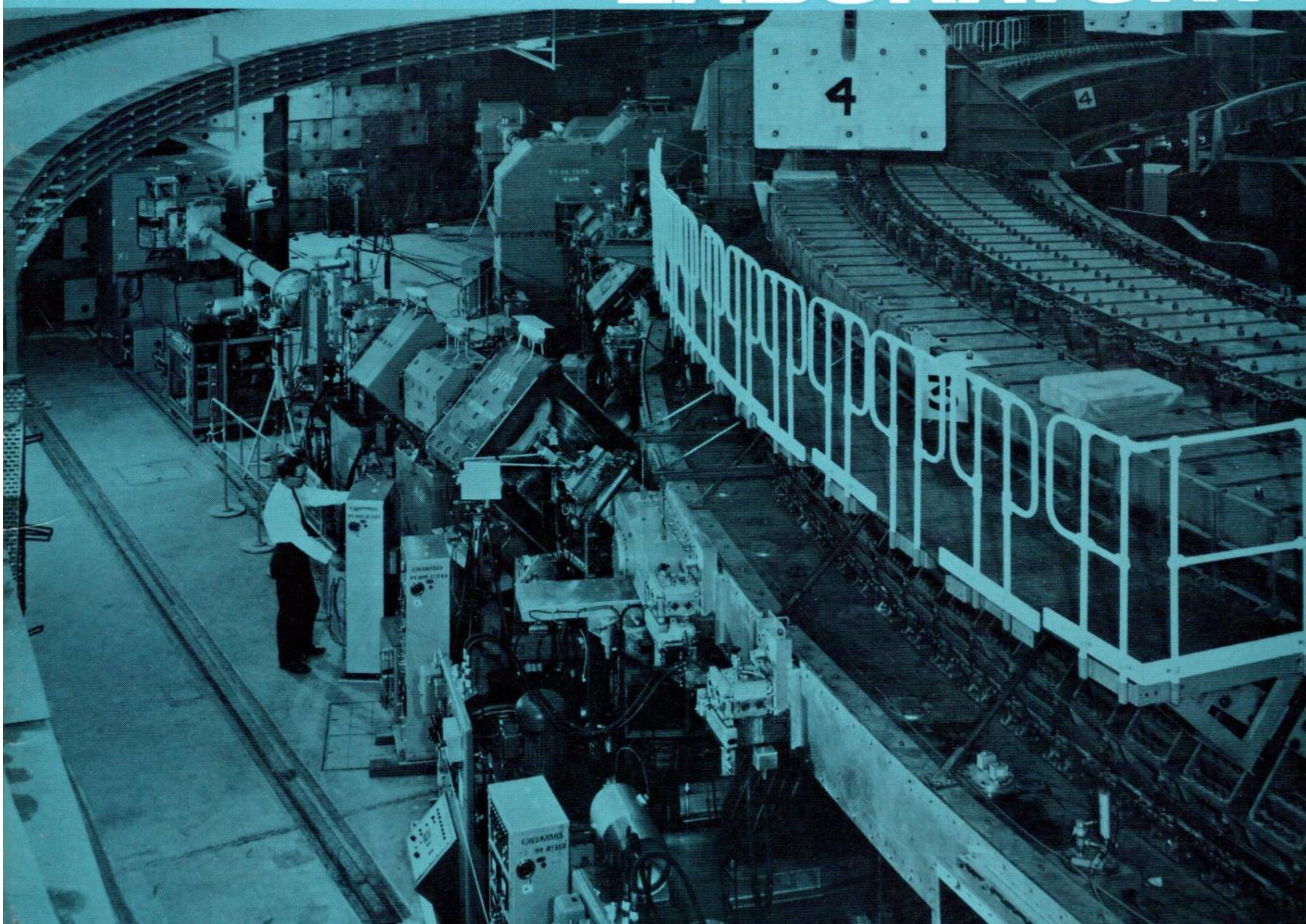
Science Research Council

RUTHERFORD LABORATORY



NIMROD
7GeV Proton Synchrotron

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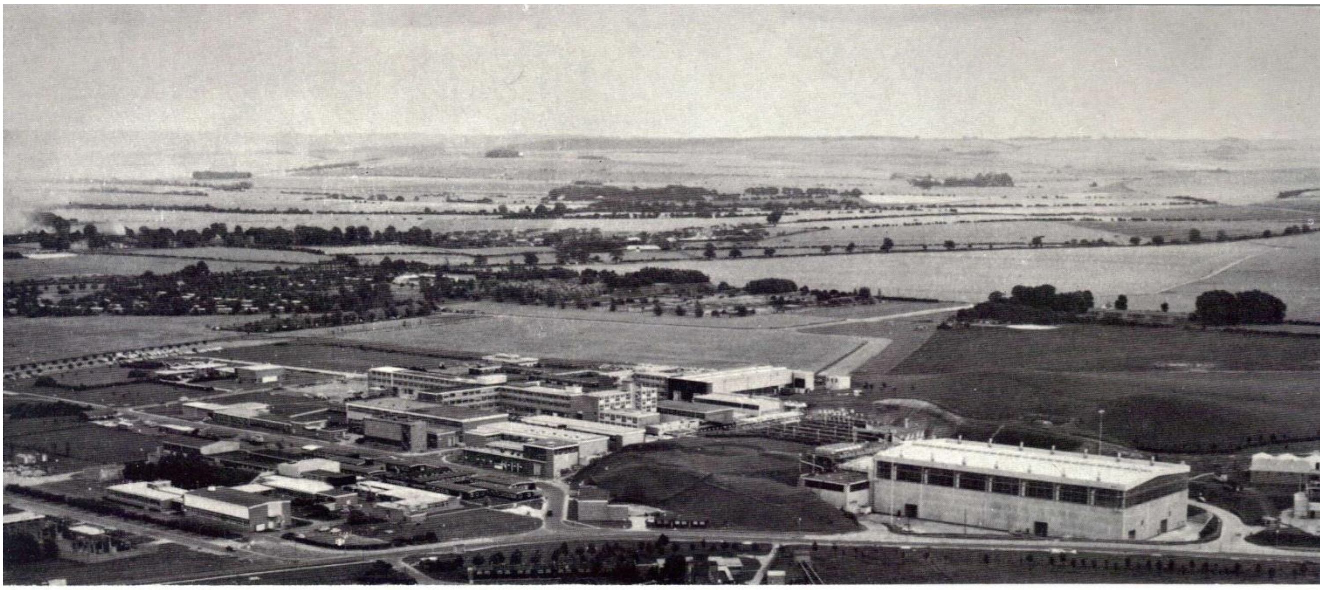


INTRODUCTION

The Rutherford Laboratory was founded in 1957 as a national research centre for nuclear science. It was particularly intended for the development and operation of nuclear research equipment for use by universities, where the size, complexity or cost of the equipment was beyond the resources of the universities themselves.

The first machine in this category to operate at the Laboratory was the 50 MeV Proton Linear Accelerator which commenced nuclear research in April 1960 and ceased operation in October 1969. The second was the 7 GeV Proton Synchrotron Nimrod which reached full energy in August 1963 and started its programme of high energy physics experiments in February 1964.

In April 1965, the Science Research Council was set up with wide responsibilities for research in the physical sciences in its own laboratories, at universities and in collaboration with international organisations. The Rutherford Laboratory and its sister establishment the Daresbury Laboratory were transferred to the Science Research Council. The Council is now responsible for the entire national effort in pure nuclear science, by its support of these two Laboratories, nuclear research in universities and also by participation in the European Organisation for Nuclear Research (CERN) at Geneva.

Over 200 physicists from universities and other institutions (both UK and overseas) and from the Rutherford Laboratory now base their research on Nimrod.

The name NIMROD–("A mighty one in the earth"–Genesis 10, 8-9) has been given to the 7 GeV proton synchrotron.

Injector

Energy of protons entering Linear Accelerator	0·6 MeV
Energy of protons entering Synchrotron	15 MeV
Linac output current	5–30 mA
Linac operating frequency	115 MHz
Estimated pulsed R.F. power dissipated	700 kW
Overall length of Linac tank	14m (46ft.)
Diameter of Linac tank	2·43m (8ft.)
Number of pumps (mercury)	10

Magnet

Beam radius mean	23·4m (77·5ft.)
Normal peak magnetic field at injection	0·028 tesla
Peak magnetic field	1·4 tesla
Useful magnetic aperture	0·23m (9in.) vertical 0·91m (36in.) horizontal
Number of magnet sectors	336
Weight of each magnet sector	19·4 tonnes (19 tons)
Number of turns in coil	42
Weight of magnet coil total	357 tonnes (350 tons)
Pulse rise time	0·72 s
Pulse decay time	0·8 s
Repetition rate of magnet pulse	0·37 Hz (22 min^{-1})
Normal peak current in coil	9150 A
Stored energy in magnet at peak field	40 MJ
Number of protons accelerated	2×10^{12} per pulse

Magnet Power Supply

Number of motor-alternator-flywheel sets	2
Alternator rating nominal	60 MVA
Alternator rating maximum	91 MVA
Alternator rating thermal	42 MVA
Weight of alternator rotor	61 tonnes (60 tons)
Weight of alternator stator	73 tonnes (72 tons)
Motor rating	3·81 MW
Motor speed	16·2 rps (970 rpm)
Flywheel diameter	3·2m (10·5ft.)
Flywheel weight	30·5 tonnes (30 tons)
Total stored energy in complete rotating plant	535 MJ
Speed reduction during pulse	4%

Vacuum System

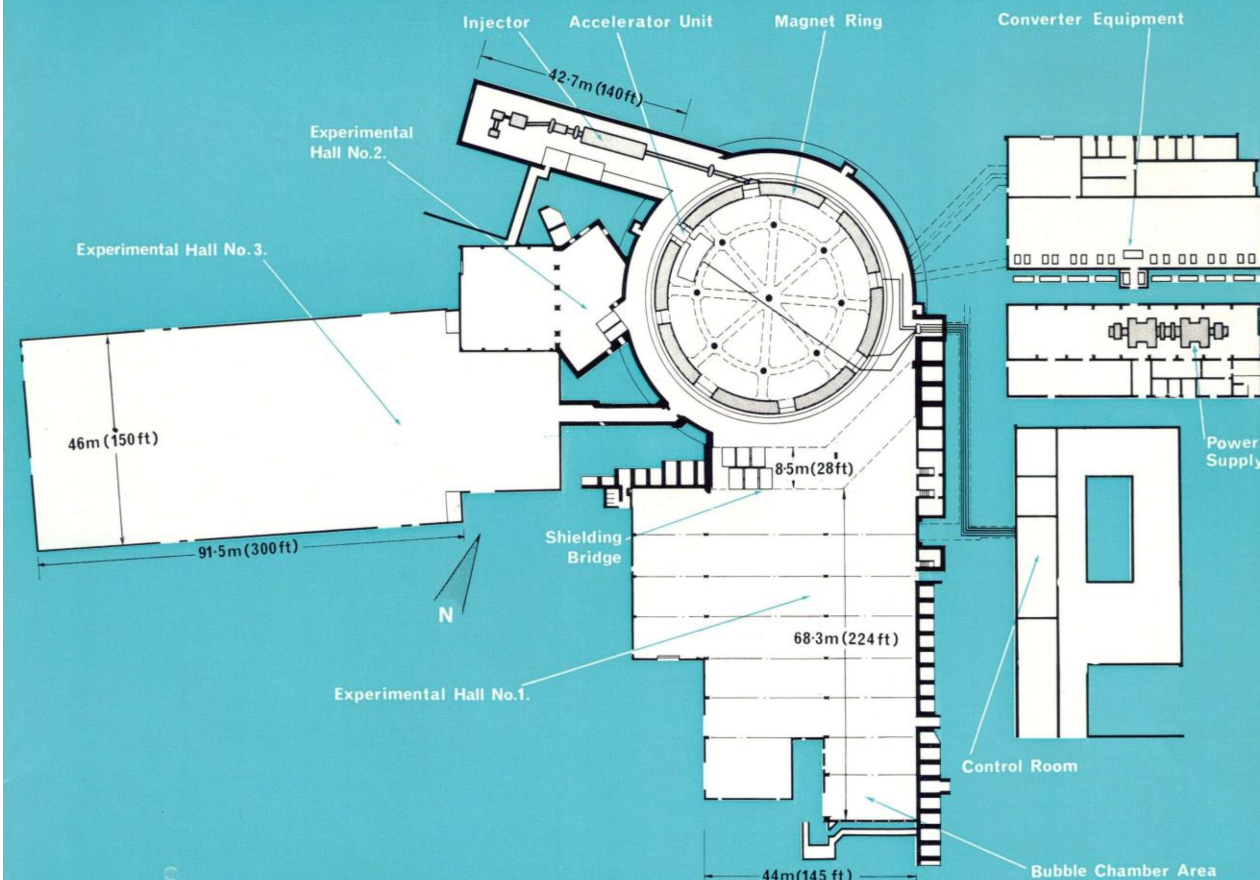
Vertical beam aperture	0·24m (9·5in.)
Pressure in inner vessel	10^{-4} Nm^{-2}
Pressure in outer vessel	100 Nm^{-2}
Pumping volume of inner vessel	100m^3 (3500 cu.ft.)
Number of pump units for inner vessel	40
Pump type	0·6m (24in.) oil diffusion
Vacuum vessel material	Epoxy glass laminate
Overall peak speed of diffusion pumps	200,000 litre s^{-1}(approx).

R.F. System

Frequency at injection energy	1·4 MHz
Frequency at peak energy	8·2 MHz
Weight of ferrite	5·4 tonnes (12000lbs)
Weight of cavity	20·4 tonnes (20 tons)
Peak R.F. volts per gap	7 kV
R.F. power dissipation	45 kW
Ferrite working temperature	25°C
D.C. bias winding ampere turns	8000

General Parameters

Diameter of magnet building	60·9m (200ft.)
Weight of concrete in building . approx.	102,000 tonnes(100,000 tons)
Radiation shielding wall thickness	9·1m (30ft.) of concrete (equivalent)
Roof thickness	4·9m (16ft.) of concrete (equivalent)
Distance travelled by particles during acceleration	160,000 km (100,000 miles)

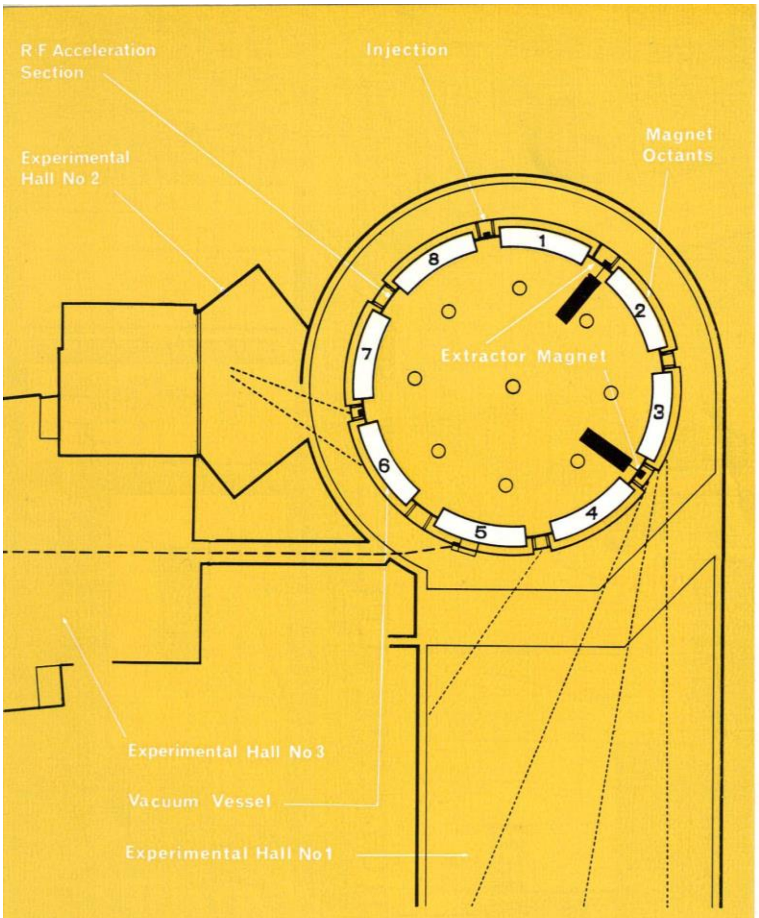


Nimrod Parameters

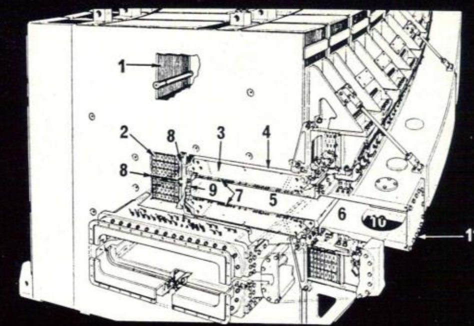
The main physical feature of NIMROD is a large ring-shaped electromagnet, 49 m. (160 ft.) in diameter, which weighs 7,100 tonnes (7,000 tons). A toroidal shaped evacuated chamber made from glass-fibre reinforced epoxy resin is situated between the poles of this magnet. A pulse of protons, given an initial 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 are 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 61 m. (200 ft.) in diameter with a 5 m. (16 ft.) concrete roof on which a 6 m. (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-flywheel set in which the alternators are connected to the magnet through a bank of rectifiers. This equipment supplies direct current of gradually increasing strength during the 0·72 s. acceleration period, and the current decays again to zero in a further 0·8 s. ready for the next pulse. Energy is thus stored in the magnet during the current-rise period and is subsequently returned to the fly-wheels as the current is reduced again to zero. The amount of energy being shuttled to and fro amounts to some 40 mega-joules. In this way, the flywheels act as a buffer between the load (the magnet windings) and the electrical supply.

The machine produces about 2×10^{12} protons per pulse at a repetition rate of 22 pulses per minute at 7 GeV. Higher repetition rates are possible at lower energies. NIMROD is used for fundamental research into the physics of elementary particles.

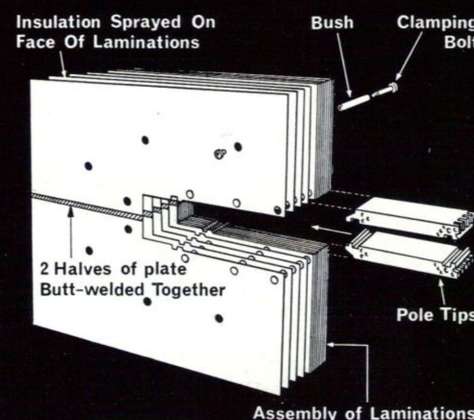


Magnet

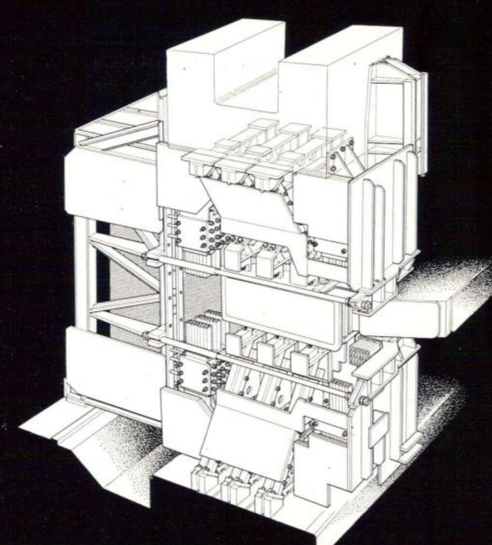


1 Magnet Sector
2 Magnet Coils
3 Pole Tips
4 Outer Vacuum Chamber
5 Inner Vacuum Chamber
6 Header Chamber
7 Pole Face Windings
8 Pressure Pads
9 Pole Tip Jacks
10 Main Pumping Port
11 Beam Exit Window

Cross section through 7GeV Magnet Octant



7 GeV Magnet Sector Assembly



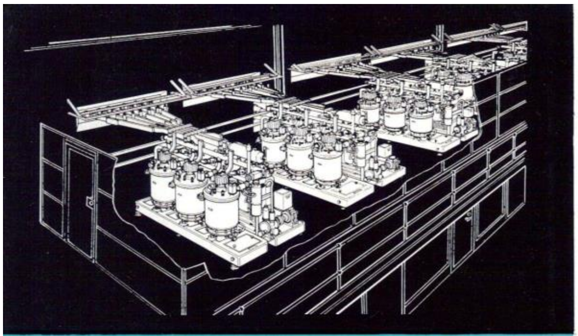
Octant End Structures

The magnet comprises eight octants separated by straight field free spaces which accommodate the R.F. accelerating cavity, and various machine components. Each octant comprises 42 sectors the whole 336 sectors weighing 7,100 tonnes (7,000 tons).

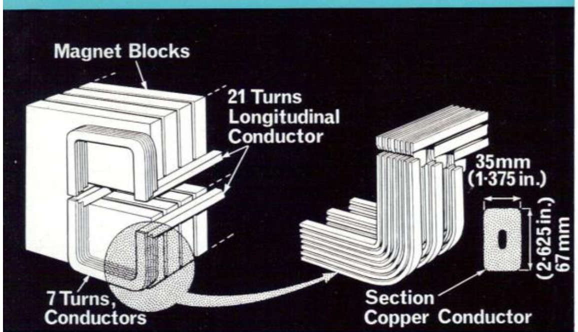
The 0·3 m. (12½ in.) thickness of a sector is made up from about 46 plates of 1 per cent silicon steel. The plates are annealed and flattened, cleaned and coated with insulation. The sector is held together by bolts and some edge welding. Finally the C-gap is machined to the final dimension.

Each pole piece weighs 36 kg. (800 lb.) and consists of a stack of about 450 steel laminations 0·5-0·8 mm. (0·020-0·030 in.) thick. These accurately formed laminations are glued together with an epoxy resin-glass cloth adhesive to accurate finished dimensions. The pole pieces are produced in matched pairs to preserve magnetic symmetry.

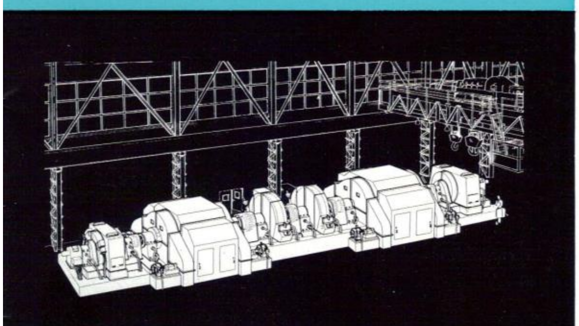
Each magnet octant has its own 42 turn winding fabricated from 50 ft. lengths of extruded copper of section 35 × 67 mm. (1·375 × 2·625 in.). The conductors are cooled by demineralised water pumped through a 130 mm^2 (0·2 in^2) hole in the centre. The windings of the octants are all connected in series and carry a peak current of 9,150 A. The total power dissipation is 3 MW at the normal repetition rate of the machine. The weight of copper in the coils is about 357 tonnes (350 tons).



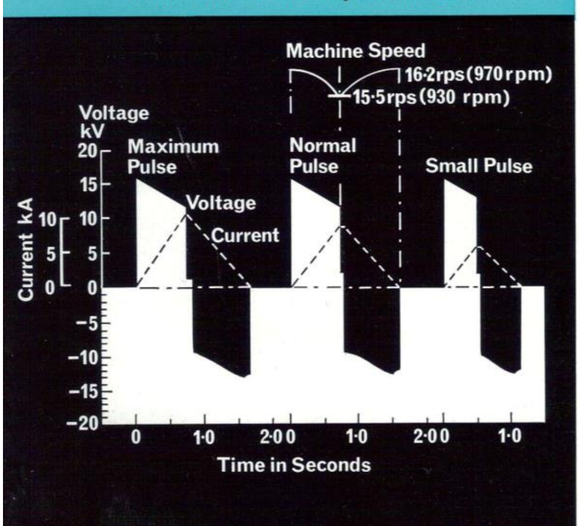
Rectifier Installation



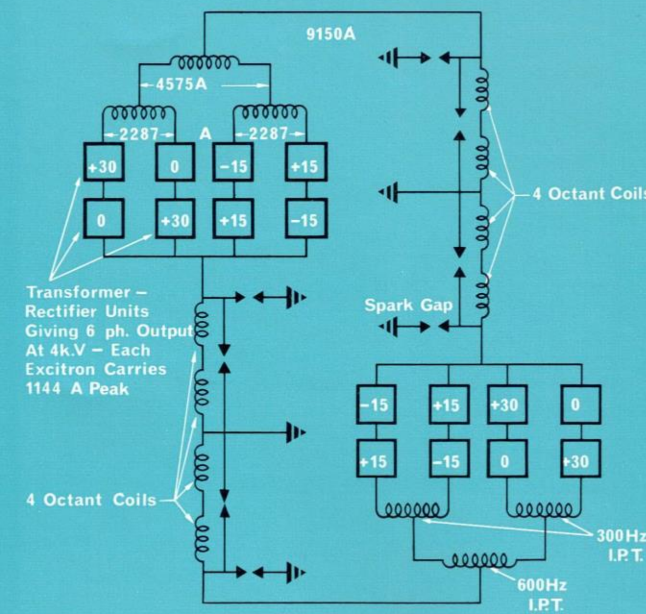
Coil Location on Magnet Blocks



Motor-Alternator-Flywheel-Sets



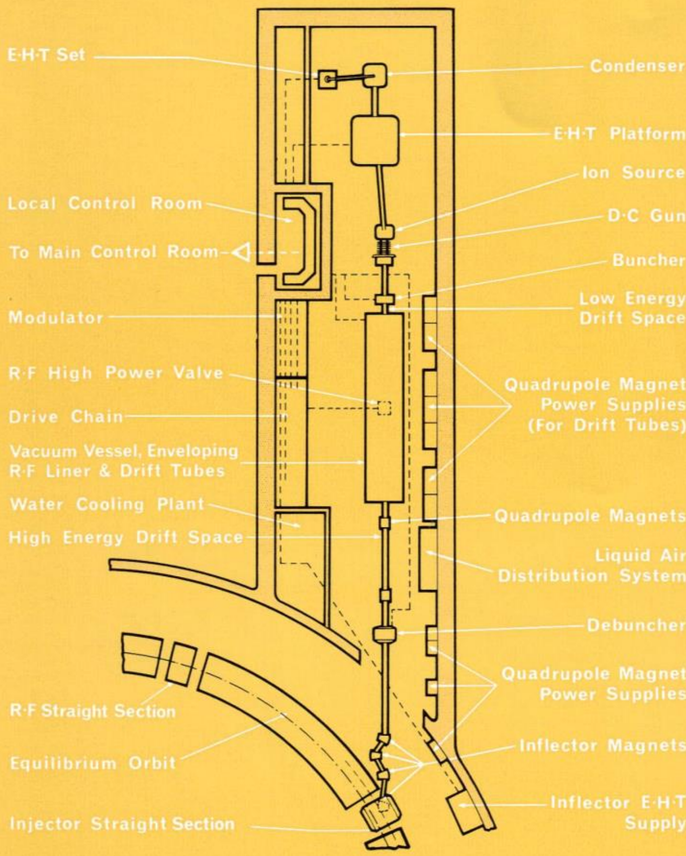
Pulse Shapes, Magnet Power Plant



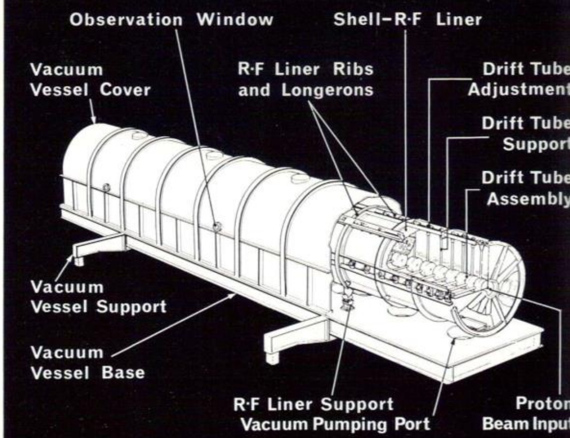
Magnet Power Supplies

The power supply for the Nimrod magnet consists of two motor-alternator-flywheel sets, the alternators being connected to the magnet via phase multiplying transformers and grid controlled mercury-arc converters. Each alternator has a nominal rating of 60 MVA, the two flywheels weight 30·5 tonnes each and the induction motors, which bring the set up to speed initially and supply the losses of the system, are each rated at 3·8 MW. The two alternators are paralleled electrically but there is no mechanical coupling between the two shaft systems. Magnet pulses up to a maximum of 10·5 kA can be obtained, the magnet voltage under these conditions being 11·5 kV DC. The corresponding total alternator loading is of the order of 160 MVA. The current rise period during which all converters act as free firing rectifiers and energy is given up by the rotating plant system, is around 0·8 s. During the decay period the converters operate as inverters and energy from the magnet is returned to the rotating system via the alternators which now act as synchronous motors.

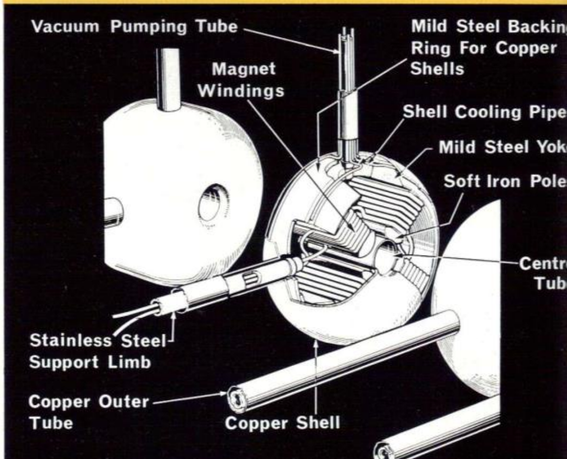
The foundation problem, arising from the rapid torque changes on the rotating plant, is relieved by supporting the massive reinforced concrete machine block on steel springs.



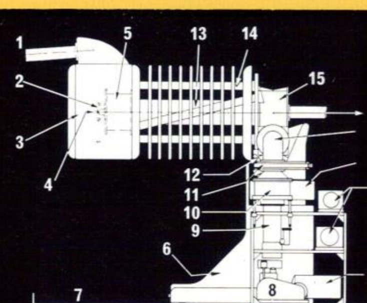
Injector



Linear Accelerator



Drift Tube



1 Tube From E·H·T Platform Carrying Electric Cable & Hydrogen Supply Pipe
2 Ion Source
3 Bun Casing
4 Hydrogen Inlet Into Ion Source
5 Focusing System
6 Light Alloy Fairings
7 Support Stand Rails
8 Backing Pump
9 Diffusion Pump
10 Cold Trap
11 Shut–Off Valve
12 Elevating Screw
13 Accelerating Column
14 Fibre Glass Tie Rods
15 Vacuum Manifold
16 Beam Path
17 Vacuum Elbow
18 Support Stand
19 Refrigerators
20 Compressed Air Cylinder

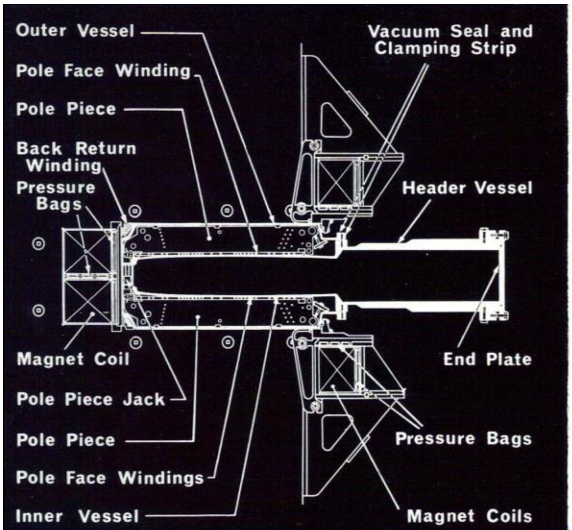
D.C. Gun Support Stand & Vacuum Equipment

The injector is a 15 million electron volt (15 MeV) linear accelerator, designed to provide a high intensity beam of protons for injection into the 7 GeV (7,000 MeV) synchrotron.

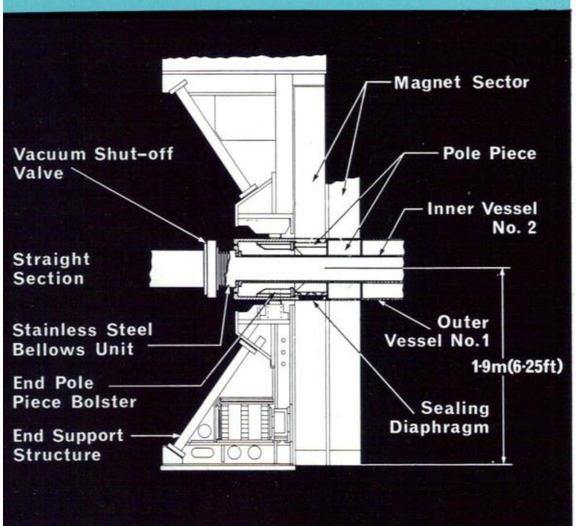
The origin of the proton beam is the ion source, where hydrogen gas at low pressure is ionised in a discharge induced by a Radio Frequency field. Pulses of protons are then extracted and accelerated to an energy of 0·6 MeV. This comprises the ION GUN or PRE-INJECTOR.

The beam next enters the LINEAR ACCELERATOR which is essentially a highly evacuated, cylindrical copper cavity, 13·4 m. (44 ft.) long by 1·6 m. (5·5 ft.). This cavity is resonated by a 115 MHz R.F. source, producing an alternating axial electrical field. The protons passing along the axis of the cylinder are shielded from the decelerating parts of this field by a series of DRIFT TUBES. Each drift tube contains a four-pole focusing magnet to prevent loss of proton beam by excessive expansion during acceleration. Since pulses of up to 0·002 seconds long at intervals of about two seconds are required by the synchrotron, the accelerating cavity is pulsed by about one Megawatt of R.F. power when required.

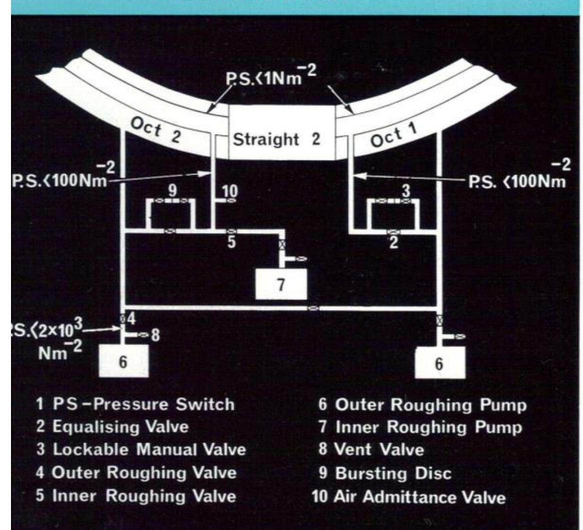
The 15 MeV proton beam is introduced into the main magnet ring by means of a 25° deflection system, consisting of four bending magnets followed by an electrostatic inflector.



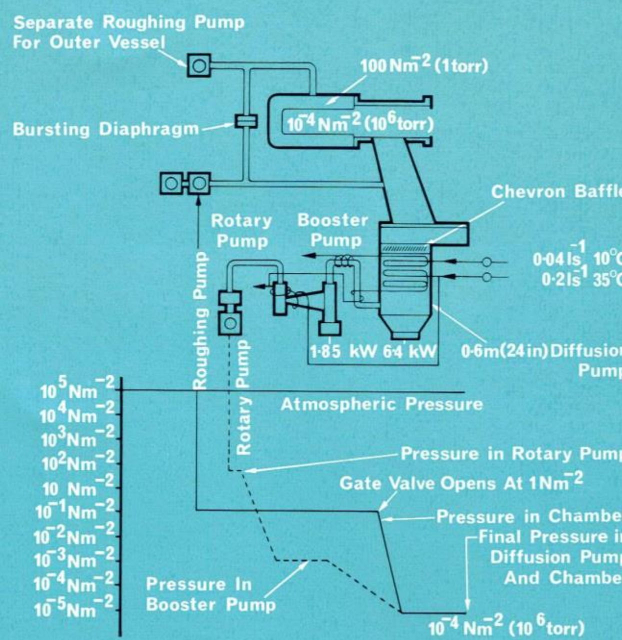
Vacuum Vessel & Support System



Octant End Structure



Layout of Roughing System

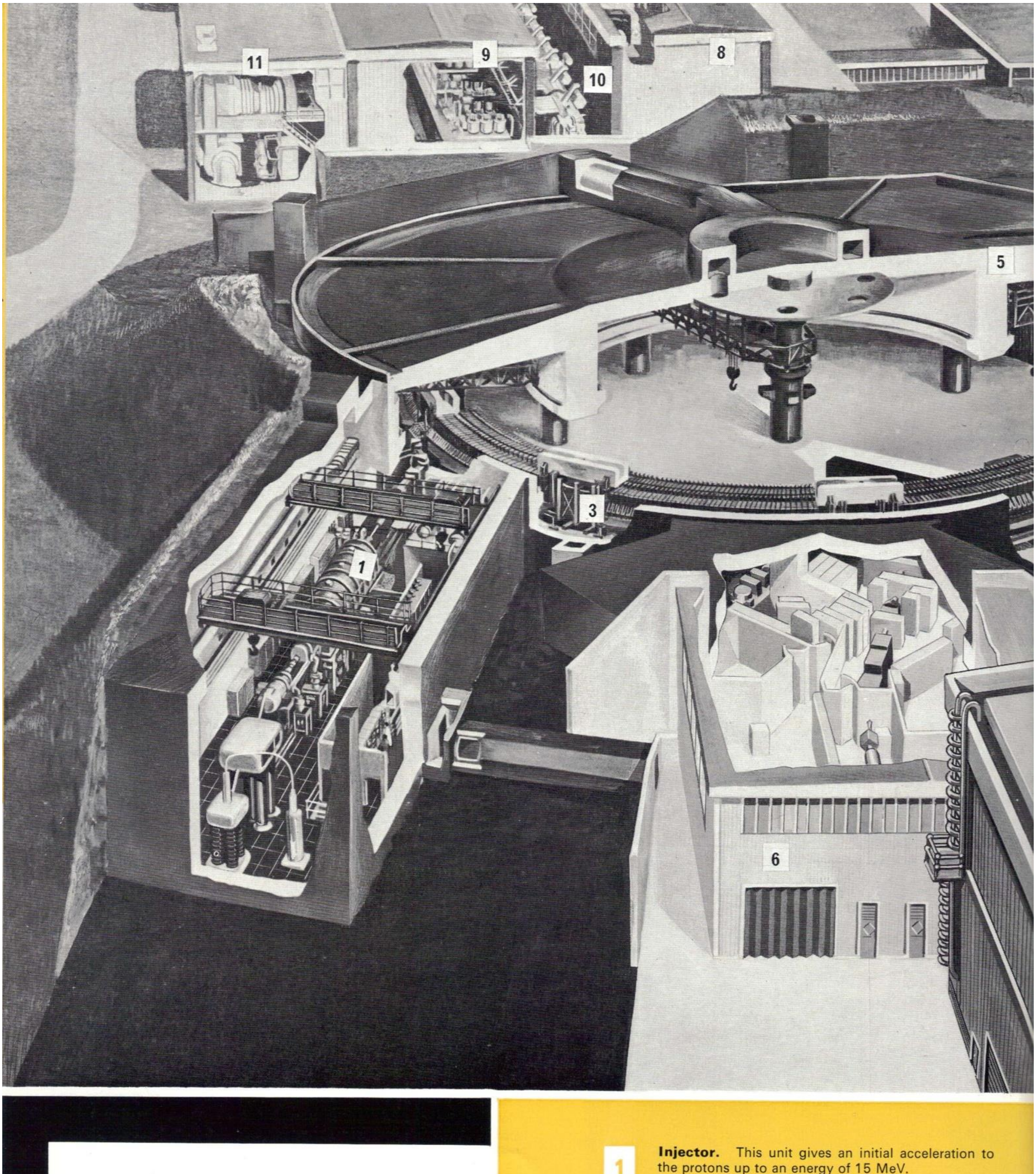


Vacuum System

The vacuum chamber comprises eight double walled vessels of glass reinforced epoxy resin each the whole length of an octant. An outer vessel with thin walls is sandwiched between the poles and yoke of each magnet octant. An inner vessel of similar length is placed within the octant gap and evacuated to 10^{-4} Nm^{-2} while the space between the two vessels is evacuated to about 100 Nm^{-2}. Thus the magnet structure supports practically all the atmospheric load and the inner high vacuum vessel has only a small differential pressure to withstand.

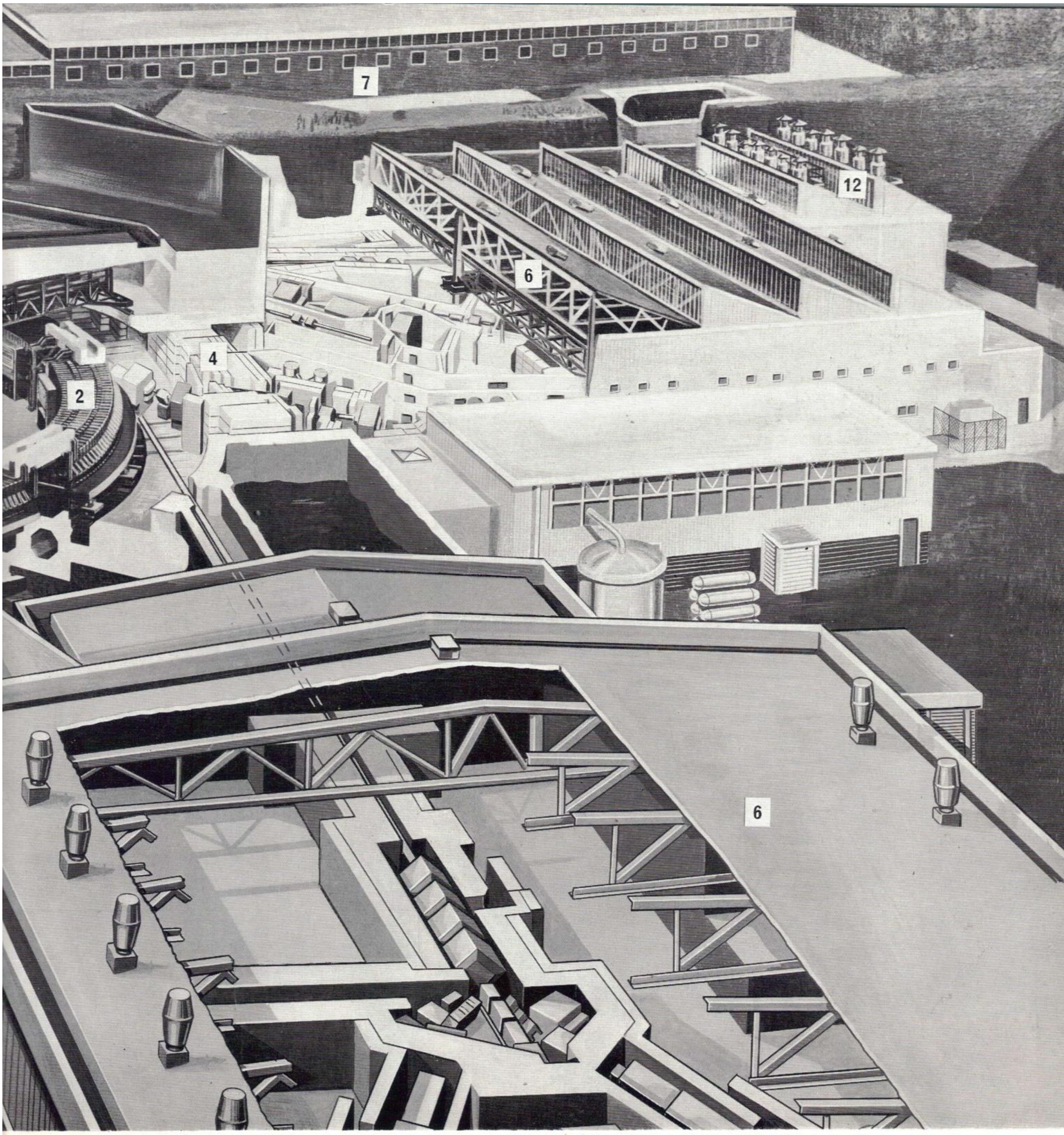
The inner vessels are evacuated by a total of forty 0·6 m. (24 in.) diameter oil diffusion pumps which exhaust the vessel via a substantial header chamber of similar construction to the main vessels.

The gaps between octants are bridged by single walled vessels, incorporating expansion bellows and shut-off valves, allowing a clear high vacuum path measuring at least 0·24 m. (9·5 in.) vertically and 0·9 m. (36 in.) radially, round the ring in which the protons can travel.



7 GeV Proton Synchrotron

1	**Injector.** This unit gives an initial acceleration to the protons up to an energy of 15 MeV.
2	**Electromagnet** The large magnet guides and focuses the protons in an orbit of constant radius.
3	**R.F. System.** The radio-frequency accelerating unit gives the protons a peak 7 kV kick on each orbit.
4	**Shielding Wall.** This is made of steel and concrete giving radiation protection to the Experimental Halls.



5 **Shielding.** The synchrotron is enclosed in a shield of concrete with additional earth shielding on the roof and around the sides.

6 **Experimental Halls.** Beams of protons are admitted to the Halls through 'beam lines'.

7 **Control Room.** Contains all the instruments controlling the operation of NIMROD.

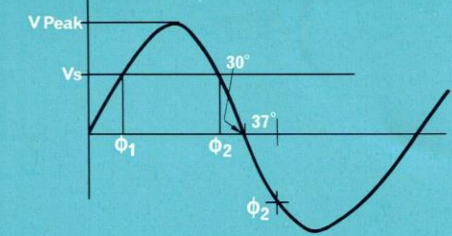
8 **Alternator House.** The rotating plant comprises two 60 MVA, 16·2 rps (970 rpm) alternators and two 30·5 tonne (30 ton) flywheels driven by two 3·8 MW induction motors.

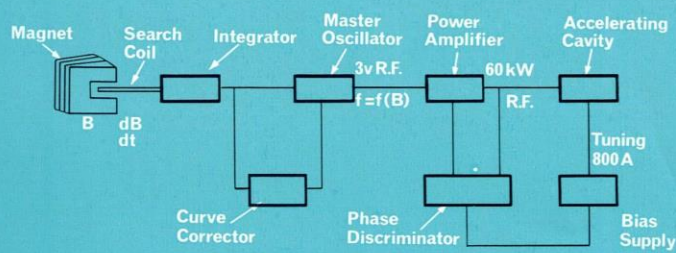
9 **Converter House.** Contains the 96 water cooled single anode, grid controlled mercury arc converters.

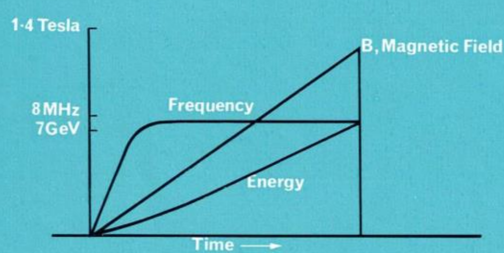
10 **Transformer Yard.** Eight 12 MVA phase splitting transformers.

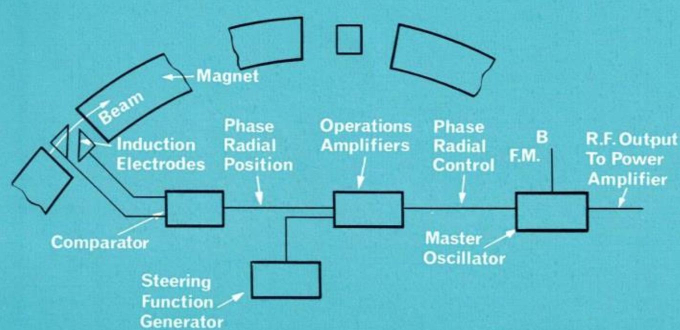
11 **Plant Room.** Contains the air-conditioning plant for the Magnet Room.

12 **Bubble Chamber.** A chamber containing liquid hydrogen used for the study of collisions between elementary particles.



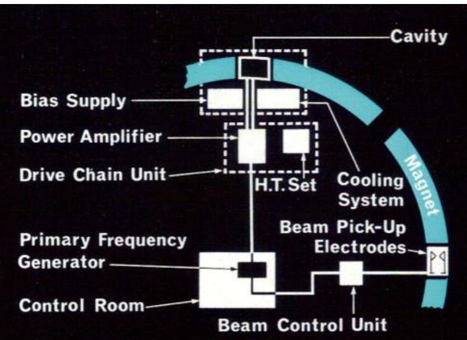




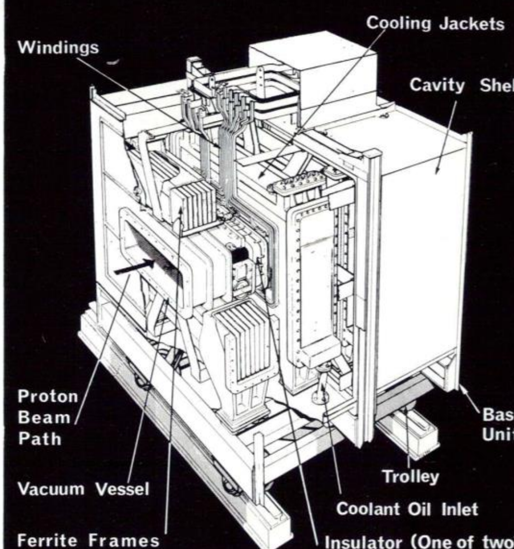


Accelerator System

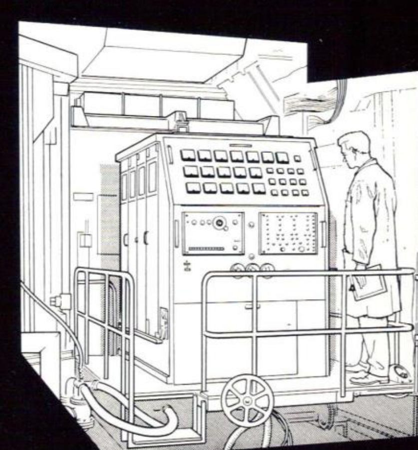
THE ACCELERATING SYSTEM comprises a primary frequency generator, a bias supply, a beam control unit and an accelerator unit. The accelerator unit is designed as part of the main vacuum system, the flanges of the vacuum vessel located within the R.F. unit actually acting as electrodes for beam accelerating purposes. The cavity is excited by a variable frequency oscillator whose frequency must vary from 1·4 to 8 MHz between beam injection and extraction. The peak voltage across each insulator rises to 7 kV. The frequency control of the cavity is obtained by magnetically biasing the ferrite cores by a direct current which changes the incremental inductance of the circuit. These cores are of a picture frame type and are produced by bonding sintered blocks with an epoxy resin cement. Some 5·4 tonnes (12,000 lb.) of ferrite is used.



Diagrammatic Layout of Accelerating Unit

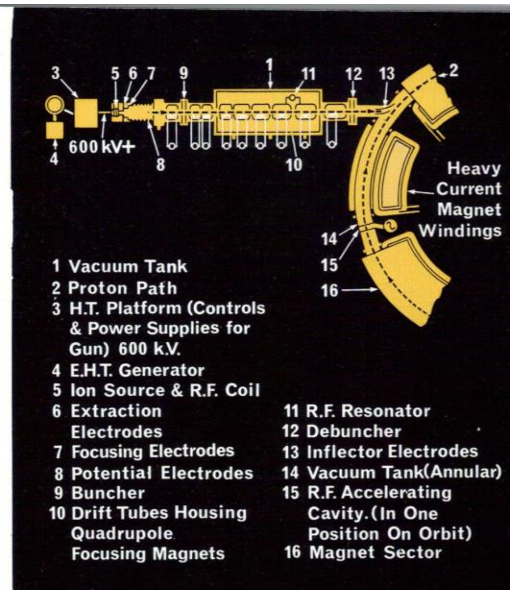


R.F. Cavity

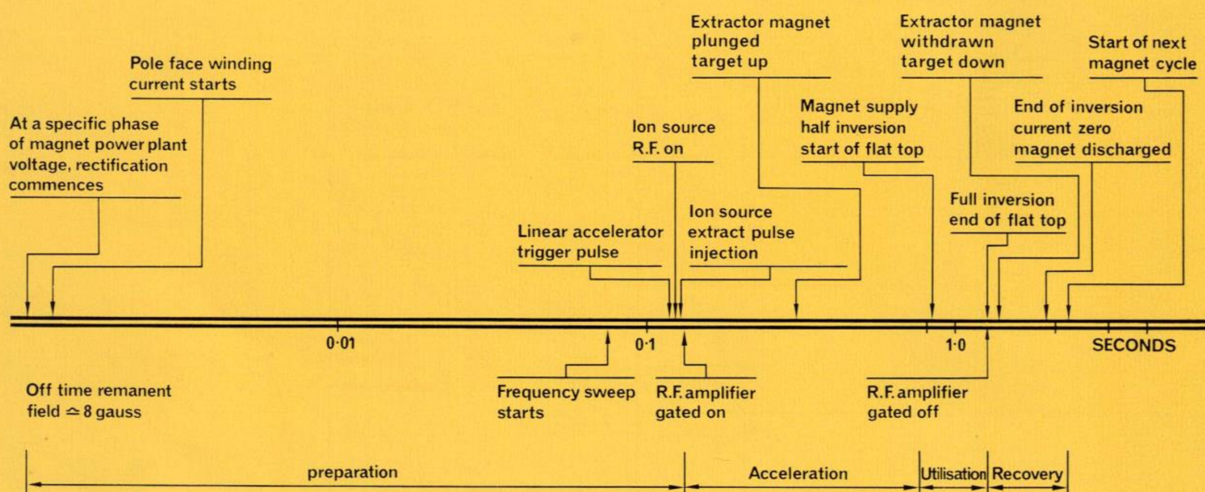


Synchrotron R.F. Transmitter

Main Control Room



Outline of Operation

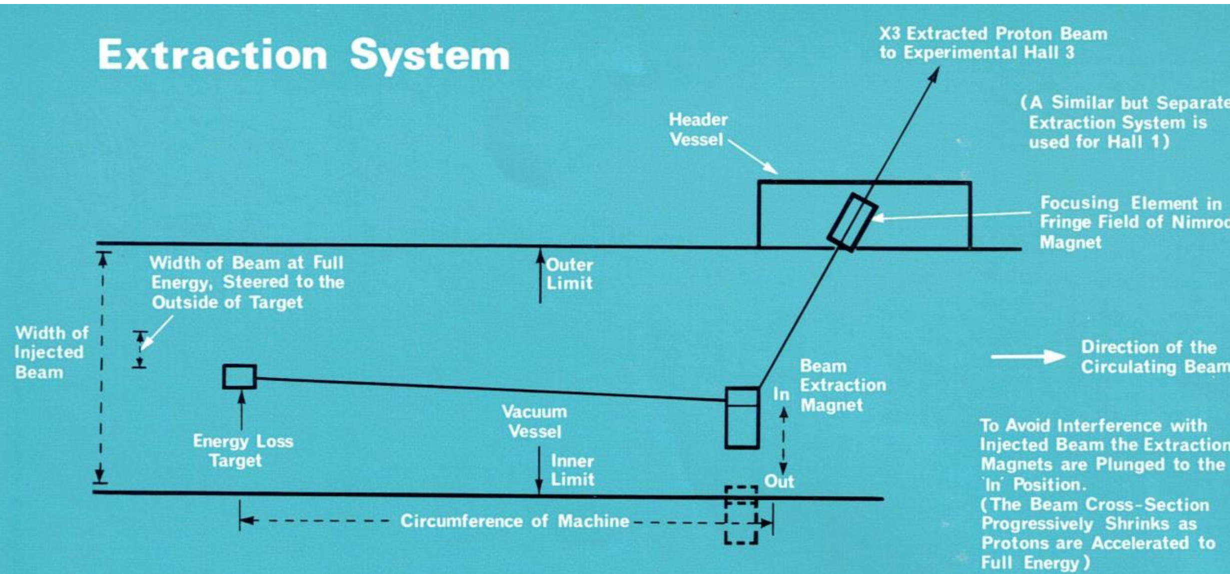


Control System

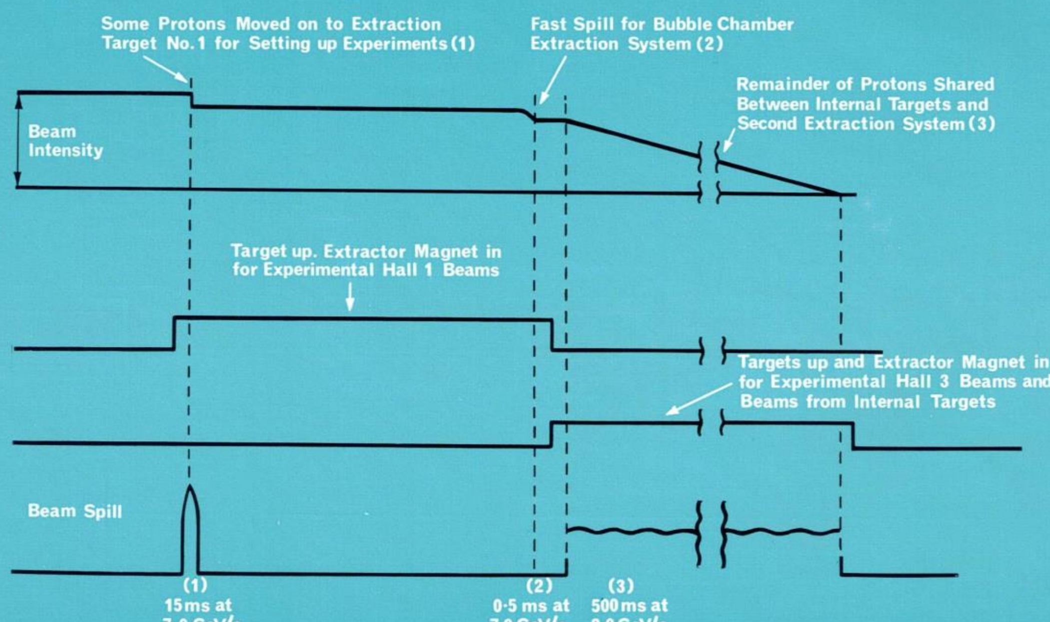
THE CONTROL SYSTEM of the proton synchrotron is required to maintain at the preselected value during successive pulses, all critical variables associated with the equipment. It must also maintain the proper sequence of events and ensure the correct relative values of the variables during the acceleration cycle. The control system also provides timing pulses to experiments.

The control room accommodates all the important instruments concerned with the operation of the plant and the control and protection of personnel. The complete plant has been interlocked in the interests of general and radiological safety and strict control is maintained over traffic of personnel into areas of excessive radiation.

Extraction System

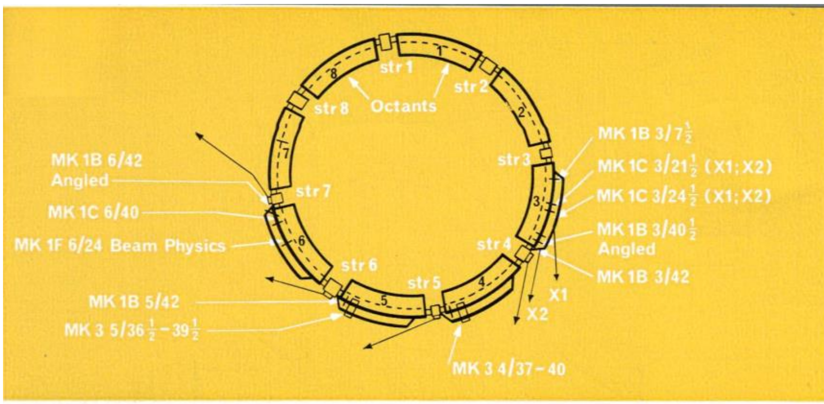


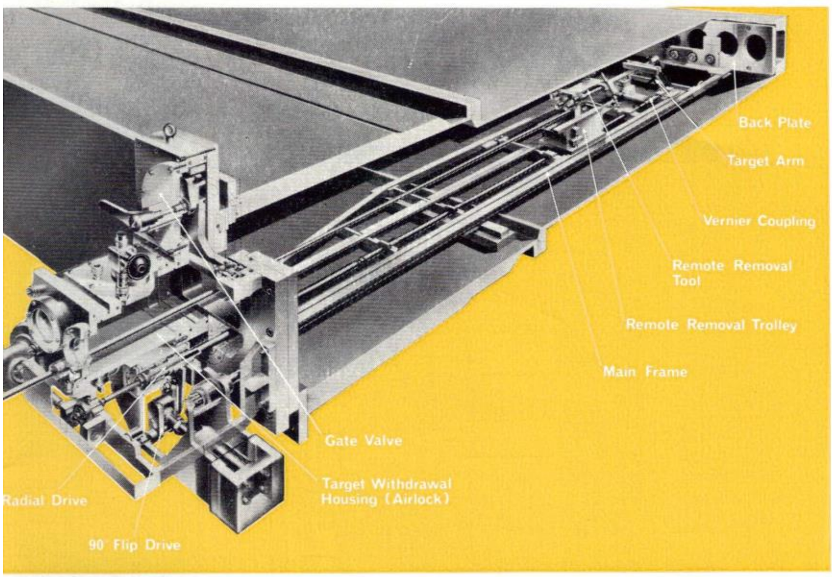
Typical Sharing of Accelerated Beam

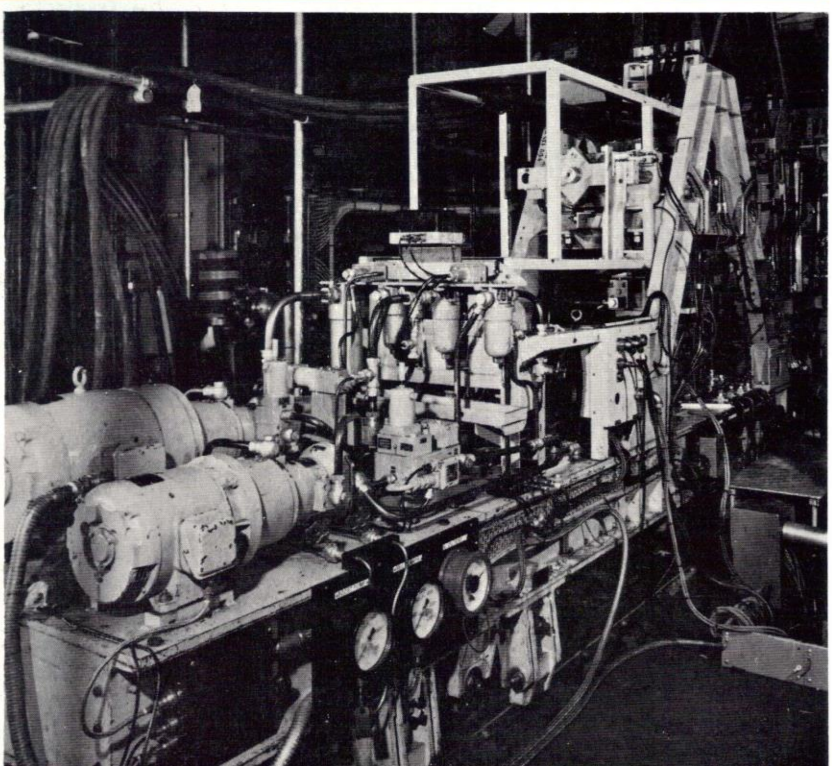


Utilisation of Accelerated Beam

After acceleration the protons are made to collide with a 'target' to produce the elementary particles required. One method is to steer the internal beam of protons on to a solid target inside the vacuum vessel using a magnetic field or the radio-frequency system. Alternatively some of the protons may be extracted from the machine and focused on to a target in the experimental area. The time taken to 'spill' on to the target is very important. For bubble chambers a spill lasting only 0·5 milliseconds is necessary; for experiments using counter techniques, uniform spills lasting several tenths of a second are required. To make full use of the capabilities of Nimrod, the accelerated protons are shared among several experiments during each Nimrod cycle.







Target and Beam outlets

A small target is raised so that the beam strikes it. When the accelerated protons pass through matter they undergo interactions resulting in the production of 'secondary particles'. These may be any of the elementary particles which the protons are energetic enough to produce. Those which are travelling at a favourable angle come out of synchrotron down a beam pipe to be focused on experimental apparatus.

Target Mechanisms

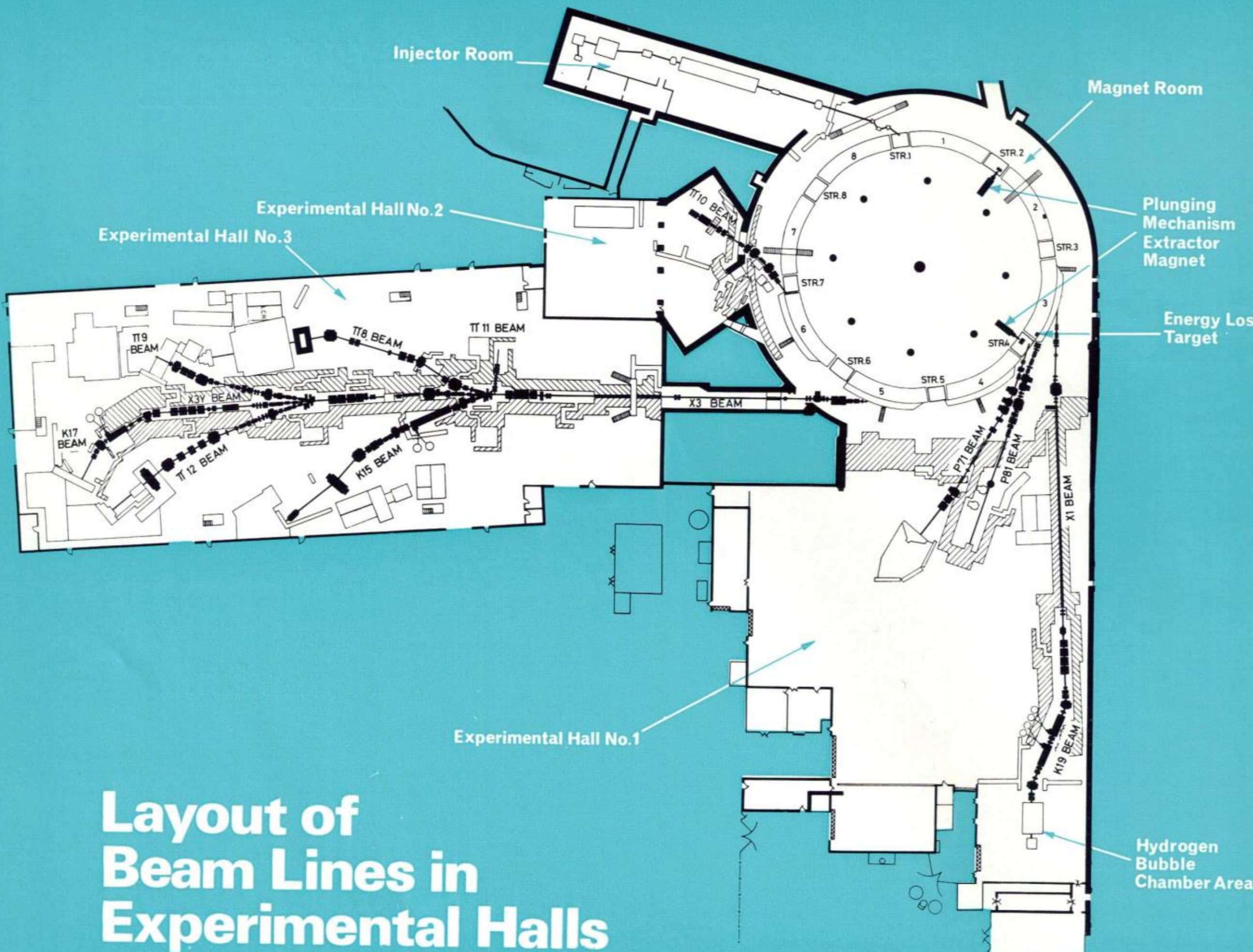
The mechanisms are located in the main magnetic field and are therefore made of non-magnetic materials. Their construction must not allow eddy currents to develop.

The target is mounted on the end of a small arm which can be rotated through a right angle. The actuating device is located outside the vacuum vessel.

Plunging Mechanism

The synchrotron proton beam is accelerated in a closed orbit and must be deflected magnetically out of its orbit. This is achieved by arranging for a target to spiral the beam into an extraction magnet, which deflects the beam outwards. To accomplish this without cutting off a major portion of the proton beam, this magnet must move in sympathy with the leading edge of the beam.

The extraction magnet weighs about 1 tonne (1 ton) and moves radially outwards into the beam orbit a distance of about 0·5 m. (20 inches).



Layout of Beam Lines in Experimental Halls

High Energy Physics using Nimrod

The physics research carried out at Nimrod is principally concerned with investigating the properties of the elementary particles and the nature of the forces that operate between them. Many particles, most of which have incredibly short lifetimes ($\sim 10^{-21}$ s.), are now known to exist and can be produced artificially at accelerators such as Nimrod. The way in which they interact and decay appears to be governed by only three types of force. These are the so-called STRONG force which is responsible, for example, for the binding together of protons and neutrons to form atomic nuclei, the WEAK force which is involved in radio-active decay processes and the ELECTROMAGNETIC force which is relevant when interactions involving photons occur or when the effect of the electric charge associated with a particle has to be taken into account.

Prominent amongst the experiments at present in progress at NIMROD are studies involving beams of π and K mesons. These particles are produced copiously by bombarding atomic nuclei with the high energy protons from the accelerator. They live long enough to be transported by suitable systems of dipole and quadrupole magnets to various parts of the experimental areas where the experiments are performed. Iron and concrete shielding blocks are used extensively around the beams to reduce hazards from radiation.

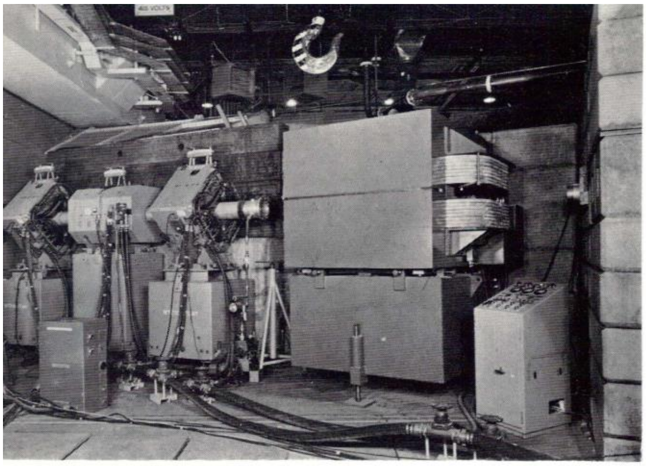
As can be seen in Table 3 there is considerable interest in carrying out experiments which study the various ways in whicn pions and kaons interact with protons. In such experiments it is usually necessary to make accurate measurements of the momenta and the directions of the incoming beam particles and of the particles which emerge when interactions occur. The detectors which have been developed to make these measurements fall broadly into the following four categories.

1. Scintillation Counters
2. Spark Chambers
3. Multiwire Proportional Chambers
4. Bubble Chambers.

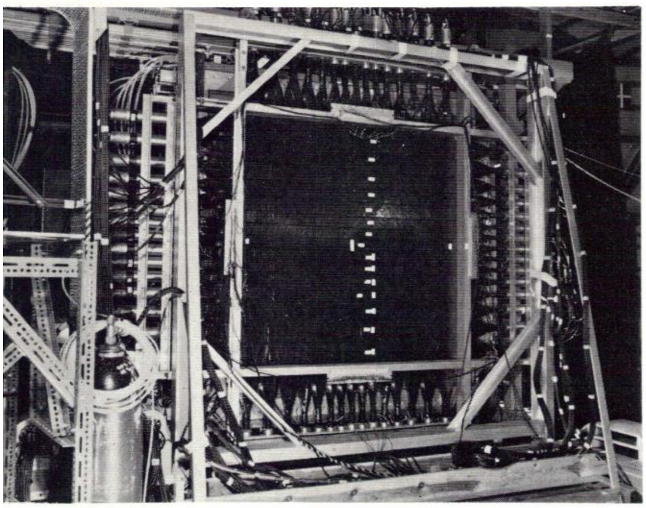
In practice two or three of these techniques may be used in a single set-up.

Many millions of interactions may be detected in an experiment, details of which are recorded and stored either on magnetic tape or photographic film for subsequent analysis by the Laboratory's central computer.

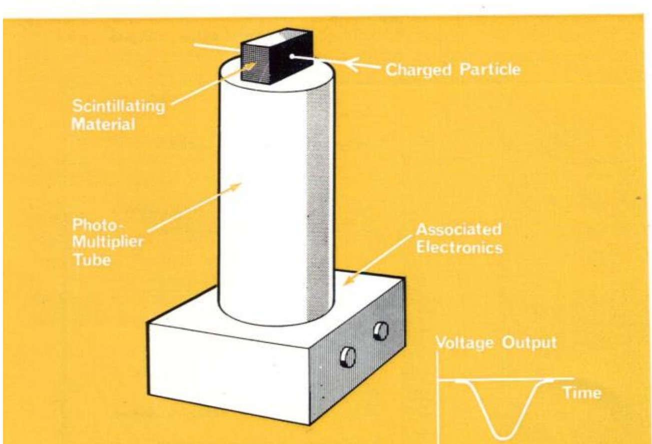
Experiments on Nimrod are carried out by collaborations involving groups from 11 Universities and Research Establishments. The tables on the right show the teams who were participating in the experimental programme in 1973 and the number of physicists, research students and support staff directly involved. These figures do not show the large numbers of support staff who, although not members of experimental teams, contribute in many ways to the success of these experiments.



Two type 2 and one type 4 quadrupole magnets with a type 2 bending magnet in a beam line. Some of the concrete and iron shielding can be seen in the background and at the sides.



Scintillation Counter Hodoscope. An example of the use of scintillation counters to form a large detection area of 150 cm. × 150 cm. There are 15 counters in both the horizontal and vertical direction and each counter is viewed by two photomultipliers to obtain high detection efficiency.



Scintillation Counter. The minute flash of light caused by the passage of a charged particle through the scintillating material is converted to an electrical signal by the photomultiplier tube.

Table 1

Teams Participating in the Experimental Programme—1973

Counter Experiments

Birmingham University/Surrey University/RHEL—K17 Beam
Bristol University/Southampton University/RHEL—K15 Beam
Cambridge University/RHEL—π12 Beam
RHEL—π9 Beam
Oxford University/IPN Orsay, France/CERN—P81 Beam

Bubble Chamber Experiments—K19 Beam

Universite Libre de Bruxelles
University College, London
University of Durham
RHEL

Radiobiological Experiments—π11 Beam

Churchill Hospital, Oxford
St. Bartholomew's Hospital, London
N.R.P.B. (R.L.)

Table 2

Composition of Teams

	Physicists	Research Students	Support Staff
Visitors	110	57	24
Residents	38	—	26
Total	148	57	50

Table 3

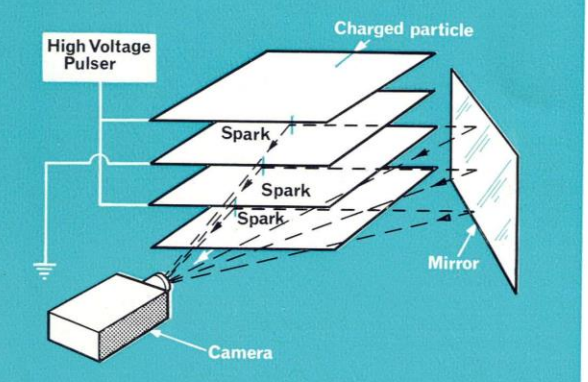
Experimental Programme

Experiments first started at Nimrod in February 1964 and by the end of 1972, sixty-two experiments had been completed.

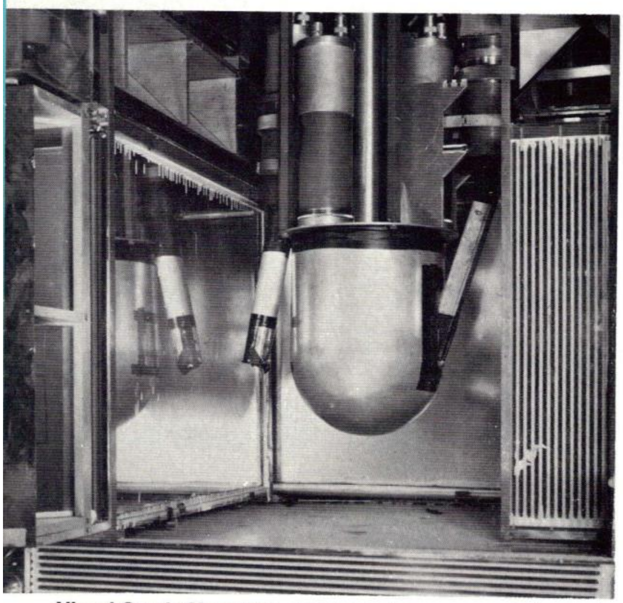
The following list shows these experiments which were operating in 1973.

Beam Line	Proposal No.	Experiment
π9	81 + 101	Differential Cross Sections and Polarisation measurements in $\pi^-p \rightarrow \pi^0n$ and $\pi^-p \rightarrow \eta^0n$ from 0·6—3·5 GeV/c.
K15	120	Differential Cross Sections in k⁻p Elastic Scattering from 1·2—1·9 GeV/c.
π12	114	Differential Cross Sections and Polarisation measurements in $\pi^-p \rightarrow \Lambda^0K^0$ from 1·4-2·0 GeV/c.
K17	113	Experiments with Stopping Kaons.
π11	—	Radiobiological Experiments.
P81	112	Spin Dependent Effects in High Energy Proton-Proton Interactions.
K19	84	Study of $K^-p \rightarrow \Sigma^0\pi^0$ from 0·4-0·8 GeV/c. in the hydrogen Bubble Chamber using a track sensitive target.
K19	117	Study of Slow and Stopped K^- interactions in the Hydrogen Bubble Chamber using a track sensitive target.

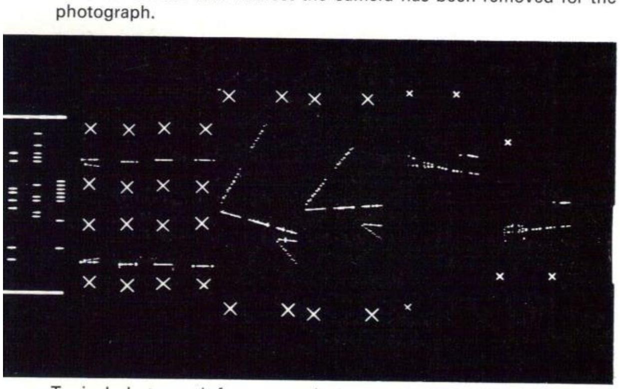
Visual Spark Chamber



Visual Spark Chamber. Sparks are formed along the path of the charged particle if the high voltage pulse is applied very quickly after the passage of the particle.

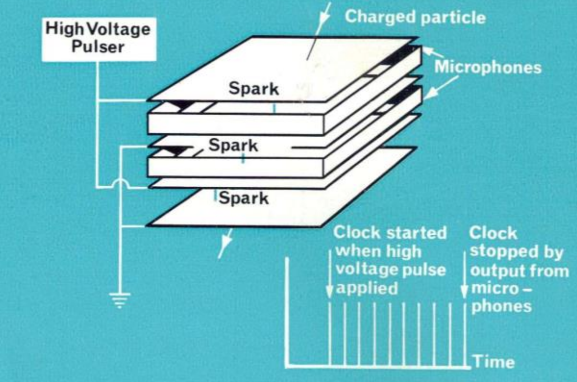


Visual Spark Chambers. These chambers are mounted around a liquid hydrogen target to define the paths of scattered particles. A chamber on the side nearest the camera has been removed for the photograph.

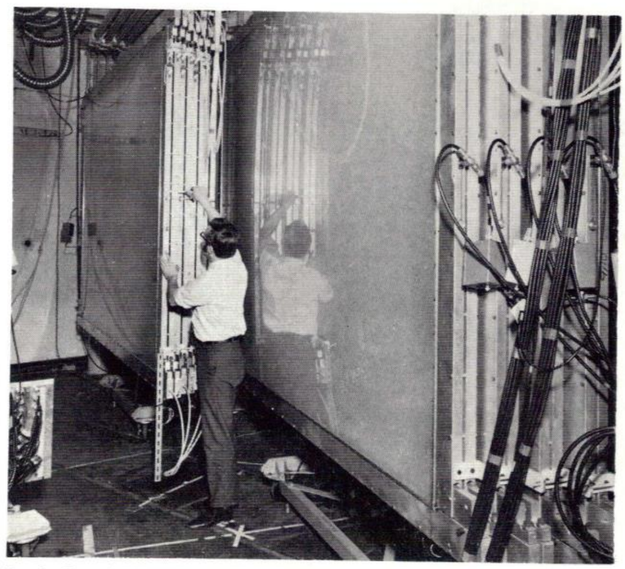


Typical photograph from an optical spark chamber experiment. Two views of each of twelve spark chambers and a set of fiducial crosses can be seen. The strip lights on the left of the photograph are on a data box which records additional experimental information.

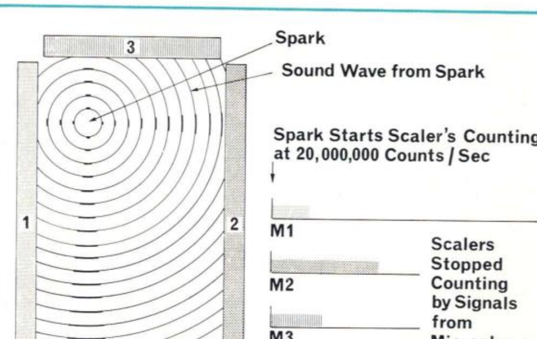
Sonic Spark Chamber



Sonic Spark Chamber. The sparks are produced in the same way as in the VISUAL SPARK CHAMBER. Instead of photographing the sparks the position of the spark in each gap is measured by timing the interval between applying the high voltage and the sound waves from the spark falling on microphones along the sides of each gap.



Sonic Spark Chambers. The chambers are mounted on front of a bending magnet to determine accurately the direction of each charged particle through the magnetic field.



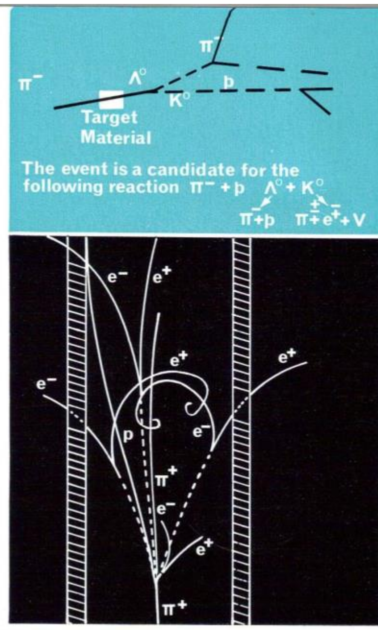
Principle of a Sonic Spark Chamber

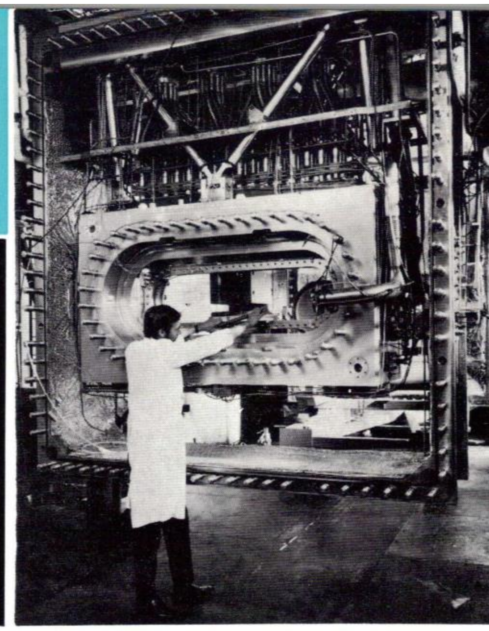
Bubble Chamber

An event taken in the 1·50 m. Hydrogen Bubble Chamber using the track sensitive target. The target volume contains liquid hydrogen whilst the rest of the chamber is filled with a mixture of liquid neon and hydrogen. The vertical shaded areas are the boundary walls of the target.
The input particle is a 4·0 GeV/cπ^+ and the event is a candidate for the following reaction.

$\pi^+ + p \rightarrow \pi^+ + p + \pi^0 + \pi^0$
- $\pi^0 \rightarrow \gamma + \gamma$
  - $\gamma \rightarrow e^+ + e^-$
  - $\gamma \rightarrow e^+ + e^-$
- $\pi^0 \rightarrow \gamma + \gamma$
  - $\gamma \rightarrow e^+ + e^-$
  - $\gamma \rightarrow e^+ + e^-$

The primary interaction takes place between the incident π^- and a proton in the liquid hydrogen. The γ rays from the π^0 conversions pass out of the hydrogen target volume and into the denser neon/hydrogen mixture surrounding the target. This mixture considerably increases the probability of the γ rays converting to e^+e^- pairs and thus enables the complete sequence of events to be rendered visible.





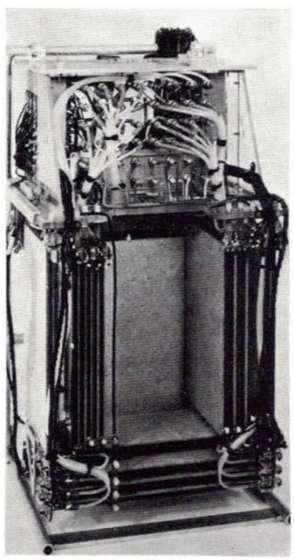
Multiwire Proportional Chamber

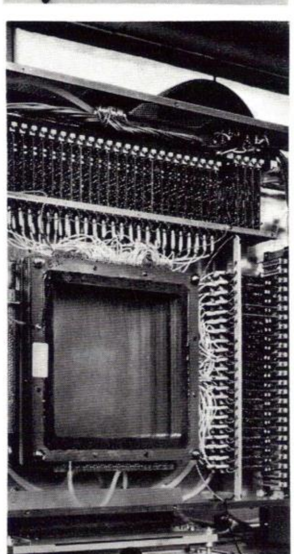
Wire chambers

In a wire chamber one or both plates of the basic spark chamber module are replaced by fine parallel wires, spaced about 1 mm. apart. This type of construction leads to several categories which differ principally in the detection method used to define the position of a particle. Two such methods give rise to the **Magnetostrictive Spark Chamber** and the **Multiwire Proportional Chamber.**

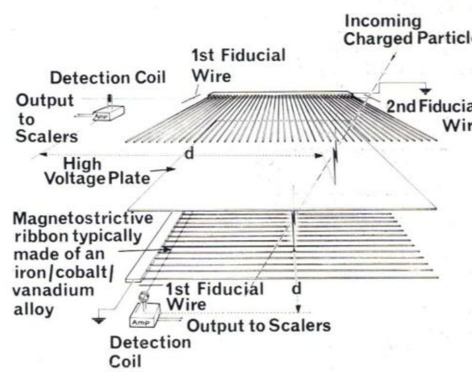
In the **Magnetostrictive Spark Chamber** a ribbon of magnetostrictive alloy is mounted at right angles to the wires and this is the readout element which measures the spark position. The spark causes a current to flow in the associated wire and this current induces a mechanical disturbance in the magnetostrictive ribbon which is detected by a coil at the end of the ribbon. By measuring the time interval between the occurrence of the spark and the pulse from the detection coil, the position of the spark and hence of the particle is defined.

In the **Multiwire Proportional Chamber** a constant potential, typically about 3 kV, is maintained across the planes of wires. The current of electrons produced by the passage of an ionising particle is amplified by avalanche processes in the high field region near each wire. (No actual spark is formed.) The small current flowing in the wire is amplified by conventional means and can then be used to define the position of the particle. The readout element in this case is an amplifier—one attached to each wire.

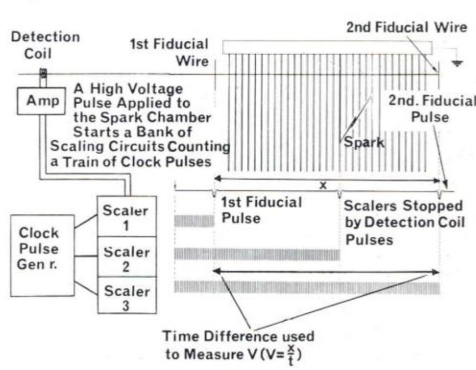




Magnetostrictive Spark Chamber



General Arrangement of a Magnetostrictive Spark Chamber



Principle of a Magnetostrictive Spark Chamber

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