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The Rutherford High Energy Laboratory

The National Institute for Research
in Nuclear Science

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The National Institute for Research in Nuclear Science

The main spearhead in experimental physics during the last fifty years has been towards probing more and more deeply the ultimate structure of matter. In this activity, the part played by particle accelerators has been an increasing one.

After the structure of the electron cloud forming the outer part of the atom had been elucidated some thirty years ago, the charged nucleus became the focus of attention. It gradually became clear that in order to understand the forces holding the nucleus together, the structure and interactions of the neutrons and protons themselves must be further explored. Such exploration is in the forefront of physics today, and has revealed phenomena quite unsuspected when the theory of the nucleus as a whole began to take shape.

In particular, many new elementary particles with short lifetimes have been discovered. Certain regularities in their properties are observed, and in many ways the situation is reminiscent of that existing fifty years ago with regard to the periodic table of the natural elements. These particles decay very rapidly, and can only be produced in nuclear collisions in which the energy available in the centre of mass system is of the same order as the particle mass; in practice this requires proton beams with energies of several thousand million volts. It seems clear that a careful study of their formation, interactions and decay will be necessary before a satisfactory description of the nature of the nucleon can be obtained.

In microscopy, closer and closer examination of small 'objects' requires shorter and shorter wavelengths, and good illumination. In a somewhat similar way to bring out the finer details of nucleon behaviour has required the provision of intense beams of particles with ever increasing energy.

This trend to more energetic beams has made the provision of increasingly large accelerators necessary. Thus, to relieve universities of the increasing burden of having to build and operate such machines, the Government in March, 1957, set up the National Institute for Research in Nuclear Science to provide facilities for nuclear physics research which would be available for common use by universities and similar institutions.

The Institute is an independent body having received a Royal Charter in 1958. The governing board comprises representatives from the universities, the Royal Society, the Department of Scientific and Industrial Research, the University Grants Committee and the Atomic Energy Authority. The first laboratory of the Institute is the Rutherford High Energy Laboratory situated near the Atomic Energy Research Establishment at Harwell and occupying a site of some 75 acres. The Laboratory is being equipped to carry out research into the physics of the nucleus, and the structure and interactions of elementary particles. The main equipment of the Laboratory will consist of two proton accelerators: a 50 MeV proton linear accelerator already in operation and a 7 GeV proton synchrotron (NIMROD) at present under construction. The Laboratory will also contain supporting facilities for conducting experimental work.

In order to use these machines profitably, to make the complicated and difficult measurements which are required to help elucidate some of the baffling problems associated with ultimate nature of nuclear matter, a considerable amount of auxiliary apparatus of varying degrees of complexity and sophistication is required. While the design of the accelerators is the task of the Institute alone, the design and provision of this apparatus and its application to the problems of measuring nuclear properties is shared between the Institute and the universities. Much of this instrumental work requires the applications of wider technologies, such as cryogenics, optics, electronics, and data handling, to the special problems of nuclear measurement.

THE PROTON LINEAR ACCELERATOR

The 50 MeV proton linear accelerator was designed by the Atomic Energy Authority and handed over to the Institute in 1959. The machine consists of three cylindrical resonant cavities, placed end to end, into which pulses of protons are injected at 500 KeV from a Cockcroft-Walton generator and accelerated successively to energies of 10, 30 and 50 MeV. Each resonant cavity is contained in an evacuated tank, the total length of three tanks being some 100 ft. Each cavity is excited into resonance at 200 Mc/s from pulsed high frequency power supplies and contains a series of hollow cylindrical electrodes known as drift tubes spaced at intervals down its axis, and it is in the gaps between successive drift tubes that the acceleration occurs. Each pulse lasts 200 microseconds and the repetition rate is 50 pulses per second.

Emergent pulses of protons pass through a concrete shielding wall into the experimental area where the apparatus for experiments in nuclear physics is set up. In order to make the most efficient use of the machine, a bending magnet has been installed which deflects the proton beam in one of five or more directions, thus enabling several sets of apparatus to be set up and left undisturbed. In addition to performing experiments with 50 MeV protons, the machine has been designed so that it is possible to obtain protons at energies of 30 and 10 MeV. It is also possible to accelerate protons with their axes of spin substantially aligned in one direction; such 'polarized' beams enable those features of the complicated proton-nucleon and proton-nucleus interaction which are connected with the proton spin to be explored in more detail.

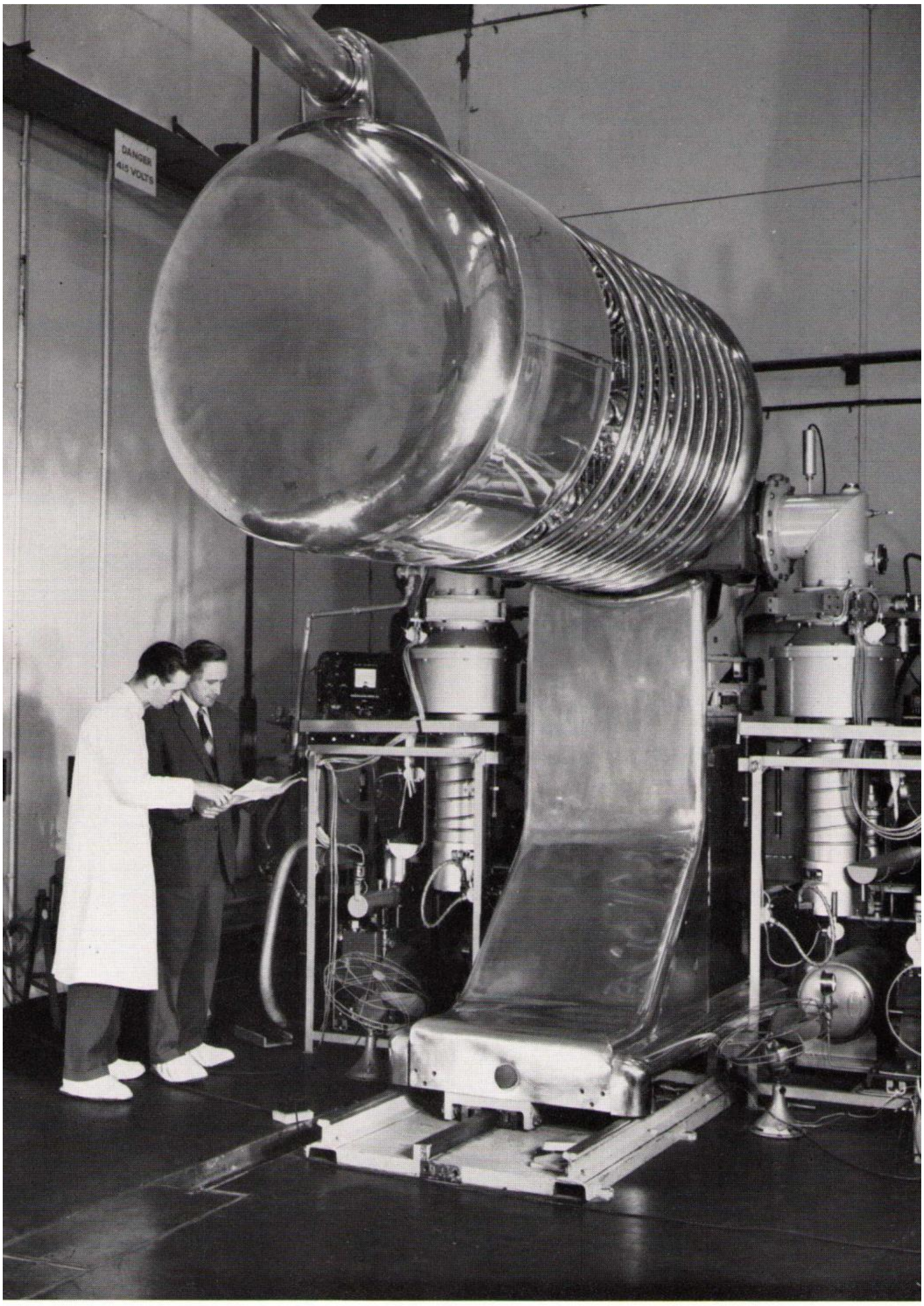
The maximum proton current which has so far been achieved is 4.5 micro-amperes (2.7×10^{13} protons/sec). This is many times greater than has been achieved with other accelerators of this kind. Furthermore, the beam has a well defined energy, giving the high resolution required in precise measurements. The machine may be extended at a later date by the addition of further sections to give a beam of higher energy.

NIMROD (7 GEV PROTON SYNCHROTRON)

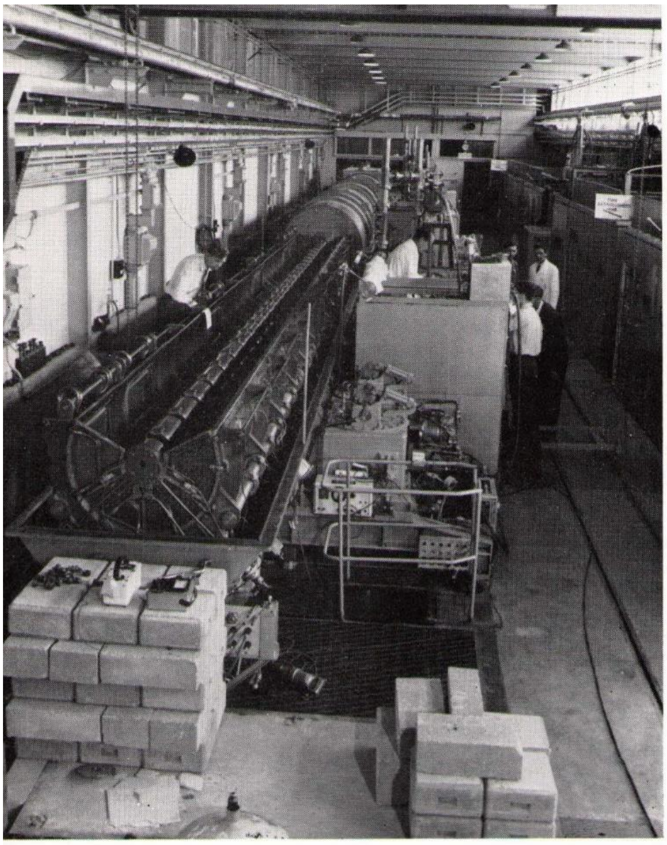
The main physical feature of the 7 GeV proton synchrotron, at present under construction, is a large ring-shaped electromagnet, 160 ft in diameter, which weighs 7,000 tons. A toroidal-shaped evacuated chamber made from glass-fibre reinforced epoxy resin is situated between the poles of this magnet A 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 orbit in which they receive an acceleration from a radio-frequency electric field once in each revolution. After approximately a million revolutions the protons reach their maximum energy; they are then either extracted from the vacuum chamber or allowed to bombard internal targets, the resulting secondary particles being channelled into an adjoining area where they will be used for experiments. During the acceleration period, lasting about three-quarters of a second, the magnetic field strength and the frequency of the electric accelerating field have both to be increased steadily 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 a 6 ft concrete roof on which a 20 ft layer of earth is placed as additional radiation shielding.

Heavy currents up to 10,000 A with an applied voltage up to 15 kV are needed to energise the electromagnet during the short acceleration time. The power supply used consists of a motor-alternator set, incorporating flywheels connected to the magnet through a bank of rectifiers. This equipment supplies direct current of gradually increasing strength during the $\frac{3}{4}$ sec acceleration period, and the current decays again to zero in a further 0.8 sec, ready for the next pulse. Energy is thus stored in the magnet during the current-rise period and is subsequently returned to the flywheels as the current is reduced again to zero. The amount of energy being shuttled to and fro amounts to some 40 megajoules. In this way, the flywheels act as a buffer between the load (the magnet windings) and the electrical supply.

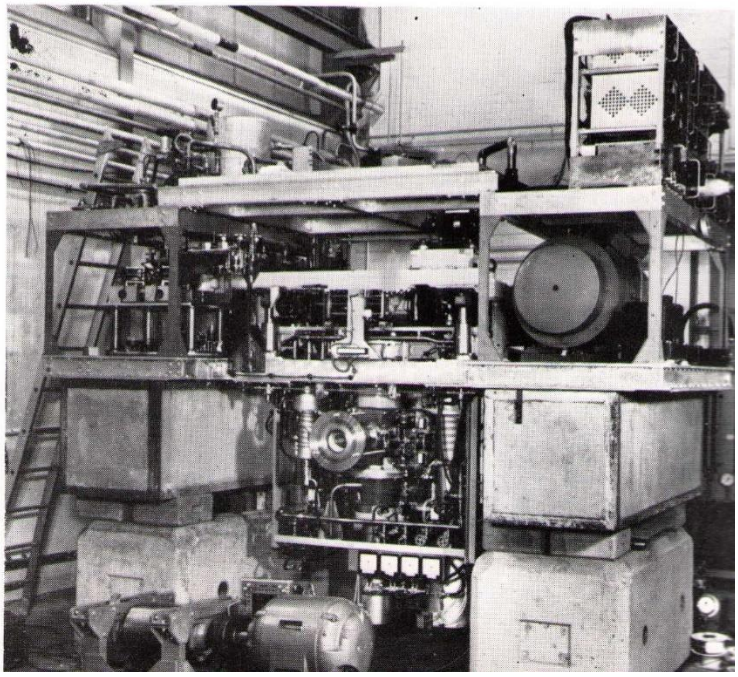
The machine is designed to produce at least 10^{12} protons per pulse at a repetition rate of 28 pulses a minute; this is equivalent to about one-tenth of a microampere which, although small in some contexts, represents a high current for such a machine. When completed NIMROD will be used for fundamental research into the physics of elementary particles, in particular the recently discovered unstable strange particles (hyperons and heavy mesons) and antiparticles.



600 KeV ion gun or pre-injector



A general view of the 50 MeV proton linear accelerator from the output end, with the vacuum and lower lid off the third tank, showing the drift tubes



Polarized proton source on support frame (under test)

As described above, NIMROD will produce pulses of some 10^{12} protons about every 2 sec. In order to make good use of these protons, much remains to be done. In general, the beam has to be extracted, or else the particles produced when it strikes an internal target have to be extracted as a beam. This leads to many challenging experimental and theoretical problems in charged particle optics; beams have to be formed and 'cleaned' so that they contain only the required type of particle, and a limited range of energies. The design of deflecting, focusing and particle separating systems is made more difficult by the large physical size and power consumption of the units involved. Economy as well as precision in design is, therefore, essential.

Having produced a beam, interactions with some 'target' must be observed. Such interactions are generally complicated in the sense that collisions may occur in which one of several things can happen, and more than one particle is produced. When sorting out the statistics of such events the advantage of visual techniques in which these collisions can be 'seen' is obvious. At these high energies the pioneer visual detector, the cloud chamber, has been largely replaced by the 'bubble chamber' in which the roles of gas and liquid are interchanged. A further visual device, the 'spark chamber' where the particle betrays its path by triggering a series of sparks is now gaining in importance.

The bubble chamber is a complex and expensive piece of apparatus, requiring the merging of several branches of technology, viz., magnet engineering, cryogenics, optics and photography. A table showing bubble chambers being prepared for use on NIMROD is given overleaf.

These chambers have been initiated by university groups, but a considerable contribution to their design and operation is being made by the staff of the Rutherford Laboratory.

Although visual techniques are especially important at high energies, considerable use is made of counter techniques also. Scintillation counters may be used for particle detection, as at lower energies, and much use will be made of Cherenkov counters. Since the direction of the Cherenkov radiation from a moving charge is a function of its velocity and of the medium through which it travels,

Chamber	*Length of active material*	*Universities involved*	*Remarks*
'National Hydrogen'	150 cm	Imperial College, Birmingham and Liverpool	Nearing completion at the Rutherford Laboratory; to be used at CERN before returning for NIMROD operation
16 in. Hydrogen	40 cm	Imperial College	Completed, and presently at Saclay
Heavy Liquid		University College, and National Institute	Under construction
Helium	100 cm approx.	Oxford	Design study under way

optical systems can be devised which effectively measure the velocity of the particle.

Having obtained a large number of photographs of the tracks in the bubble chamber, for example, considerable effort is needed to sort them out and elucidate the information which they contain. To do this such topics as 'picture recognition' and large-scale 'data handling' by computers become very important, and much development is needed. These problems have much in common with those in other branches of applied physics and engineering, and involve extensive use of computers. At present the Institute's computing programme is carried out using the Mercury and IBM computers of the U.K.A.E.A. but a Ferranti Orion is now on order for delivery in September, 1962. The Orion is a fast, modern computer using transistors and having a very comprehensive instruction code and built-in time-sharing facilities. The version on order will have a 16,000-word core store, two 16,000-word drum stores and six magnetic tape decks.

RADIOCHEMICAL LABORATORY

A radiochemical laboratory consisting of four 'hot' laboratories is being set up for use by chemists from universities and the Atomic Energy Authority who wish to study chemical problems using the particles from the high energy machines.

2

The work of the Rutherford Laboratory

The previous section has described sufficient of the work of the Laboratory to show that exploration of the nucleon, like the exploration of space, is an enterprise which requires the co-ordination of very many specialised skills and interests. Although very few physicists are able to understand fully the intricacies of nuclear theory, or even to assess the precise significance of the experiments they are doing, most will be able to get a feel for the general nature of the limitations to our understanding of the behaviour of the elementary particles, and the progress which is being made, by attending some of the frequent lectures by specialists held at the Laboratory. An effort is made to avoid a too rigid division of the work in to specialised groups, and changes of staff from one sphere of work to another are encouraged.

Below, to illustrate further the diversity of work covered, are brief reports of the various sections at the time of going to press.

THE PROTON LINEAR ACCELERATOR

The Proton Linear Accelerator (P.L.A.) group is divided into three sections, all strongly dependent on one another, concerned with engineering, accelerator physics and nuclear physics.

The engineering section is responsible for operation and maintenance of the machine, and for supporting the work of the other two sections; in particular by designing and manufacturing either locally or in collaboration with outside firms much of the apparatus which they require.

The accelerator physics section is concerned with the study and understanding of the accelerator in its present form, with studies towards possible improvements (including extending the energy by the addition of further accelerator cavities), and with studies which might lead to the construction of radically new types of P.L.A.

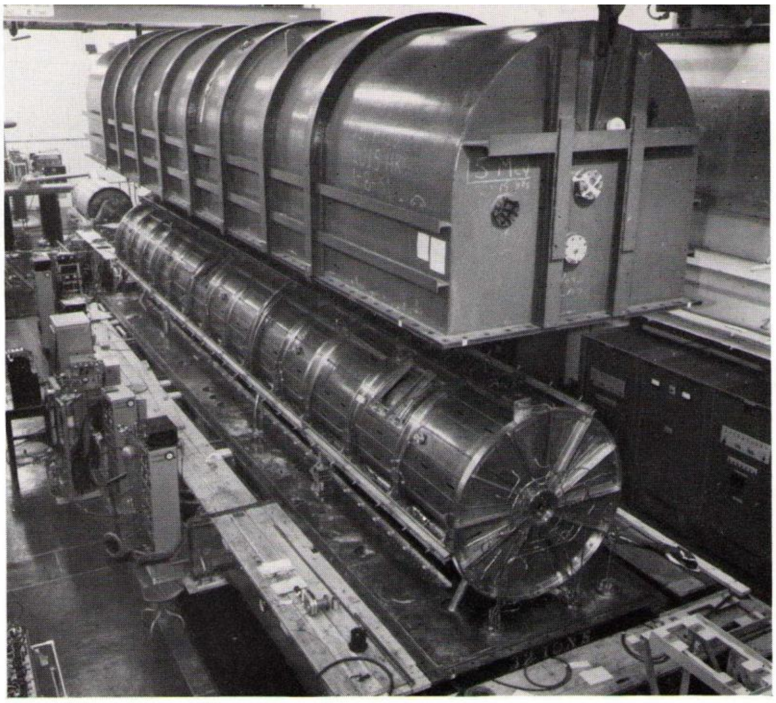
The most important adjunct to the machine provided by this group so far has been the polarized ion source; beams of nearly 10^8 protons per second with 30 per cent polarization have been achieved. The combination of high polarization, control of polarization direction, intensity, energy range and flexibility make this installation unique in the world.

Looking further towards the future the group is also studying the possibility of using superconducting cavities. These hold promise of reducing by orders of magnitude the high frequency power requirements, so that continuous rather than pulsed operation can be contemplated.

The experimental nuclear physics programme is at the moment being carried out by teams of physicists from the universities of Oxford, Birmingham, Manchester and Glasgow, King's College and University College, London, and the Atomic Energy Authority, together with the resident Nuclear Physics Group of the Rutherford Laboratory.

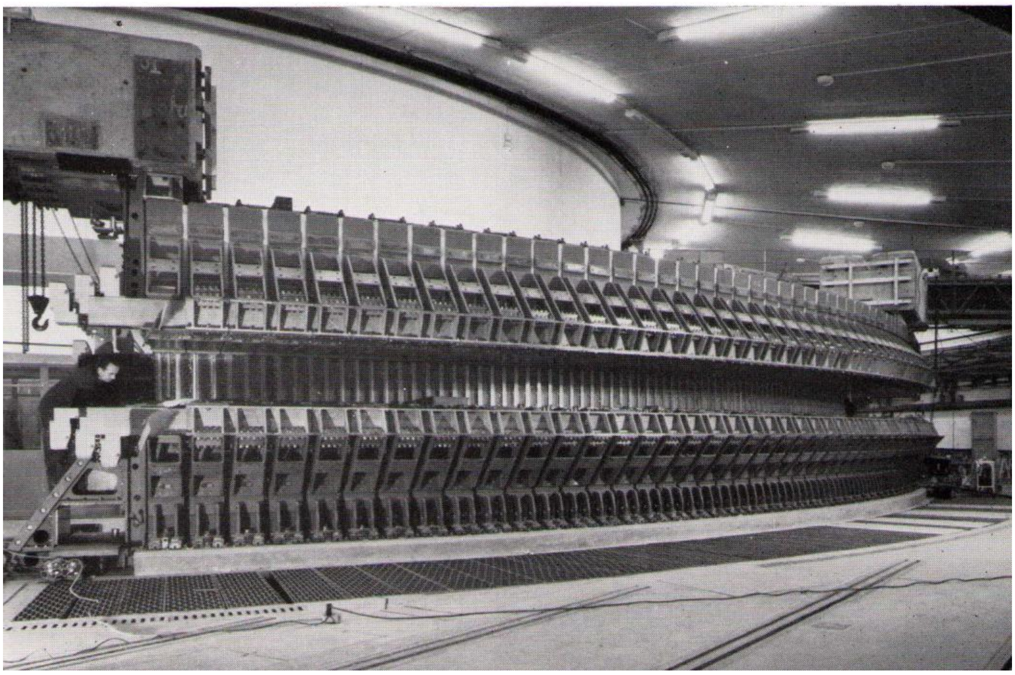
Two main fields of study at present are the proton-proton interaction, and the interpretation of interactions between the proton and the nucleus in terms of the 'optical model'. In the first of these topics the effect of spin on the direction of scattering is being studied with the polarized beam. In a further experiment, where an unpolarized beam strikes a liquid hydrogen target, the relative spins of recoil and scattered protons are determined. The spin direction of these protons can be found by letting them impinge on a further target (for example, helium gas at a pressure of 20 atmospheres) in which the direction of scatter depends in a known way on spin.

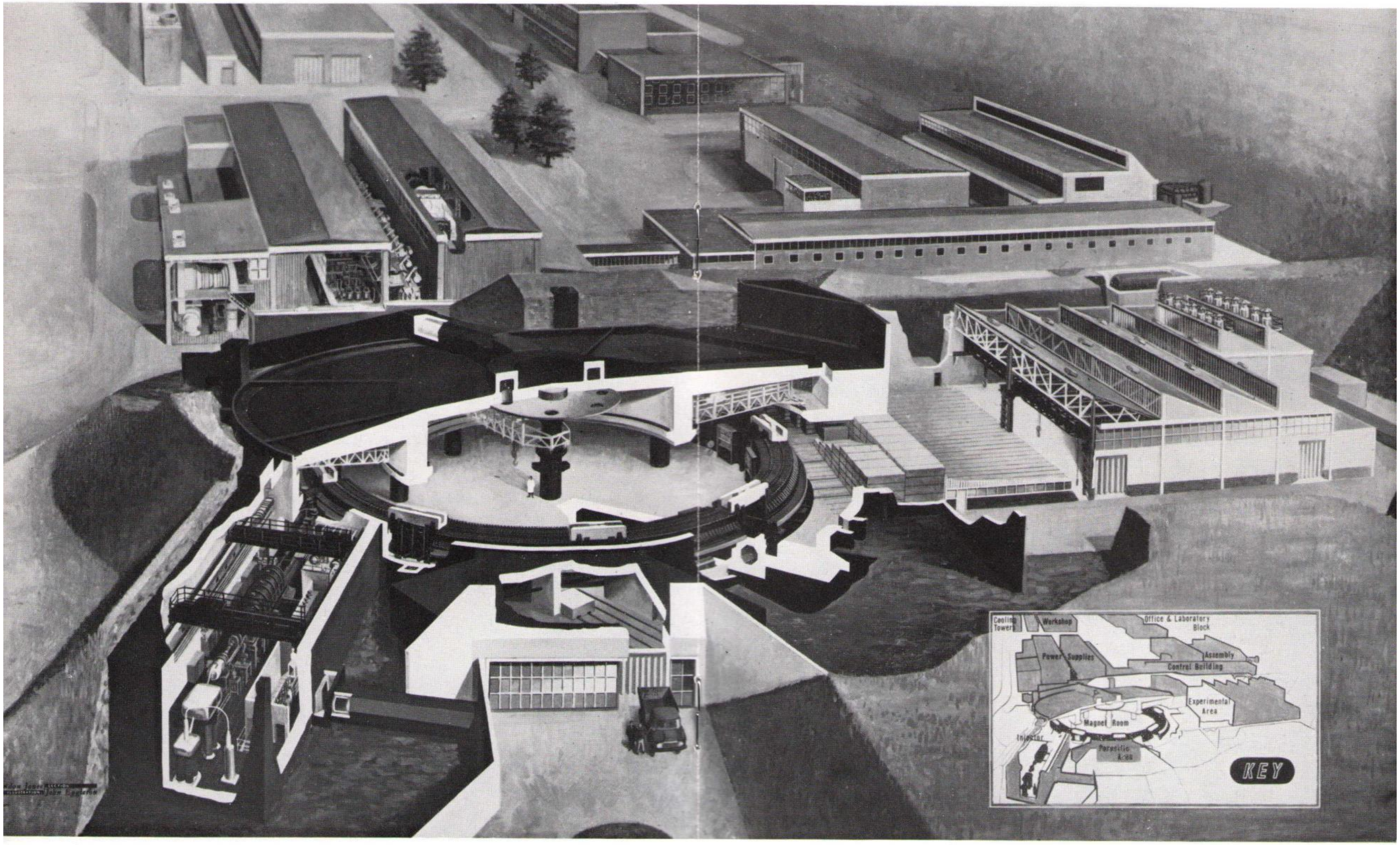
In evaluating the optical model, attempts are made to represent the nucleus as a system with a local 'refractive index' to the incoming proton wave. This refractive index, which is complex (to take account of absorption) and spin-dependent, does not depend on the nuclear fine structure, and only varies slowly from one nucleus to another.



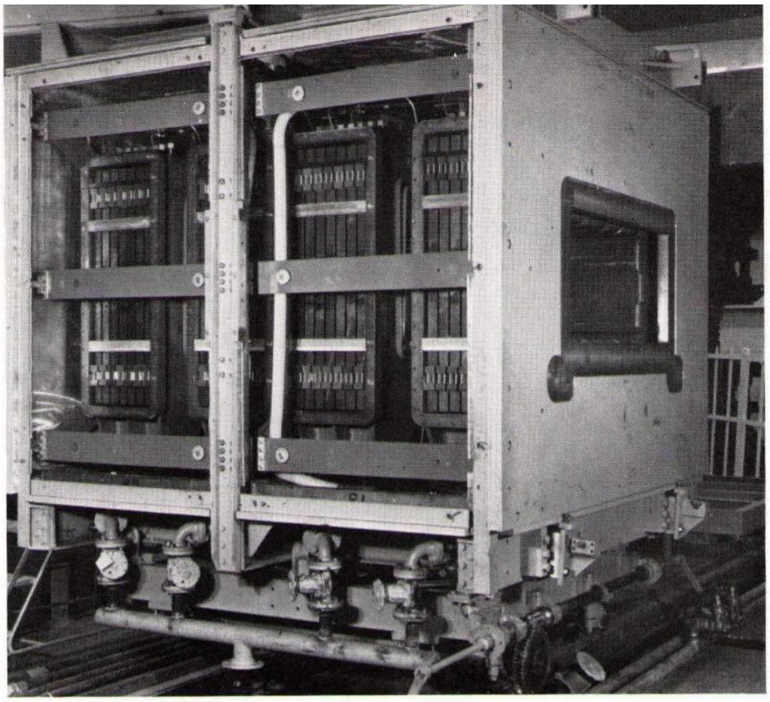
15 MeV linear accelerator injector for NIMROD with vacuum vessel cover raised. 600 KeV pre-injector equipment in background

Interior of NIMROD magnet hall, showing one of the octants nearing completion



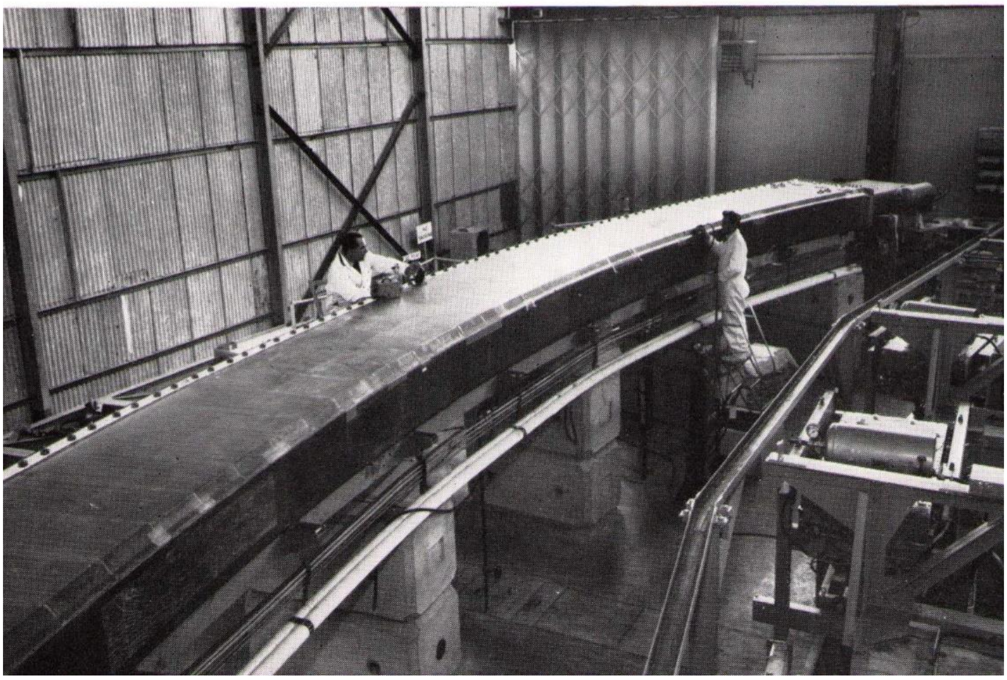


Artist's impression of NIMROD in cut-away view. The magnet hall is seen in the centre, with the injector hall on the lower left of the picture, and the experimental area on the right



Radio frequency accelerating cavity of NIMROD

Prototype section of outer vacuum vessel for NIMROD under test. The section, 50 ft in length is made of an epoxy resin fibre glass laminate



To test the model measurements of elastic scattering, polarization and total absorption probability are made.

In addition to this work, the (p, γ) reaction, the converse of the (γ, p) 'giant resonance' phenomenon is being studied. In some of these experiments chemical methods are used to extract the radioactive product nuclei which are formed.

The demand on the machine by these experimental teams for these and other experiments has been heavy, and the running time will shortly be increased from 16 to 24 hours per day. A second experimental area with more target stations is being commissioned.

THEORETICAL GROUP

The activities of the theoretical group cover a wide range of interests in the field of high energy physics. Integration of the work of the group with the experimental programme is particularly emphasized, and this is maintained through frequent contact with Institute and university groups. In 1962 the Rutherford Laboratory will have an Orion computer; at a later date an Atlas computer will be added to the facilities of the National Institute.

Among the topics at present being studied are: accelerator design, including studies of possible future machines of various types; particle optics, which includes the manipulation of charged particle beams through bending and focusing systems, or through various types of separator; data reduction, whereby physical information is extracted from the records (photographic or otherwise) of various experiments, and finally fundamental elementary particle theory, with an emphasis on those problems where the computer can be usefully employed.

The varied nature of the work offers opportunities for physicists with an aptitude for theory, applied mathematicians interested in electromagnetism and particle dynamics, computer programmers as specialists or working on physics problems, and theoretical physicists interested in elementary particle theory.

RADIO FREQUENCY GROUP

At present the work of this group is directed towards the design and construction of the accelerating system for NIMROD. The function of the R.F. system is to supply an alternating electric field along part of the orbit, of frequency equal to the angular rotation frequency of the protons. This changes by a factor of about six during the accelerating cycle, so that a signal of varying frequency has to be produced, and then amplified by a broad band amplifier to a power level of some 50 kW before being applied to the ferrite transformer, located in one of the straight sections, which acts as the accelerating element.

In order that the frequency may be kept in step with the angular rotation frequency of the protons, electrostatic 'pick-up' electrodes are placed in the vacuum chamber. The signals induced in these enable the radial beam position to be calculated, and if it wanders from the centre of the vacuum chamber the frequency is adjusted to bring it back.

This work involves a wide range of electronic and electrical engineering techniques, among which are: broad band high power amplifier design in the few mc/s range, feedback with non-linear elements, study of electrical noise, and fast pulse circuit work. It is hoped soon to start microwave studies on model cavities for possible new accelerators.

NIMROD INJECTOR GROUP

Before entering the ring magnet of NIMROD, the protons are accelerated to 15 MeV. This is done in three stages; ions are pulled out of an ion source at about 25 keV, they are then accelerated to 600 keV through an accelerating tube fed by an electrostatic generator, and finally the energy is brought up to 15 MeV by passing the particles through a single tank proton linear accelerator similar to the machine described on p. 7. The design of these accelerators, and the optical systems for producing a well focused beam and injecting it into the NIMROD magnet is the responsibility of the Injector Group.

The whole system has been very carefully designed with the aim of producing as intense a beam as possible; facilities will be provided for adjustment of various beam parameters and many monitoring devices will be installed so that it is possible to learn just what the beam is doing. It is intended eventually to produce currents of more than 20 ma at 15 MeV; this entails perhaps as much as 100 ma from the ion source.

This work has called on many special fields in physics and engineering, such as gas discharge physics, high voltage engineering, vacuum physics, radio frequency engineering, electronics, as well as more usual electrical and mechanical problems.

Basic work is undertaken, both in support of the project work and also of wider interest, for example, investigations of the optical properties of ion sources and beams, and problems of space charge and focusing.

MAGNET AND BEAM HANDLING GROUP

The NIMROD magnet, which is being assembled at the time of going to press, is a ring 160 ft in diameter, weighing 7,000 tons. The ring is divided into octants, with straight sections, four of 11 ft and four of 14 ft, between them, for injection and extraction of the beam. The cross-section is C-shaped, with the vacuum chamber between the arms of the C.

Much careful physical and engineering design work has gone into producing this magnet to the required tolerances. A detailed survey will be made to check the design, and the required corrections to the magnetic field shape will be made by means of conductors carrying currents which are programmed from measurements of the field in the gap. During the running up of the machine further field trimming will be made, to optimise the optical 'quality' of the beam.

When the protons reach the required energy they will be 'steered' to hit a target to produce secondary particles, or be extracted from the vacuum vessel. The Magnet and Beam Handling Group is responsible for the design of target mechanisms and carries out theoretical and experimental work on extraction devices and equipment for transporting and refocusing particle beams. This includes bending magnets, quadrupole focusing magnets and electrostatic velocity separators.

A small section is investigating the possible use of superconducting materials for particle accelerators and associated equipment.

The techniques used in the group cover a wide range. They include development of equipment for measuring magnetic fields, vacuum and high voltage work, and development of electronic devices from transistor electronics to audio work at kilowatt levels. Digital computers are used for both theoretical problems and data processing.

THE VACUUM GROUP

The Vacuum Group is concerned with the research and development necessary to build the complex vacuum system of NIMROD and its allied experimental facilities.

The vacuum system of NIMROD consists of two toroidal vessels, one within the other, the combination having a mean diameter of 155 ft. The vessels are constructed of laminated glass cloth and synthetic resin, the inner one being lined with non-magnetic stainless steel foil. Both vessels are initially simultaneously evacuated to 10^{-2}torr, the inner vessel being subsequently evacuated to 10^{-6} by means of forty 24 in. diffusion pump sets.

The Research Section of the group investigates the vacuum properties of materials, particular emphasis being given to synthetic resins and elastomers and the effect that irradiation has on vacuum and mechanical properties. Pump design and new pumping methods using ion, getter and sorption pumps, are investigated and new methods evaluated.

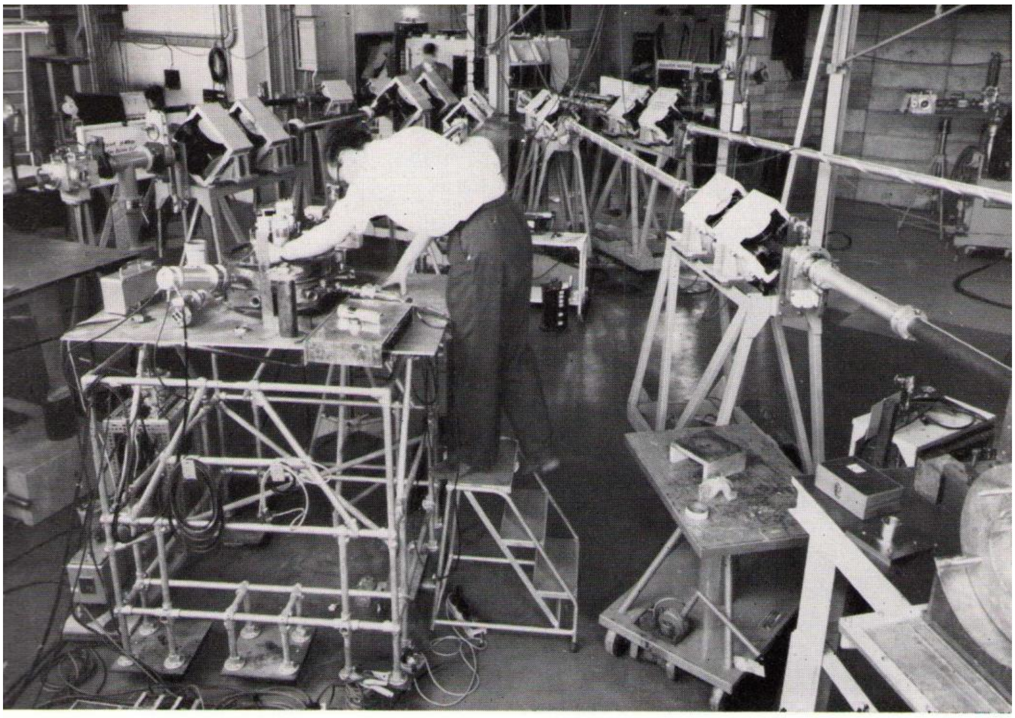
Development work on the measurement of low pressures is carried out and new forms of vacuum switches, for automatic pumping stations, are being evolved. A separate Resin Laboratory within this section is concerned with the development and use of synthetic resins.

The Development and Commissioning Section is responsible for leak testing and evaluating the performance of all items of equipment for the NIMROD vacuum system. Life tests on prototypes and acceptance tests on complete items of equipment are carried out.

The group as a whole also supplied a service to other groups, giving advice and practical assistance in the design, construction, commissioning and use of high vacuum plant for special purposes.

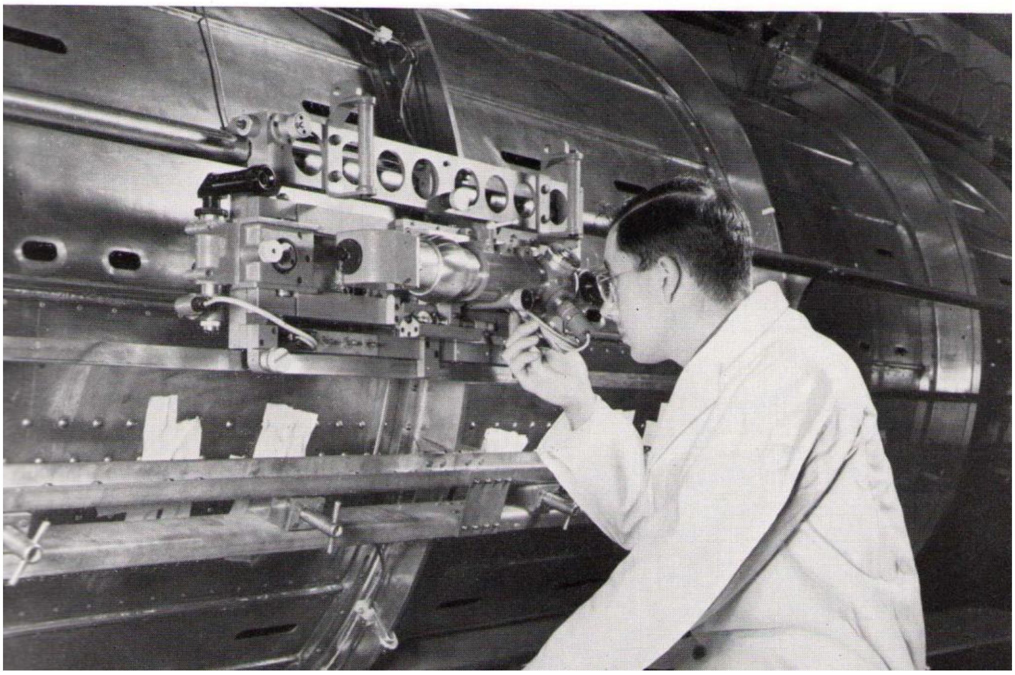
CYCLOTRON GROUP

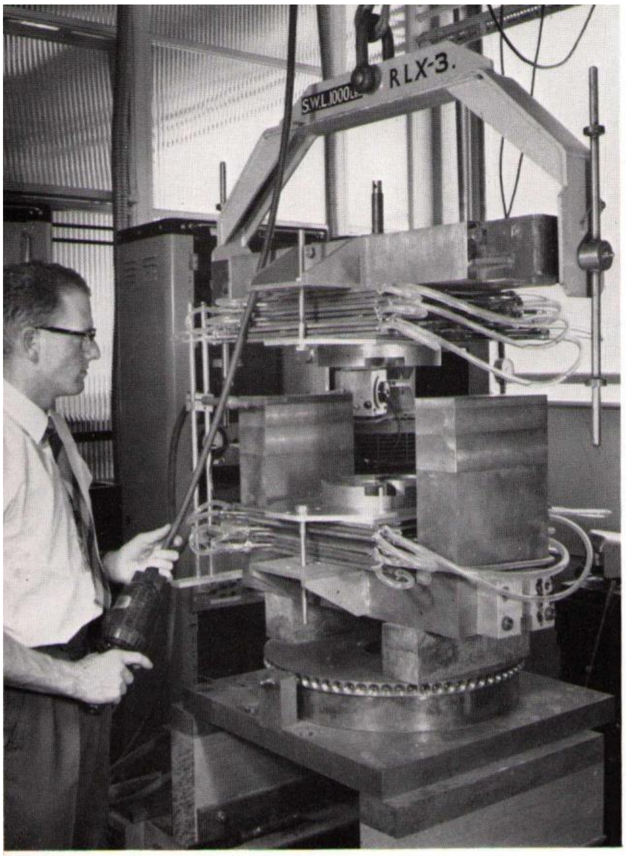
In addition to the design and construction of actual accelerators at the Rutherford Laboratory, there must always be some work of a rather more general and tentative nature looking toward the future. Much of the work of what is now the Cyclotron Group has been in this category; studies of 'spiral ridge' focusing have been made here and in the Theoretical Group, and a small experimental spiral ridge machine, designed for the study of orbit dynamics, has been constructed. It had been hoped originally to convert the Harwell 110 in. synchrocyclotron to an isochronous spiral ridge machine



Part of P.L.A. experimental area, showing bending magnet and beam pipes with magnetic quadrupole lenses

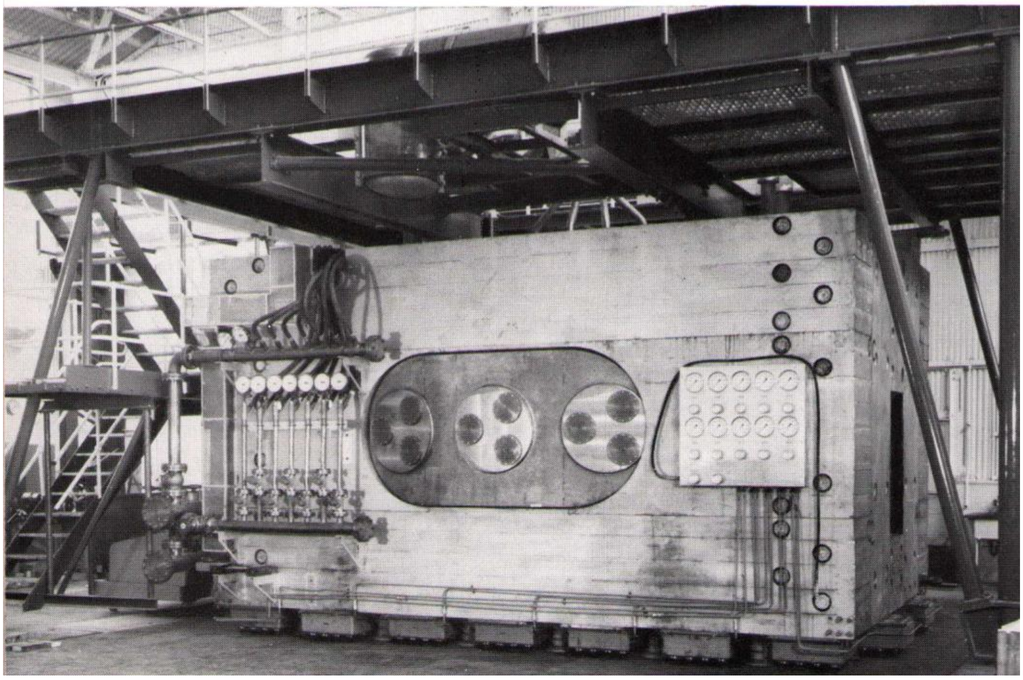
Optical alignment of drift tubes inside 15 MeV linear accelerator cavity





Model magnet for studying the design of a cyclotron with 'spiral ridge' pole faces

(*Below*) General view of the joint universities' 60″ liquid hydrogen bubble chamber equipment



operating above the meson threshold; the difficulties are great, however, and the scheme is now in abeyance.

At present an extensive design study is being prepared of a versatile isochronous cyclotron to accelerate heavy ions to energies up to 12 MeV/nucleon or protons up to 50 MeV; this project is of interest to the Atomic Energy Authority since such a machine could be used for research in radio-chemistry, and into radiation effects of interest in metallurgy and solid state physics.

A number of important problems of general interest in advanced cyclotron design await further study; in particular methods of injecting particles at the centre and extracting them at the edge need to be improved.

BUBBLE CHAMBER GROUP

Bubble chambers are now established as a very important measurement technique in the field of high energy physics. Two large bubble chambers are to be installed at the Rutherford Laboratory for use with NIMROD. Both are approximately 1.5 m long and one will operate with liquid hydrogen or deuterium while the other can be operated with various heavier liquids such as freon or propane.

A nuclear physics experiment on bubble chambers of this size and complexity is a large undertaking and involves a considerable amount of additional equipment. Magnets and particle separators have to be controlled and monitored with great precision in order to ensure satisfactory exposure of the chamber. In this field there is unlimited scope for development towards more precise and accurate experiments.

The actual run on the accelerator, however, is only the prelude to the data handling which must be done before experimental results are obtained. Here the work at the Rutherford Laboratory will be helped by the use of automatic track measuring machines and a fast computer, Orion. Developments on this aspect of the work are proceeding rapidly and one may hope to have some form of pattern recognition applied in the near future.

RADIATION PROTECTION GROUP

The types of radiation around high energy accelerator installations range all the way from low voltage X-rays to multi-GeV nucleons and mesons. In addition β and γ-ray activities are built up in targets and other components used near the accelerated beams. Although most of the radiation ceases when the apparatus is switched off, induced radiation persists for times depending on the decay period of the particular activity produced.

Massive shielding assemblies are needed around accelerators because of the high intensity of the radiation and strict control must be exercised where beams are brought through the shielding for experimental purposes. It is, therefore, necessary to know the magnitude of the radiation at all points around the accelerator and to limit the radiation dose received by the staff.

The responsibility of the Radiation Protection Group is to assess the levels of radiation and to ensure that doses received by personnel are kept within the recommended tolerances. For this purpose radiation surveys are carried out before any new experimental arrangement is used and advice given on the use of shielding. Although standard monitors already exist for many purposes it is necessary to develop special instruments in some cases. This is particularly so for very fast nucleons and mesons. The Group is in close touch with the health physics work in this country and has good contacts with other accelerator laboratories abroad.

THE OXFORD ELECTROSTATIC GENERATOR PROJECT

The Department of Scientific and Industrial Research is to contribute over three-quarters of a million pounds towards a new nuclear physics research centre at Oxford University. This will provide a particle accelerator of novel design with which extended programmes of long-term research on nuclear structure may be carried out. In addition the National Institute for Research in Nuclear Science will carry out the design of part of the accelerator which, with further aid from the University Grants Committee, brings the total Government support for the project to approximately one million pounds.

This specially designed equipment will consist of an 8-10 MeV vertical Van de Graaff generator which will be coupled to a 12 MeV horizontal tandem Van de Graaff generator.

Equipment of this size and cost must be regarded as a national asset and this accelerator will, by agreement between D.S.I.R. and Oxford University, be available to other research workers.

The single-ended electrostatic generator has two major virtues as a tool in nuclear physics: precision and flexibility. Its limitation is that, for smaller machines, voltages much above six million are not easy to achieve. Therefore, the goal of this project, namely the production of protons in a beam of energy 20 MeV, is achieved by a three-stage process. A large vertical machine houses a negative ion source in its centre terminal: these are injected at 8 MeV into a horizontal tandem machine with its centre terminal at 6 MeV. The energy gain through this machine, by virtue of the charge exchange process, is 12 MeV, so that the total particle energy is 20 MeV. This opens the entire periodic table to studies in nuclear physics with precision beams: it also makes possible several types of investigation in the light elements which are not possible with beams of less energy. Further, the vertical machine can operate as a machine in its own right, so that operation with two separate beams in separate target rooms is possible.

The type of vertical generator required is not, as such, commercially available anywhere, and will be developed by the National Institute for Research in Nuclear Science.

The two generators will occupy 19,000 sq ft in the new Nuclear Physics Laboratory, to be built in the Keble Road Triangle, near the Clarendon Laboratory. The horizontal machine will be in the basement and the vertical machine in the tower. There will be an additional 6,000 sq ft for maintenance and experimental work and shielding for the machine.

ENGINEERS AT THE RUTHERFORD LABORATORY

The scale of the research instruments and apparatus now being built and installed at the Rutherford Laboratory is such that professional engineers have an important part to play in their design, installation and operation.

The work of the Laboratory demands a very wide range of engineering experience, from the design and installation of standard equipment such as general power supplies and lifting gear, to challenging and unusual problems such as the provision of the magnet power supply with its flywheel energy storage system, or the erection of the vast electromagnet within very fine tolerances on alignment. These problems require engineers with both a good background of traditional techniques, and the flexibility to introduce ideas that are at once new and sound. These engineers not only need to work with the scientists responsible for the physical design of the apparatus, but also must be capable of following awkward 'one-off' jobs through manufacture in outside industrial firms. In short they must be professionally sound, and also particularly ingenious, imaginative and co-operative.

3

Opportunities at the Rutherford Laboratory

THE SCIENTIFIC OFFICER CLASS

The Scientific Officer Class is normally recruited from graduates and post-graduates with a first or good second-class university honours degree in scientific, engineering or mathematical subjects. These officers have the responsibility of initiating and directing the scientific research and development work of the Laboratory.

The class has three main grades: Scientific Officer, Senior Scientific Officer and Principal Scientific Officer. The basic salary payable to a Scientific Officer is £790 for the first year, £840 for the second year, and £980 for the third year, and so on rising to a maximum salary of £1,310. Approved post-graduate experience is taken into account in fixing the initial salary: for example, a graduate with two years' approved experience is appointed at £980.

Promotion to the grades of Senior and Principal Scientific Officer is made according to merit and ability; seniority plays no part in this and it is usual for a scientist in his early thirties to be earning around £1,800. The maximum salary of the Principal Scientific Officer grade is £2,590.

In addition to these appointments to the permanent staff of the Institute, there are opportunities for physicists to be given fixed-term appointments for periods up to five years. Salaries in such cases are closely related to those payable to permanent appointments in the Scientific Officer Class.

THE ENGINEER CLASS

Professional engineers are normally required to be corporate members of a senior engineering institution or at least to hold qualifications exempting them from further academic attainment. The basic grade is Engineer III, the maximum salary for which is £1,535, while there are two more senior grades with maximum salaries of £2,090 and £2,560 respectively.

For graduates who have not had the opportunity to gain the experience necessary for corporate membership of an institution appointments are sometimes made to the grade of Technical Assistant. Such appointments are made according to age: e.g., £800 at age 22; £840 at age 23, and £920 at age 24.

GENERAL CONDITIONS

For both classes there are generous provisions for paid sick leave and holidays. There is also a contributory superannuation scheme similar in its benefits to that of the Civil Service for the Scientific and Engineer Classes, while the 'fixed term' appointments are made under F.S.S.U. benefits.

STAFF STRUCTURE

The total permanent staff of the Rutherford Laboratory is in the region of 800; it is expected to rise to about 950 by the end of 1964.

The ratio of the professional grades to the total staff is about 35 per cent; the supporting grades (experimental, scientific assistant, drawing office, technical, semi-technical and administrative) are about 40 per cent while industrial labour (skilled and semi-skilled) make up the balance with 25 per cent.

Membership of the Governing Body of the National Institute for Research in Nuclear Science

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