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HEAVY PARTICLE ACCELERATOR

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FROM: A. Zucker, J. L. Fowler, R. S. Livingston

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STATUS REPORT ON THE 63" CYCLOTRON
HEAVY PARTICLE ACCELERATOR

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A. Zucker
J. L. Fowler
R. S. Livingston

May 25, 1951

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STATUS REPORT ON THE 63" CYCLOTRON
HEAVY PARTICLE ACCELERATOR

On May 3, 1951 approval was granted to the Electromagnetic Research Division of this laboratory to build a cyclotron capable of accelerating triply charged nitrogen ions to an energy above 20 Mev. The necessary magnetic field was to be provided by a section of the magnet originally designed for the electromagnetic separation of uranium isotopes, thus eliminating the need for a new magnet, the most expensive component of any cyclotron.

Due to the existing magnetic field certain adaptations had to be made which will distinguish the heavy particle accelerator from conventional cyclotrons. The dees are to be mounted in a vertical plane, and the beam will emerge in an upward direction. In addition, existing calutron equipment is to be used whenever possible, which makes many of the heavy particle accelerator components considerably different from standard cyclotron designs. The circular pole pieces which have been fabricated and mounted in the tank are 63" in diameter. The gap between them is $6\frac{1}{2}$ " and the field strength 15,500 oersteds. A 2% radial drop-off in magnetic field is achieved by shimming. So far the desired magnetic field shape has been obtained to within $\pm 0.3\%$, which will be improved by repeated addition of thin shims until the field is accurate to $\pm 0.2\%$ or better. To energize the magnet, a current of 2,100 amperes, produced by existing generator facilities is passed through six standard coils. Oil cooling for the magnet is provided by the cooling arrangement used in the calutron magnet.

The vacuum tank in which the cyclotron will be housed is a slightly modified calutron vacuum tank. A schematic drawing of the assembled cyclotron is shown in Figure 1. The front of the tank has been reserved for rf connections, and removable face plates will facilitate speedy disassembly of the dees and liner for inspection and repairs. The back of the tank will be used for pumping; two 20" oil diffusion pumps will provide a pumping speed of 10,000 liters/sec. Liquid nitrogen traps will be provided. A vacuum lock in the pumping manifold will permit easy interchangeability for the ion source as well as an entrance for a beam current probe.

The maximum beam radius will be 25.3", the dee-to-dee gap 1.5". An ion source and a probe will be placed in the gap. The overall thickness of the copper dees will be $3\frac{1}{2}$ ", and a $1\frac{1}{8}$ " space has been provided between the dees and the grounded liner. The liner walls will be made of stainless steel, copper plated to obtain satisfactory rf characteristics, and will be $\frac{3}{8}$ " thick. The dee-liner assembly will then just fit into the $6\frac{1}{2}$ " magnetic field gap. Both the dees and liner will be water cooled, and mounted on separate face plates. Under ordinary operating conditions it is expected that the liner will remain in the tank permanently, while provisions will be made for the easy removal of the dee assembly. The dees themselves will be insulated from ground by means of large bushings at the face plate. Seventeen foot shielded dee leads will connect the dees to the oscillator.

One hundred kw of rf power will be provided by a grounded-grid oscillator using a 5770 (RCA) power triode. The operating frequency will be 5 mc,

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developing 35 kv dee-to-ground voltage. A full scale electrical model of the cyclotron has been built of wood and lined with copper foil. From it we are now determining the rf constants of the cyclotron, which will aid us materially in the final construction of the oscillator.

The beam will be deflected through an arc of 95° by means of an electrostatic deflector of conventional design. Sixty thousand volts/cm will provide the field necessary to extract the ions from their original path and bring them out of the vacuum tank through a port on top of the cyclotron.

One of the first problems that had to be solved in connection with the heavy particle accelerator was the construction of an ion source which will provide sufficient output of triply charged nitrogen ions. Two such sources have been developed in this connection. The first, a hot cathode source, is described elsewhere¹. In addition, a cold-cathode hollow-anode source has been found to give better N^{3+} outputs and to be more easily constructed to comply with the stringent space limitations which are imposed by the geometry of the cyclotron gap. The following outputs have been obtained with the two sources.

	N^+ <u>ma</u>	N^{2+} <u>ma</u>	N^{3+} <u>ma</u>	N^{4+} <u>ma</u>	Total Output <u>ma</u>
Hot Cathode	48	57	22.3	2.2	175
Hollow Anode	26	29	28.0	9.0	95

The hollow anode source, then, offers considerable advantages. Not only does it produce more N^{3+} but it does so with smaller accompanying total ion output which contributes to the ion loading of the cyclotron. In addition, the N^+ output in the hollow anode source is only half that of the hot cathode source. This is a substantial improvement since some N^+ will be accelerated by a subharmonic frequency of the cyclotron. At present both types of sources are undergoing further development and both will probably be tried in the cyclotron under operating conditions.

In general the heavy particle accelerator has been thought out in considerable detail. Parts of it, such as the vacuum tank and pole pieces are already in place. The vacuum manifold and the liner are currently being fabricated, while the dee assembly, for example, is still in the design stage. Experimental work is being conducted on various aspects, such as the rf model, the ion source, and the magnetic field shape. Calculations for the deflector have been completed, and the deflector itself has been designed. Similar calculations for the rf system have been completed and the results obtained are in good agreement with the experimental findings on the model.

The function of the heavy particle accelerator is to provide high energy N^{3+} ions, and the most important aspect of the machine is undoubtedly the utilization of these heavy nuclear projectiles. A number of experiments have been

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¹ R. J. Jones, A. Zucker, High Intensity Ion Source for N^{+++} , Y-734, March 1, 1951

planned and the apparatus for them is currently being built or on order from commercial suppliers. Most of the planned experiments are built around a reaction chamber shown in Figure 2. This is a cylindrical chamber, two feet in diameter and 9" high. The nitrogen beam will pass through the port on the left and enter through a very thin foil at the center of the chamber. The reaction chamber will be connected to the vacuum tank by large sylphon bellows; an arrangement which will allow adjustment of the position of the chamber until the beam is centered in it. A movable counter in the reaction chamber will permit observation of various particles at all angles with the beam and at various distances from the target. Provision has been made for the addition of another movable counter which will enable us to perform coincidence experiments. With this flexible arrangement, it is expected that a variety of experiments will be performed.

The first experiment will be one to determine the energy of the accelerated nitrogen ions. In order to do this the reaction chamber will be filled with deuterium gas to a pressure of about 20 cm Hg, and the counter placed at 90° to the beam. An air filled range cell will enable us to vary the absorbing path between the deuterium gas target and the counter. By observing the range of the protons produced by the reaction $N^{14}(d,p)N^{15}$ the energy of the incident nitrogens will be determined. Once the energy of the beam is determined, a range vs energy curve will be investigated for nitrogen nuclei. At present no data exist in the region above 5 Mev. We plan to measure the range energy relation by observing the range of N^{14} scattered by N^{14} at various angles. Knowing the incident energy and the scattering angle we can calculate the energy of the scattered nucleus. The ranges of the scattered nuclei in various materials can be observed in the reaction chamber directly and the energy can be varied merely by setting the counter at different angles.

After these experiments, nuclear reactions will be studied which involve high energy nitrogen nuclei. Again the reaction chamber will be used, this time filled with nitrogen gas at 10 cm Hg pressure. The following reactions, for example, will be investigated:

In all of these the light product particles will be observed, and in the case of neutrons threshold detectors may be used. Charged particles will be observed in the counter, and their energy determined from the pulse heights produced in the counter. The pulses will be analyzed in a ten channel pulse height analyzer which is now being built. One purpose of these experiments is to investigate the mechanism of this type of reaction. The absolute cross sections as a function of the energy of the incident nitrogen nuclei should indicate whether a compound nucleus is formed, or whether some other process must be involved in the reaction.

$N^{14} + N^{14}$ can produce such reactions as:

The cross section of the first can be determined rather simply by bombarding a nitrogen gas target with nitrogen nuclei and then looking for the 10.1 minute β^+ activity of N^{13} . Figure 3 shows the ranges in air of carbon nuclei resulting from this reaction. It is to be expected that the reaction products are not likely to be left in the ground state. The ranges, therefore, are shown for the first four excited states of C^{12} as well as for the first two excited states of O^{16} . The scattered nitrogens are also shown in the figure, and it can be seen that their ranges do not overlap those of the more energetic and lighter C^{12} nuclei. The second reaction will be observed in the reaction chamber in the following way. The chamber will be filled with N_2 to a pressure of a few centimeters of Hg. C^{12} nuclei will be observed in the counter, at various angles with the incident beam. The pulse height analyzer will enable us to distinguish C^{12} nuclei by their specific ionization, from other particles in the reaction chamber. In this way we will obtain a differential cross section for the reaction, and hope to get experimental data useful for theoretical treatment of nuclear interactions.

We have, then, three different types of experiments for which the heavy particle accelerator is uniquely suited. First there is the range energy relation for medium weight particles. There is at present a lack of data on the ranges of these particles, and their determination will provide a real advance in the empirical and theoretical knowledge of high energy particles. Second, a check on the compound nucleus theory of nuclear reactions seems most valuable, and can be accomplished with relatively little difficulty in the heavy particle accelerator. The third type of experiment exemplified by

is perhaps the most interesting. Here a whole new field is being opened up, and the possible experiments are too numerous to mention in detail. Reactions of this type can be carried out with different target gases up to neon, where the Coulomb barrier becomes too high for the available energy. The cross sections of these reactions are of great value for any theory of light nuclei.

Figure 1
HEAVY PARTICLE CYCLOTRON

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Figure 2

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Figure 3

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