

Mr. Snowden.

MINUTES OF THE 6th MEETING OF THE CYCLOTRON PANEL HELD ON 26th JUNE,
1946, AT BIRMINGHAM UNIVERSITY.

The following were present :-

Mr. J.B. Adams (Harwell)	Dr. L.H. Gray (M.R.C.)
Mr. J. Boag (M.R.C.)	Dr. J.R. Holt (Liverpool)
Mr. M.E. Boston (Harwell)	Mr. M.J. Moore (Liverpool)
Mr. J. Cassels (Cambridge)	Dr. T.G. Pickavance (Liverpool)
Dr. R. Dawton (Harwell)	Dr. J. Rotblat (Liverpool) (Chairman)
Mr. S.H. Duke (Harwell)	Dr. H.W.B. Skinner (Harwell)
Dr. R.W. Fremlin (Birmingham)	Mr. M. Snowden (Harwell)
Mr. R.L. Gilbert (Cambridge)	Mr. R.S. Wilson (Birmingham)

1. Harwell Cyclotron

Mr. Adams reported on the progress made on the design of the Harwell cyclotron. The diameter of the pole tips has been increased to 88"; the length of the yokes and the diameter of the coils have also been increased in order to allow for the oil cooling tank. Messrs. Parsons estimate the total cost of the magnet with the vacuum chamber to be of the order of £100,000. The delivery date has been somewhat upset, due to a delay in placing the formal contracts. This has also affected the building of the model magnet, which will not be ready until the end of next month.

With regard to the tank, it was found that it will be possible to provide shimming gaps even with the Harvard design. In view of the advantages of this type of tank, and since it seems now that frequency modulation will be used in the first stage of the programme, the Harvard tank design has been adopted and an order for it includes with the order for the magnet to Messrs. Parsons.

The dee feeder circuit has been designed at T.R.E; it is proposed to approach a Royal Ordnance Factory to build the coaxial feeder lines and the dees. A hydraulic method of operating the sliding shorting bars on the dee lines will be employed.

Mr. Snowden reported that he has been in touch with the G.E.C. about the R.F. system for the Harwell cyclotron; they estimate the cost of a 300 kW transmitter unit to be £12,000. As this unit consists essentially of two CAT 17 valves and a box with the associated gear, the cost was considered by the panel to be rather excessive; it was agreed to ask the G.E.C. to give a more detailed estimate.

The 700 kW H.T. set from B.T.H. will cost about £10,000 and could be ready in 15 months.

It was stated by Mr. Moore that Messrs. Phillips could supply a 250kV, 10 m.a. set suitable for the Harwell deflector, and it was agreed that an approach should be made to the firm.

The question of the small experimental cyclotron has been raised again. Originally it was intended to use this cyclotron mainly for experiments on various methods of frequency modulation, while the large cyclotron was operated with constant frequency. Since it appears now that frequency modulation will be immediately applied to the large cyclotron the need of a smaller model becomes doubtful. It was agreed that the decision about the small cyclotron should be postponed until the problem of frequency modulation is more clarified.

2. 65" Cyclotrons.

Dr. Gray stated that the Panel's recommendations about the design of the cyclotron for the Medical Research Council will meet all requirements and that these suggestions will be put forward at the meeting of the Council that will be held in July. It is expected that this meeting will approve the recommendations and authorise the ordering of the cyclotron. On the question of the uses of this cyclotron, Dr. Gray stated that it is primarily intended for neutron therapy. The production of radioactive elements, which are not

manufactured in a pile, or which have a short lifetime, is also envisaged, but it is not intended to spend more than one third of the time for this purpose. The elements produced would be supplied to research workers in the medical and biological sciences.

Mr. Cassels stated that Cambridge is now ready to place an order for the magnet for a 65" cyclotron.

Mr. Moore reported on talks which the Liverpool representatives had with Metro-Vicks. Metro-Vicks are willing to undertake the building of complete cyclotrons, but they would prefer to do it on a cost plus basis; the delivery of the first cyclotron could be in 18 months from the date of placing the order. A detailed quotation has been received from Metro-Vicks, and it appears that the total cost of a 65" cyclotron will be £70,000 \pm 25%. This sum includes the magnet with generator and stabilising unit, tank and feeder lines, vacuum system, R.F. system, ion source, deflector, target (probe) and assembly, control circuits, water circulating system, as well as delivery and erection on the Liverpool site.

It was felt that the Metro-Vicks estimate for the magnet compares favourably with that of Parsons, who have unofficially quoted about £60,000 for the magnet and tank alone. Moreover, some reduction in the Metro-Vicks price may be expected if three magnets are ordered at the same time.

The R.F. system suggested by Metro-Vicks, and which is to consist of a power amplifier with continuously evacuated valves and a drive unit containing 8 stages, was thought to be unnecessarily complicated and bulky. It was agreed to ask Metro-Vicks whether they could build a simpler system, and at the same time to investigate the possibility of using an R.F. system of the type which will be built by G.E.C. for Harwell.

3. Frequency Modulation.

The information which some members of the Panel have received from Professor Oliphant on the results of frequency modulation at Berkeley caused a lengthy discussion on the relative merits of constant wave and of frequency modulated cyclotrons. According to Professor Oliphant the progress made with the frequency modulated 37" Berkeley cyclotron is very encouraging indeed. They have obtained on the target a 2 micro-amp beam of protons of 22 MeV; striking a copper target, this beam produced a greater neutron yield than that obtained in the same cyclotron, with C.W. operation, using deuterons on a beryllium target. The most important fact is that the cyclotron can be operated with extremely low R.F. power, only a few kilovolts between the dees being required. This eliminates all troubles caused by discharges and overheating; combined with the freedom from shimming difficulties, it makes the running of the cyclotron a very easy matter. In addition, the pole gap can be reduced, and also the poles need not be shaped, so that the effective diameter of the magnet can be considerably increased.

In view of these facts, it would appear that one should dispense with C.W. cyclotrons altogether and use only frequency modulation. On the other hand it was felt that the problem of changing over completely to the new system should be approached with some caution. For example, it is not certain whether the favourable yield of neutrons observed with proton reactions will continue to hold good for very high energies. It may also be that frequency modulation will introduce a considerable energy spread of the beam. But foremost is the problem of the intensity of the beam; if the Harwell cyclotron is to be employed for the production of transuranic elements and a high neutron flux the beam intensity is of primary importance. Professor Oliphant's estimate that it may be possible to approach with F.M. 15-20% of the intensity of a C.W. cyclotron is probably correct at low energies, but it was feared that at high energies the average beam may be much lower.

The main problem was whether it will be possible to meet both requirements set out in the original specification for the Harwell cyclotron, i.e. very high energies and great intensities. If frequency modulation results in a low beam intensity the possibility of C.W. operation should be retained. This would require separate tanks and dees and also different shaping of the magnet poles. It was generally felt that the saving in cost of the R.F. system which would result if only F.M. were used would be insignificant, since the cost

of the 300 kW R.F. system necessary for C.W. operation is only about 10-15% of the total cost of the cyclotron.

It was agreed that before making any recommendations on the final design of the cyclotron more information about frequency modulation should be sought, particularly on the problems of the expected neutron yields, the energy spread of the particles and the estimate of the beam intensities. It was agreed to ask Professor Oliphant to try to obtain an answer to these questions during his visit to the United States.