Mr M. Snowden.
TRE

MINUTES OF THE 5th MEETING OF THE CYCLOTRON PANEL HELD on 13th MAY,1946, AT LIVERPOOL UNIVERSITY.

The following were present :-

Mr.J.B.Adams (Harwell)
Mr.J.Boag (M.R.C.)
Mr.M.E.Boston (Cambridge)
Dr.R.Dawton (Harwell)
Dr.O.R.Frisch (Harwell)
Dr.J.R.Holt (Liverpool)
Mr.K.Kandiah (Cambridge)
Mr.M.J.Moore (Liverpool)
Dr.T.G.Pickavance (Liverpool)
Dr.J.Rotblat (Liverpool)(Chairman)
Mr.M.Snowden (Harwell)
Mr.R.S.Wilson (Birmingham).

1. M.R.C.Cyclotron.

Mr.Boag stated that the cyclotron for the Medical Research Council would have two main functions: the production of radioactive elements and the provision of a high neutron flux for therapeutic purposes. He was interested in obtaining information about the output of radio-elements, neutron intensity and dosage distribution. It was stated that the neutron flux requirement and not the production of radio-elements would be the deciding factor in determining the size of the cyclotron. The most efficient source of neutrons is the deuteron bombardment of beryllium; with deuterons of 40-50 MeV and at a beam intensity of 200 microamps a flux of 1-2 x 10^{13} neutrons per cm. sq.per sec. could be obtained; the neutron yield is not expected to increase appreciably at higher energies of the deuterons. Deuteron energies and beam intensities of that order could be obtained in a 65" cyclotron (60" dee diameter), that is to say of the same size as the proposed Cambridge and Liverpool Machines. It was therefore agreed to recommend that the M.R.C. should build a similar cyclotron.

The question whether the cyclotron should be of the constant frequency or general purpose type was then discussed. It was stated that although there may not be a need for changing the energy of the particles in the M.R.C.cyclotron, it may be worth while providing for such contingency, since the saving in cost if a fixed frequency were used would be negligible, and since the other two machines would be designed as general purpose cyclotrons. The Urbana method of bringing out the beam was also recommended. It was stated that for therapeutic purposes a focussing magnet could be provided to enable the beam to be brought out in a tube several metres in length.

2. Harwell Cyclotron.

Mr.Adams reported on a meeting of the Harwell Group at which the design of the magnet was discussed. The information which the Panel has sought about the 92" Harvard cyclotron has been obtained; it appears that the depth of the dees is only 6" and the tank depth 12"; this cyclotron is designed to be used with frequency modulation only, and therefore shimming is not of very great importance. For the Harwell cyclotron, however, in which beams of great intensity as well as of high energy will be required, provision for shimming is essential; it was stated that provision for shimming coils could be made in the tank if it had a depth of 14". After some discussion it was agreed that the tank for the Harwell cyclotron should be 14" deep with 6" dees,tapered so as to provide space for shimming coils.

It was reported that the contract for the Harwell magnet has been given to Messrs. Parsons and that they will use oil cooling. The contract was on a cost plus basis and the delivery date five months. The Panel felt that this short delivery date made this contract very satisfactory, but some app rehension was expressed about the contract being placed before receiving answers from several other firms which have been approached.

It was reported that the core for the model magnet will be built by Messrs. Parsons and delivered in about a month.

The design of the tank was discussed at some length. It was reported that in the design of the Harvard cyclotron the lids of the tank are bolted to the pole pieces and shaped to produce the desired

field. Such a design provides a very rigid mechanical system, but on the other hand the advantage of the shimming gaps is lost. Electrical shims can be used to introduce radial variations of field but variation with polar angle cannot be dealt with easily and reliance would have to be placed on homogeneity of the pole tips. It was finally agreed that before deciding on the design of the tank, the possibility of providing electric spot shimming should be investigated and that Dr.Bunemann should be consulted on that matter.

A suggestion was made that a small (20-30") cyclotron should be built for Harwell. This would be for experimental purposes only and would enable the testing of new designs and methods of frequency modulation without hampering the work of the main cyclotron. It was agreed that such an experimental cyclotron would be very valuable.

3. Cambridge and Liverpool Cyclotrons.

It was stated that Cambridge is not yet in a position to place contracts. Liverpool has approached several firms concerning the magnet and R.F. system. No estimate has yet been received but Metro-Vick could give an 18 months delivery date for the magnet and for an R.F.set with continuously evacuated valves.

The following figures were quoted for the performance of these cyclotrons: With a 29" radius at the exit slit, deuterons of 45 MeV could be obtained with an R.F.power of 200 kW and 65° phase angle, without frequency modulation. The magnetic field is then 18,000 gauss and the frequency 14 megacycles. These figures are based on a 12" pole gap and a 5½" dee depth, with a dee voltage of about 500 kV. The proton energy under the above conditions of power and phase is 35 MeV at a frequency of 17.5 megacycles. Using frequency modulation the energy limit for protons is at 65 MeV. Deflector voltage, at ½" spacing and 4" change of radius is 188 kV for deuterons of 45 MeV energy. The total power dissipation of the cyclotron will be about 850 kilowatts.

The question of the maximum R.F.voltage was discussed and Mr. Boston was asked to make measurements on the breakdown of the R.F. voltage on the Cambridge cyclotron.

4. Frequency Modulation.

Some information regarding the experiment with the 37" cyclotron at Berkeley was provided by Dr.Frisch. The magnet was shimmed so as to simulate the conditions which will be experienced by high energy particles in the 184" cyclotron, and low R.F. power used giving a dee voltage of about 5 kV. A motor driven multi-section condenser was used for the production of a sinusoidal change of frequency with a period of 800 microseconds. It was found that beam pulses of 20 microseconds duration were produced and the mean beam current, recorded on an internal probe, was 3 microamperes.

There was considerable discussion on these results, and it was agreed that the outlook for frequency modulation was hopeful where very high energies on the Harwell cyclotron were concerned.

It was reported by Dr.Frisch that in the above experiment about 10% of the circulating beam could be led into the target chamber by using the normal deflector technique. This was surprising in view of the very low dee voltage used, with consequent nearness of neighbouring orbits. The explanation suggested by the Berkeley people was that the radially varying magnetic field and the effects of frequency modulation produced a precession of the orbits, causing a larger effective separation of the orbits. It was appreciated that this effect would simplify the problem of extracting the beam from the Harwell cyclotron during high energy operation with frequency modulation.

5. R.F.Systems.

Mr.Snowden reported on his investigation of the valves for the R.F.systems. The G.E.C. CAT.17 valves seem to be most suitable;

they are expected to be 50% efficient in a grounded grid oscillator at 20 megacycles; two of these valves will easily handle a 300 kW output. The valve made by Standard Telephones and Cables is similar but has higher electrode capacities. The question whether a push-pull or parallel circuit should be employed was discussed. It was stated by G.E.C. that the parallel circuit should not give rise to parasitics as has been feared; the advantage of the parallel system is that the valves can be coupled directly to the trombones and that there is no need for a separate grid line. In view of this it was agreed to employ, for the Harwell cyclotron, a parallel circuit composed of two CAT.17 valves. G.E.C. will undertake to build the system within a year if a development contract is placed with them. Mr.Adams was asked to obtain from the G.E.C. an estimate of the cost of such a system.

With regard to the 65" cyclotrons, it was stated that two valves will be required to produce the desired 200 kW. The Metro-Vick continuously evacuated valves would just provide this power; two CAT.17 valves would be adequate and under run. It was agreed that quotations should be obtained from Metro-Vicks and G.E.C. before deciding on the type of circuit and valves to be used.

Mr.Snowden and Mr.Wilson were asked to look into the matter of capacity tuning for changing the frequency.

6. H.T.Equipment.

It was reported that the B.T.H. had a 700 kW mercury pool rectifier in the factory at present and could complete the set in 18 months. This would have step control on the power transformer by means of "on load" taps, and fine control on the grids of the rectifier to provide variation of output voltage. The supply of an induction regulator would take more than a year. It was decided to try to reduce the delivery date for this set.

For the 65" cyclotrons an H.T.set of about 400-500 kW would be required. It was agreed that an approach should be made to Metro-Vicks and English Electric.

7. Deflector H.T.Set.

It was stated that the G.E.C. could build a voltage doubler set to give 10 mA a t 250 kV. It was agreed that Mr.Adams should approach G.E.C. and Victor X-ray Corporation about such sets.

8. Next Meeting.

The next meeting will be held at Birmingham, the exact date to be determined later.