B. G. Loach.

A·E·R·E

The Atomic Energy Research Establishment

Harwell, Berkshire

1950

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FOREWORD

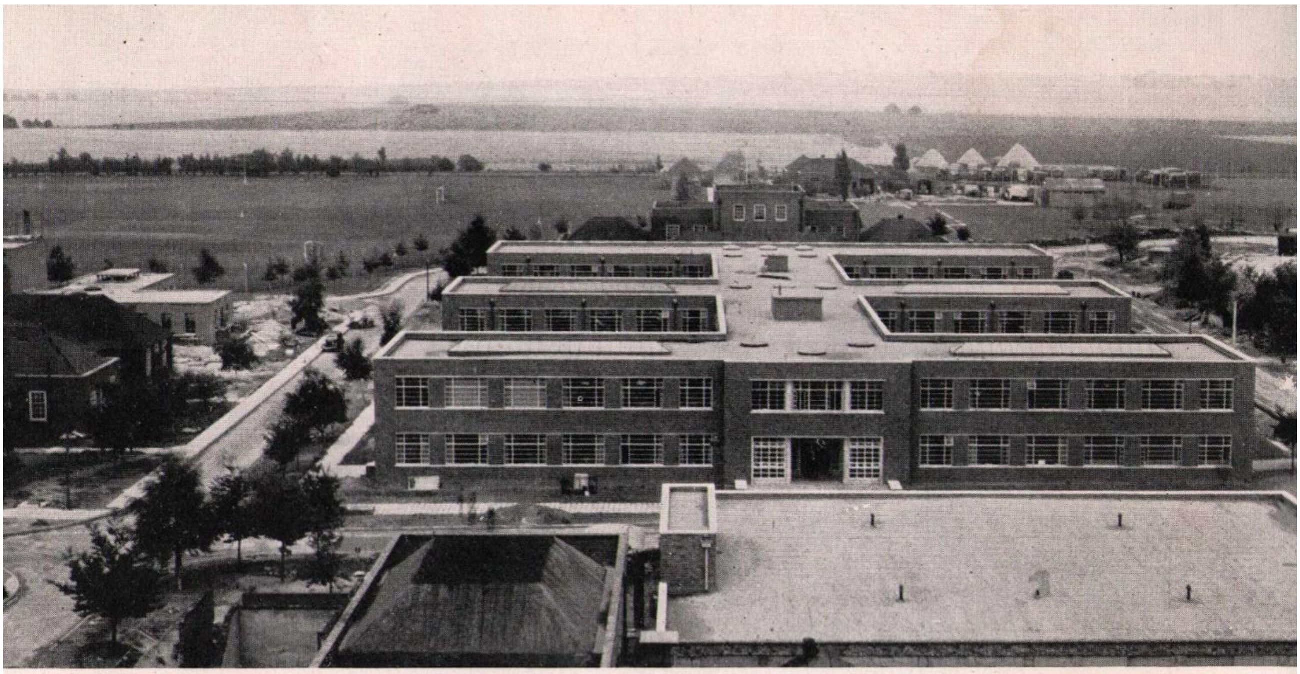
By SIR JOHN COCKCROFT, C.B.E., F.R.S.

The Atomic Energy Research Establishment was founded in 1946 to carry out research and development in the fields of knowledge which are important in the country's programme of Atomic Energy. Since that time we have built very fine laboratories and equipment and have assembled a first-class scientific and technical staff who are establishing the reputation of Harwell as a centre of research.

To assist in the solution of the many problems in atomic energy development we need to recruit more young graduates from the Universities and technical assistants from the technical colleges and schools of this country. Those of you who come will find good opportunities for developing your career in this important and growing field of work.

J. D. COCKCROFT,
Director.

Illustrated on Front Cover. New Radiochemical Laboratory.



A.E.R.E., Harwell. View looking East towards the Berkshire Downs.

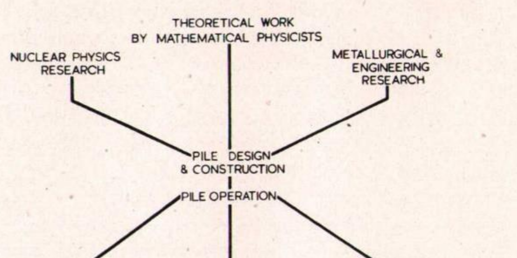
THE ATOMIC ENERGY RESEARCH ESTABLISHMENT

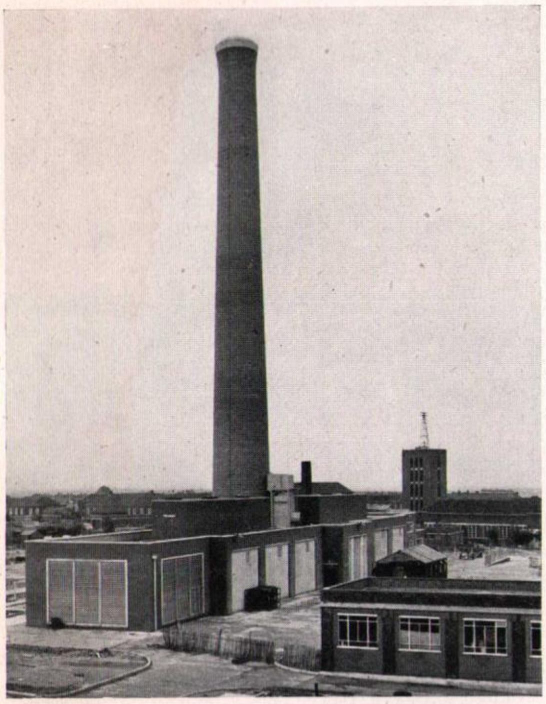
INTRODUCTION

When the Prime Minister announced the formation of the Atomic Energy Research Establishment in the House of Commons on 29th October, 1945, he used these words: "The Government have decided to set up a research and development establishment covering all aspects of atomic energy." This is an immense field to cover: it takes us to the very frontiers of theoretical and experimental physics, chemistry and metallurgy: it demands the efforts of large numbers of specialists in the electrical, mechanical and chemical branches of engineering and to ensure the health of the workers strong teams from the medical and biological services must be available.

An important part of the establishment's programme is to provide information for the atomic energy production organisation ; which is responsible for building and operating the plutonium production piles and chemical separation plan in Cumberland, and for the production of uranium metal from ores.

Harwell consists of eleven divisions, the larger ones being about the size of a university research department, with the head equivalent in status to a university professor. There is a scientific Division for each of the following subjects:—Chemistry, Chemical Engineering, Engineering, Electronics, General Physics, Health Physics, Isotopes, Medical, Metallurgy, Nuclear Physics, Theoretical Physics. The rough schematic diagram gives an indication of the way in which their work is related.





Bepo Chimney. The buildings below the chimney house the fans which suck cooling air through the pile.

Of the Divisions not shown in the diagram General Physics includes in its responsibilities the production of stable isotopes, and a number of general services such as X-ray, electron microscopy, vacuum technique, cloud chambers and glass-blowing. The Electronics, Health Physics, and Medical Divisions serve the whole establishment.

In addition there is an extra-mural Division, responsible for looking after the many contracts placed by Harwell with industry and universities ; and a scientific administration Division responsible for the library and information services, preparation of reports, declassification and other technical services. The Medical Research Council has established a Radio-biological Research Unit at Harwell, under the direction of Dr. J. F. Loutit.

It will be seen from this outline that the work at Harwell covers a very wide field including nearly all the sciences, and that fundamental research must go hand in hand with development work which may be on a considerable scale. It is impossible here to give a comprehensive account of even the non-secret part of the work. However, many papers have been published [(1)(2)(3)] dealing particularly with the publication of physics and electronics to atomic energy work: in this booklet there is an outline of Harwell's pile and power programmes followed by some details of the work in other sciences, which are not usually so closely associated with atomic energy in the popular press.

ATOMIC PILES

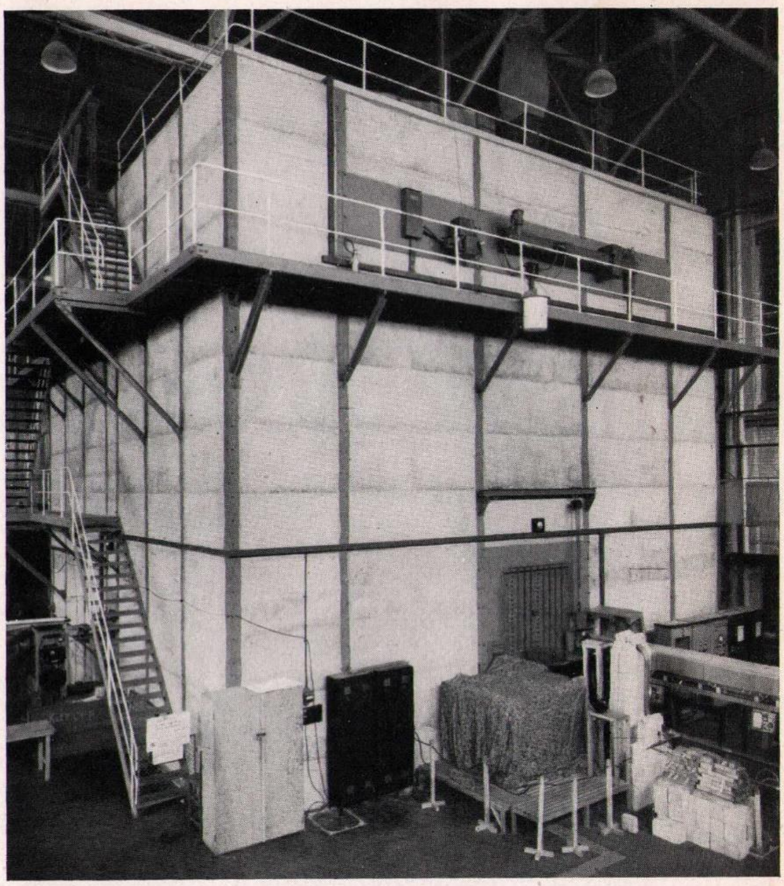
One of Harwell's first tasks was to get experience in the construction and operation of piles, and to this end two natural uranium graphite moderated piles have been built. The first, Gleep (graphite low energy experimental pile), started up in August, 1947, little more than a year after construction began: the second, Bepo (British experimental pile), started up in July, 1948. Fairly full descriptions of Gleep have already been published [(2)(4)], and only one photograph is shown here. Gleep is being used principally for measuring the properties of atomic nuclei, and for testing the properties of pile materials.

Bepo [(5)] is a similar type of pile to Gleep, but it is provided with air cooling and this allows it to be run at about 60 times the power level of the smaller pile. The neutron flux available is correspondingly higher and a much wider range of experiments is possible. The pile is being used for experiments on neutron diffraction, for studies of the effects of neutron irradiation on materials, for experiments in nuclear physics, for engineering development required for the design of new reactors, and for the production of radio-isotopes and new elements.

PLUTONIUM

Plutonium is produced by the irradiation in a pile of the U238 isotope of uranium, but the metal then has to be extracted by a chemical separation process which presents some of the most difficult problems in the atomic energy programme. Small amounts of plutonium are being extracted from uranium that has been irradiated in the Harwell piles, so as to gain experience in the chemical and chemical engineering processes involved.

For this and other chemical work with radioactive materials a new radio-chemical laboratory is being built: the first half has been completed and work in it started in July, 1949 [(6)]. The building is probably the most advanced of its kind in the world: only the ground floor is used for offices and laboratories, the whole of the upper part being occupied with ventilating ducts and other services.



Gleep. General view. In the centre of the right face, lead blocks cover a graphite thermal column from which thermal neutrons can be obtained. At the top of the same face is the mechanism operating the control rods.

NUCLEAR POWER

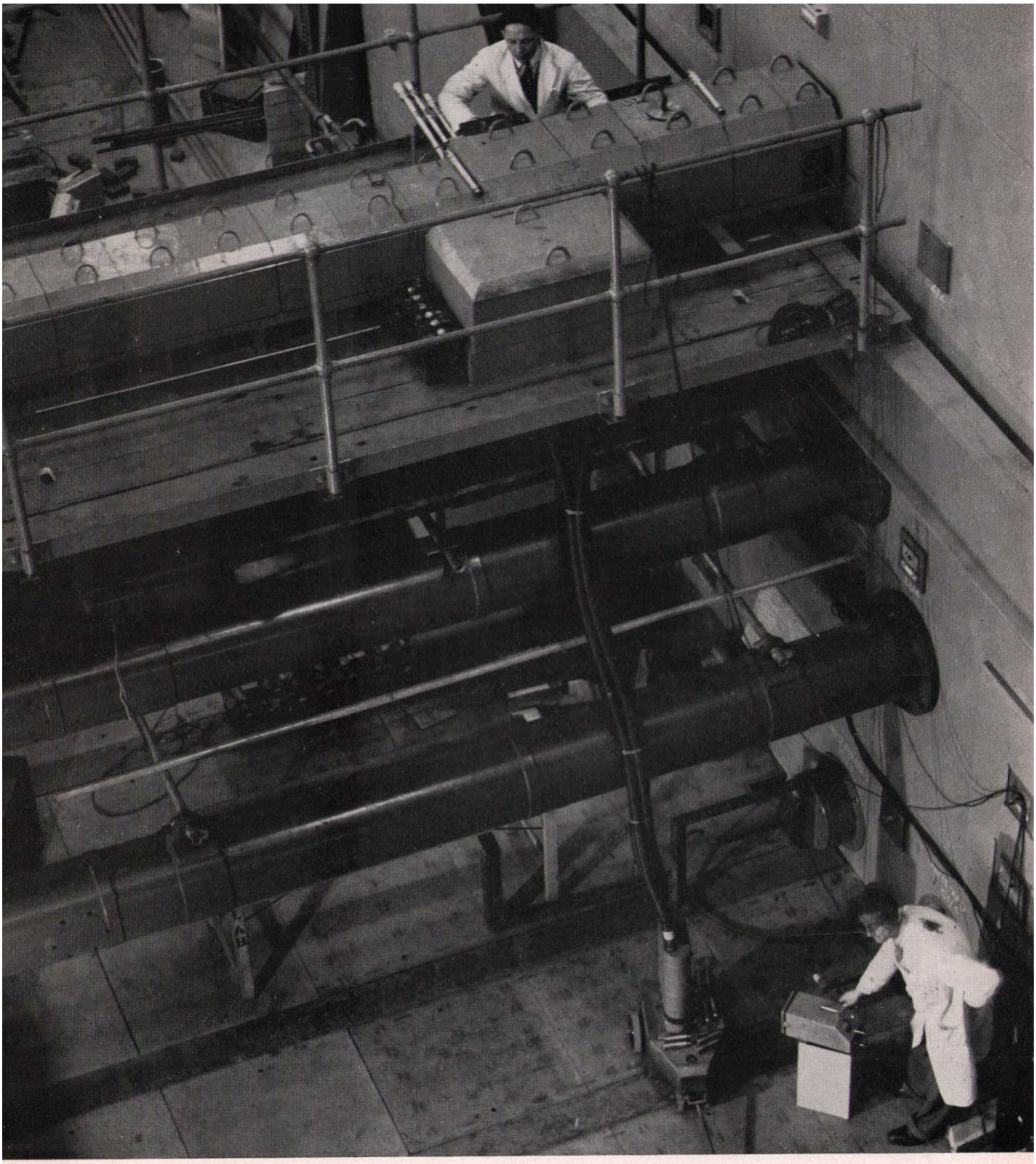
A great deal has been written about the possibilities of nuclear power, but it is now generally accepted that a considerable amount of development work is required before nuclear power can be produced on an appreciable scale. Three major problems in the field have to be solved, and Harwell is working on all of them. They are:—

(1) Breeding
(2) Materials
(3) Chemical processing

Breeding

The production of nuclear power depends on the "burning" of fissile material and only one fissile material—uranium 235—occurs naturally. However, in a natural uranium pile, the new fissile material plutonium is formed from U238 at the same time as U235 is consumed. It may be possible to design a pile in which more fissile material is produced than is consumed, and this process has been called breeding. Another possible method of breeding fissile material is to use the more readily available metal thorium, from which a fissile isotope, uranium 233, can be formed by a reaction similar to the production of plutonium from U238. Successful breeding would therefore make it possible to burn up stocks of U238 or thorium, and this is essential if economic power production on a significant scale is to be achieved.

The design of breeding piles is being studied, particularly by the Theoretical and Engineering Divisions. In addition to structural problems, the engineers are specially concerned with methods of removing by a suitable cooling fluid, the large quantities of heat produced. Neutron economy is of primary importance in any pile design, and apart from the data on raw materials mentioned in the next paragraph, the characteristics of all the nuclear reactions involved must be measured by the nuclear physicists.



Arrangements for radio isotope production in Bepo. Radio isotopes are produced in small aluminium cans, which are placed in graphite blocks and slid into the pile. After irradiation, the graphite blocks are withdrawn into the lead tunnel (on platform) and the cans automatically discharged through the flexible tube into the shielded container below.

Materials

There are three main requirements for a material which is to be used in a high power pile:

(a) It must not have a high capture cross section for neutrons.

(b) Its physical properties must not be adversely affected by neutron irradiation.

(c) It must be able to withstand moderately high temperatures.

Typical purposes for which materials are required in a pile are a moderator, a cooling fluid and a material for sheathing the fuel element. The investigation of new materials for such purposes involves the nuclear physicist, the metallurgist, the engineer and the chemist, and ranges from fundamental investigations of the molecular and crystalline structure of solids to engineering tests of the strength of materials.

Chemical Processing

After the fuel elements in a pile have been irradiated for some time, they must be removed, and the new fissile material produced separated from unused uranium or thorium and the unwanted fission products. This process must be economical, particularly in conserving fissile material, and it presents great practical difficulties because of the intense radioactivity of the materials. In addition, the large quantity of fission products, which include most of the activity present, much of it very long lived, must be disposed of safely. The solutions to these problems must be found mainly by chemists and chemical engineers.

The Future

Development has started of pilot scale power producing reactors to obtain experience in the technical problems to be solved. Five to ten years' work on these problems will probably be required before a good estimate of the economics and potentialities of nuclear power can be made, but there is cautious optimism about the long term future.

ISOTOPES

The production of radio-isotopes at Harwell began only a month after Gleep started up, and this work has received much press publicity, particularly following the successful exhibit at the British Industries Fair in May, 1949 [7]. In February, 1949, production was transferred to Bepo, and of the 150 irradiations carried out each month about two-thirds are for users outside the establishment ; principally hospitals and university research departments. Quite a number are sent overseas, including even air deliveries to New Zealand. The increasing applications of radio-isotopes and the new techniques involved are investigated by the establishment, often on behalf of industry.

The use of radium and radon in medicine has been well established for many years. These elements are still widely used but the new uses of radio-isotopes as tracer elements has spread into many fields of medicine. They help the study of the workings of the body, diagnosis of illness and, in some cases, treatment of disease. As an example radio iodine can be used to diagnose cancer of the thyroid gland and has been used experimentally for treatment of this disease. In industry too [8], tracer elements can be used to follow a particular substance through a complicated plant as, for example, the production of petrol from crude oil. In the metallurgical industry radio-isotopes are used to study the making of steel and cast iron and to measure the wear of metals by friction between surfaces. They can be used to measure the thicknesses of thin sheets, such as paper, and will probably be used to avoid the effects of static electricity in the paper, textile and plastic industries.

The Isotope Division is responsible for the production and distribution of isotopes and for assistance to users. Its constituent groups are briefly indicated below.

The technical and production group plans the weekly loading of the pile and designs special containers for sending active material by rail, post and air. The latter method of delivery is essential when short-lived isotopes are sent overseas.

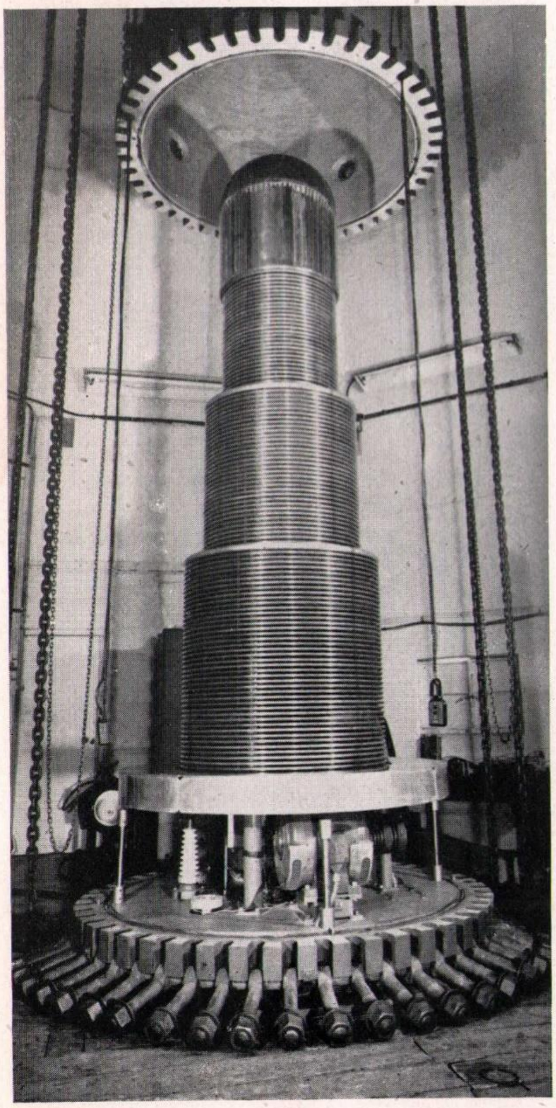
The physics group is responsible for standardization of active material, the investigation of special nuclear reactions and the application of isotopes to industrial purposes as outlined above. The work is largely that of applying existing counting and photographic measuring techniques and the development of new techniques to problems which arise.

The chemistry group is separating active material produced by nuclear reactions which result in an active product differing chemically from the initial target material. This group develops new methods of incorporating radioactive materials in suitable substances for medical treatment.

The production of stable isotopes of carbon and oxygen is carried out using the fractional distillation of liquid carbon monoxide in the case of carbon and thermal diffusion in the case of oxygen. By electro-magnetic separation processes milligram quantities of stable isotopes are being produced.

A mass spectrometer group provides a service which measures the isotopic abundances of stable isotopes, and also develops new mass spectrographic techniques.

Van de Graaff machine.



PHYSICS

Fundamental research in physics must play a large and important part in the work of A.E.R.E. For this work, several high energy particle accelerating machines [9] have been constructed.

A 110 in. frequency modulated cyclotron has been built to accelerate protons and deuterons up to an energy of about 200 MeV, which will enable the nuclei of most atoms to be broken up. It will also be used to make some new types of nuclei, which cannot be produced in piles, and it is hoped that the artificial production of mesons will be possible, as the maximum particle energy is in the region required to do this.

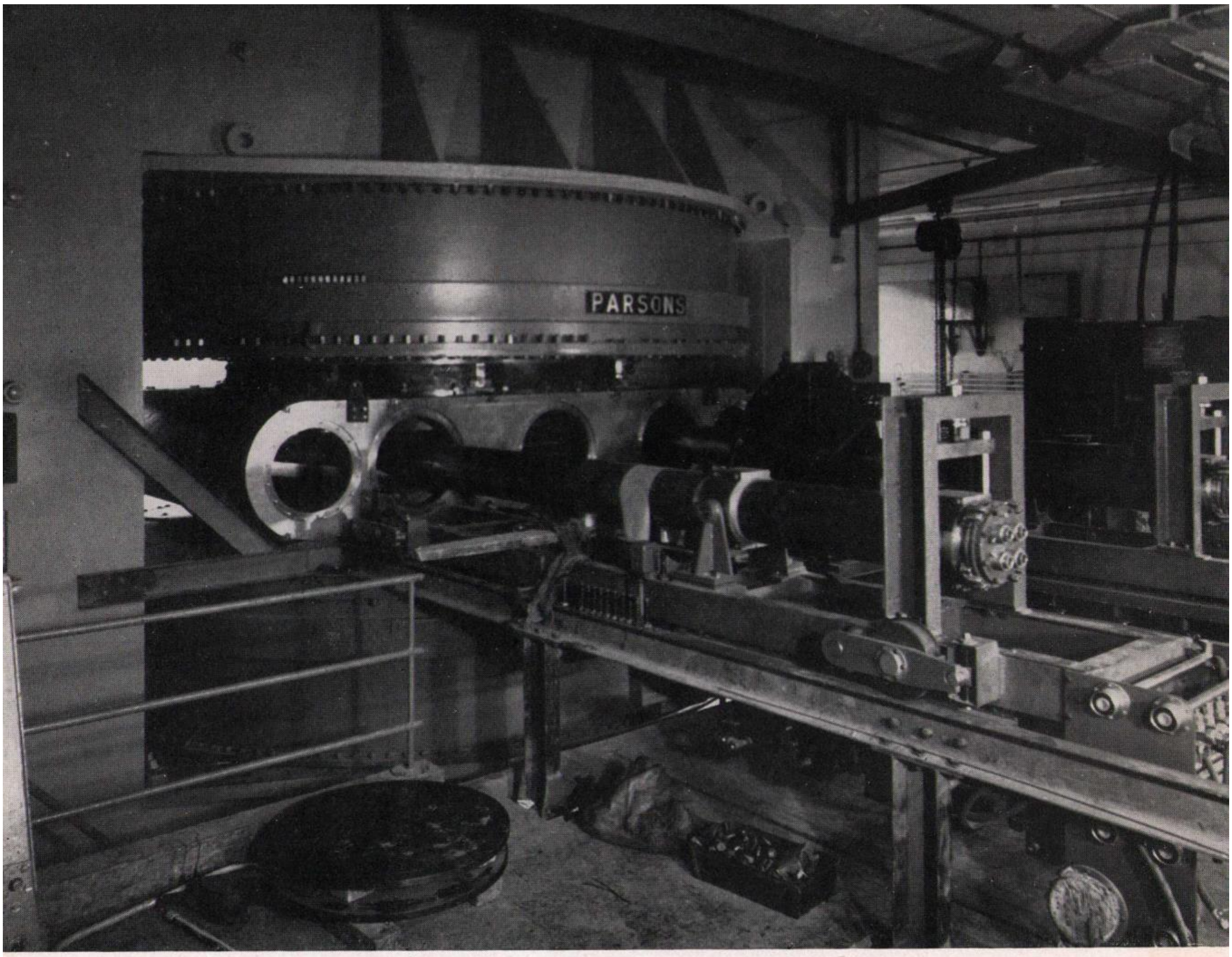
A 5 million volt Van de Graaff generator has also been built, and effort is now concentrated on the development of accelerating tubes suitable for the high potential gradient involved.

An A.E.R.E. group at Malvern is investigating linear accelerator and synchrotron methods of accelerating electrons to energies in the 1-1,000 MeV region[10]. Its main successes so far have been the production of the first working electron synchrotron in the world; the design, construction and successful operation of three 30 MeV synchrotrons; and the development of the travelling wave type electron linear accelerator for energies up to 4 MeV.

New techniques are being developed for the linear acceleration of electrons which will use dielectric loaded waveguides and high power pulse amplifiers working on a wavelength of 10 cms. When established these techniques should be satisfactory for electron accelerators to work in the region of 1,000 MeV.

Two operational 30 MeV synchrotrons are being used partly in studying further synchrotron developments but mostly in nuclear physics research. Photographic plate, ion chamber and counter techniques are being exploited to study new photo-disintegration phenomena. These include emission of alpha particles by light nuclei and fission in heavy nuclei.

The group is in very close touch with the physics departments of most of the major universities of the country, as well as with the Medical Research Council, since they are "customers" for these particle accelerators.



The cyclotron, showing the D leads being assembled.

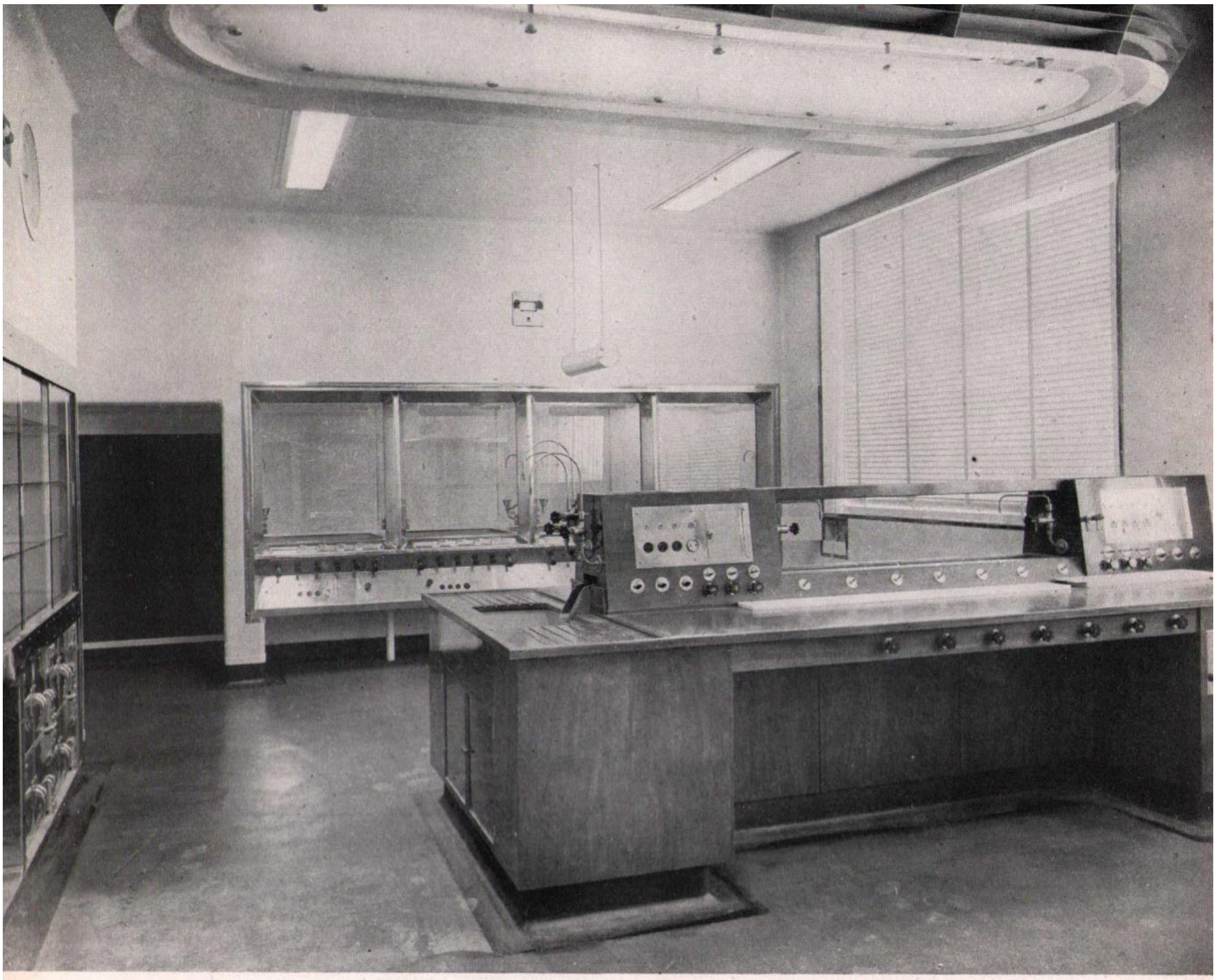
CHEMISTRY

Many vital steps associated with the atomic energy programme are chemical,[11] as for instance the separation of uranium and thorium from ores and the separation of plutonium and the fission products from uranium after irradiation in the pile. Furthermore, piles and other nuclear reactors consist of assemblages of materials which are frequently potentially reactive in a chemical sense, particularly at elevated temperatures and in high neutron fluxes.

Before the engineer can build a plant for the separation of plutonium or construct a new nuclear reactor, a vast amount of chemical work has therefore to be carried out, and since in many cases the basic sources of information in the scientific literature are inadequate, much of this work is quite fundamental in character.

Apart from the immediate demands of atomic energy technology, the chemistry must also press forward with research, sometimes in parallel with the nuclear physicist, on many lines which at present appear to have little immediate practical application.

The Chemistry Division is at present organised along the following lines. Research which is essentially technological in character, and short-term problems arising directly from pile or chemical plant development, are carried out by an operational group. Long-term problems of a more scientific nature, and also *ad hoc* problems for the operational group are undertaken by associated scientific groups



General view of a typical radiochemical laboratory. In the background is a fume cupboard for work with radioactive materials: left, glass-fronted store cupboards above lead lined storage space: right foreground, a bench for general work, in the ceiling above which is seen the ventilating air-inlet. Suspended from the ceiling, centre, is a cylindrical ionization chamber and, on the wall above the fume cupboard, an indicator for the measurement of radiation.

working on inorganic chemistry, physical chemistry, radiation chemistry and analytical chemistry. Work on fission products, and transuranic elements is carried out in a special radiochemical laboratory or 'hot' laboratory where all the facilities required for such work are available.

Special attention is being given both by the inorganic chemistry group and by the radiation chemistry group to the study of solid systems. The principles of ion exchange and chromatography are being investigated amongst other problems by the physical chemistry group; whilst a wide variety of analytical problems ranging from the determination of extremely small amounts of plutonium in urine to the analysis of uranium are tackled by the analytical group. There is a well-equipped spectrochemical laboratory with facilities for working in the infra-red, visible and ultra-violet spectral regions. Micro and ultra - microchemical techniques are being developed in connection with the work on the transuranic elements and there is a 2 million volt Van de Graaff machine for use by the radiation chemistry group in the study of the chemical effects of intense β and γ radiation.

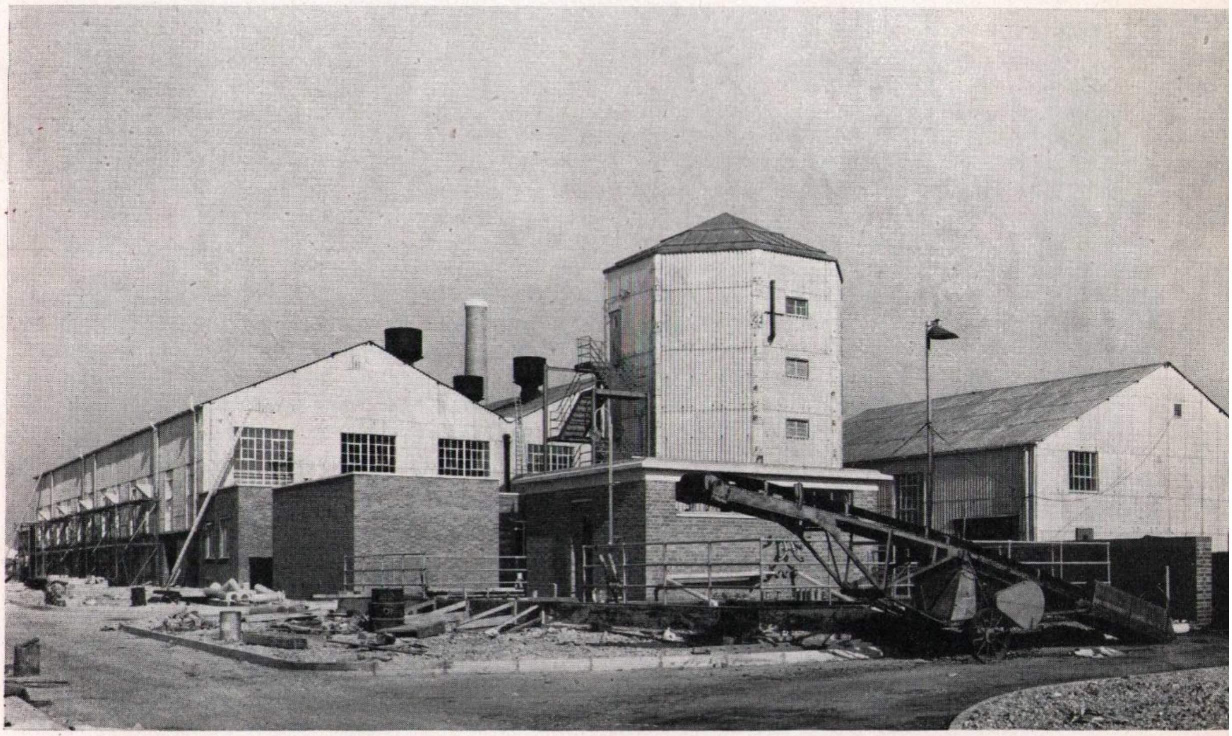
CHEMICAL ENGINEERING

The chemical engineer has an important part to play in almost all stages of the development of atomic energy, from the economic recovery of uranium from its ores to the reprocessing of the nuclear fuel and the safe disposal of the radioactive waste products. Many of the chemical engineering problems are similar to those met in other industries ; some are old problems in new guise; in others the physical and chemical properties of the radioactive elements introduce new problems. The chemical engineer in atomic energy makes use, somewhere or another, of all the unit operations and finds, sometimes to his surprise, that there are gaps in the fundamental information which have to be filled by extemporised experiment until the results of further fundamental research are obtained. Thus the chemical engineer at Harwell is required not only to apply his knowledge to a new field but to extend it in ways which may also be of wider general application.

The Chemical Engineering Division at Harwell has been divided into several inter-related groups, viz., Pilot Plant, Chemical Engineering Research, Mineral Dressing and Technology.

The pilot plant group's main job is the development of chemical processes, e.g. the separation of fission products from the nuclear fuel to enable it to be reused, both to prove the processes on the pilot plant scale and to obtain the data for full scale design. This group must make heavy calls on the chemist not only for the original processes but also for the large amount of analytical work required, and it is therefore staffed not only with chemical engineers but

The new Chemical Engineering laboratories.



with plant chemists and analysts. In the course of its work the group encounters problems of a fundamental nature ; sometimes existing design methods are not applicable or an explanation of anomalies is required. These problems are the concern of the chemical engineering research group. This group includes some physical chemists because many of the problems are of a physico-chemical nature, but in this field, as indeed in most others, there are close contacts with the Chemistry Division.

The mineral dressing group investigates methods, especially physical methods, for the enrichment of low grade uranium and thorium ores. In order to do this it needs mineralogical and chemical analysis for the selection of appropriate methods and for the appraisal of experimental results. This group therefore, comprises a team of mineral dressing specialists, mineralogists and chemists. This group too has its fundamental problems which, for example, may take the form of a new application of flotation technique or the study of the mechanism of electrostatic separation.

While the pilot plant and mineral dressing groups are mainly interested in the production and processing of the nuclear fuel, the technology group is interested in other materials used in reactor construction, e.g. graphite and ceramic refractories. The preparation and fabrication of these materials in an extreme state of purity introduce technical problems outside ordinary industrial experience. The technology group leans more to engineering than chemistry and therefore contains a high proportion of engineers.

It is characteristic of the work of the chemical engineer that he usually works in a team with his colleagues from other professions and the groups of the Chemical Engineering Division are in fact small teams in which the chemical engineer is the dominant element. Besides these internal teams there are, of course, inter-divisional teams working on the larger projects. The chemical engineer at Harwell has a wide field of interesting and intriguing problems and the benefit of contact with fellow scientists whose different outlooks and specialisations provide stimulation and encouragement in the solution of their common problem.

The groups whose functions are briefly described above have laboratory facilities to suit their needs. One laboratory block caters for work with materials that do not present any radiation hazards. This block includes laboratories specially designed as solvent areas with complete flameproofing, sections for the erection of pilot plant and for the mineral dressing equipment, workshops and stores together with laboratories of conventional type for laboratory scale work on unit operations, physical and chemical analysis and microscopy. Crushing, grinding and sampling of ores are provided for in an adjacent building of special design. Work with ceramic materials, and in particular beryllia, introduces dust hazards, and a building in which very special attention has been paid to ventilation and air filtration has been provided for it. Pilot plant work with radioactive materials has been given accommodation in the main radiochemical laboratory but plans to provide further accommodation for this type of work in a new 'hot' chemical engineering laboratory are in the design stage.

ENGINEERING

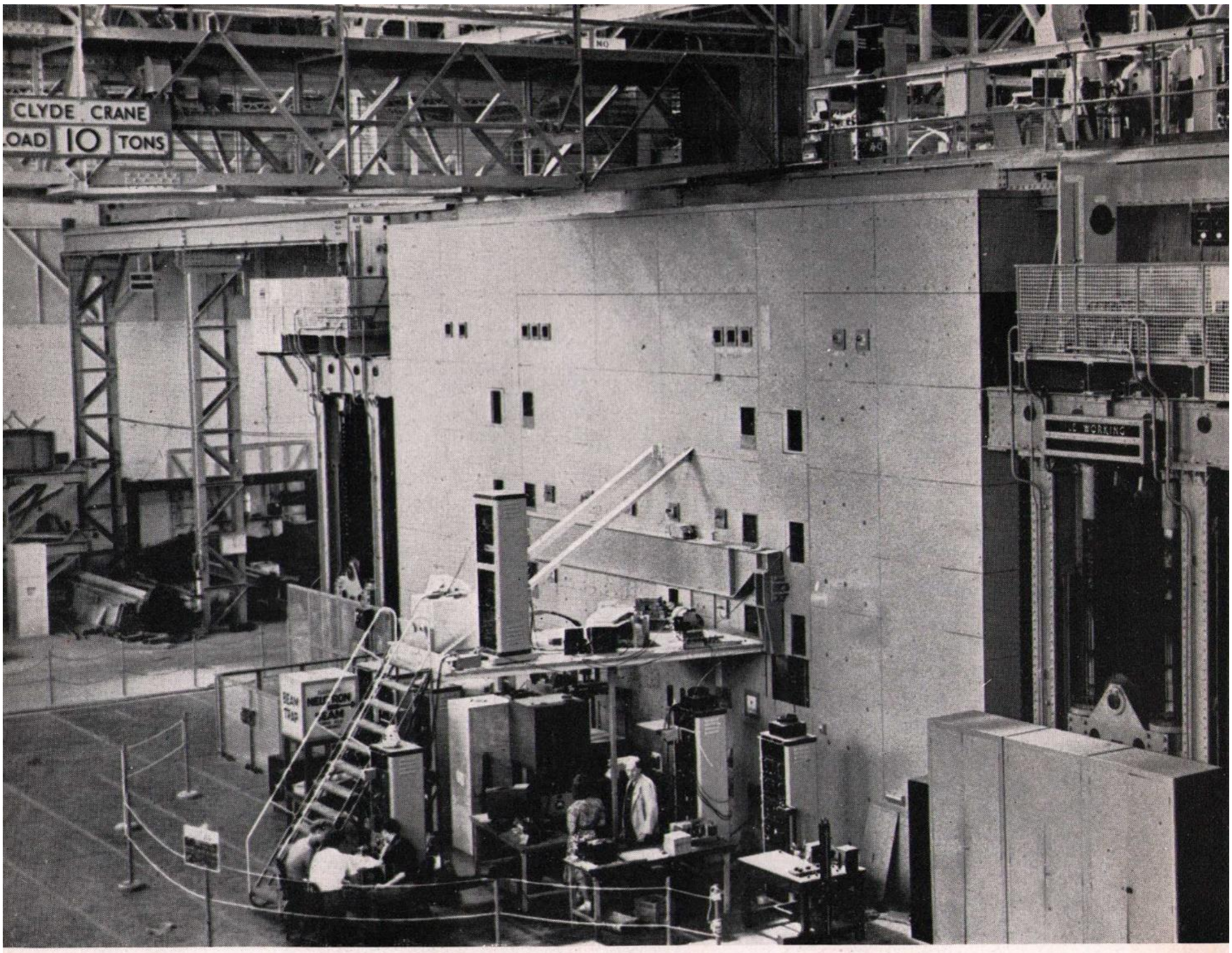
It is characteristic of research and development in the field of nuclear energy that the plant and apparatus required is large, complex and of a type that presents quite new problems.

The Engineering Division is responsible for the design, construction, operation and maintenance of much of this special plant, and for the engineering research and development required for future machines, notably reactors for the study of power generation. The scientific staff at Harwell have a continuing need for new apparatus and plant, and the design and drawing offices and the large workshops are designed and staffed to meet this demand, which covers many branches of mechanical, electrical and chemical engineering.

The workshops are equipped with almost every type of modern machine tool, and the standard of workmanship must necessarily be high. An important feature of the workshops organisation is the apprenticeship scheme for the training of craftsmen and future engineers in highly specialised work, as well as in normal workshop practice.

The operation and maintenance work carried out includes that of the Harwell piles and of the engineering equipment associated with the large machines used for nuclear physics research, such as the cyclotron and the Van de Graaff, and also the safe disposal of the liquid radioactive effluent and solid radioactive wastes.

The site services embrace water, electricity, steam, gas, compressed air, and more special



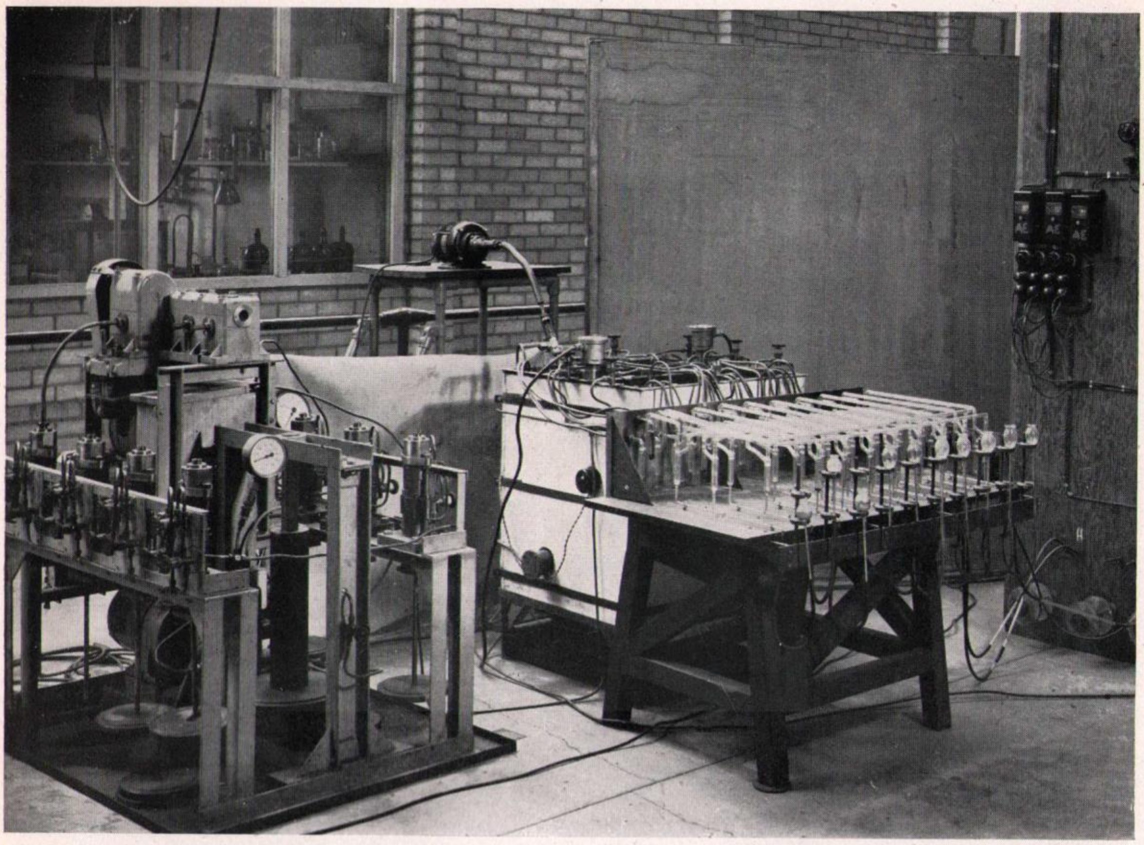
General view of Bepo experimental face.

services such as the operation and maintenance of the air conditioning plant in the "hot" laboratory, and of special experimental equipment in other laboratories.

The engineering laboratory, a new building, is equipped to deal with many special problems arising in nuclear research. Amongst these, heat transfer problems appear in the design of any pile, and particularly in the case of power-producing reactors these may be outside the limits of previous experimental work.

In the course of the design of the Harwell and production piles, experiments have been carried out on the flow of cooling fluids through pile channels and on the most efficient way of removing heat from the uranium cartridges. In view of the limits on the temperature at which aluminium canned cartridges can be used, these experiments have been of importance in ensuring a sufficient cooling rate for the piles. Similar problems are being studied in connection with the design of new reactors, including the use of liquid metal coolants.

Plans for the future naturally involve many other engineering studies, and here there is scope for the engineer who is interested in the fundamentals of his subject and who wishes to cross the arbitrary borders between engineering, physics and chemistry. There is opportunity for research and development on problems ranging from pure physics to very practical engineering and also in the project stage of the design of reactors and other future machines. There can be few better opportunities for the



Metallurgy Division. Equipment for measuring creep of metals during irradiation in a pile.

engineer to broaden his knowledge in the scientific as well as the practical aspects of his work than in the solution of these problems.

METALLURGY

The research activities of the Metallurgy Division cover exploration of methods for the extraction and fabrication on a laboratory scale of metals peculiar to atomic energy development, determination of the properties and behaviour of metals and their alloys for reactors, and investigation of such fundamental metallurgical pheonomena as diffusion in the solid state and creep. The division is also developing ceramics for use in metal extraction and processing, and as fuel and structural elements in piles.

Atomic piles with their ancillary power equipment and chemical processing will find application for many of the ferrous and non-ferrous metals and alloys of standard engineering practice, but the metallurgy of several metals, e.g. plutonium, uranium, thorium and beryllium, has to be learnt without the benefit of much previous knowledge and experience. It is on these specialised metals that effort is concentrated.

The work of the division is divided among groups of scientists with particular interests. One group is concerned with developing new or modified techniques for extracting uranium of high purity. Another group is exploring various methods of fabricating the special metals referred to above by casting, forging, pressing, rolling, extruding, drawing and swaging. The physical and mechanical properties of these metals (for which micro-techniques have to be developed in some cases) are being investigated. A third group is investigating powder metallurgical methods, and the problem of "canning" fissile materials is a major research for a fourth group.

Reactors developing useful power will use gaseous or liquid coolants and a section which studies the corrosion behaviour of reactor materials in a variety of media has been formed. This same group covers corrosion problems outside reactors, and it is attempting, for example, a fundamental study of the mechanism of pitting corrosion.

Within a reactor the materials of construction will be subject to irradiation by neutrons and γ-rays of high intensities. The effect of such bombardment upon the properties of reactor materials (and on metals and alloys in general) is being studied. For this study, special testing equipment and remote control gear is being devised for measurements on samples during and after irradiation.

Alloy systems of uranium are being explored since some alloys might have particular physical or chemical characteristics suited to special designs of reactor. It is hoped to relate the results of this work to present fundamental alloy theory. This requires a study of the crystal structure and metallography of the metals and their alloys, and the facilities for doing this are available. The ceramics group is exploring methods of preparing, fabricating, and testing non-metallic compounds of fissile metals, since the properties of such materials might be attractive in other types of reactors.

The production at Harwell of radioactive isotopes affords a unique opportunity to the metallurgist there to develop tracer techniques in the solution of his problems, the use of radio tracers in such a way is being explored.

THEORETICAL

A great variety of problems arises in the work of the Theoretical Division. Most attention has naturally been focussed on the design of piles and the development of advanced types of nuclear reactors, in particular for the production of power in useful form. The theoretical workers are closely associated with experimenters and engineers in the initial conception of the general development programme, in the detailed design and research work for each reactor, and in the construction and early stages of operation. A great deal of this work is of a nature to appeal to those who prefer to contribute to a definite practical project. At the same time many associated problems lead to research of mathematical interest. 'Laplace transforms', 'Spherical harmonics method', 'Integral equations', 'Systems of orthogonal functions' are household words. They are associated with the systematic development of neutron diffusion theory beyond the stage which it had reached in wartime researches, in order to make it applicable to the new problems arising in the development of atomic energy. The more fundamental work in the field is not secret and several papers have been accepted by scientific journals for publication[12] [13].

The nuclear properties of isotopes and the properties of the radiations they emit are being studied ; in many instances they are related to practical problems such as nuclear cross sections for reactor design, radiations from fission products, penetration of gamma-rays through shields, Bremsstrahl spectrum for the synchrotron. But with the start up of the cyclotron, and other high energy particle accelerators, more attention will be focussed on fundamental problems in nuclear physics.

A field which has as yet barely been touched by theoretical physicists is the use of neutron radiation for the investigation of the properties of solids. The possibility of producing interstitial atoms by neutron impact and of studying their effect on various properties of the solid, as well as their return to normal lattice positions, promises a method for obtaining a deeper understanding of the kinetics of atoms in the solid state, and perhaps for the production of materials with specific desired properties.

The theoreticians are also concerned with some of the medical and health problems arising from the use of radioactive materials. Problems of turbulent diffusion of fission products in the sea and their subsequent dispersion or deposition on the shore have been treated. Maximum permissible concentrations in air, sea or drinking water have been calculated and the problem of neutron dosimetry for medical applications has been tackled.

A small computing section is attached to the Theoretical Division ; the nature of the jobs for this section varies from routine computing to intricate analysis. This work offers considerable scope for the use of advanced numerical techniques.

Using a personal health monitor. Clothing is being tested for contamination by a counter. The rubber-covered apertures are for hand testing. Footwear is tested by the stand.

ELECTRONICS

Electronic equipment is used in nearly every part of Harwell and the electronics division is responsible for the design and development of the apparatus required, which falls in three main classes:

(*a*) Electronic measuring apparatus

(*b*) Radiation monitoring apparatus

(*c*) Electronic control apparatus

In the first class, Harwell is concerned with the development of electronic counting equipment for nuclear physics investigations, for radio assay, and for field surveys. The equipments range from single counting sets comprising Geiger-Muller counters, amplifiers and scalers, to elaborate pulse analysers [14]. About 30 different equipments are being developed.

In the second class, radiation monitoring equipment is being developed for use both by Harwell and by universities and other research organisations working with active materials. About 20 different types of monitor are required, usually in quantities of the order of 100-500. In most cases thermionic valve instruments are used for this class of work, but some use is made of quartz fibre electrometers.

Electronic control equipment is used in most major projects, particularly the Harwell Piles, and new apparatus is being designed for the production piles and chemical separation plant.

Development and production of special components is undertaken for all classes of electronic equipment, particularly Geiger-Muller counters, ion chambers, electrometer valves and high value resistors.

HEALTH

Some of the work at Harwell involves exposure to radiation and toxic substances, and because of the possible health hazard, very strict precautions are taken [15]. The health of all staff is the responsibility of the Medical Division, which examines all newcomers when they join the establishment and at periodic intervals afterwards. Blood tests are made on workers exposed to radiation, as changes due to exposure can be detected in this way before any harm is done.

The Health Physics Division is responsible for monitoring the amount of radiation and radioactive contamination present in laboratories. This division is also responsible in collaboration with the Electronics Division, for the design of instruments for this purpose. For all types of radiation a maximum safe weekly dose is laid down, and measurements are aimed at ensuring that this dose is not exceeded. The simplest 'meter' is a small photographic film carried by all workers in active areas, which is developed each week, the exposure being deduced from the amount of blackening. In very active areas, workers carry pocket condenser chambers, from which they can see visually the amount of radiation to which they have been exposed since the chamber was charged.

In pile buildings, in active laboratories and in the grounds, fixed monitoring instruments are installed which provide a continuous record of radiation. Portable instruments are used for many purposes, such as detecting contamination of laboratory benches or clothes, and checking the radiation present during operations such as unloading materials from a pile.

As a result of these precautions, the actual exposure of staff to radiation is maintained well below the level which has been recommended by the Medical Research Council as the maximum permissible value which can be accepted over an indefinite period.

SCIENTIFIC CONFERENCES LECTURES AND TRAINING

You may have read in the pamphlet 'Scientists in the Civil Service', something of the way in which Government scientists can participate in meetings with scientists from universities, industry and other research establishments, and of arrangements for post graduate training. Such activities are regarded at Harwell as being an essential way of stimulating the research worker to keep up to date in his field.

Many of the conferences and meetings mentioned in the succeeding paragraphs are of such interest to the work of the establishment that they are considered as part of the official duties of the staff who attend them. In other cases the official interest is less direct, but may still be sufficient to justify giving special leave to a man who is keen enough to go to a conference or lecture at his own expense.

Harwell has been represented at most important scientific meetings held since 1946, including during the last year the International Physics Conference at Basel and Como, the International Conference on Electron Microscopy at Delft in Holland, the Faraday Society Discussion on Chromatographic Analysis and the Instruments and Measurements Conference at Stockholm.

The establishment also plays its part in organizing conferences ; in March, 1949, a Symposium on 'The chemistry of the heavy elements and on the preparation and use of radio tracer

Main Workshops.

elements' was organised jointly by the Chemical Society and the Harwell Chemistry Division, and an International Nuclear Physics Conference is to be organized in 1950.

Other formal contacts with universities are maintained through attendance at summer schools: in 1949 these included post graduate courses on the theory of crystal growth at Bristol and on X-ray crystallography at Leeds—but there are, of course, many informal contacts to supplement formal visits. A special arrangement with Oxford University enables Harwell staff to attend university lectures.

Fortnightly colloquia are held in the Establishment and these are often given by well-known visiting scientists: the range of subjects covered in this way is very wide, as can be seen from the fact that among the many visitors who have lectured to us during the last year are Professor E. N. da C. Andrade and Professor D. R. Hartree, Dr. B. Schonland of the South African C.S.I.R., Professor E. R. W. Steacie of N.R.C., Ottawa, Professor M. Born, Professor M. A. Bethe of Cornell University, Professor I. I. Rabi of Columbia University, Professor Teller of Chicago University and Professor MacMillan of Berkeley University.

More general lectures about the work of the establishment are arranged for junior staff and most of the research divisions organize colloquia or discussion groups covering their own particular fields.

A considerable proportion of the work at Harwell is not secret, and staff may publish the results of such work and exchange visits with other scientists. Over 100 papers by members of Harwell have been accepted by the Scientific Journals in the last three years, among them being several on the linear accelerator and synchrotrons, chemical papers on ion exchange and spectrographic analysis, and papers on isotope production and use, electronics, nuclear physics, and neutron diffraction.

The establishment and individual members of the staff are frequently asked to give lectures to learned societies and other organisations. For example, an important series of lectures on 'Engineering Problems of Nuclear Power' was given in 1949 at Imperial College, London, by Dr. Buneman and Mr. Diamond. Such important lectures are given by the Director and by senior members of the staff, but lectures to restricted groups—such as college scientific societies—or on special topics are often undertaken by junior staff.

The policy of the establishment is to encourage interchange of staff with the universities. Five university chairs have been filled from Harwell and a number of other university appointments have gone to Harwell staff.

In addition to post-graduate training, which has already been mentioned, provision is made for junior staff to continue their education by part time study. In approved cases time off is given up to a maximum of one day per week, and assistance is given with fares and course fees. The amount of assistance given depends on the course taken and the grade of the student.

HOUSING AND AMENITIES

The R.A.F. aerodrome at Harwell, which was taken over to house A.E.R.E., is in the Berkshire Downs, 13 miles South of Oxford. The illustration on the back cover shews a general view from the downs to the South of the site. The 'hot' chemistry laboratory is at the extreme left, the four hangars housing piles, cyclotron and Van de Graaff machines are in the centre, and on the right can be seen one of the two estates of 100 prefabricated houses which have been built along the old aerodrome runways.

The first picture in the book is taken from within the establishment looking East and shews one of the new blocks of laboratories and offices completed in 1949. On the left is the sports field which includes cricket, hockey and football pitches. There are also tennis and squash courts and rugby pitches. Just off the picture is the old R.A.F. Officers Mess, now one of five hostels for unmarried staff.

All the living quarters and recreational facilities are outside the perimeter fence, and there are, of course, no restrictions whatever on private visitors to residents. New brick houses have been built in Abingdon and Wantage, and about 350 families are housed on new estates in these towns.

Access to London and Oxford from Harwell is quite easy. There is a local bus service to Didcot, whence there is a good train service to London, the journey time averaging $1\frac{1}{4}$-$1\frac{1}{2}$ hours. There is an hourly bus service from Oxford to Newbury which runs past the establishment.

RADIOCHEMICAL CENTRE, AMERSHAM

Since the body of this booklet was prepared, it has been announced that the Radiochemical Centre at Amersham, Bucks, previously operated by Thorium Ltd., as agents for the Ministry of Supply, becomes an outstation of the Atomic Energy Research Establishment as from 1st April, 1950.

The Radiochemical Centre was set up after the end of the war to provide central facilities in this country for processing and distributing radon and radium to meet the requirements of medical and industrial users and for research workers. These materials are produced in a wide range of sizes and forms to meet specialist requirements, and although the use of radioactive isotopes is extending in many spheres, the natural radioactive substances, particularly radon, are likely to remain in heavy demand for a long time yet.

The conditions under which radium and radon are handled at Amersham represent a considerable advance over those applying to earlier production ; ventilation, monitoring, and general health precautions follow the latest accepted standards.

In addition to the radon and radium processing laboratories there is a chemical section at Amersham which has specialised in the synthesis of organic compounds containing C_{14}, which are in considerable demand for research work. The activities of this group are likely to be extended, and Amersham is also taking on other radiochemical work in aid of the atomic energy research programme.

There is a physics section which is responsible for the measurement and standardisation of radioactive sources produced at Amersham, and also for the health physics requirements of the establishment.

REFERENCES

(1) Nature, **162,** No. 4113, p.317 (1948).

(2) The Engineer, **186,** No. 4826, p.91 (1948).

(3) Bull. of Atomic Scientist, **4,** No. 4, p.107 (1948).

(4) Nature, **160,** No. 4066, p.451 (1947).

(5) Research, **2,** No. 2, p.73 (1949).

(6) The Engineer, **188,** No. 4876, p.48 (1949).

(7) Nature, **163,** No. 4155, p.942 (1949).

(8) Paper Making and Paper Selling, Oct. 1949.

(9) Proc. I.E.E., **36,** Pt. I, p.77 (1949).

(10) Reports on Progress in Physics, **12,** p.102 (1949).

(11) Research, **2,** No. 3, p.115, (1949).

(12) Nature, **163,** No. 4136, p.211 (1949).

(13) Reports on Progress in Physics, **12,** p.291 (1949).

(14) J. Sc. Inst., **26,** No. 4, p.124 (1949).

(15) Royal Inst. of Chem., Lectures, monographs and reports, No. 4, p.49 (1949).

General view of A.E.R.E. from the Ridgeway, which runs along the downs South of the site. One of the prefabricated housing sites is seen on the right.

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