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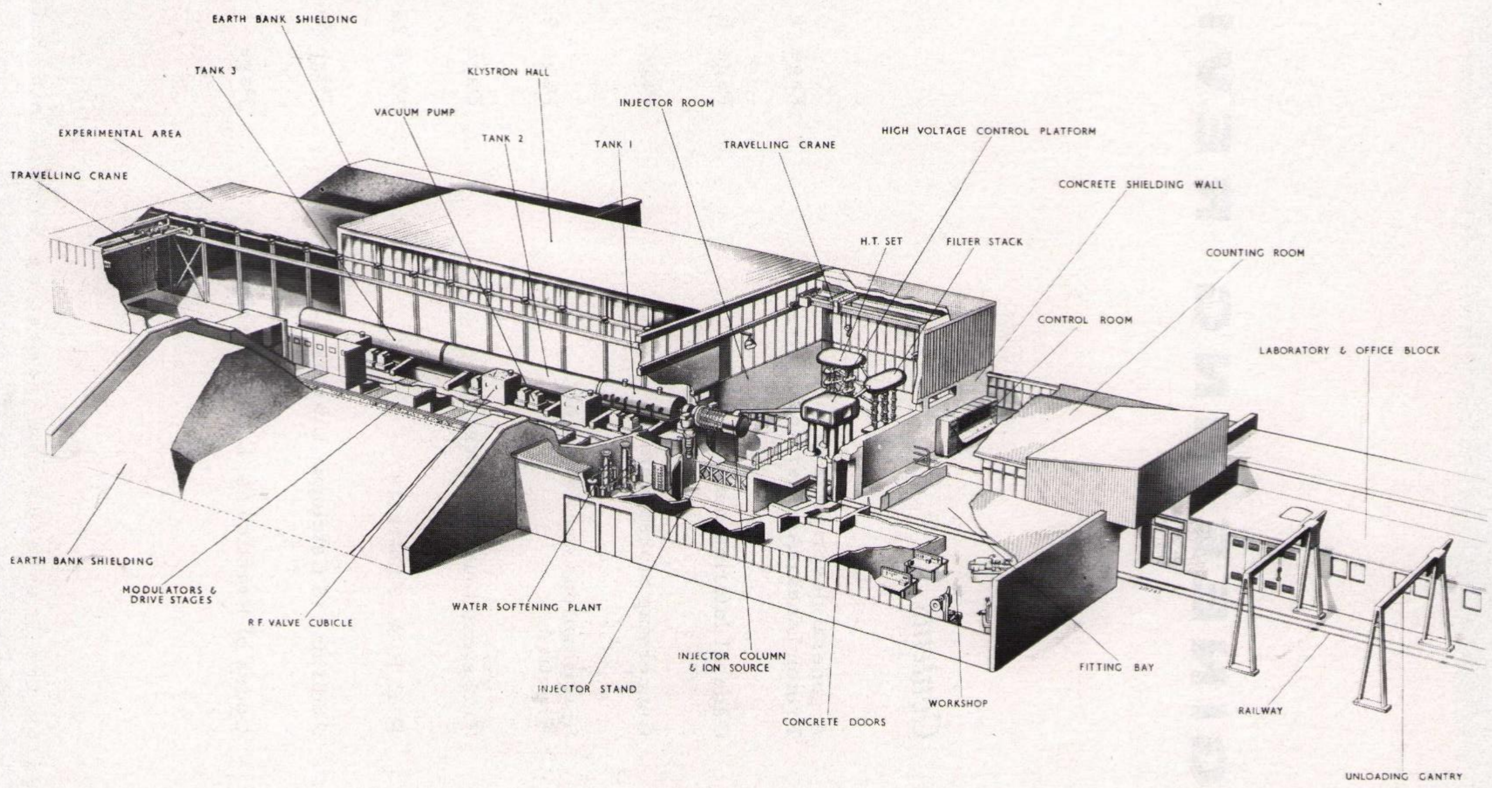

Fig. 1 50 MeV Proton Linear Accelerator.

A General Description of the

PROTON LINEAR ACCELERATOR

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1. Introduction

In 1953, a group was formed from the General Physics Division, Harwell, to design and build a 600 MeV Proton Linear Accelerator. From the end of the war there had been many large accelerators built both in the U. S. A. and Russia for High Energy Nuclear Physics Research, and a machine of this size was necessary in this country to keep abreast of fundamental Nuclear Physics research work. The reason for spending such large sums of money on these projects the world over, is to obtain fundamental data on the binding forces of atomic nuclei, which can only be evaluated from nuclear physics experiments carried out on these machines.

The principal advantages of a linear machine are that 100% extraction of the accelerated particles is obtained, and also that the beam is finely colimated with small angles of divergence, thus experiments involving the scattering of protons from targets in the beam may be performed with good angular resolution.

Due to developments in other accelerators, both in this country and the U. S. A., it was later decided that only the first 50 MeV portion of this machine would be built for the time being. A duplicate of this plant was also being constructed to serve as an Injector for the 25 GeV Proton Synchrotron at Geneva. It has been shown that it was a good decision to build this machine, as both the 50 MeV Proton Linear Accelerator and the Proton Synchrotron are now operational, and much of the experience and plant design from the 50 MeV P. L. A. was available for use in the construction of the NIMROD Injector.

2. *Details of the Machine*

The P. L. A. as designed, is capable of an output of protons with 50 million electron volts (30% of the speed of light) and a pulsed current of 250 micro-amperes peak or 1.5×10^{13} protons per second. The machine is pulsed at 50 pulses per second, each beam pulse having a length of 200 micro-seconds, which gives the machine a 1% duty cycle.

A brief summary of the principles of operation is given herewith, the lay-out of the main components being shown in Fig. 1.

2.1. *Injector*

The proton beam is generated and fired into the main accelerating cavities at 0. 5 MeV energy by means of a D. C. Injector. The 500, 000 volts are generated by means of a Cockcroft-Walton voltage generator, which feeds this potential to the injector via a control platform. The plant on this platform supplies the services to the Ion Source, in which the beams are generated, and also to the beam control and focusing electrodes in the injector.

The power supply for the control platform equipment comes from a 2000 cycle generator driven from a 16 h. p. motor by a 6" wide endless belt 16' between pulley centres, the belt providing the insulated drive having 0. 5 MV across it. The ion source generates the protons in a plasma formed by a radio frequency discharge, in an evacuated glass bottle into which hydrogen is bled at a low pressure.. The protons are then extracted from the plasma with a negatively charged plate into the injector where they are electrostatically accelerated to 0. 5 MeV.

2.2. *Buncher*

From the D. C. Gun the protons pass through a single gap resonant cavity, which is driven with R. F. power related in phase to the rest of the machine in such a way that some protons in each pulse are slowed down, and some protons are speeded up. The protons then arrive at the beginning of the R. F. accelerating part of the machine in short bursts with the correct phase relationship to the R. F. for optimum acceleration. This device increases the proton output by a factor 3 in intensity.

2.3. *Accelerating Cavities*

The accelerator is constructed in 3 tanks, each containing an R. F. resonant cavity, the approximate dimensions of which are, one 20 ft. long by 3 ft. 6 ins. dia. and two 40 ft. long 3 ft dia. These are made of 16 s. w. g. copper and are mounted in vacuum vessels (see Fig. 2.) which must be maintained at pressures of less than 5×10^{-6} mm. of mercury for the machine to operate. The resonators are fed with R. F. power at a frequency of 202. 5 megacycles/ second, the peak power levels being approximately 600 KW, 1. 2 MW, 1. 3 MW respectively. For these units to resonate at this frequency, the temperature must be controlled to $38^{\circ}C \pm 2^{\circ}$ by water cooling. Inside the resonators are mounted 107 drift tubes (see Fig. 2), which form the accelerating gaps, such that when the cavities are fed

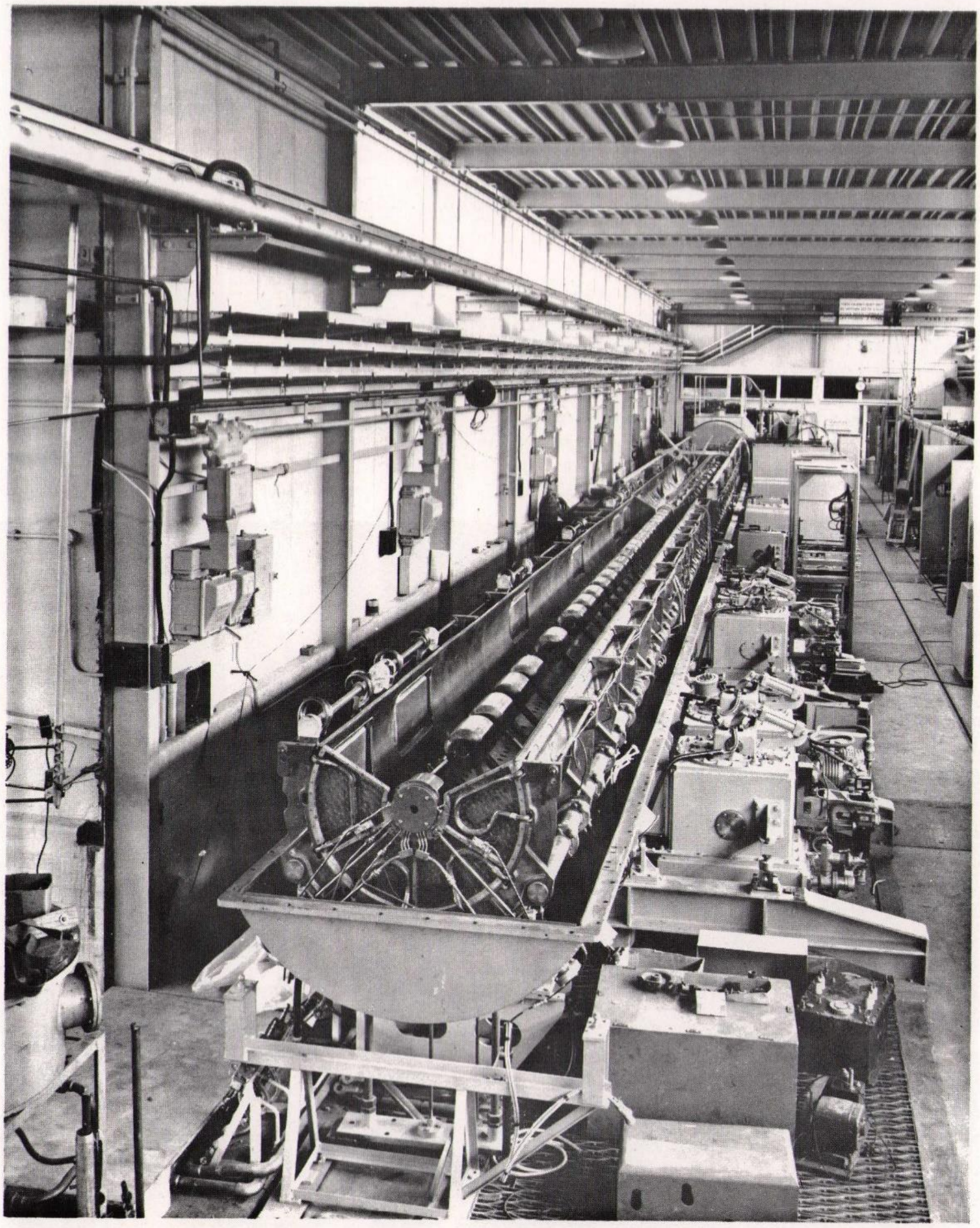

Fig. 2 The drift tubes are clearly visible inside the resonators.

with R. F. power an alternating potential appears across these gaps. This potential is phased so that as a pulse of protons enters a gap, the face of the drift tube it is leaving is positively charged and the face of the tube it is about to enter is negatively charged, the resulting field accelerating the protons. The protons are screened from the reversal of potential as they pass through the inside of the next drift tube.

In the first tank the beam is focused by means of thin tungsten strips forming grids in the input apertures of the drift tubes, and in the second and third tanks by means of quadruple magnets mounted inside the drift tubes.

2.4. Experimental Area

In order to use the machine time efficiently, bearing in mind that a plant of this size is very expensive to operate and maintain, it is essential to have many experimental positions, so that the setting up and breaking down of experiments can be minimised, (perhaps the machine may be considered as a "50 MeV Proton Factory" for this purpose). In the existing experimental area there are eight such positions, the beam being bent into any one of these by a 26 ton magnet, the field and angular position of which can be pre-set for any position (see Fig. 3).

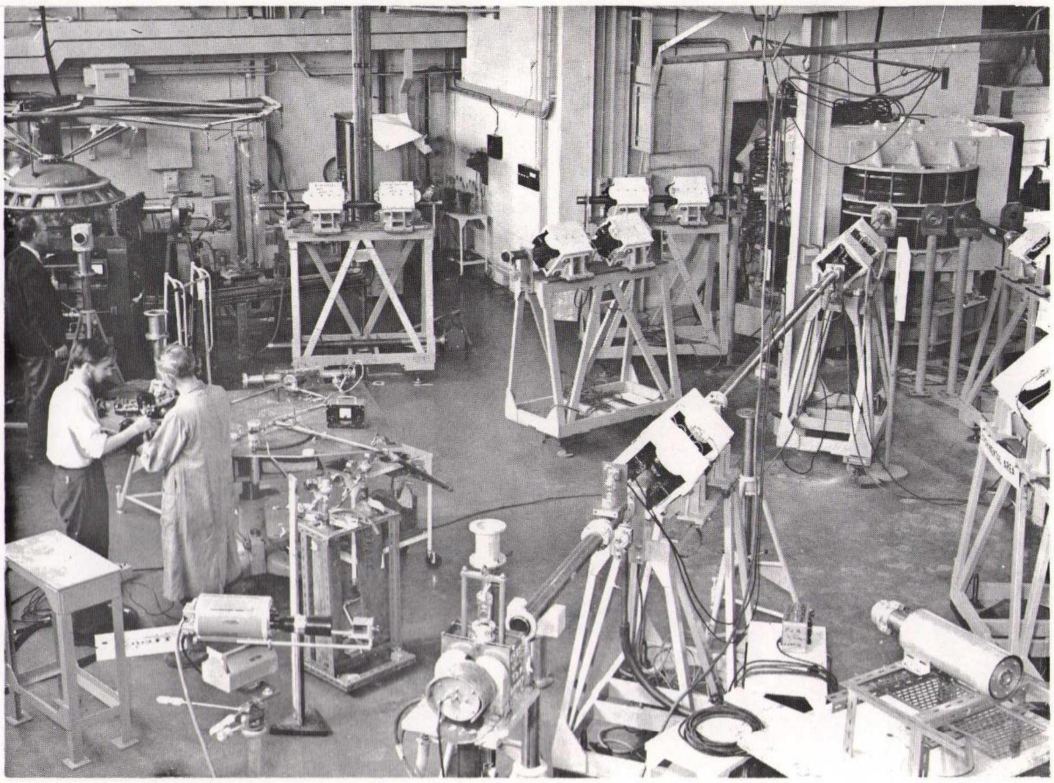

Fig. 3 Experimental Area looking towards Beam Bending Machine.

A second experimental area with 5 further positions and an additional beam bending magnet is now in operation. This area has been specially designed for very large experiments, one of which contains a 70 ton spectrometer magnet.

3. *Operation and Future Development*

The machine has been used for nuclear physics experiments since April 1960, and has been generally operated on a double shift from 8. 30 a. m. till midnight, five days a week. Due to the demand for more experimental time (the machine serves the Universities, U. K. A. E. A. and the National Institute) the accelerator now operates 24 hours a day, 5 days a week.

Since the machine became operational an intensive amount of development and modification has been carried out to improve its reliability and performance. An advantage of the linear type of machine is its inherent flexibility, allowing for easy adaptation: recently a polarised proton source has been added, for example, which allows the preferential selection of protons spinning about a defined axis. That is, only those protons spinning predominantly clockwise or anti-clockwise about a vertical axis, are injected into the machine for acceleration. Experiments are also being carried out to investigate the possibility of increasing the beam intensity; for example, the fitting of quadruple focusing lenses in the drift tubes in the first accelerating cavity would increase the beam of intensity five times.

Study work has also commenced on the design of further conventional accelerating cavities for increasing the beam energy above 50 MeV, and also on cavities cooled to super-conducting temperatures with liquid helium.