RUTHERFORD HIGH ENERGY LABORATORY

OPEN DAYS 1970

Thursday July 2
Friday July 3

GUIDE BOOK & MAPS

These Open Days have been certified by the Board of Trade as an exhibition for the purposes of Section 51(2) of the Patents Act 1949 and Section 6(2) of the Registered Designs Act 1949.

Rutherford High Energy Laboratory
Chilton, Didcot, Berkshire.
Tel. Abingdon 1900

RUTHERFORD LABORATORY

Open Days 1970

Guide Book and Maps

A recent aerial view of the Rutherford Laboratory from the North-West; Nimrod is under the grass covered mound at bottom centre with its Experimental Halls to the right and behind.

THE RUTHERFORD LABORATORY

During the late 1950's, it was decided to establish a national centre for research in elementary particle physics, the facilities of which could be used by Universities and other research institutions who could not individually build and operate a large particle accelerator. The National Institute for Research in Nuclear Science was set up with membership and powers appropriate to the task of controlling the design, construction and utilisation of a 7 GeV proton synchrotron. This was soon christened Nimrod and around it grew the Rutherford High Energy Laboratory. With the passing of the Science and Technology Act in 1965 the Institute was dissolved and its Laboratories (Rutherford, the Daresbury Nuclear Physics Laboratory in Cheshire with its 4 GeV electron synchrotron NINA and the Atlas Computer Laboratory) came under the control of the Science Research Council, funded through the Department of Education and Science.

Nimrod has been fully operational since 1964, and at present supports the research of some 200 University visitors in addition to that of the 40 resident experimental high energy physicists. Support facilities are provided on a substantial scale, notably in the field of computing, and there is a large investment of effort in applied research topics particularly superconductivity. Research teams from the Laboratory also make use of the accelerator facilities of the European Organisation for Nuclear Research (CERN) in Geneva of which Britain is a leading member.

The staff of the Laboratory now totals nearly 1,250 and the annual budget is £7.5 million.

RUTHERFORD LABORATORY INTERNAL ORGANISATION

Director G. H. Stafford

High Energy Physics Division

Experimental research programme on Nimrod. Resident counter, bubble chamber and electronics groups.

Division Head and Deputy Director G. Manning

Nimrod Division

Operation and development of Nimrod and bubble chambers. Experimental Hall management including beam-line design and installation.

Division Head D. A. Gray

Applied Physics Division

Superconducting magnets. High Field Bubble Chamber project. Polarized proton targets. Radiation Protection.

Division Head L. C. W. Hobbis

Computing and Automation Division

Operation and development of Central Computer System. Film Analysis. Theoretical High Energy Physics.

Division Head W. Walkinshaw

Engineering Division

Design and manufacture of research equipment. Mechanical, Electrical and Building Services. Chemical Technology. Safety Services.

Division Head and Chief Engineer P. Bowles

Administration Division

Personnel, Finance, Stores, Library, General and Specialised Administrative Support.

Division Head and Laboratory Secretary J. M. Valentine

GENERAL OPEN DAY INFORMATION

Arrival and Departure. For the convenience of visitors travelling by car, a route map is enclosed. The event will be signposted from the A34, and there will be car-parks for visitors in the centre of the site. Cars and coaches will meet trains at Didcot Station according to the information provided by visitors on their invitation reply cards. Return transport to Didcot will also be provided as required; departure times will be posted at the Information Desk.

Reception. On arrival, visitors are asked to go first to the Information Desk in the marquee and to collect a name-badge. Arrangements to meet particular members of staff may be made here.

Refreshments. Coffee and tea will be available in the marquee on each day; on Thursday only tea will also be served in the Restaurant from 3.15 p.m. to 4.15 p.m. A wide selection of hot and cold lunches may be purchased in the Restaurant from 12.45 p.m. to 1.45 p.m. each day.

Visiting the Exhibits. Visitors are free to inspect the Exhibits in any order they choose. This guide-book is intended to help visitors to select the items of most interest, since it will be found difficult, if not impossible, to see every Exhibit in the day. A ferry-bus will circulate at frequent intervals between the points marked Z on the site plans which also show the location of the Exhibits.

Technical Information. The majority of Exhibits will be manned by Laboratory staff who will be pleased to explain their displays and to help in more general ways. Technical leaflets giving detailed information will be freely available at many Exhibits.

LIST OF EXHIBITS

Exhibit A
Marquee

INTRODUCTORY EXHIBITION

The introductory exhibition interlinks the other specialised exhibits by showing where each of them fits in to the Laboratory's research programme. The Open Day theme – 'The Forces of Nature and the laws they obey' – is introduced by concise explanations of our present state of knowledge, and of technical terms, peculiar to elementary particle physics, which may be unfamiliar to some visitors. The stages of an experiment using either electronic or bubble chamber detection methods are outlined, to show both the time-scale of an experiment and the range of skills needed to prepare and run it, and to evaluate the results.

This exhibition is not intended as an Open Day in miniature, and it is envisaged that visitors will wish to spend only about ten minutes here before moving on to other exhibits. The reception and enquiry desk will be in the marquee. Morning coffee will be served from here and tea will be available during the afternoon for the convenience of visitors who may wish to return in order to inter-relate exhibits already seen.

Exhibits B–H are within a short distance of the marquee; to visit Exhibits J–V, visitors may wish to make use of the ferry-bus which will circulate at frequent intervals between the points marked Z on the site plan.

Exhibit B
Building R1
Ground Floor West

SUPERCONDUCTING MAGNET TECHNOLOGY

Many devices used for elementary particle physics research require strong magnetic fields over regions of substantial size. One of the most significant advances in the associated technology has been the development in recent years of high field superconductors – materials which when cooled to low temperatures (typically 4°K) have no electrical resistance and which will carry large electric currents in high magnetic fields without consuming any power. These superconductors can be used to construct electromagnets which are at least five times more powerful than the 10–20 kG conventional magnets used at present, and allow experimental devices to be considered which would be technically impossible or prohibitively expensive using conventional techniques.

Immediate applications in high energy physics include bending and focussing magnets for particle beams, and magnets for bubble and spark chambers. Longer term possibilities include superconducting synchrotron ring magnets, illustrated by a display showing a possible 25 GeV replacement for our 7 GeV proton synchrotron Nimrod which could be housed in the same buildings. Applications in other fields include d.c. motors and generators, MHD power conversion and plasma containment devices.

The technology required for the successful development of superconducting magnets has received special attention at the Rutherford Laboratory. In collaboration with Imperial Metal Industries, the research team has developed a new type of conductor consisting of a twisted array of very fine superconducting filaments (e.g. of niobium-titanium) embedded in a matrix of normal metal. These composites are free from the electrical and thermal instabilities which for many years handicapped the construction of medium- and large-sized coils with satisfactory characteristics. Full-scale evaluation tests of these new materials are in progress and it seems probable that superconducting magnets embodying them will eventually supersede the traditional iron-cored type.

The twisted filamentary composites can also be designed to operate satisfactorily under pulsed conditions. This property is of interest for the superconducting synchrotron application mentioned earlier, and also enables serious consideration to be given to superconducting circuits as energy storage devices for such accelerators. Such a device would not be subject to the performance limitations of conventional motor-alternator-rectifier systems connected to the public electricity supply network.

Of the applications under consideration for the more immediate future, the largest is the 70 kilogauss, 2 metre bore magnet for the proposed High Field Bubble Chamber. Details of this magnet are included in Exhibit E.

The successful construction of superconducting magnets requires materials which retain their mechanical properties at liquid helium temperatures. Equipment will be shown that has been developed to provide design data on materials likely to be of value.

The recovery of helium gas from cryostats is a necessary complication of experimental work on superconductivity on account of its scarcity and cost. The recovery plant is located close to the superconducting magnet exhibits; it recovers for re-liquefaction about 65% of the 1.4 million cubic feet of helium gas produced from liquid helium usage each year.

Exhibit C
Building R1
Ground Floor East

FILM MEASURING AND DATA PROCESSING

The bubble chamber and the visual spark chamber are widely used in elementary particle physics. The passage of a charged particle is made visible as a trail of bubbles or as sparks between parallel electrodes, and by rapid stereo-photography can be recorded for later off-line analysis. This is done by methods that have to a large extent been automated in order to cope with the vast quantities of film (tens of miles per experiment). All stages of the measurement sequence for bubble chamber pictures will be on display.

Scanning and predigitizing. Not every photograph contains events currently interesting to the experimenter, and the first stage consists of the examination, by a trained scanner, of each picture re-projected to roughly life-size. Selected events pass on to the next stage where the co-ordinates of key features of each collision are measured. This is to provide guidance information for the fully automatic next stage, and since high accuracy is not needed in the pre-digitization, it is a quick and simple process.

HPD* and CYCLOPS Flying Spot Digitizers. These automatic measuring machines are housed in a suite of rooms adjacent to the scanning and pre-digitizing area. A spot of light traces a raster across each film frame, and a particle track causes a reduction in the transmitted light intensity; the spot co-ordinates are transmitted to the IBM 360/75 computer. From a single frame the computer may receive as many as 40,000 co-ordinates. The majority of these are not associated with the desired event and are rejected by making use of the pre-digitizing information. After further filtering processes, the remaining genuine co-ordinates are written onto magnetic tape and subsequently subjected to further computer pro-

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* Hough-Powell Device

grammes which reconstruct the events in three dimensions and identify the particles involved by using particle momemtum (from the radius of curvature of the tracks due to the magnetic field of the bubble chamber) and other kinematical information and constraints. HPD will measure all 3 stereo views of 100 events per hour and is currently in use on bubble chamber film. CYCLOPS is basically similar to HPD but uses a cathode ray tube as a light source; it can measure 300 events per hour and is at present used for spark chamber film. Both machines will be in normal operation.

Light-Pen Patch-up System. In some cases, the computer programmes cannot make sense of the information supplied by HPD or CYCLOPS, a common cause being when one of the tracks of an event has a sudden kink in it due to scattering. Failed events are held in the computer, and can be called up by the light-pen operator for display on a large cathode ray tube screen. Additional information can be fed in by use of the light-pen – e.g. that part of a track after a kink can be deleted, and ambiguities in the stereo views can be resolved. After correction the events are fed again to the IBM 360/75 for re-analysis.

Computing Facilities. The RHEL central computer is an IBM 360/75 with 1 million bytes* each of fast (0.75μs) and slow (8μs) core store, and a 4 million byte drum. Peripherals include 8 magnetic tape drives and 11 disks. Many on-line devices are connected via satellite computers, and a multiprogramming system allows 3500 batch jobs per week to be run while on-line operations such as film analysis and Nimrod experiment data collection continue. Information on the facilities and work load, and on plans for expansion, will be on show, but for operational reasons the computer itself will be shown only at 11.30 a.m. and 2.30 p.m. Visitors wishing to join these tours, which will be somewhat restricted in numbers, are asked to register in the computer reception area. The machine will be visible at all times through windows in the corridor.

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* 1 byte = 8 bits (binary digits)

Exhibit D
Building R20

RADIATION PROTECTION

The operation of a particle accelerator such as Nimrod produces both stray radiation and radioactive materials. These are potential health hazards and can also interfere with experimental measurements unless properly controlled. Other Laboratory equipment such as high voltage sets and radioactive sources used for calibration and irradiation damage work can also create radiation problems.

The hazards are reduced as much as possible by correct operating procedures and by the provision of shielding, which in the case of Nimrod involves the optimum placement of thousands of tons of concrete and steel. It is, however, necessary to monitor the radiation levels in many areas and to measure the small radiation dosages received by the individuals working there.

The radiation fields produced by Nimrod are complex in nature, and moreover are pulsed rather than steady. These features have made it necessary to develop special techniques for both environmental and personal monitoring. The Radiation Protection exhibit includes displays of work on instrumentation, personal dosimetry, neutron spectrometry using activation detectors, high resolution gamma spectroscopy and particle track registration using etch pits in dielectrics.

The magnitude of the shielding problems can be seen in the Nimrod magnet room and the Experimental Halls in which are located Exhibits J – V. Installed monitors of various types will also be seen. All areas to which visitors will have access will have been surveyed to ensure that radiation levels are negligible.

Exhibit E
Building R7

BUBBLE CHAMBER DEVELOPMENT

The bubble chamber, in which particle tracks are recorded by photographing trails of tiny bubbles, has for many years been a vital tool in elementary particle physics. At this Laboratory and elsewhere the basic technique has undergone substantial development in order to keep pace with the requirements for high precision and faster data acquisition rates. This exhibit shows two recent advances.

The High Field Bubble Chamber. This proposed chamber is a high precision device, intended primarily for strong interaction studies such as the spectroscopy of elementary particle states. Detailed design studies have been in progress for about 3 years and the project received Science Research Council approval in April 1970.

The chamber filling will be liquid hydrogen, contained in a vessel 1.5 metres diameter by 1.8 metres long. This is photographed by a system embodying retro-directive illumination and four cameras using fish-eye optics; the optical precision aimed at is 50 microns in chamber space.

The chamber magnetic field will be 70 kilogauss, provided by a pair of superconducting coils designed to give a field uniformity of ± 10%. The conductor proposed for use has been successfully energised in a test magnet known as RACOON.

Five to ten chamber expansions per second will be possible, the characteristics of the expansion system having been chosen so that it is resonant at this frequency. A hydraulic latching system is released to initiate expansion and this is re-engaged on the rebound during which a small amount of make-up energy is added. The seal between the piston and the chamber body poses many problems. Piston rings are unsuitable since they generate heat, as would a metal bellows due to eddy currents induced by its motion in the magnetic field. The solution adopted uses a plastic bellows developed at RHEL since nothing suitable was available commercially. A one-fifth scale model has operated successfully for over 20 million cycles in liquid hydrogen.

The exhibit will include displays of the optical system, the magnet and the expansion system components as well as a model and drawings of the complete chamber.

Composite Chambers. Conventional chambers are filled either with liquid hydrogen (for target simplicity) or with a heavy liquid such as propane (for good gamma-ray detection). Each loses where the other scores. A recent collaboration between CERN and RHEL has resulted in the successful operation of the 1.5 metre British National Hydrogen Bubble Chamber in a modified form. A thin perspex vessel containing liquid hydrogen occupies the central region and is surrounded by a neon-hydrogen mixture to give good gamma detection in the outer region. It is possible to choose the chamber operating conditions and the perspex vessel flexibility so that tracks are obtained in both regions simultaneously; the first high energy physics experiments to use this style of chamber will begin soon. For operation and safety reasons it is not possible to allow free access to the chamber itself. It can be shown on request to visitors with a specialist interest.

Explosive Venting of Buildings. With flammable liquids in use, steps must be taken to minimise the effects of an explosion, remote though this possibility may be. A building has been constructed in which some of the walls are of expanded polystyrene; wall collapse occurs at an internal over-pressure of only 0.14 psi.

Exhibit F
Building R2

COMPUTER CONTROL OF NIMROD BEAM-LINES AND NIMROD MAIN CONTROL ROOM

A small computer (PDP–8 with 8K of core store) is used on-line during the tuning and running of the X3 extraction system and beam-line which feeds Experimental Hall 3.

During tuning, magnet currents and collimator jaw positions can be set and read, and in the running mode the magnet currents are continuously monitored. Data showing the beam conditions (e.g. proton flux per pulse) is continuously acquired. Data transmission and control functions are carried out via an interface system known as STAR. A suite of programmes is available by which, for instance, graphs may be automatically produced showing the effect on beam current of magnet excitation or collimator position. Print-out of selected data is also available. Remote setting and current monitoring of magnets in the X3 beam line will be demonstrated. The PDP-8 is housed in the Nimrod main control room (MCR). Remote control of Nimrod is necessary on account of the radiation hazard, and after start-up all operations are conducted from the MCR with the exception of main magnet powering which is controlled from a special centre in Building R3 (see Exhibit G). The 15 MeV linear accelerator injector for Nimrod has its own control room (through which visitors will pass to see Nimrod itself, Exhibit J), which is used only for start-up and special tests.

The high energy physics experiments are controlled from local control rooms in the Experimental Halls; those associated with the three experiments on display (Exhibits L, M, N) are open to visitors.

The magnetically shielded TV cameras which feed the monitors in the MCR are shown in Exhibit U.

Exhibit G
Buildings R3 and R4

NIMROD MAGNET POWER SUPPLY AND ASSOCIATED EXHIBITS

The excitation current required by the Nimrod main magnet rises from zero to 10,000 A in 0.7 second, remains constant for about half a second to allow slow beam extraction to occur ('flat-topping') and is then reduced to zero again ready for the next acceleration cycle. Voltages of about 15 kV are needed; the maximum stored energy in the magnet is 40 MJ and under normal operation resistive losses amount to 3 MW. Such a violently pulsating load cannot be connected directly to the public supply network, and a complex motor-alternator-flywheel-rectifier system is installed to act as a buffer. Two 5,000 horse-power motors each drive a 60 MVA alternator with a 30 ton flywheel. The alternator outputs are fed to phase-multiplying transformers giving a 24-phase system. 96 grid-controlled mercury arc rectifiers are used to control the shape of the current pulse. During the current-rise phase they function as conventional rectifiers; when the magnet is being de-energised they are switched to act as inverters. The magnet stored energy (less resistive losses) is recovered and fed back to the rotary plant, with the alternators now acting as motors. During the cycle which is repeated 20–30 times per minute, the rotary plant speed varies between 930 and 970 r.p.m. To minimise the transmission of vibrations to adjacent buildings, the entire 400 ton plant is mounted on a damped and spring-supported concrete slab weighing 1,200 tons. Plant operation is controlled from a special control room from which, for instance, the precise shape and duration of the 'flat-top' is controlled by means of sequential switching from rectification to inversion. Basic data is transmitted to the Main Control Room.

Dynamic Ripple Filter System. Ripple voltages during acceleration and particularly during 'flat-topping' must be held to a minimum to avoid disturbing the accelerated beam. The power plant output, though 24-phase, requires further correction and this is done by means of a feed-back system.

The effect of ripple reduction may be seen in a demonstration in which the proton beam is simulated by a wire in a magnet gap.

Alternator Rotor Bolt Fatigue. The severe torsional forces resulting from the variation in rotary plant speed have on two occasions resulted in failure of alternator rotor parts with consequent interruption of the research programme. One of these failures was due to fretting fatigue in the $1\frac{1}{2}$ inch bolts holding the rotor coils in place. The display shows the methods used and results obtained in the subsequent investigations which led to a much improved design of bolt and which showed that in some circumstances fretting can reduce fatigue strengths by factors of over 15.

Electronic Analogue Wattmeter. This device, which has been patented, was developed to measure changes in power levels (such as occur in the magnet power plant) that are too rapid to be followed by a conventional wattmeter. The multiplications involved are performed by high speed analogue multipliers, and additions by a summing amplifier. The wattmeter output is a d.c. voltage which may be used for diagnostic, recording or control functions, and the instrument can cope with a wide range of impedances, frequencies and phase multiplicities.

Exhibit H
Building R36

FAST ELECTRONICS FOR HIGH ENERGY PHYSICS

The demonstration chosen to exemplify the role played in high energy physics research by modern fast electronics embodies a small digital computer. Until recently such computers have performed tasks such as fast temporary storage of experimental data, magnetic tape writing and simple continuous data checks to give warning of possible errors. It is now possible to use the computer to automate the setting-up of the electronic circuitry associated with counters, spark chambers etc.

The demonstration shows a Modular One computer, together with Camac electronics, optimising the performance and coincidence of two photomultipliers which are widely used in scintillation and Cerenkov counters. The computer has been programmed to measure the photomultiplier response curves, set their working voltages and then to adjust their relative time delays for optimum coincidence. Histograms of the process are seen on an oscilloscope and data printout is available. Visitors will be able to vary a delay setting and see the system compensate for the change.

The Camac system of electronics is the new internationally agreed modular system, and Rutherford Laboratory personnel took part in defining it. It is commercially available from UK and Continental firms and shortly from the USA also. The more advanced modules are made here, or in industry to Rutherford designs, before becoming 'off the shelf' items. The value of the compact nature of this system can be appreciated by visiting the local control room of Exhibit N.

Exhibit J
Building R6

THE 7 GeV PROTON SYNCHROTRON NIMROD, AND ASSOCIATED EXHIBITS

Visitors will be able to see the machine itself and displays of a number of items which are best shown close to positions where they are actually used. In order that items may be seen in a logical sequence, and to avoid congestion, entry to Nimrod will be via the Injector Control Room only (close to which is a Bus Stop) and exit will be via the tunnel leading to Experimental Hall 1 in which are situated Exhibits K, L and M.

The route through Nimrod, which is clearly signposted, leads from the Injector Control Room through the preinjector 600kV area to the linear accelerator which produces 15 MeV protons for injection into Nimrod itself. Passing into the magnet hall, the route goes around the machine the same way as the protons themselves and leads to a group of displays that are mentioned below. There is then a choice of routes. Visitors wishing to do so may go directly to Exhibits K, L and M in Experimental Hall 1, while those wishing to see Nimrod in more detail may ascend to the gallery running around the top of the 150 foot diameter magnet. The gallery goes half-way round the machine and from it may be seen the beam lines as they emerge from the vacuum vessel. At the end of the gallery visitors will be directed into the centre of the ring and out over the magnet to the exit via the tunnel to Experimental Hall 1. Key components of the machine will be labelled, and there will be illustrations and photographs to show the details of items not easily visible.

Extraction Magnet Power Supplies. Special power supplies are required for the magnets that deflect the proton beam into the external beam lines. Protons may be fed to beams X1 and X2 during the same machine pulse by varying the excitation of the extraction components which are common to both. Initially currents are set at the X2 level and then switched to the higher X1 level for the fast (1 millisecond) beam pulse required for the bubble chamber. The currents are then returned to the X2 level for slow (0.5 second) extraction down to X2 for counter experiments such as K12A and K14A (Exhibits L and M). The accurately controlled levels required are obtained from a transistor regulator bank fed by a conventional d.c. generator. Recently developed thin septum extraction magnets (which give higher extraction efficiencies) require currents of up to 21,000 A. This will be supplied by a homopolar generator being developed by IRD Ltd., with regulation by a transistor bank based on that used in the switched extraction scheme. The actual components of these power supplies are housed in a somewhat inaccessible region, but may be inspected on request by visitors with a specialised interest.

Hydrogen Pressure Dosimetry. The Nimrod vacuum vessel is made from glass fibre reinforced epoxy resin, the mechanical strength of which is degraded by prolonged exposure to radiation. The hydrogen pressure dosimeter monitors the dosage by sensing the pressure changes in sealed capsules containing polythene, which evolves hydrogen when irradiated. The device will record integrated doses in the 10^5–10^8 rad range, and a large number are installed in Nimrod to give warning of vacuum vessel deterioration.

Target Mechanisms. At present almost all experiments using Nimrod require incident pions or kaons rather than protons. These secondary beams are produced by allowing the primary proton beam to strike a suitable target, typically 10 centimetres of copper, which can be either external or internal. The external version is fitted to the X1, X2 and X3 beam lines, enabling several secondary lines to be fed from the one target thus improving machine utilisation; it enables any one of four targets to be used. The internal version raises the target from the bottom of the Nimrod vacuum vessel in the last 0.15 second of the acceleration process so that the circulating beam can be steered on to it. The mechanism is required to last for at least a million operations (about a month) and embodies an airlock and other facilities to enable targets to be changed without destroying the Nimrod vacuum.

Plunging Mechanism and Extraction Magnet. These items are displayed inside the magnet ring and can be inspected when crossing this area after walking round the gallery. At injection time the whole of the Nimrod magnet aperture is used by the beam. This shrinks during acceleration, permitting the introduction of extraction magnets such as that shown. This is done by means of the plunging mechanism which is required to move the 2,000 lb. magnet 20 inches in 0.4 second to an accuracy of 1/32 inch. There are four such mechanisms on Nimrod (two for X1/X2, two for X3) one of which will be shown operating. The motion is obtained from an electronically controlled hydraulically operated ram driven by a variable delivery swash pump.

Exhibit K
Building R6
(Hall 1)

HIGH FIELD PULSED BEAM-LINE MAGNETS

An experiment to be done using the 1.5 metre bubble chamber requires a beam of neutral hyperons (heavy unstable elementary particles). This will be produced by allowing the 7 GeV extracted proton beam to strike the windings of a special magnet in which a pulsed field of 70 kilogauss can be produced. This field sweeps aside the many charged reaction products into heavy metal beam stops so that only the few uncharged hyperons (and neutrons) reach the bubble chamber. The magnet is required to have a life in excess of 100,000 pulses. Examples of the magnets themselves and their power supplies will be on view, and design and performance data will be shown.

Also on display will be a fast pulsed flat-top magnet that can be used to switch particles from one beam line to another in microsecond time intervals. A specially shaped air-cored winding is used, driven by a high-power pulsed valve circuit.

This exhibit will be located on a gallery forming part of the natural route from Nimrod to Experimental Hall 1. It runs over the X1/K9 beam line that feeds the bubble chamber and forms a good vantage point from which to view Hall 1. It also affords a good view of the spectrometer and spark chamber system that forms part of the K12A experiment (Exhibit L).

Exhibit L
Building R6
(Hall 1)

ELASTIC KAON-NEUTRON SCATTERING – THE K12A EXPERIMENT – BIRMINGHAM UNIVERSITY AND RHEL

This experiment measures the angular distribution of positive and negative kaons scattered elastically (i.e. without producing extra particles) from neutrons. The kaons are produced from a metal target in the X2 proton beam and conveyed to the experiment by a magnet-lens system. The kaon lifetime is only 10^{-8} seconds and at the momenta being used (450–950 MeV/c up to 20% can be lost by decay over each metre; the external target allows the length of the secondary beam K12 and hence this loss to be minimised.

The simplest neutron-containing target material is deuterium used here in liquid form. This also gives rise to kaon-proton events which are eliminated by detecting the proton. Elastic Kn events are identified by precision measurement of the kaon momentum, which in an elastic event is related to the angle through which it has been scattered. The kaon is identified by velocity measurement in a Cerenkov counter and momentum analysed by a large spectrometer magnet. Kaon position and direction before and after the spectrometer is measured by means of large sonic spark chambers, and magnetostrictive spark chambers are used in the incident beam.

Data from these counters is conveyed to the local control room which contains a DDP 116 computer capable of storing up to 30 events per Nimrod pulse. In the two second interval between pulses the data is written onto magnetic tape for detailed analysis on the IBM 360/75, and monitoring information is produced. For the Open Days, a Nimrod pulse will be simulated and spark chambers fired so that visitors can control the experiment from the computer. The whole of the experimental equipment and most of the beam-line will be open for inspection.

Exhibit M
Building R6
(Hall 1)

POLARIZATION EFFECTS IN PION-PROTON ELASTIC SCATTERING – THE K14A EXPERIMENT – OXFORD & WARWICK UNIVERSITIES & RHEL

This experiment is investigating the pion-proton interaction by measuring the scattering of an incident pion beam (produced from a metal target in the X2 extracted proton beam) by protons in a target. The details of the interaction are complicated by the fact that the proton has spin. In an ordinary (e.g. liquid hydrogen) target the proton spin directions are randomly oriented and any spin-dependent effects average out. In this experiment a special polarized target is used in which the spin directions of the protons in the water of crystallisation of lanthanum magnesium nitrate are aligned by the simultaneous action of a strong uniform magnetic field, a temperature of 1°K and 4 mm wavelength microwave power.

Scattered pions and recoil protons are detected by scintillation counters surrounding the target. In the elastic scattering process being studied, the angles and energies of scattered pion and recoil proton are inter-related; this information is used to sort out genuine events from the far larger number of interactions between the incident beam and target particles other than free protons. Signals from the scintillation counters, after passing through logic circuits, are fed in the usual way to a small local computer (DDP 516) which monitors data acquisition and writes magnetic tapes for subsequent off-line analysis on the IBM 360/75.

During the Open Days the polarized target assembly, the scintillation counters and other detectors, and parts of the beam line will be on show while inside the local control room the electronic system, the on-line computer and the polarized target controls may be seen.

Exhibit N
Building R55
(Hall 3)

CHARGE ASYMMETRY IN THE 3-PION DECAY OF THE ETA MESON – THE π8 EXPERIMENT – WESTFIELD COLLEGE, LONDON & RHEL

This experiment will determine whether charge conjugation invariance C is violated in electromagnetic interactions (i.e. are positive and negative charges treated alike at short distances). The process studied is the decay $\eta \rightarrow \pi^+ \pi^- \pi^\circ$; if C is violated, the positive pion will receive more (or less) energy on average than the negative pion. The present most reliable determination indicates a violation of $(1.5 \pm 0.5)\%$, and a 3-fold increase in precision is now being sought.

The eta mesons are produced by bombarding a liquid hydrogen target with a negative pion beam, using the reaction $\pi^- + p \rightarrow ? + n$. The neutrons are detected in a ring of 60 counters 5 metres downstream; the time of flight is measured and a gating signal produced when this time corresponds to ? being an eta. The eta decays practically instantaneously and the charged pions travel in arcs of circles due to the field of the large electromagnet which surrounds the hydrogen target. The pions pass through an array of spark chambers which are fired by the time of flight gating signal. The spark chambers are viewed by an array of vidicon (closed circuit TV) cameras which give digital electrical outputs representing the spark positions. These co-ordinates are recorded onto magnetic tape by a local IBM 1130 computer, and are used in the subsequent data analysis, in conjuction with information on spark chamber position and magnetic field strength, to deduce the energy of each pion.

The asymmetry is defined as $A = (N_+ - N_-)/(N_+ + N_-)$ where N_+ is the number of events where the π^+ was more energetic than the π^-, and N_- the reverse. To achieve the desired accuracy, 400,000 η decays must be measured.

The spark chamber and target systems may be seen in more detail in Exhibits S and T.

Exhibit P
Building R55
(Hall 3)

AUTOMATIC DATA READ-OUT FROM SPARK CHAMBERS USING AN ON-LINE DIGITAL COMPUTER

As visitors to other exhibits (e.g. L and N) will realise, spark chambers are used extensively in high energy physics to define the trajectories of charged particles. A fast detector (usually a scintillation counter) gives a signal indicating the passage of a particle; this signal triggers the application of a high voltage pulse (typically 10–12 kV) to the spark chambers which break down preferentially along the trail of ionisation left by the particle. A variety of methods (optical, sonic, magnetostrictive) is available for sensing the spark position.

In this demonstration cosmic rays are being detected. Optical spark chambers at the top and bottom of the array enable the trajectories to be seen, while the centre of the array consists of digitizing chambers. The outputs from these are fed to the Honeywell DDP 516 computer which can be seen compiling histograms of data such as the spatial distribution of tracks over the area of the chambers, which enable the chambers to be checked for edge effects and general uniformity of performance.

Exhibit Q
Building R55
(Hall 3)

GENERAL VIEW OF HALL 3 FROM THE GALLERY

Visitors will be able to ascend either of two staircases on the south side of Hall 3 in order to obtain an overall view of this area. The beam-line layout cannot readily be appreciated from floor level on account of the large amounts of radiation shielding. The gallery is used to house packaged sub-stations and power supplies; the power consumption of experimental, beam-line and ancillary equipment in the three Experimental Halls exceeds that of Nimrod itself.

Exhibit R
Building R55
(Hall 3)

BEAM LINE COMPONENTS

Visitors who have seen Nimrod (Exhibit J) and the three high energy physics experiments that are on show (Exhibits L, M and N) will know that a wide variety of beam line components are needed between the accelerator and the experimental positions to ensure that the incident particle beams have the required characteristics. A selection of such devices, and displays showing possible future developments has been assembled for inspection in the centre of Hall 3.

Beam Line Magnets. Focussing and bending magnets are used to collect and transport extracted proton beams or secondary beams. Focussing is achieved by using quadrupole magnets which act like optical lenses. Dipole magnets, the equivalent of prisms, are used for bending. Examples of each are displayed separately to facilitate inspection.

Electrostatic Particle Separators. A frequent requirement is for a beam of particles (e.g. kaons) uncontaminated by other particles (e.g. pions). The procedure is to subject the beam to momentum analysis in a magnet-slit system (thus defining the mass-velocity product of the transmitted particles), followed by a velocity selection which then fixes the mass. Velocity selection is performed by means of electrostatic fields, created by applying voltages of up to 600 kV to long parallel electrodes in a vacuum chamber. Two types of electrostatic separator are shown – the conventional type using conducting glass electrodes and a new type, developed at the Rutherford Laboratory, which uses wire mesh electrodes. This version has improved voltage characteristics, can be conditioned more rapidly and is less critical to operate.

Superconducting Radio-Frequency Particle Separators. The flux of secondary particles and their available momentum range can be increased by using radio-frequency separators in place of the electrostatic type. Very high radio-frequency power levels are needed to achieve the required field strengths in a cavity operating at normal temperatures. A reduction in power consumption by a factor of about 10^5 is possible by using superconducting cavities operating at 1.85°K. It is intended to utilise such a device in a future beam-line in Hall 3 and details of this plan and of the cavities will be shown.

Concrete Insulated Magnets. Organic based magnet insulating materials such as epoxy resins are damaged by ionising radiations, to the eventual detriment of their electrical and mechanical properties. Inorganic materials are not affected in this way, and considerable progress has been made in the use of fine cementaceous aggregates as an insulating binder. Pre-stressing techniques can be applied and it seems likely that synchrotron ring magnets as well as beam-line elements can be made by this method. Prototype magnets will be shown.

Magnetic Field Measurement. To ensure optimum operation of the complex beam lines associated with Nimrod, it is necessary to monitor the strength of the field in the many magnetic devices that are used. A low cost field monitor, capable of 0.1% accuracy has been developed for this purpose and can be seen in use on a beam line magnet. The sensing element is a semiconductor magneto-resistor fed from a high stability current source. Readout is by means of a digital voltmeter.

Exhibit S
Building R55
(Hall 3)

INSTRUMENTATION FOR HIGH ENERGY PHYSICS. SPARK CHAMBER CONSTRUCTION AND ALLIED TECHNIQUES

Considerable technological effort is required to produce operational particle counters in the quantities and to the exacting specifications required by modern high energy physics. This exhibit consists of a varied selection of items illustrating the problems that arise and the solutions adopted. Brief details of some of the equipment to be shown are given below.

Spark Chambers. The electrodes in a spark chamber can be of metal foil or tightly stretched wires. Spark chamber areas are now reckoned in square feet and a high degree of ingenuity and craftsmanship is needed to achieve the requisite geometrical precision. The constructional techniques used for foil and wire chambers will be shown. A wide gap (4 inch) chamber will be operating, the short duration high voltage pulse being supplied by a spark gap-capacitor system. The optical spark chambers developed for the $\pi 8$ experiment (Exhibit N) will be shown. A commonly used spark chamber is the sonic type, in which the spark position is deduced from the transit time of the sound of the spark to peripherally mounted microphones. The microphones developed at the Rutherford Laboratory use strips of piezoelectric ceramic, the signal rise times from which are typically 1 microsecond giving positional accuracies of 0.2 mm.

Gas Systems for Spark Chambers. Spark chambers are very sensitive to the presence of impurities in their filling gases. Now that chambers are becoming both larger and more numerous, it is necessary to use closed circuit gas systems to conserve helium-neon gas supplies, rather than flushing continuous and venting to waste as in the past. A recirculation and purification system using molecular sieve material has been devised. Flow rates of up to 20 litres per minute are possible, and to avoid rupturing thin spark chamber foils the pressure is regulated to less than one inch water gauge. A continuous monitor of gas purity is provided by a relaxation circuit, the sensing element in which is an electrical discharge cell. Impurity gases have ionisation potentials different from the helium-neon mixture and give rise to a change in the oscillator frequency.

Electroluminescent Materials. Optical spark chambers are provided with fiducial marks whose positions relative to other parts of an experiment are accurately known and which are photographed along with the sparks to enable the particle position in a series of chambers to be inter-related. In the past filament lamps have been used for this and for data display purposes. These lamps have short lives and slow rise times. Electroluminescent panels are available in suitable sizes, and consist basically of a thin capacitor, the dielectric of which contains phosphors such as zinc sulphide. Light pulses are produced at each reversal of an applied a.c. voltage.

Light Guides. The flash of light produced when a particle passes through a Cerenkov counter or a scintillator must be conveyed to the photomultiplier which produces the electrical signal. The photomultiplier must often be a foot or more away because of space limitations or stray magnetic fields. The optical coupling is achieved by means of light guides, accurately machined pieces of perspex within which the light is totally internally reflected.

Other Items. These include vacuum evaporation methods and displays of electrical and mechanical craftsmanship.

Exhibit T
Building R55
(Hall 3)

LIQUID HYDROGEN TARGETS

Many high energy physics experiments require a proton target and the choice normally falls on pure hydrogen, which contains no other particles that could give rise to complicating background effects. Hydrogen is usually used in liquid form in order to have a sufficiently dense target; low temperature techniques are therefore involved in addition to safety problems arising from the flammability of hydrogen. This exhibit displays components such as the target flask and closed cycle refrigeration system that are used in the standard hydrogen target, one of which forms part of the apparatus of the $\pi 8$ experiment (Exhibit N, adjacent to this exhibit). For safety reasons the total volume of liquid hydrogen in the system is kept down in the 1–10 litre range.

Exhibit U
Building R55
(Hall 3)

TELEVISION CAMERAS IN HIGH MAGNETIC FIELDS

Closed circuit television is a convenient method of observing equipment behaviour in areas such as the Nimrod magnet hall which, because of high radiation levels, are not accessible to human observers when in operation. It can also be used to observe particle beams when they strike a fluorescent target. Television cameras are, however, adversely affected by strong magnetic fields, particularly if pulsed, as is the case in the fringe field of Nimrod's magnet. A special camera has been designed by Electronic Consultants Ltd., to which the Laboratory has added a magnetic shield; picture quality is good even close to the Nimrod magnet. The demonstration compares the performance of this special unit with a conventional camera in a varying magnetic field.

Exhibit V
Building R55
(Hall 3)

ENGINEERING SUPPORT SERVICES FOR HIGH ENERGY PHYSICS

To sustain a vigorous research programme it is important to provide a wide range of supporting activities. A small selection of the less usual of these has been put on display.

Materials Technology. Many of the materials used in high energy physics equipment are required to withstand severe working conditions (high or low temperatures, high radiation doses), and a continuous programme of material evaluation (principally on plastics and impregnants) operates in order to meet these needs.

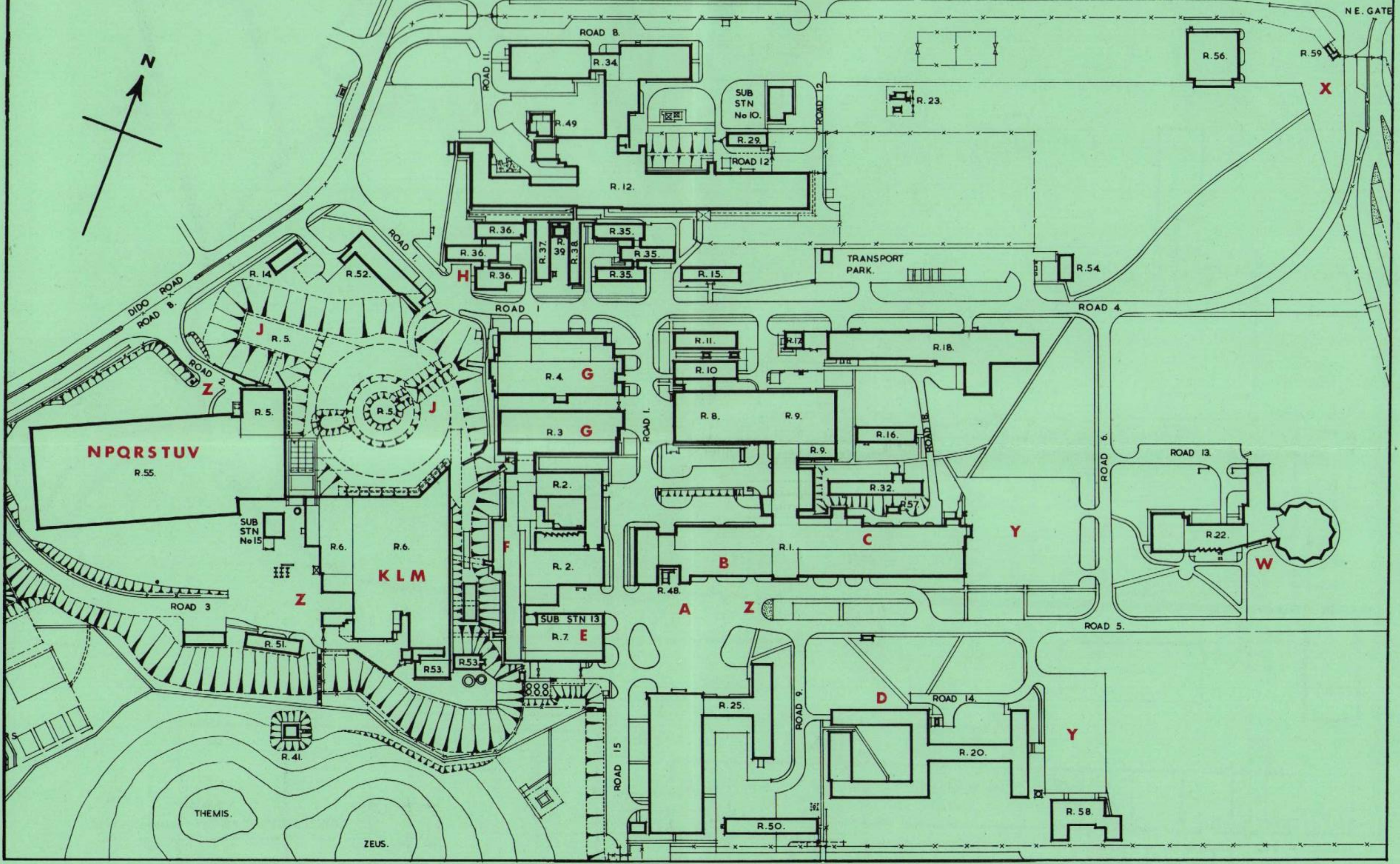
Workshop Technology. Pieces of experimental equipment frequently require components that are difficult to make and which require a high degree of precision and skill. Among the items shown are an experimental film gate for the High Field Bubble Chamber camera, and a swash plate for the hydraulic pump used on the Mk II Plunging Mechanism for Nimrod.

Magnet Winding Techniques. Superconducting magnet coils require novel techniques of construction, since both conductor shapes and their mechanical properties are unusual. A substantial development programme of coil forming methods is planned to cater for future needs.

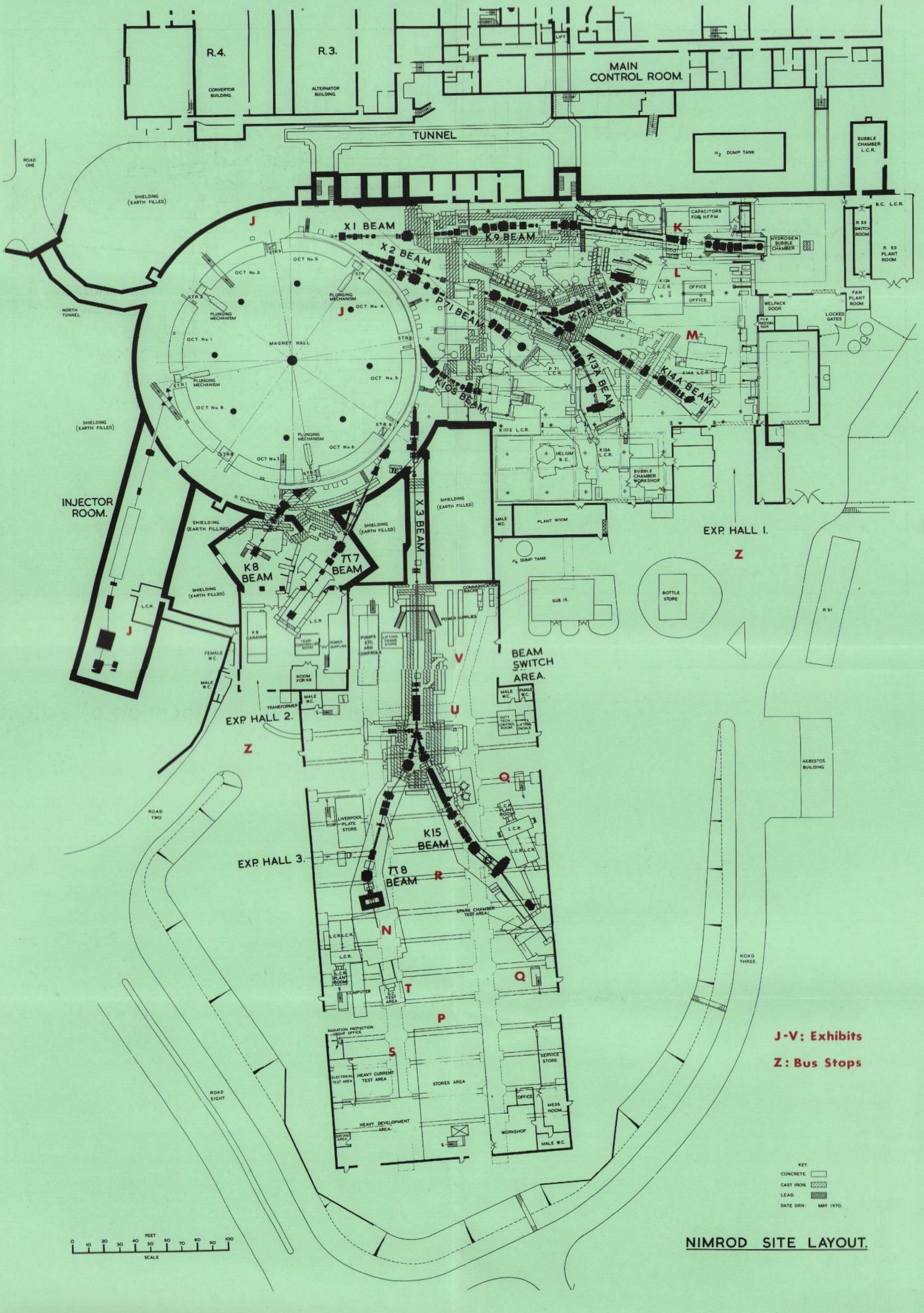
Site Electrical Distribution. The Laboratory has an installed transformer capacity of 38½ MVA, with 8 MVA supplied direct at 11 kV; peak demand is over 21 MW and the annual consumption is approximately a 100 million kWh. Details will be shown of the sub-station system and of features necessitated by the special nature of the equipment supplied.

Electronic Development. The exhibit will show examples of a range of printed circuit boards and grids used at the Laboratory, with samples of electronic assemblies used in the NIM and CAMAC systems, and a display illustrating a high voltage light link interface for controlling a Heavy Ion Accelerator.

Site maps showing location of exhibits



A–V : Exhibits W : Restaurant X : Entrance Y : Car Parks Z : Bus Stops



J-V: Exhibits

Z: Bus Stops

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NIMROD SITE LAYOUT.

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