NUCLEAR EQUIPMENT PROJECT COMMITTEE

HEAVY LIQUID BUBBLE CHAMBER

Minutes of the final meeting of the Heavy Liquid Bubble Chamber Section of the Nuclear Equipment Project Committee held at the Rutherford Laboratory on Thursday, 25th November 1965.

Present: Mr. L. B. Mullett - Chairman
Mr. A. G. Ashburn
Mr. A. Miller
Mr. H. Rudkin
Mr. G. E. Simmonds
Mr. M. Snowden
Mr. H. S. Tomlinson - University College
Mr. F. M. Telling - Secretary

1. The Chairman remarked that with the Heavy Liquid Bubble Chamber now in the initial operating stage it was a convenient time for the Management Committee to discuss any outstanding technical and financial points with a view to formally winding up the Committee. An appropriate note would then be drafted for submission to the Nuclear Physics Board.

2. A statement on the technical aspects of the Bubble Chamber given in paper NEPC/Part III/P59 was noted. Additional points made in discussion were:

2.1 Trial runs had shown the need for a direct chamber liquid filtration system that could be applied during operation

2.2 Some looseness of the outer covering of the coil insulation had occurred during the initial operation of the magnet. This had been brought to the contractor's attention. This looseness had not perceptibly increased during further operational tests.

2.3 A slight scratch in one of the highly stressed windows had been noted. This particular window although adequate was lower in surface compression that the second window.

2.4 The original specification had made provision for the use of propane. During the design and construction stages a shift of emphasis towards the fluoro-carbon liquids had however been made. In the light of present knowledge a reappraisal of the safety precautions would require to be made before propane could be used.

2.5 Every effort would be made to bring up to date the technical drawings and records particularly with respect to the main design parameters. A review of the spare parts for the project would also be carried out. It was agreed that Mr. Walker would co-ordinate these requirements with the UCL team.

3. The Agreement with University College for the operation of the Heavy Liquid Bubble Chamber had recently been extended for a further period. From 1st January 1966 the UCL staff covered under this Agreement would be reduced to two engineers, who would continue with the project until 30th September 1966. Mr. Tomlinson would be leaving the project on 1st January, but would be available on a consultancy basis. It was noted that Dr. Henderson proposed using the Bubble Chamber for an experiment next February and that a UCL physicists, engineers and technicians team would be available for that period.

4. An assessment of the final project costs given in paper NEPC/Part III/P58 was tabled for discussion. It was noted that the current commitments were:

Plant ...	£331,862
Buildings	£ 41,000
R. & D. .	£ 99,000
	£471,862

The approved estimate was £474,000 and this gave a balance of £2,138 to cover any final adjustments in prices and possible contractor claims. The payments recorded to date amounted to £450,913. There was every expectation that the final costs would be a few hundred pounds less than the approved estimate.

5. A technical run would be made on the Bubble Chamber for approximately a week commencing 3rd December. Following this run a final report would be prepared on the project for submission to the January meeting of the Nuclear Physics Board. The report would include a brief description of the Bubble Chamber together with some suitable photographs. A concise graphic presentation of the commitments made against the approved estimate would also be included.

6. The Chairman wound up the meetings of the Committee by warmly thanking all those whose efforts had contributed towards the success of the project.

F. M. Telling.

Scientific Administration
Building R.20,
6th December 1965

APPENDIX II

THE 1.5 m HEAVY LIQUID BUBBLE CHAMBER

The heavy liquid bubble chamber proposed originally by University College London and built by engineers and physicists from the College and the Rutherford Laboratory, operated for the first time at the Rutherford Laboratory on 29th October 1965. It has undergone final tests in preparation for its first experimental run in conjunction with Nimrod, due to operate again at full energy in early 1966.

The basic principles are common to all bubble chambers. The liquid is normally held just below its boiling point by external pressure. In operation the pressure is rapidly reduced to a level which permits boiling, after which there is an interval of a few thousandths of a second before boiling becomes general. During this time a pulse of high energy particles is injected and the liquid starts to boil in minute bubbles which form along the paths of the electrically charged particles which have traversed the chamber. Electronic flash tubes illuminate the tracks of bubbles which are photographed by an array of cameras. A magnetic field maintained throughout the chamber causes the particles to move on curved paths, the curvature providing information on their electric charge, mass and speed.

The heavy liquids, such as the fluorocarbons, are particularly effective in stopping charged particles and detecting high energy gamma rays, although their complexity often introduces difficulties in interpreting the results not encountered with simpler liquids such as hydrogen. Both types of media have their own special uses in high energy physics research.

The completed equipment shown in the various photographs is designed for liquids with operating pressures in the range 15 to 35 atmospheres and temperatures from 30°C to 80°C. The chamber is pneumatically cycled. The total weight of the equipment including magnet is about 200 tons and the capacity of the chamber 100 gallons. The strength of the magnetic field is 21.4 kilogauss which is about the maximum which can be generated using conventional techniques.

The chamber proper is made of austenitic stainless steel with inside dimensions 55" x 26" x 18", and is sandwiched between 2 sub-assemblies which include the poles of the magnet. The whole makes a closely located assembly weighing about 40 tons. The sub-assemblies go into the magnet through openings in the end faces of the yoke, and are free to move on pads fixed to it. The chamber enters transversely through the gap between the exciting coils, and the whole is clamped with 1.5/8" through bolts. A hydraulic test pressure which produces an end opening force of about 700 tons has been applied. All the components are doubly sealed with the pump-outs connected to pressure switches.

Looking from the cameras through the assembly there are the camera plate, a pole of the magnet hollowed for viewing the chamber, a 9" thick optically worked glass observation window, the bubble chamber, a 1/4" thick polyeurethane diaphragm which transmits the gas pressure cycle to the chamber, a hole plate for its support, and finally the rear pole of the magnet containing the pressure cycling valves.

The camera plate houses 4 windows, 3 of them for steroscopic photography of the tracks. The hollow pole, termed safety vessel, serves a dual role, since it is pressurised slightly in excess of the compression pressure applied to the liquid. This is a safety measure which directs the net force on the window inwards and keeps it small except during the momentary expansions of the chamber liquid.

The beam from the accelerator is directed along the 55" length of the chamber through either of the double beam-windows covering the openings in the end walls. The bubbles are illuminated by twelve 500 joule linear

Xenon filled flash tubes inside the liquid, but shielded from it by Pyrex envelopes mounted close to the top and bottom walls. An extractor enables faulty tubes to be replaced during operation. Ten 3" bore pilot pressure operated valves cycle the chamber. The valves fit in holes bored longitudinally through the rear pole, and are stalk mounted to minimise the volume behind the diaphragm. When in position, the valves open non-return valves set at the ends of the holes. This feature allows valve replacement during operation. At present the chamber is being expanded by six valves which pass 20 cu.ft. of standard air in 25 millisecs. with a 5 atmosphere mean pressure difference.

The pneumatic system comprises a 300 H.P. compressor which delivers gas via buffer vessels at 600 p.s.i. max. at a rate of 1200 cu. ft. of standard air per minute into a loop formed by the bubble chamber, and a by-pass which is back-pressure controlled and rated to pass any output not taken by the bubble chamber. Gas leakage in the system is automatically restored. For safety, the system gas will be Nitrogen when the chamber is operating with a hydrocarbon. At the chamber end are pressure controlled vessels which define the pilot and chamber compression and expansion pressures.

Temperature controlled water circulates through 1.1/4" diameter holes drilled through the top and bottom walls of the chamber assembly. Five pumping channels circulate the water which is temperature monitored. Heating is at a rate of 3 KW or 6 KW per channel. The circulated water may also be cooled at a rate of 3 KW per channel, but a $5^{\circ}C$ temperature difference must then exist between the circulated and cooling water in the heat exchangers. The temperature is controlled to $0.2^{\circ}C$.

The magnet yoke, weighing 140 tons, is made up from twelve 24" thick mild steel members. A 400 G.P.M. flow of cooling water is passed through the exciting windings at 4 MW. The windings weigh 25 tons and are vacuum impregnated with polyester resin. The central field values are 16.3 Kg and 21.4 Kg and 4 MW for 2 MW respectively, with 5.5% variation over the chamber volume. The chamber and its magnet can be readily moved over the smooth floor of the annexe on a set of three air flotation pads.

There are a number of devices associated with the detection and control of faults. Faults appearing in the compressor system or in the chamber, lead to the isolation of the compressor and closure of the chamber cycling valves. If an increased pressure develops in the chamber through the mixing of gas with the vapour of the chamber liquid, the pilot-pressure closing the chamber cycling valves is increased above the sum of the partial pressures. Leakage of the chamber liquid to the atmosphere, whilst very unlikely in view of the test pressures and double sealing that has been applied, will require the removal of the contents. With the dumping system installed, the chamber liquid is emptied in $3\frac{1}{2}$ minutes into a tank outside the building. A mixture of gas and liquid in the chamber, can also be routed into a P.T.F.E. bag, which is of sufficient capacity to bring the pressure down to atmospheric pressure.

The photographic system is designed to reproduce the position of a point in the chamber to an accuracy of better than 1/250th of an inch. The window is a block of first quality optical glass 9" thick by 60" long and 25" wide, weighing about half a ton. The faces are ground parallel, so that the thickness varies by no more than 4 thousandths of an inch, and finally polished until their flatness is comparable to that of an optical flat. Three separate cameras look at the chamber from a distance of about 6 feet. They are situated at the corners of an equilateral triangle of side 50 cms, one of the sides being across the direction of the particle beam arriving from Nimrod. 3.1/4" focal length Air Survey lenses, stopped down to $^{f}/20$, are used to photograph the chamber, at a demagnification of about 20, on 35 mm unperforated film. The lens distortions, though small, are accurately measured and allowed for in the computed reconstruction of tracks from film measurements. The effect of chromatic aberrations is minimised by the use of filters to isolate a band of orange wavelengths. Each camera holds 1000 feet of film which in normal Nimrod operation during an experiment, would be exposed in about 2 hours. An average size experiment would demand about 250,000 pulses of the chamber resulting in a film record some 50 miles long.

The chamber can be used with a wide variety of liquids and mixtures of liquids tailored to suit the particular experiment. In all cases the interaction length is much less than in a hydrogen chamber, hence giving a higher probability of seeing secondary interactions. At one extreme is the hydrogen rich propane C_3H_8 which contains as many free protons per unit volume as liquid hydrogen. Towards the other extreme are liquids such as trifluorobromethane, CF_3Br (the present filling) whose chief virtue is the high conversion of gamma rays. The chamber size is such that 80% of all gamma rays produced within it are converted to electron positron pairs. Neutral pions convert with similar effeciency to two gamma rays giving an overall probability of detection of 64%.

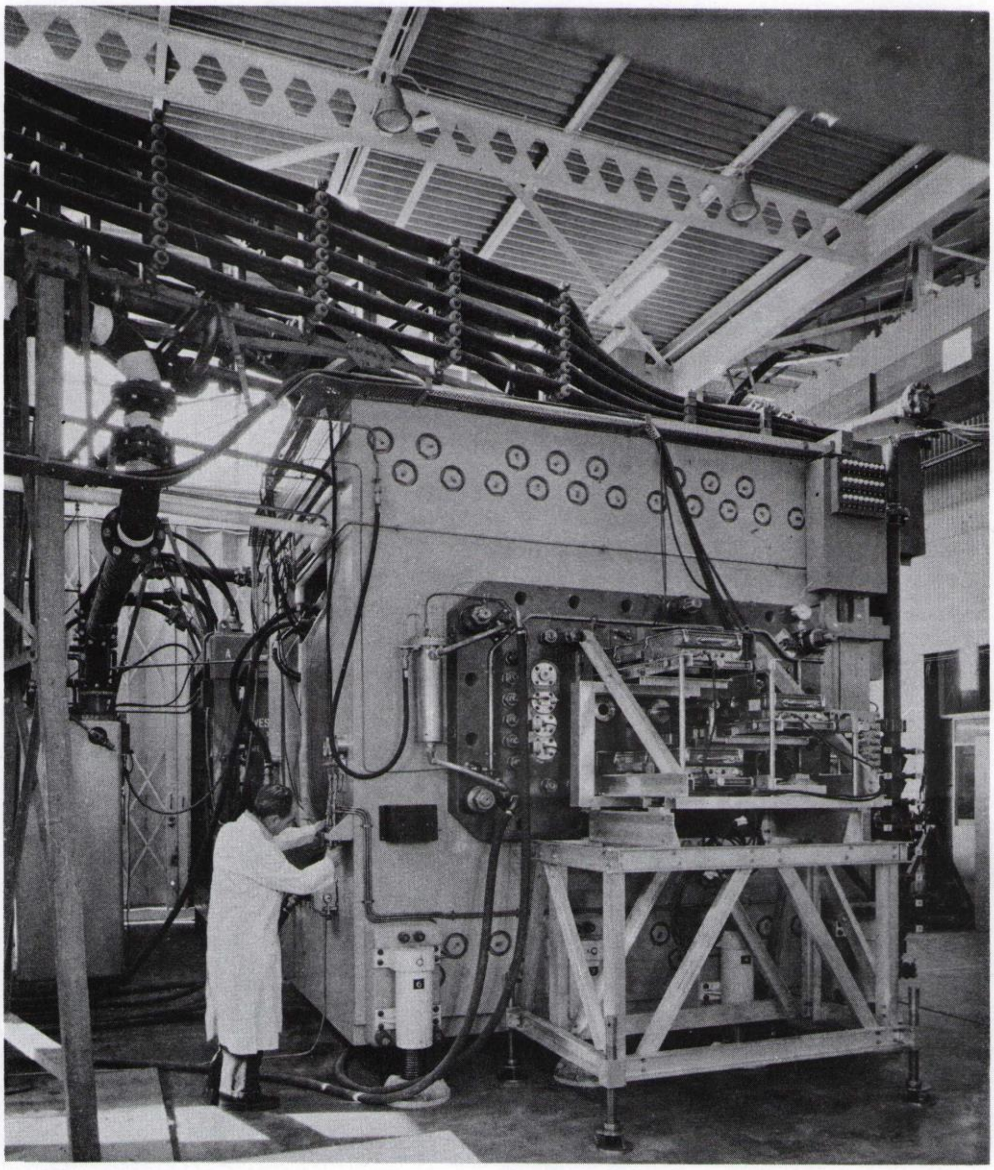


Fig I General view showing the Magnet Yoke and the Photographic Assembly

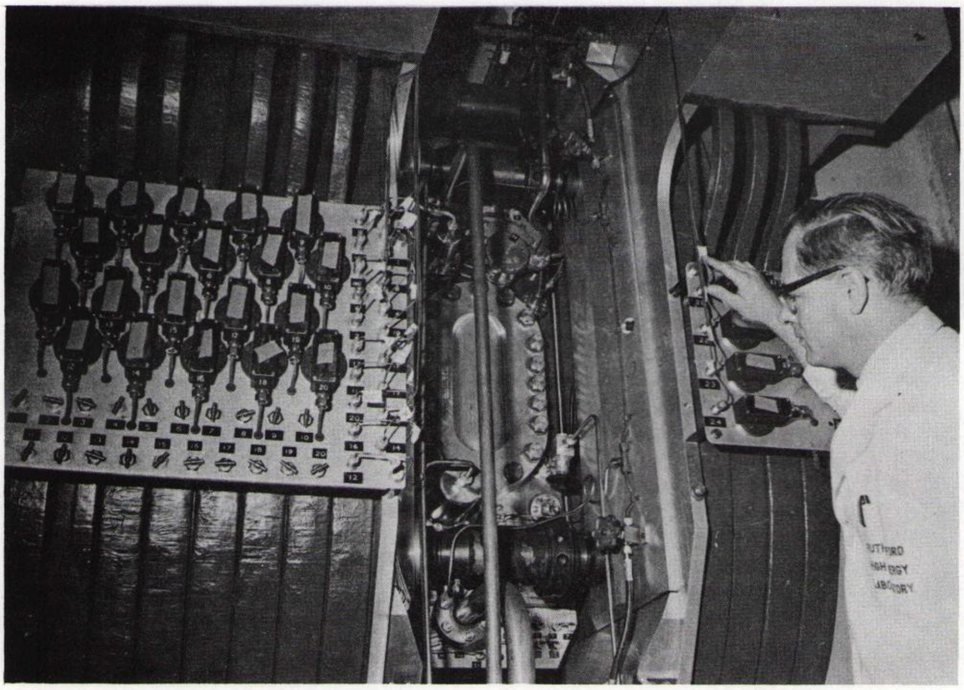


Fig II The "Beam End" of the Heavy Liquid Bubble Chamber

Fig III Cosmic Ray tracks in the Chamber

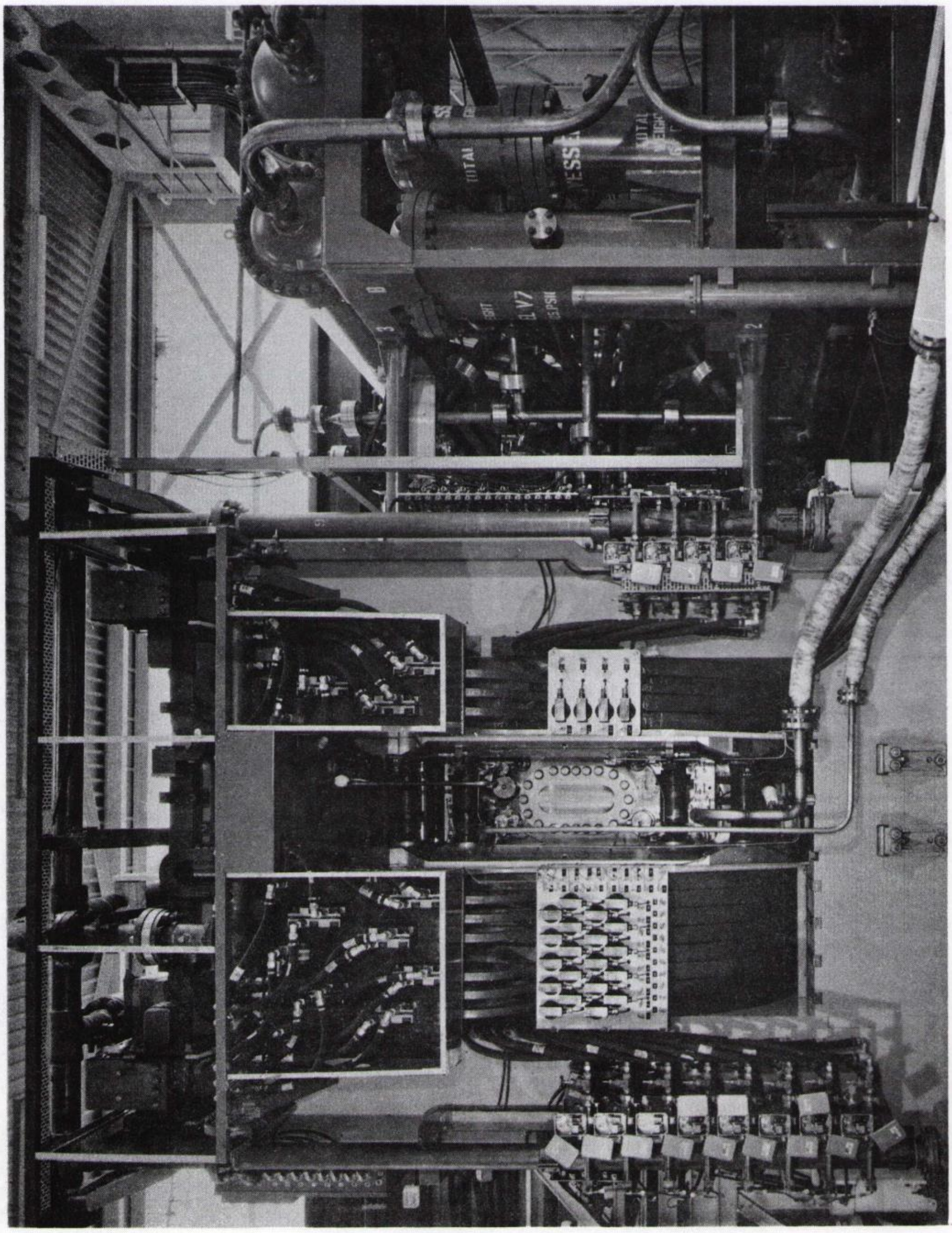


Fig IV View showing the Pneumatic Cycling Plant, Beam Window and the Coils for energising the Magnet

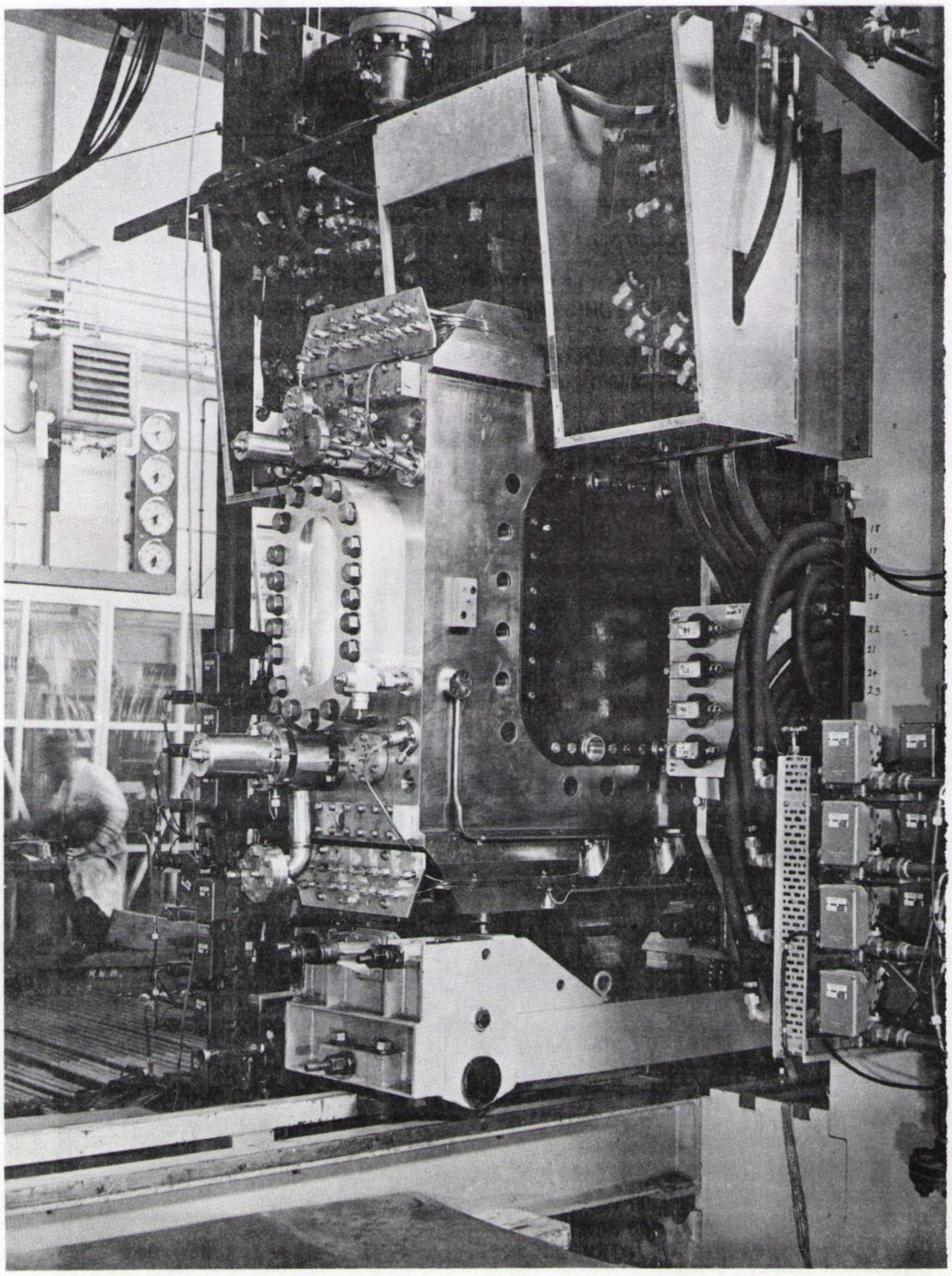


Fig. V. Chamber body on loading trolley

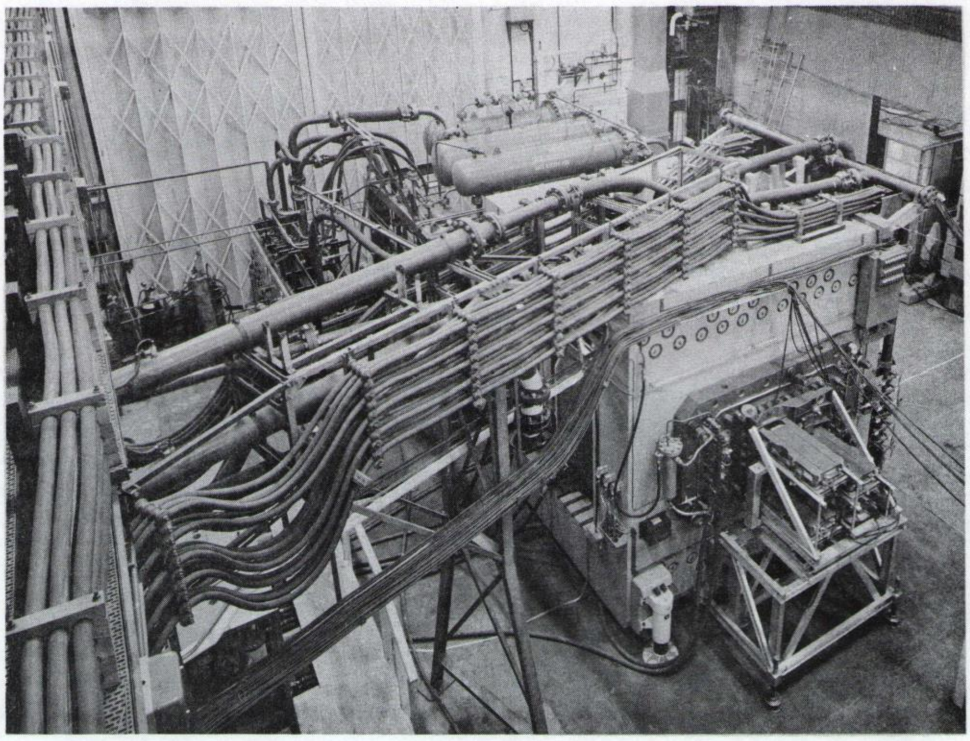


Fig. VI. General view showing service bridge in foreground

Fig. VII. 1 BEV p^+ beam from NIMROD in the chamber

APPENDIX III

Heavy Liquid Bubble Chamber

Assessment of Final Project Costs

1. The final commitment return for the project shows:

   1.1 The current plant commitment to be £331,862 against an estimate of £333,200. No further new commitments will be made to the project and therefore the balance of £1,300 approx. is available to cover the adjustments between present commitments and final prices on those orders not yet paid, and to cover any claims not yet received from contractors. No further contractors' claims are expected and the £1,300 should be adequate for finalisation adjustments.

   1.2 The R. & D. estimate is shown at £99,800. The latest evaluation of commitment is approximately £99,000 leaving £800 for any finalisation adjustments. Once more this is expected to be adequate.

   1.3 Buildings are expected to finalise very close to the £41,000 estimated cost.

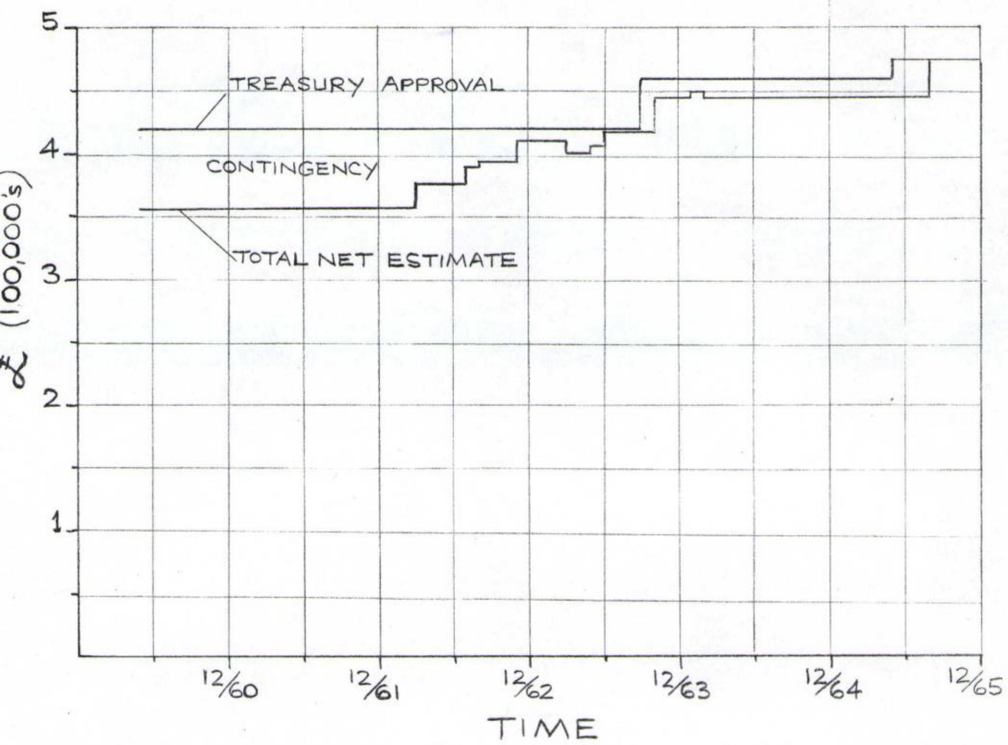
2. The project finances have been summarised graphically in Appendix IIIA.

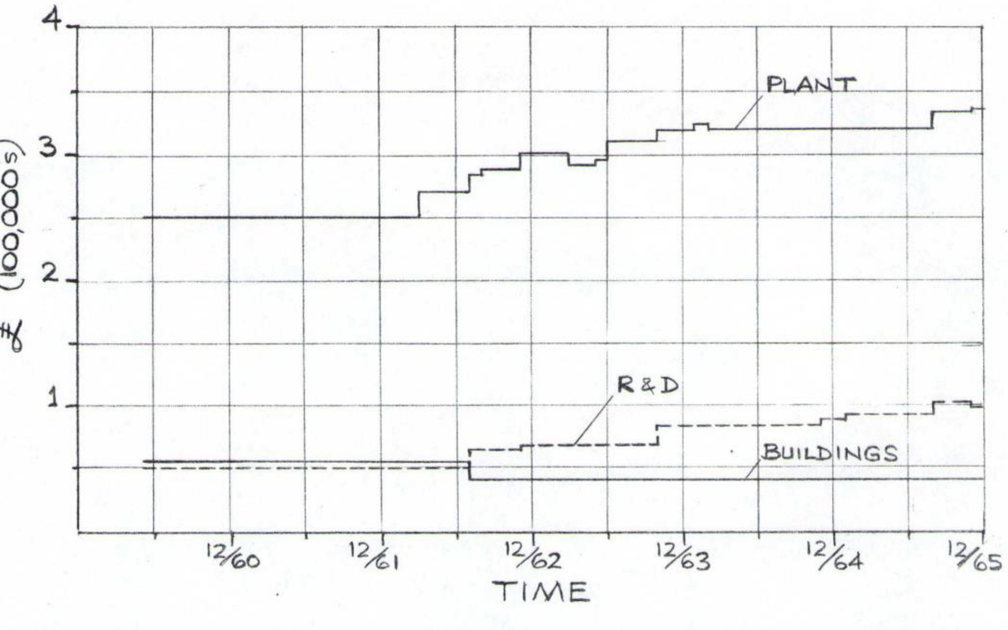
   2.1 The initial plant estimate, including a plant contingency, was £290,000. The final cost represents an increase of £42,000 which is equivalent to a rise in prices of approx. 5% p.a.

   2.2 The buildings have cost less than estimated.

   2.3 R. & D. has cost more than the original approval because the time required was longer than that initially estimated.

3. Two increases have been received in the Project Approval, and there is every expectation that the final costs will be a few hundred pounds less than the present approval.





Note: Fluctuations of contingency reflect in the main the fluctuation of the anticipated final cost of plant as individual orders were placed and contractors' claims were settled.