7 GeV PROTON SYNCHROTRON (NIMROD)

National Institute for Research in Nuclear Science

Rutherford High Energy Laboratory, Harwell

(presented by T. G. Pickavance)

SYNCHROTRON DATA

Person in charge	T. G. Pickavance	Person supplying data	T. G. Pickavance

History and Status

Design study	1955	Completion date	Dec. 1961
Model tests	1956 -	Scheduled operation	
Engineering design	1956 -	Magnet cost	
Construction started	1957 (buildings)	Total cost	approx. £7 million

Design Specifications

Magnet

Focusing type	Weak
Focusing, order	
Field index, *n*	0.6
Orbit radius	18.78 m, 61.62 ft
Mean radius	23.63 m, 77.53 ft
Sectors, number	8
Field, at inj.	296 G
Field, maximum	14 000 G
Power input, maximum	114 000 kVA
Storage system	Flywheel
Rise time	0.72
Weight	Fe 7 000 ton; Cu 250 ton

Aperture

Width	91.4 cm, 36 in.
Height	24.1 cm, 9.5 in.

Shielding . . . . . { 6 ft concrete + 20 ft earth overhead, 30 ft concrete shielding wall.

Design Goals

Particle accelerated	Protons
Energy	7.0 GeV
Pulse rate	28/min
Output	10^{12} part/pulse

Injector System

Type	Linear accelerator
Energy	15.0 MeV
Injector output	$\nless$ 5 mA
Injection period	360 turns
Inflector type	Electrostatic

Acceleration System

Frequency	1.43 to 8.04 MHz
Accel. cavities	One (double)
Harmonic number	4
Orbit freq. final	2.01 MHz
Gain, average	5.5 keV/turn
Input to RF, maximum	

Unusual Features of Installation

C-type magnet, " crenellated " poles achieved by holes in pole laminations, to compensate for effects of saturation on field gradient. Epoxy-resin fibreglass vacuum vessel (double wall, with rough vacuum between the walls).

Two external proton beams to be provided.

LINEAR ACCELERATOR DATA

Person in charge	T. G. Pickavance
Person supplying data	L. C. W. Hobbis

History and Status

Design study	April 1956-Dec. 1957
Model tests	May 1957-March 1959
Engineering design	From Oct. 1957—80% complete
Construction started	Nov. 1958—15% complete
Completion date	June 1960
Scheduled operation	120 hrs/wk
Total cost	

Design Specifications

Injector System

Type	Cockcroft-Walton accelerator
Energy	600 keV
Output	$\nless$ 25 mA

RF System

Frequency	115 MHz
Field mode	Eolo
RF power	~ 750 kW
Power units	One Siemens RS 1041 triode
Equilib. phase	Approx. 30°
RF pulse duration	Up to 2 050 μs
Ions focused by	Electro-magnetic quadrupoles
Multipactoring overcome by	Use of driven RF system, mercury pumps

Beam Characteristics

Particle accelerated	Protons
Energy	15 MeV
Energy spread	60 kV after debunching
Output, peak	$\nless$ 5 mA
Beam pulse	Not greater than 2 000 μs
Beam emittance	3-6 millirad cm at 15 MeV

Mechanical Details

Tank length	44 ft 1.51 in.
Tank diameter	66.71 in.
Drift tubes, number	½+48+½
Length 1st tube	3.169 in.
Dia. 1st tube	11.084 in.; aperture 0.829 in.
Length 1st gap	0.735 in.
Length last tube	12.591 in.
Dia. last tube	11.084 in.; aperture 1.939 in.
Length last gap	5.249 in.

Unusual Features of Installation

The ion gun HT set will be of the electrostatic type developed at Grenoble by N. J. Felici.

It is intended to study the problems arising in acceleration of proton currents exceeding 50 mA. It is hoped to overcome some of these difficulties at low energies by use of space-charge neutralisation.

Units cells maintained resonant by changing both gap/pitch ratio and outside profile radius of drift-tube ends.

Drift tube apertures increase smoothly.

STATUS REPORT

The 7 GeV proton synchrotron NIMROD, now under construction at the Rutherford Laboratory, is of the constant gradient type. A major aim of its design is a high intensity output, in the region of 10^{12} protons per second. Preliminary design work was started in 1956, and the first manufacturing contract was placed in the second half of 1957. Excavation of the building site also began in 1957. The target date for assembly of NIMROD is early 1962.

1. Descriptive Notes

The NIMROD magnet ring will be about 160 ft in overall diameter, with eight field-free straight sections, four of 14 ft and four of 11 ft length. The C-shaped magnet yoke will contain about 7 000 tons of ¼ inch steel plate. Each of the eight magnet sectors will have a 30 ton, 42 turn coil of water-cooled copper bar. Detachable polepieces will provide a useful magnet aperture measuring 36 in. radially by 9¼ in. vertically. The magnet will be

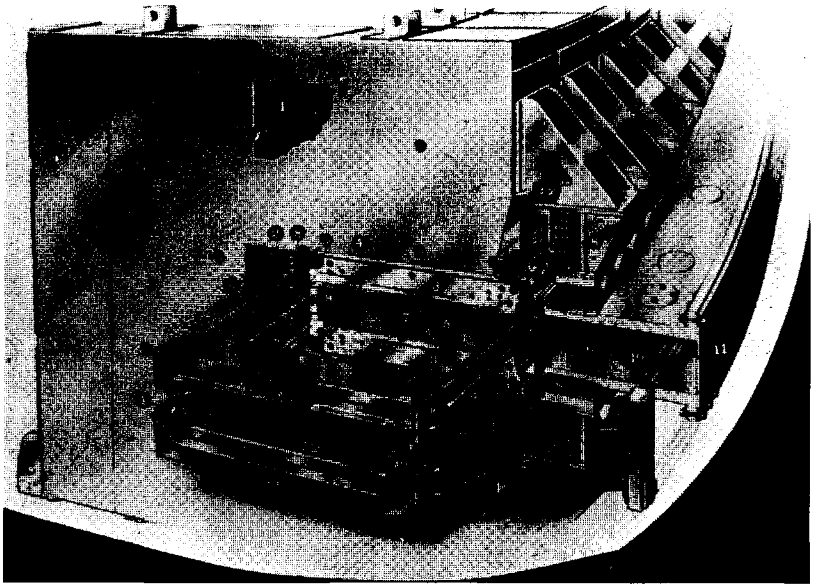

Fig. 1 View of cross section through 7 GeV magnet octant.

1 Magnet sector
2 Magnet coils
3 Pole tips
4 Outer vacuum chamber (low vacuum)
5 Inner vacuum chamber (high vacuum)
6 Header chamber (high vacuum)
7 Pole face windings
8 Pressure pads
9 Pole tip jack
10 Main pumping port
11 Beam exit window

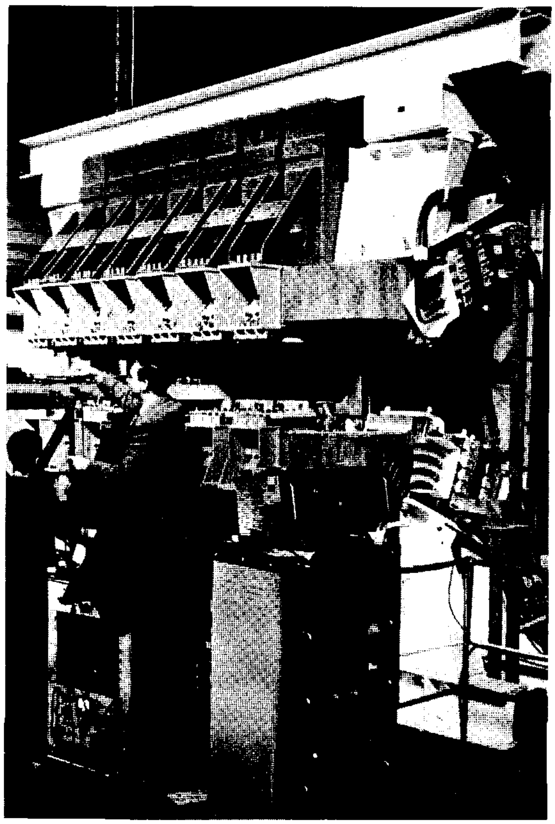

Fig. 2 Magnet model for polepiece design, made from 7 production magnet blocks.

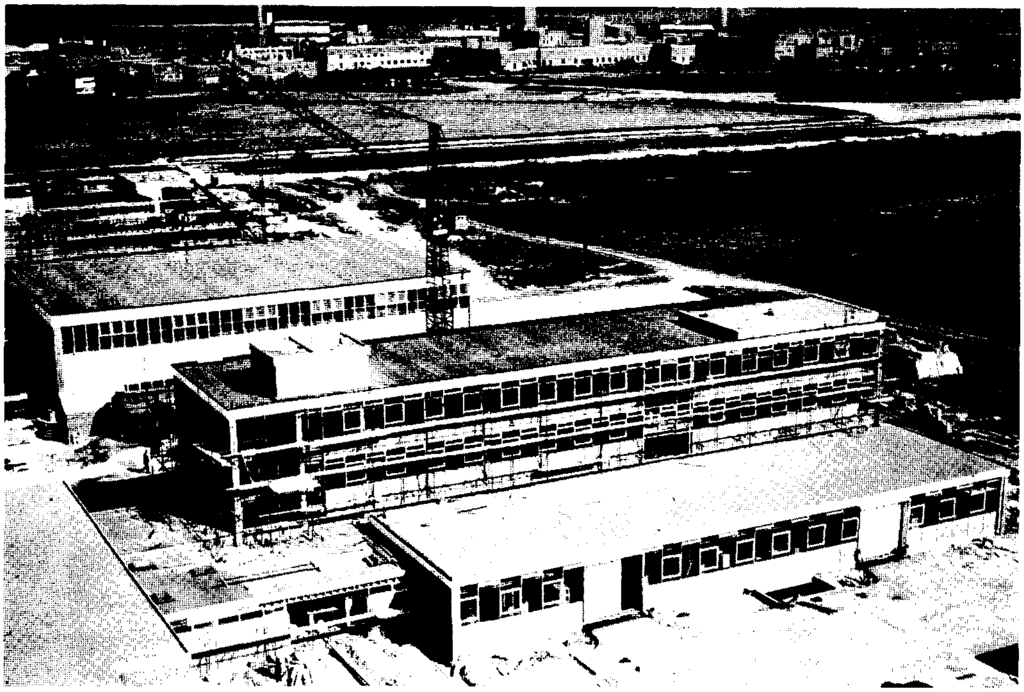

Fig. 3 Laboratory buildings at Rutherford High Energy Laboratory.

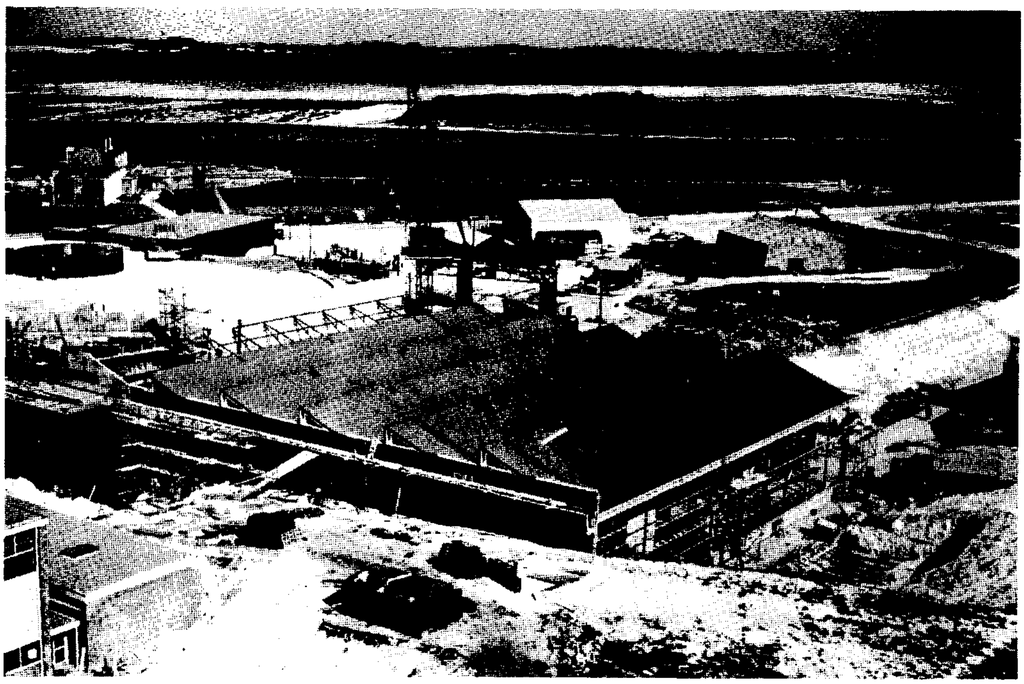

Fig. 4 Experimental hall and magnet building.

pulsed up to 14 000 G maximum field with 0.72 second rise time, and at an overall repetition rate of 28 pulses per minute.

Injection will occur at 15 MeV (229 G). The injector will consist of a 600 keV proton gun, followed by a 115 MHz linear accelerator with magnetic quadrupoles for strong focusing. Proton pulses of up to 2 ms duration and at least 3 mA peak current will be available for inflection into the magnet ring. The rate of rise of the magnetic field at injection will be reduced to a few gauss per ms in order to increase the injection acceptance time.

RF acceleration in the ring will be achieved by two ferrite-tuned cavities assembled as a single unit in one of the longer straight sections. The RF system will operate at four times the proton orbital frequency, over a frequency range 1.4 to 8.0. Beam sensing electrodes will be installed in another straight-section with the ultimate aim of obtaining beam-control operation of the system.

The vacuum chamber will be of double-wall construction, with an outer rough-vacuum ($\sim$ 1 mm) space containing the magnet polepieces and poleface windings. Both inner and outer chambers will be of glass-cloth reinforced epoxy resin. The design target is a pressure of 10^{-6} mm mercury in the inner chamber.

The power supply for the magnet will be based on a 1000 r.p.m. motor-flywheel-alternator set comprising two 5 000 h.p. motors, two flywheels and two 79 MVA peak, 50 Hz, alternators all on one shaft. The 3 phase power output from this set will be "converted" first to 24 phase a.c. by means of 8 phase-multiplying transformers, and then to the required pulse by 96 excitron valves.

The main building for NIMROD consists of a circular "magnet room" 200 ft in diameter, with a tangential injector room 170 ft long. The whole building is of massive reinforced concrete construction, and will be earthed over to a depth of 20 ft for radiation shielding. Adjoining the main building, and separated from it by a removable concrete wall, is an experimental area measuring 145 ft by 170 ft. A further, smaller experimental area is also provided, and there is considerable space available for future extensions.

2. Progress on main items

2.1 Buildings

The magnet and injector rooms are structurally complete, with installation of services in progress. Earth mounding of walls and roof remains to be done. The main experimental area, equipped with 30 ton cranes, is already in use for casting the removable shieldwall blocks.

Progress on other associated buildings is a follows :

Control building :	complete
Laboratory and office building :	nearing completion; one laboratory just ready for occupation.
Assembly and test building :	complete
Power supply building :	construction just begun

2.2 Injector

Installation of the 600 keV proton gun is well under way in the injector room. Contracts for manufacture of all major parts of the 15 MeV linear accelerator have been placed. Design work is still in progress on many details of the injector system and on the 25° inflector system. (The latter will use 18° magnetic deflection followed by 7° electrostatic deflection.)

2.3 Magnet

The magnet yoke is being manufactured in the form of 336 separate blocks, of which about 70 have been delivered to the Rutherford Laboratory so far. The rate of delivery has reached 6 per week, and manufacture should be completed in May 1960. The blocks are being measured magnetically at the laboratory in an assembly of four full-size magnet blocks (Model IV). Magnet models I, II and III were 1/3 scale models used for yoke and preliminary polepiece design.

Detailed design of the magnet coils is practically complete. Manufacture of the hollow copper bar has begun, and a contract for fabrication of the complete coils has been placed. Some of the first coil components produced will be assembled on to 9 magnet yoke blocks taken from production to form magnet model VI, which will provide a check on the methods of coil clamping to be used, crossconnection design, etc. Assembly of model VI should begin in October of this year.

The basic design of the majority of the polepieces has been established by small-scale model work, and the main manufacturing contract is being negotiated. Final design adjustments will be made on a full-scale magnet model V which has just been constructed from seven of the production blocks.

Further design work also remains to be done on polepieces for the magnet sector ends.

2.4 Magnet power supply

Contracts for manufacture of the power supply have been placed with two firms, one for the rotating machinery and the other for the power convertor equipment. Detailed design of the rotating machinery is virtually complete and manufacture has begun. Final details of the power convertor components and circuit arrangement are still being worked out.

Great importance is being attached to efficient ripple-smoothing of the power supply output. A complete model system is being prepared for test on magnet model V.

2.5 RF accelerating system

Construction and manufacture of most parts of the RF system are well under way. For example the ferrite-tuned double cavity is almost ready for low-power tests, and all the 5.5 tons of ferrite have been delivered and tested.

2.6 Vacuum chamber

The design of the outer vacuum vessel, which will be sandwiched between the magnet yoke and polepieces, has been completed and manufacture has begun. The inner chamber design is well advanced. Tests are being carried out to determine the best formulation of epoxy resin for this chamber and to find the best form of metallic coating for the inside surface; thin stainless steel strip is a likely solution.

Manufacture of the forty 24 in. oil diffusion pumps required has begun, and the first pumping unit has been delivered.

2.7 Control system

The general control system scheme for NIMROD has been worked out and detailed design work is in progress.

3. Other aspects

Attention is being given to many aspects of the NIMROD project not mentioned in the above brief account. For example a theoretical study has been made of a Piccioni-type beam extraction system, and the main parameters of this system have been determined. The study is being extended to the system of " shims " for guiding and focusing the extracted proton beam through the magnet fringe field. Possible secondary beams, beam transport and analysing systems are also being studied. A general layout of extracted and secondary beams has been worked out as a basis for specific design and experimental work.

Provision of facilities for the use of bubble chambers is another matter now being studied intensively. Plans have been drawn up for necessary extensions and additions to buildings and experimental areas to solve this particular problem.