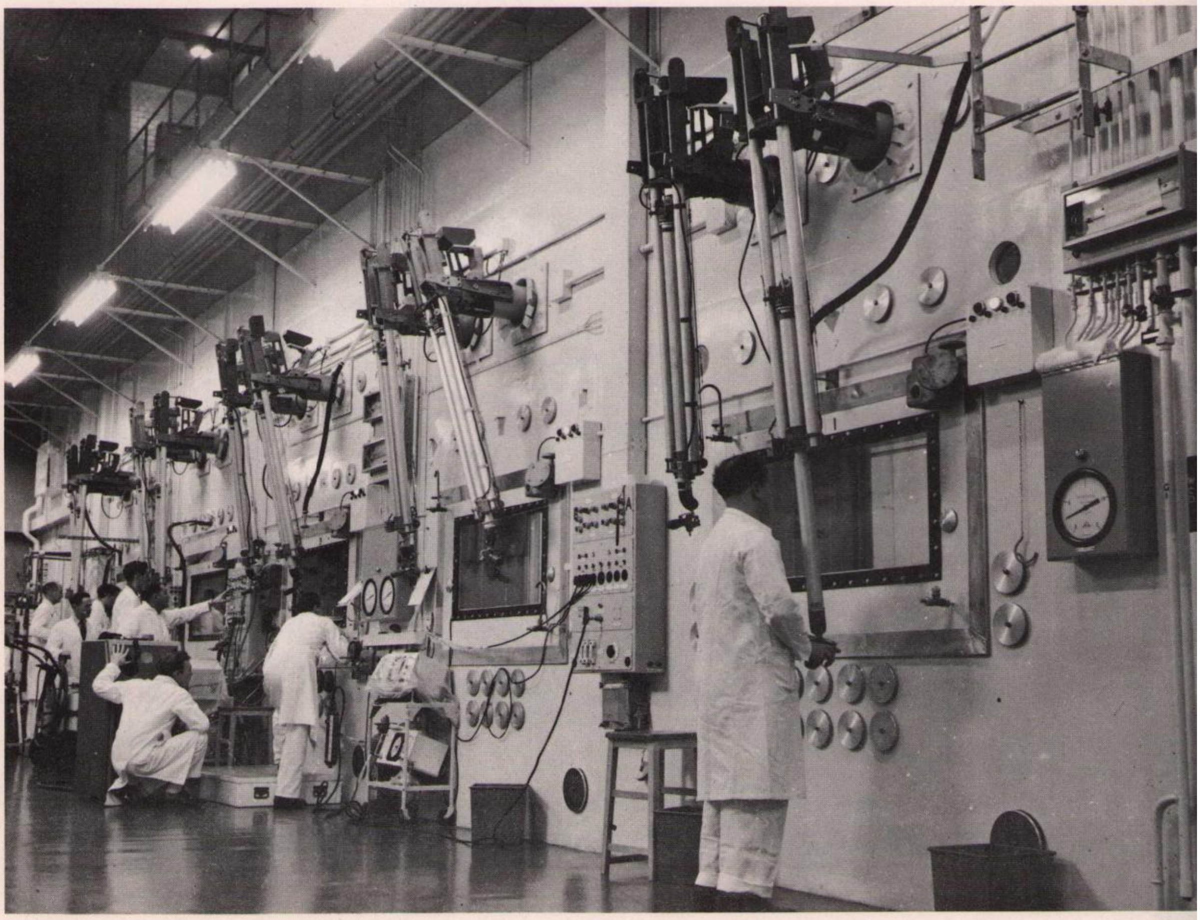
Four principal kinds of radioactive material are dealt with; cobalt-60 sources of high specific activity, in quantities up to 1,000 curies, for medical purposes; very large (100,000 to 150,000 curies) cobalt-60 sources of fairly low specific activity, for industrial irradiation and sterilisation; industrial radiographic sources of iodine-192, thulium-170, and cobalt-60; and materials or components irradiated to customers requirements.



Lead-walled cells in which gamma-active isotopes are handled remotely, by means of tongs, at the Isotope Production Unit

High-activity Handling Building (B.459)

Much of the research into the effects of radiation on materials involves performing mechanical operations on extremely active specimens. Experimental rigs or 'hot loops' irradiated in DIDO or PLUTO, which may be 12 ft long and 10 ins in diameter, have to be dismantled; complete fuel elements of various kinds have to be cut up and machined, and test pieces manufactured from them for measurements of mechanical and metallurgical properties. Activities of rigs or fuel elements may reach 100,000 curies. This work is done in the High-activity Handling Building (B.459), in cells which have protective walls of concrete 5 ft 6 in. thick, with the help of remote manipulators and remotely-controlled cranes and trucks; the machine tools - drills, saws, lathes, milling machines - are also remotely controlled. Operations are watched through large windows, 5 ft 6 in. thick, which are glass cells filled with zinc bromide solution. There is a second line of cells designed for activities up to 1000 curies. These have walls 4 ft thick and the windows are either zinc bromide cells or are made from special laminated glass blocks; occasionally closed-circuit television is used for viewing. These cells are used mainly for metrology and for chemical, physical and metallurgical tests and experiments.

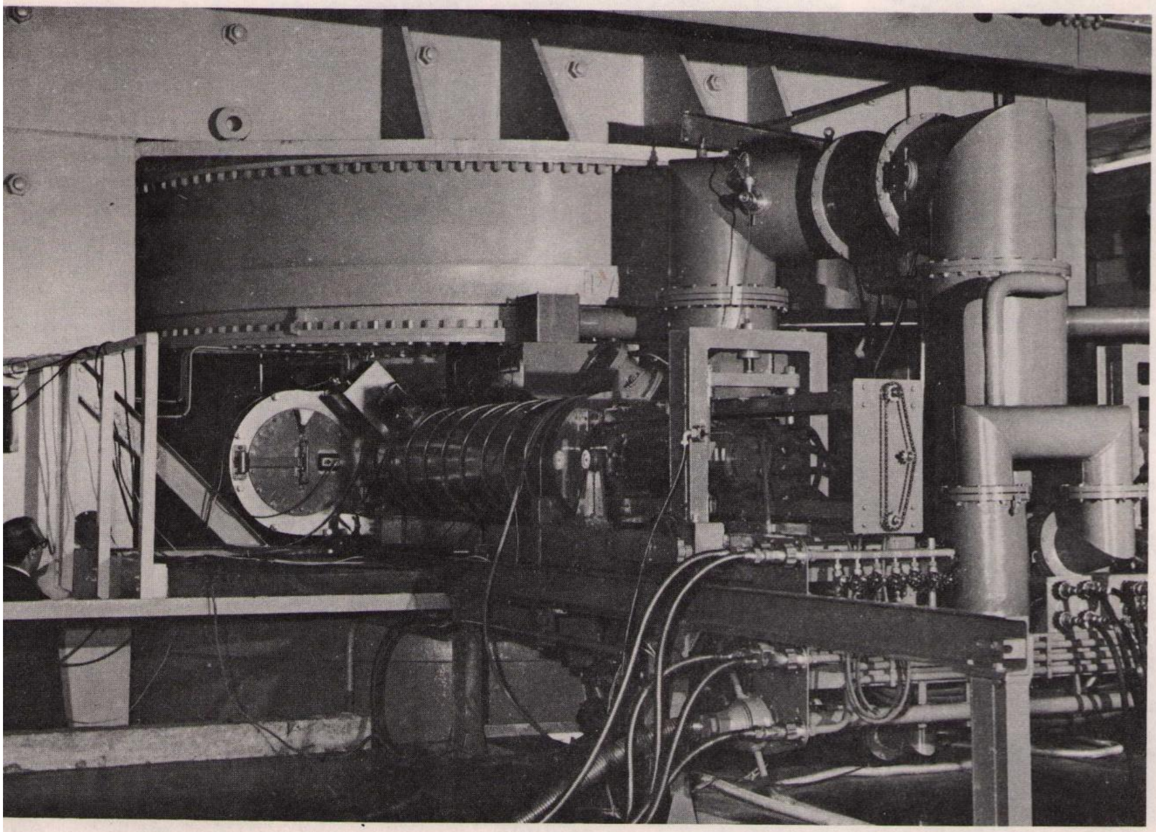


Remote manipulators at the high-activity cells in Building 459

The Synchrocyclotron

Completed in December 1949, the 110" diameter synchrocyclotron is capable of accelerating protons to an energy of 166 MeV, with a mean current in the beam of about 2 microamperes and a pulse repetition rate of 200 a second.

The accelerator is used for a wide range of experiments, especially on proton-proton and neutron-proton scattering. The study of the scattering of fast neutrons in the energy range 15-120 MeV is carried out by time of flight techniques, a method which is unique to this machine. Recent work on proton scattering has been concerned with changes in the state of polarization of polarized protons after scattering by hydrogen, and in studying the mechanism whereby a fast proton knocks another proton out of a nucleus.

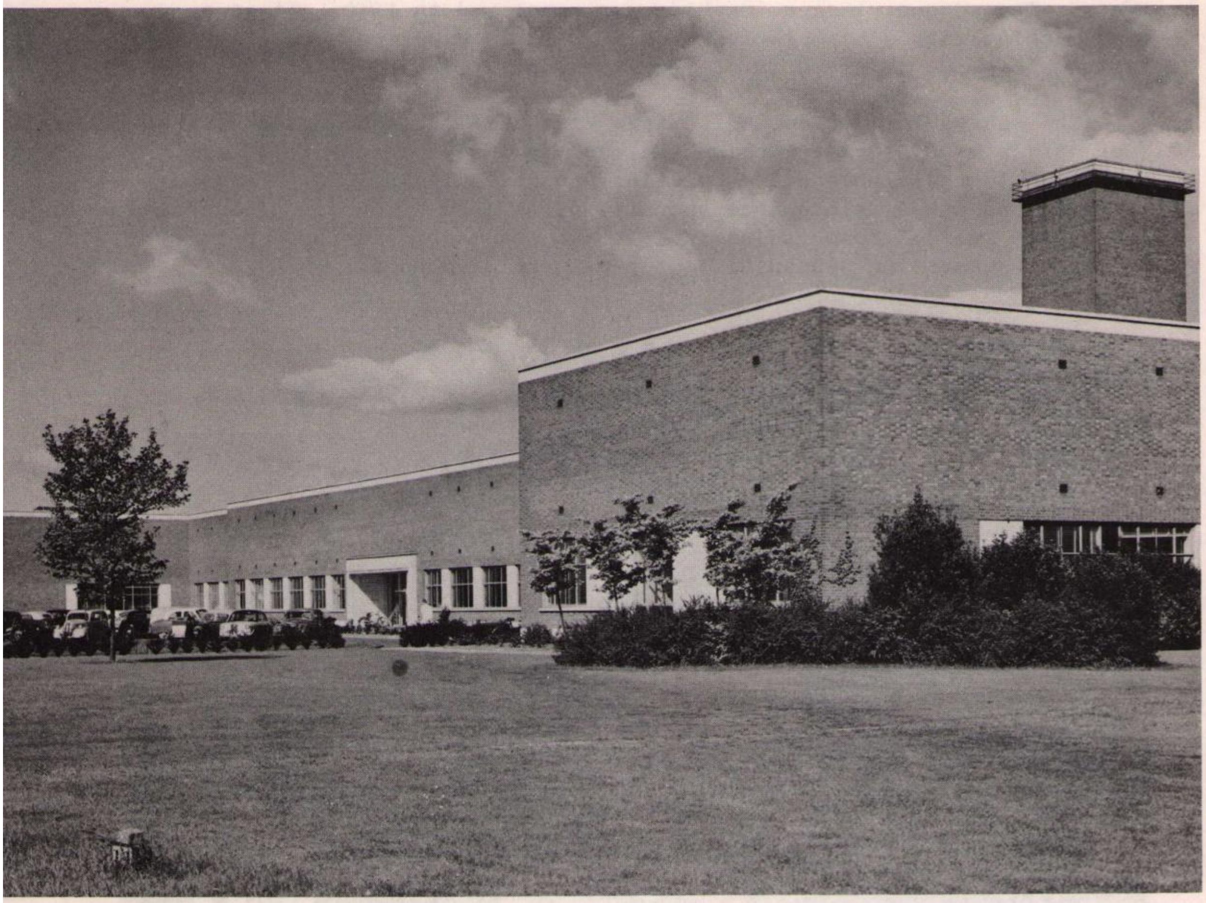


Electromagnetic Isotope Separators

Harwell has three electromagnetic isotope separators, two for inactive and one for active materials. The smallest machine was completed in 1948 and operated as a 180^{o} machine (beam radius 6 inches) until in 1955 it was reconstructed as a 60^{o} sector machine with a radius of 2 ft. It is used for separating milligram quantities of light elements. The second, larger, machine was completed in 1949. It is a 180^{o} machine with a beam radius of 2 ft. It is used for separating isotopes of some 40 elements on the gram scale.

The Heavy Element and Radioactive Material Electromagnetic Separator (Hermes) is a 90^{o} sector machine enclosed in a sealed room which is connected to the alpha-active handling area of Building 220. Target changing and other maintenance operations are done by men in pressurised protective suits. Beam radius is 4 ft and the machine is used principally for separating plutonium isotopes in gram amounts.

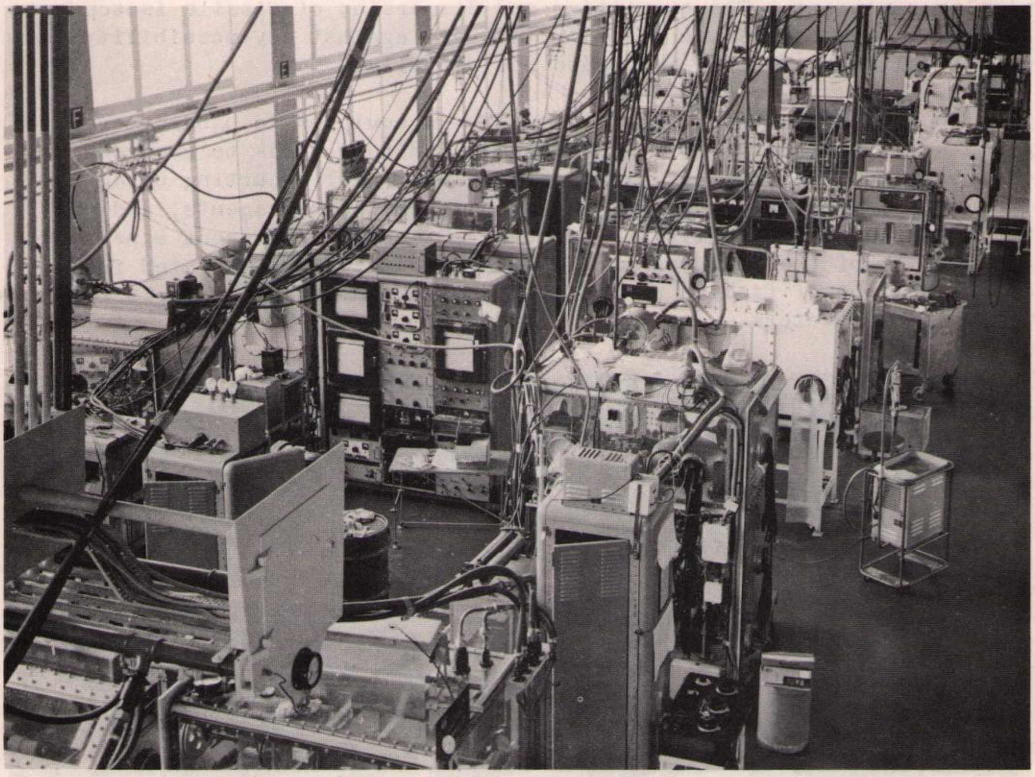
Workers in frog-suits making adjustments within the active area of Hermes



The radiochemistry laboratory, Building 220

Radiochemical Laboratories

Besides more usual accommodation and apparatus, chemistry research at Harwell requires certain special laboratories. These are the radiochemistry laboratory, Building 220, and its extension 220.8. Building 220, completed in 1949, was designed for work on alpha active and beta/gamma active materials; the extension was built in 1954 to provide for work with large amounts of the alpha-active fissile isotopes, especially plutonium.

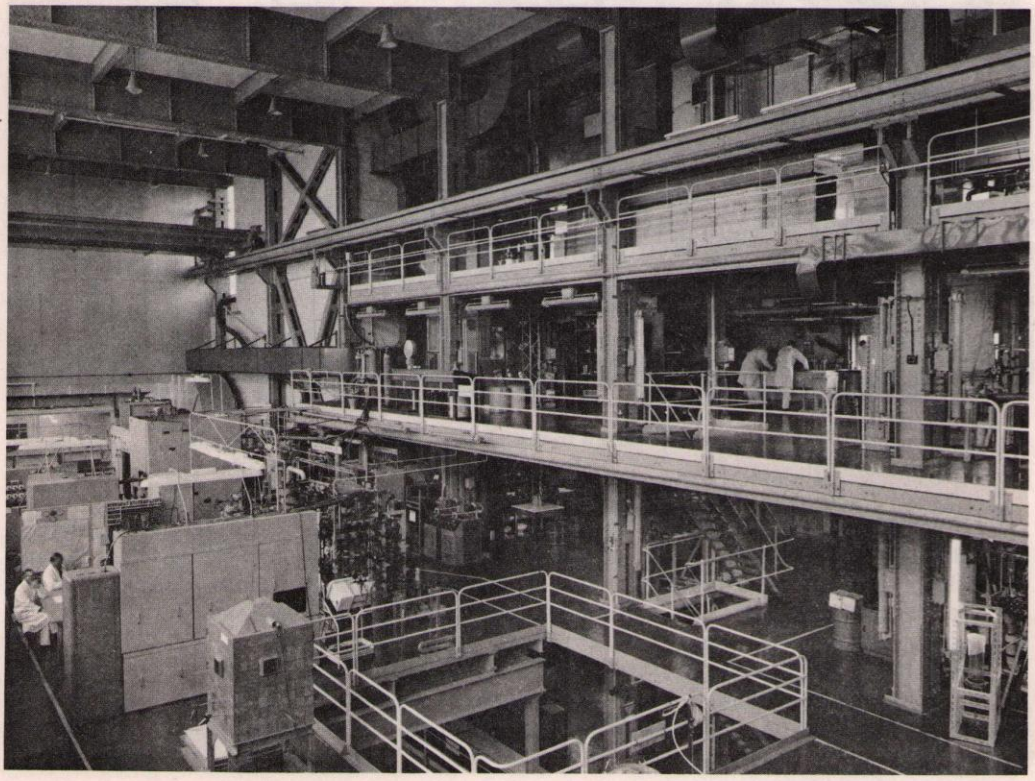


Free-standing glove boxes in the plutonium laboratory Building 220.8

Broadly the difference between laboratories for alpha-active work and those for handling beta/gamma activity is that in the first protection is required against inhalation and ingestion, so that containment of active material is the essential, whereas in the second protection against penetrating gamma radiation is more important, so that the accent is upon shielding. A feature of Building 220 is the elaborate ventilating system, which occupies the whole of the upper story. The laboratories on the ground floor are grouped into two wings. In the alpha wing work at low levels of activity is carried out in fume hoods (for very low levels) and glove boxes i.e. completely closed boxes with transparent perspex walls in which chemical apparatus, instruments, and tools may be manipulated manually through neoprene gloves sealed into the walls. Among the researches being done in this wing are studies of the chemistry of fuel processing methods and of the chemistry of the heavy elements and the oxides of uranium and plutonium.

In Building 220.8 free-standing gloves boxes are used with services of all kinds brought from mains in the ceiling. The boxes are miniature laboratories for chemical and metallurgical work and may contain machine tools as well as furnaces, vacuum apparatus, tensile test machines, and similar equipment. The quantities and dispersion of fissile isotopes in the boxes are carefully controlled to guard against any possibility that a critical mass might be assembled accidentally.

The beta/gamma wing of Building 220 is equipped to handle levels of gamma activity from a few curies in shielded fume hoods to hundreds of curies in concrete cells. Experiments often involve cutting up active specimens in the cells, dissolving them in suitable reagents, and preparing aliquots for analysis elsewhere. Examples of current experiments are studies of the dispersion of fission products in irradiated fuel, determinations of fission product yields, and the study of fuels for high temperature reactors.



Chemical Engineering Laboratory

One of the largest single buildings at Harwell, the chemical engineering laboratory, Building 351, was designed for pilot-plant experiments and chemical engineering development involving radioactive materials with activities up to 500-1000 curies. It was completed in 1952. Typical of the plants that have been installed was the pilot plant for separating uranium-233 from thorium irradiated in the Authority's reactors.

The building comprises a main experimental hall, with ancillary 'hot' analytical and development laboratories, separated from an office wing by changing and wash rooms. The main hall extends vertically through five stories of the building, with working galleries on the south side, but is divided into two floors. There are 25,000 square feet of working space and the hall is spanned by a 10-ton travelling crane. When Building 351 was first brought into use, the main hall was not divided vertically, but its full height was available for experiments with tall separation columns; when interest moved to research involving less lofty apparatus, the dividing floor was put in.

The building does not have permanent concrete cells for active work but instead shielding enclosures are built round experimental equipment or pilot plants, when and where they are required. These temporary enclosures are made from interlocking shielding blocks and can be dismantled, and the blocks re-used, as desired. Some of the shielding blocks are made of plain reinforced concrete, some are mild steel cases filled with concrete; the largest weigh 5 tons.

The main experimental area has plenum and extract ventilation: in addition, there is an extract ventilation system, through filters, for such special needs as fume cupboards and glove boxes. Both ventilation systems are in the roof of the building. On the north side of the main building, but still under cover, is a pit area housing shielded tanks to which active effluent is brought by underground pipes. There is a workshop on the active side of the building to supplement the main Establishment workshop.

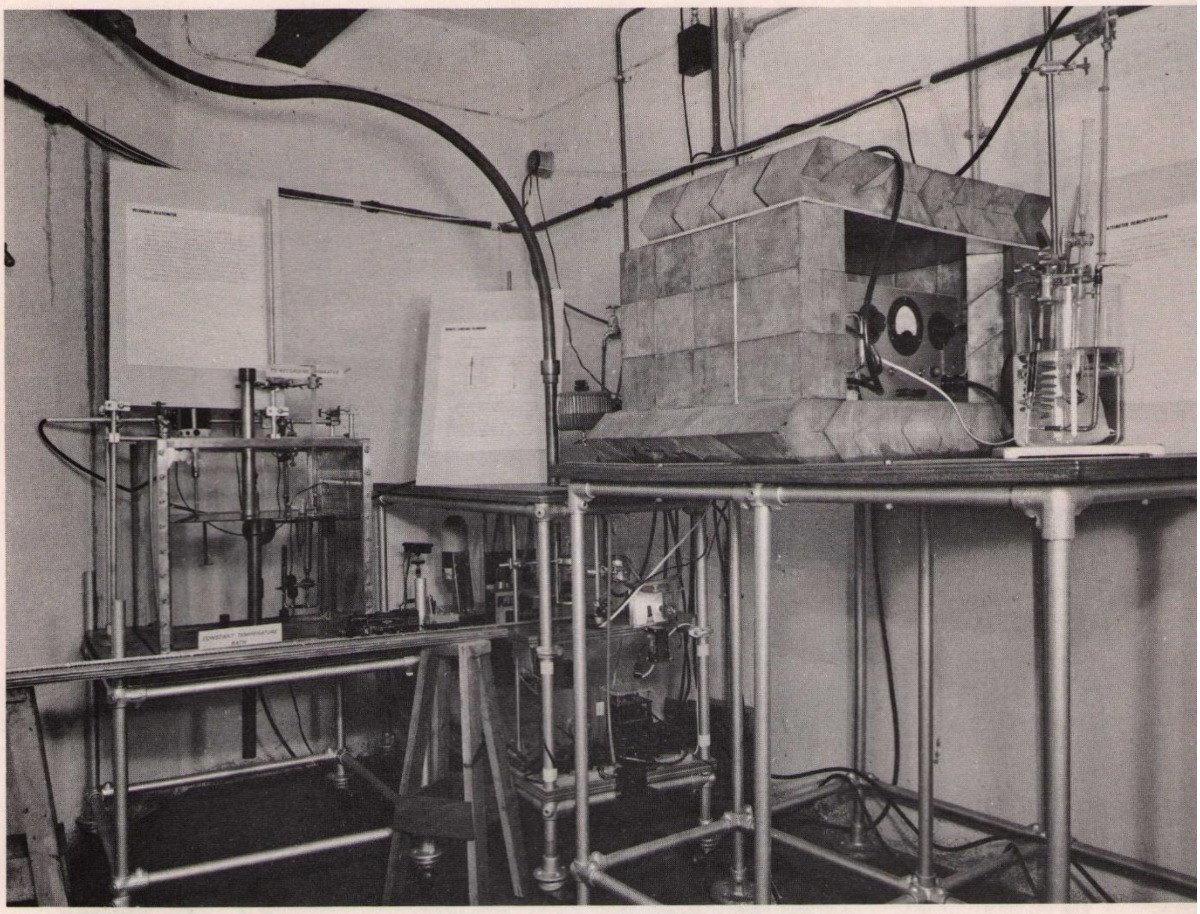
The Wantage Research Laboratory

Research on the applications of radioisotopes and the use of radiation has been concentrated in the Isotope Research Division, at the Wantage Research Laboratory, which was formally opened by the Minister for Science in May 1960. One task of the Division is the study of possible uses for massive sources of radiation. This work originated in a desire to find economical uses for the almost unlimited quantities of radiocaesium which will become available as the nuclear power programme develops. A demand for large caesium sources has not yet developed to an extent that would justify the construction of large chemical plant for separating the isotope, but big quantities of radiocobalt could be made by irradiation in reactors of the power programme and for some years irradiation work will be based on cobalt sources.

For work on massive radiation Wantage is equipped with 23 irradiation cells, concrete-shielded rooms in which experimental apparatus can be set up and then irradiated by a pre-determined configuration of sources. The source strengths at present in use range from 100 to 10,000 curies and several of the cells are temperature controlled. There is also a 4 MeV linear electron accelerator, which is used principally for treating small samples to high dose levels, of the order of 10^8 rad, and to study dose rate effects; it gives dose rates a hundred times those available from the gamma-ray sources. The Division's two large irradiation units, the package irradiation plant at Wantage and the fuel-element cooling pond at Harwell, are descibed separately.

At Wantage there are medium-level and tracer-level chemistry laboratories, a standardisation laboratory, physics laboratories, and the laboratories of the experimental and advisory service; the latter will visit firms and discuss general and particular problems, and will make special investigations, either at the firm or back in the laboratories.

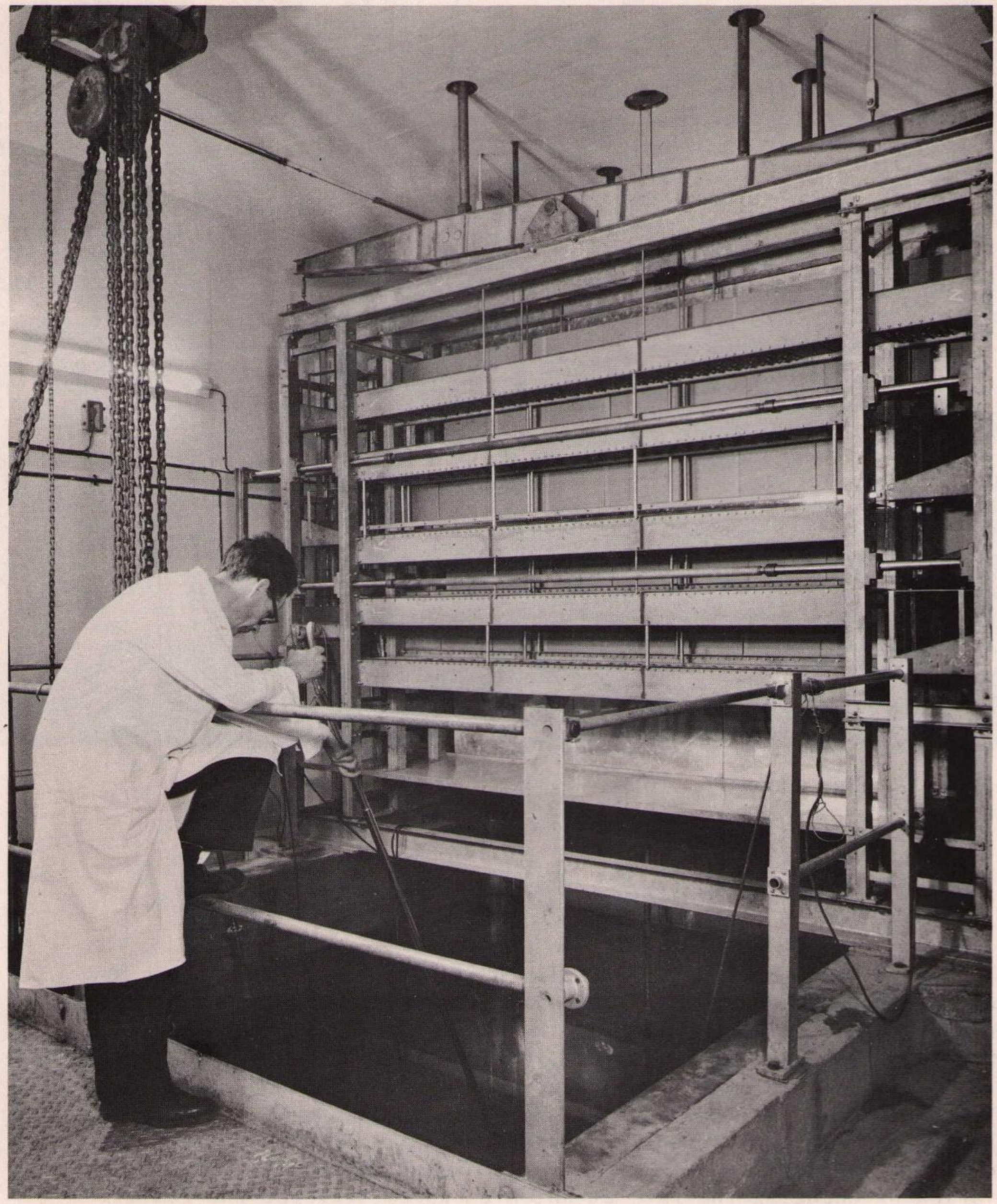
For a fixed capitation fee firms can attach a scientist to the Laboratory to work on a problem of either general or commercial interest. Wantage also houses the Isotope School, in which basic training is given in the uses of radioisotopes in research, industry, and medicine.



Interior of Irradiation Cell

The Package Irradiation Plant

To gain experience of irradiation projects on the pilot scale and to allow manufacturers to make extensive trials, a Package Irradiation Plant has been built at the Wantage Research Laboratory. In this plant packages of materials of standard size (roughly a foot cube) are exposed in the radiation field of a cobalt source for the time necessary to give the required dose, which may be in the range 10,000 to 5,000,000 rads; packages are moved continuously and automatically from bulk store through the irradiation cell to a treated-material store. The dose can be varied by changing the rate at which packages traverse the radiation field. The capacity of the plant is about 100 cubic feet a day at the sterilising dose of 2,500,000 rads, or correspondingly larger quantities at lower total doses. Initially the plant is loaded with 150,000 curies of cobalt-60 but it has been designed to accommodate 500,000 curies. It is planned to lease four-fifths of the capacity to industrial concerns.



The cobalt-60 sources in the Package Irradiation plant are stored under water; in operation they are raised on either side of the conveyor belt (at back of picture)

Addresses of A.E.A. Establishments

United Kingdom Atomic Energy Authority
11 Charles II Street, London, S.W.1.
Telephone: Whitehall 6262

U.K.A.E.A. Research Group
Atomic Energy Research Establishment,
Harwell, Didcot, Berks
Telephone: Abingdon 1220

U.K.A.E.A. Development and Engineering Group,
Risley, Warrington, Lancs.
Telephone: Warrington 31244

U.K.A.E.A. Production Group,
Risley, Warrington, Lancs
Telephone: Warrington 31244

U.K.A.E.A. Weapons Group,
Atomic Weapons Research Establishment,
Aldermaston, Berks
Telephone: Reading 55811 and Newbury 1800

Atomic Energy Establishment
Winfrith, near Dorchester, Dorset.
Telephone: Dorchester 1700

Culham Laboratory,
Culham, Abingdon, Berks
Telephone: Abingdon 1840

Radiochemical Centre,
White Lion Road, Amersham, Bucks.
Telephone: Little Chalfont 2701

A.E.R.E. Out-stations

A.E.A. Factory,
Western Road, Binfield, Bracknell, Berks.
Telephone: Bracknell 1078

Chatham Outstation,
Riverside, Chatham, Kent
Telephone: Chatham 44201

Wantage Research Laboratory,
Grove, Wantage, Berks
Telephone: Wantage 600

Woolwich Outstation
Building C. 37, Royal Arsenal, Woolwich, London, S.E.18
Telephone: Woolwich 2044 Ext. 1404

Some Publications on the Work of the U.K.A.E.A.

Ministry of Supply
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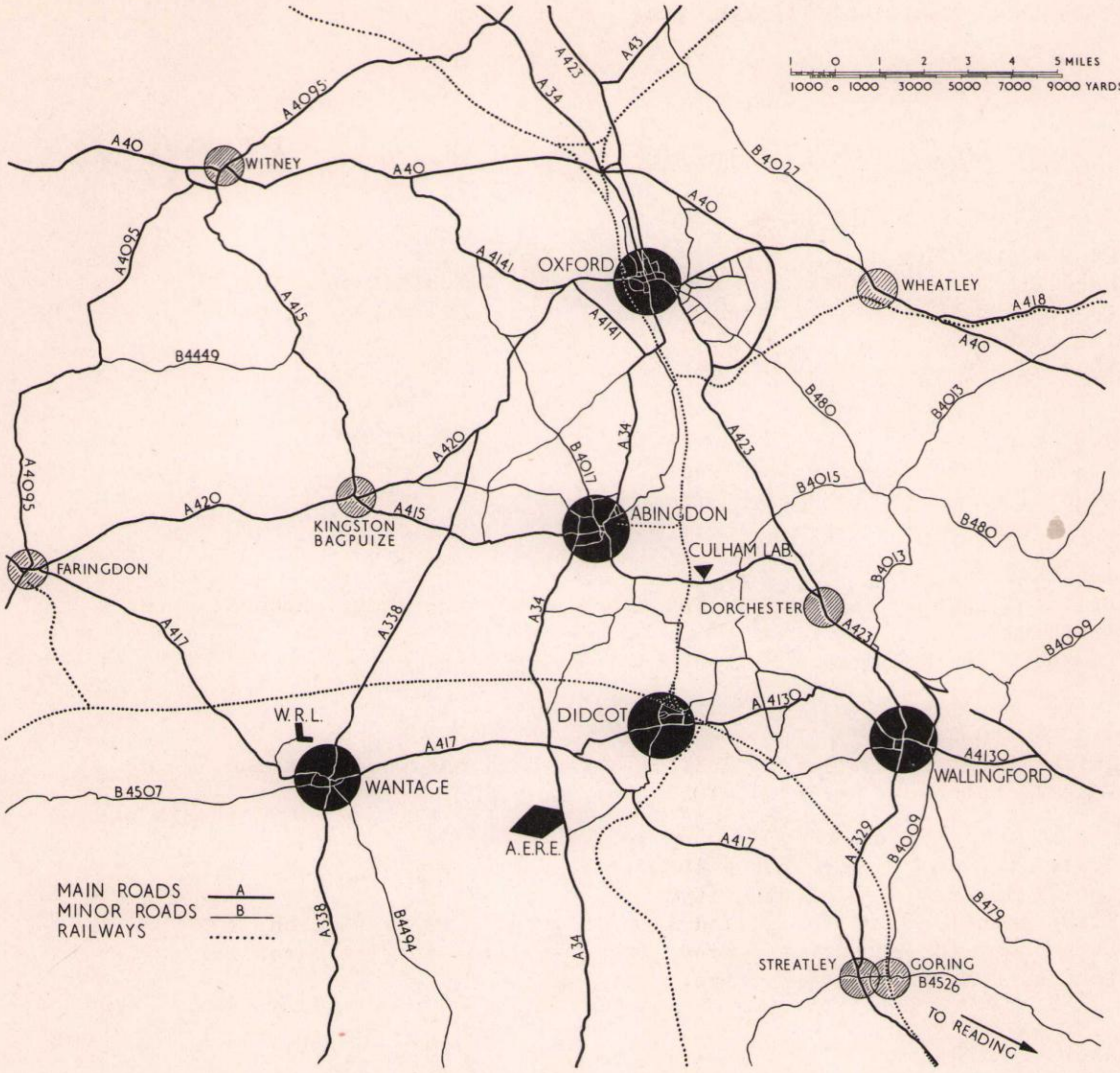
Subsequent Reports cover periods from 1st April to 31st March following.
London, H.M. Stationery Office.

Atom (Monthly)
(Information bulletin and news journal of the U.K.A.E.A.)
London, U.K.A.E.A., Public Relations Branch,
11 Charles II Street, S.W.1.

Films on atomic energy

A list of films on atomic energy available on free loan from the Authority can be obtained from the London Office, Public Relations Branch Film Library, Room 101, 11 Charles II Street, London, S.W.1.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