

MINUTES OF THE THIRD MEETING OF THE CYCLOTRON PANEL HELD ON 1st APRIL, 1946, AT THE CAVENDISH LABORATORY, CAMBRIDGE.

The following were present :-

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| Mr. J. B. Adams (T.R.E.) | Mr. M. J. Moore (Liverpool) |
| Mr. M. E. Boston (Cambridge) | Dr. T. G. Pickavance (Liverpool) |
| Mr. J. Cassels (Cambridge) | Dr. J. Rotblat (Liverpool) (Chairman) |
| Dr. R. Cockburn (Harwell) | Dr. H. W. B. Skinner (Harwell) |
| Dr. R. Dawton (Harwell) | Mr. M. Snowden (R.R.D.E.) |
| Dr. J. R. Holt (Liverpool) | Mr. H. C. Whitby (T.R.E.) |
| Mr. K. Kandiah (Cambridge) | Mr. R. S. Wilson (Birmingham). |

1. Frequency Modulation.

The Panel had before them a letter from Professor Cockcroft in which he suggests that the difficulties due to the relativistic correction should be overcome by applying frequency modulation rather than by using very high R.F. power. In the ensuing discussion it was pointed out that frequency modulation would indeed considerably reduce the R.F. power requirements (by a factor of about 3) but at the same time the intensity of the beam would be reduced by a factor of about 50. It was felt that some other method of preserving the resonance (e.g. using a radially increasing magnetic field and electric focussing) might prove to be more efficient, and that it would be worth while obtaining more information about experiments done in other laboratories on such methods, but, in the meantime, frequency modulation should be pursued as this method does not present any fundamental difficulties. It was agreed to accept Professor Cockcroft's suggestion of a two stage programme :-

1. Maximum current of deuterons at an energy which can be achieved with a reasonable R.F. power without frequency modulation.
2. Maximum energy of protons with frequency modulation.

About 300 KW R.F. power fed into the dees was accepted as a reasonable figure to be aimed at for the 84" cyclotron. With this amount of power it should be possible to obtain a deuteron beam of 50 MeV without frequency modulation, and a proton beam slightly more than 50 MeV with frequency modulation. Messrs. Adams, Kandiah and Pickavance were asked to prepare more detailed calculations of the energies to be expected with and without frequency modulation at that power level. Mr. Snowden was asked to look into the matter of methods of producing frequency modulation.

2. Magnet.

The Panel discussed the specification for the Harwell magnet drawn up by Professor Cockcroft. The pole gap (distance between lids of tank) suggested by Professor Cockcroft is much smaller than that assumed in the Panel's specification (10" as compared with 18"). It was generally felt that a larger pole gap would be valuable for several reasons and that its main disadvantage, namely, the larger cost of the magnet, would be more than compensated by the reduced R.F. power requirements. The effect of the fringing field at such deep gap was thought to be not very formidable; it was stated that with an 18" gap in a 84" cyclotron the maximum diameter of the ion path could be 70"-72". The discrepancy between the two specifications in the weight of steel was probably due to the fact that Professor Cockcroft assumed in his calculations a higher quality steel and a smaller pole diameter. It was finally agreed that the original specification for the magnet, proposed by the Panel, should be maintained.

It was reported that an estimate has been received from Messrs. Colville Ltd. for the building of the magnets (excluding the coils). The cost of the 84" magnet would be £40,000 and of the 65" magnets £20,000 each. These magnets would be made of 3" slabs of steel of a low carbon content (about 0.06%) and the estimate included machining, assembly, and inspection at the Works, and delivery to the sites. The 84" magnet could be delivered in about six months and the remaining magnets in the following six months. Some members of the Panel felt that the cost was rather excessive and some doubts were expressed as to the necessity for using steel of very low

carbon content and of machining the individual slabs. It was agreed to ask Mr. Moore to enquire from Messrs. Colville about the cost of a magnet of lower quality steel (0.2% carbon content).

It was reported that Messrs. O. Parsons, Newcastle, would undertake to build the whole magnet, including the winding. It was felt that it may be more advisable to entrust one firm with the task of building the complete magnet rather than to deal with several firms. It was agreed to postpone a decision on that matter until a rough estimate of the cost and delivery date is obtained from Messrs. Parsons. In the meantime, an approach should also be made to Messrs. I.C.I. Metals, Biltons and Metropolitan-Vickers about winding the coils.

After a further discussion on the suggestion to build the cyclotron vertically, it was agreed not to adopt this scheme since it does not present great enough advantages over the classical method to merit the extra development work which this modification would necessitate.

With regard to the method of bringing out the beam, it was pointed out that in the Urbana method the increase of the capacity of one of the dees is quite small and that therefore it would not cause an appreciable increase of the R.F. power. It was agreed to adopt in principle the Urbana method of bringing out the beam with some modifications in the design of the tank and dees.

3. R.F. System.

It was pointed out that the Berkeley type valves would stand only **200 kW** anode dissipation and not 500 kW as reported at the previous meeting. This does not, however, create any new difficulties in view of the revised power requirements; two Berkeley valves in push-pull should comfortably supply the 300 kW required now. It was reported that none of the firms approached so far have agreed to build the Berkeley valves and that only Metro-Vicks remain to be approached. It was agreed to explore this last possibility and if a negative reply is received T.R.E. should be asked to undertake the building of the valves.

The reduction in the power demand opened the possibility of employing commercially produced valves. It was reported that the G.E. in America are now building a Power-Amplifier R.F. System, using standard R.C.A. valves and giving an output of 350 kW in a frequency range 7-17 Mcs. In this country Messrs. Standard Telephone and Cables Ltd. are developing sealed off valves which will stand **250 kW** anode dissipation; this firm would undertake the building of the whole R.F. system. It was felt that it would not be advisable to place such a big order abroad at the present moment. It was agreed that the offer made by Standard Telephone and Cables should be further explored.

With regard to the H.T. power supply, it was reported that B.T.H. are producing sets giving 700 kW (20 KV-35 amps.); such a set would be ample for the R.F. system of the 84" cyclotron. It was agreed that an approach should be made to that firm.

Tank and Feeder System.

The merits of the shielded pair system of feeders were again the subject of a long discussion. It was found that the actual amount of saving in R.F. power was not as great as originally thought. It would appear that this method is more adaptable for movement of the shorting bar and thus for changing the frequency in vacuum than twin coaxial feeders. There was still some disagreement about the mechanical difficulties involved in this system and it was agreed to ask Messrs. Boston and Moore to look into these problems and prepare a recommendation for the next meeting.

It was agreed that the tank and feeder system is a major piece of equipment and that therefore some outside firm should be approached about building it. Messrs. Vickers, Barrow, were suggested as an appropriate firm for the supply of the tank.

With regard to Professor Cockcroft's suggestion to build a standard tank as a temporary measure, it was pointed out that the bottle-neck will probably be the magnet or the R.F. system and that by the time these items

are finished a tank made to our own design, and fitting the magnet, could be built.

5. Deflector.

It was reported that for a deuteron energy of 65 MV and a final radius of the ion path of 36" the required deflector voltage would be about 200 kW. It was agreed that a conventional H.T. set supplying about 220 kV would be sufficient and that such a set might be purchased from Metro-Vicks.

6. Control System.

It was stated that the control systems employed on the present cyclotrons in this country are quite up to date and that therefore no special development is required in this field. It was agreed to collect the circuit diagrams and the designs of the control systems of the Cambridge and Liverpool cyclotrons.

7. Target Chamber.

It was stated that the cooling methods employed on all present designs of target chambers are insufficient and limit the beam striking the target to about 400 microamps. It was felt that an improved method of bringing out the beam is required and that the problem merits some attention.

8. Radiation Shielding.

The problem of the best way of shielding the personnel from radiation hazards was again discussed. It was pointed out that as the ground at Harwell is mainly chalk it may be more economical to excavate a sufficiently large hole to house the cyclotron than to install water tanks or erect concrete walls. It was stated that the volume to be excavated would be rather large and that the level reached may be too close to water to enable one to put in suitable foundations for the magnet. It was agreed that Dr. Dawton should enquire from the Ministry of Works about the relative costs of excavation and water tanks. There was also a need to obtain some data on the absorption properties for γ -rays and neutrons of the soil material.

9. Date of Next Meeting.

The next meeting will take place on Monday, 15th April, at 9.30 a.m. at Harwell.