THE UNIVERSITY OF MICHIGAN

COLLEGE OF LITERATURE, SCIENCE, AND THE ARTS
Department of Physics

Progress Report

THE UNIVERSITY OF MICHIGAN 83-INCH CYCLOTRON

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INTRODUCTION

This fourth quarterly report on The University of Michigan 83-inch spiral-ridge cyclotron discusses the progress that has been made in the period April 1, 1961, to July 1, 1961, on the building to house the cyclotrons (Section I) and on the design and construction of the 83-inch cyclotron (Section II). Funds to begin the construction of both the building and the 83-inch cyclotron became available July 1, 1960; hence this report reflects the accomplishments on the project since its inception just one year ago.

I. THE BUILDING

Due mainly to the improved weather conditions of the past three months, progress on the building construction has been excellent. All major exterior construction on the three units, the office and laboratory building, and the two cyclotron buildings has been completed. The exterior brick work is essentially finished; only small areas around the entrances remain to be completed. The roof slab on the main building was poured, the prefabricated concrete slabs were installed on both cyclotron rooms in June, and all three are now weatherproof. The roof slabs of the two cyclotron rooms were designed for easy removal should it become necessary to move large pieces of equipment into or out of the building. The cooling tower, located approximately 60 feet south of the main office building, is essentially complete. The only exterior work of any consequence is the installation of door and window sash, and grading and landscaping.

The interior work is proceeding rapidly; the room partitions and the major part of the plumbing and heating will be completed in the next two weeks. Construction work in the cyclotron buildings is now reduced to installation of the plumbing, air conditioning, and the electrical conduit associated with the control system for the machines. Assuming that the present rate of progress continues, we look forward to occupying the building in late September.

Two exterior views, taken June 26, of the office and laboratory building and the cyclotron rooms are shown in Figs. 1 and 2. Figure 1, a view looking towards the southwest, shows the 83-inch-cyclotron building in the left foreground, the 50-inch-cyclotron building in the right foreground, and the roof line of the office building in the background. Figure 2 is a view looking towards the west along the south wall of the office and laboratory building. Part of the interior of the 83-inch-cyclotron building is shown in Fig. 3. The picture was taken from the experimental area looking north through the opening in the shield wall. The 83-inch-diameter pole roots and part of the magnet frame are visible in the background. The temporary enclosure constructed around the magnet for protection until the roof of the machine room was finished has now been removed. The coils for the magnet are in the large boxes in the right foreground.

II. THE CYCLOTRON

While there are no spectacular changes to report at this time, progress has been made in the design and construction of the various components for the 83-inch cyclotron.

The steel frame for the main magnet is now positioned in the 83-inch-cyclotron room as shown in Fig. 3, and the coils and 360-kw power supply are in the room ready to be mounted. This phase cannot be completed until the electrical and plumbing work in the room is finished.

1. MAGNETIC FIELD REGULATOR

The regulator for maintaining the magnetic field constant to one part in 10^4 was described briefly in the last quarterly report. The system has been constructed in a semi-final form and tested on a circuit having the same regulating characteristics as the 360-kw power supply. The measured regulation is better than 1 part in 10^4 and shows no tendency to oscillate. While it may be necessary to make changes in the circuit when used with the acutal 360-kw supply, these should be minor.

The main magnet current is measured with a 50-mv—2000-amp shunt located in the power supply. The potential drop across the shunt is compared with a reference voltage. A differential d-c amplifier amplifies the difference - the error signal - which is of the order of a few microvolts, to the millivolt level. This signal is further amplified by an amplifier of a variable d-c gain (from 1 to 1,000) and having a long time constant. As a result, the a-c gain is small. The amplified d-c signal is then combined with an a-c signal taken directly from the magnet coils through an RC network having a time constant of 1 second. The combined a-c and d-c signal is further amplified and fed into a 100-watt magnetic amplifier through a driver stage. The magnetic amplifier supplies the current to the control windings of the saturable core reactors in the 360-kw power supply.

The quiescent current through the main magnet coils is determined by the reference voltage and not by the bias voltage of the saturable core reactors in the power supply as originally intended. This is made possible by the high d-c open-loop gain which is in excess of 10,000. A lower a-c open-loop gain is possible due to the high inductance of the main magnet. Since the reference voltage is adjustable from 0 to 50 millivolts, the magnet current can be adjusted from 0 to 2000 amperes. The mercury battery used as the reference voltage has negligible drift.

A Minneapolis-Honeywell d-c differential amplifier, guaranteed to drift less than ±2 microvolts per day, is used as the first amplifier in the system in order to obtain the smallest possible error caused by drift.

Several filters are used in the regulator to adjust the gain-frequency characteristic, compensate for the time constants of the magnetic amplifier and the saturable core reactors, and to attenuate undesired frequencies.

2. MAGNETIC FIELD MEASURING EQUIPMENT

The mechanical equipment to be used in the precision measurement of the magnetic field has been completed and is shown in Fig. 4. It consists of a 48-inch-diameter aluminum plate or table, with a central axle. A rotating drum supported on the axle by two bearings provides the structural support for a cantilevered beam 47-1/2 inches long, made of square aluminum tubing having a 1-inch inside dimension. Additional support to prevent deflection of the beam is provided at the periphery of the aluminum table by a wheel mounted in the indexing mechanism fastened to the beam. The center and outside edge of the table are surface-ground to provide true and flat surfaces. The table has 60 holes jig-bored into the outside edge, the spacing of the holes being 6° with a tolerance of ±10 seconds of arc. A vacuum-operated indexing pin fits into these holes and can be actuated to step the beam for one hole to the next. Torque is applied to the rotating drum by a pretensioned elastic chord.

The magnetic field sensing device is a Siemens FC-33 Hall generator housed in a constant temperature bath, which in turn is located in the square beam described above. Holes jig-bored into the beam at 2-inch intervals along its entire length allow positive radial positioning of the Hall generator. A control and sequencing circuit permits automatic data accumulation through one revolution in azimuth. The beam has then to be reset and the radial position of the Hall generator changed. It is estimated that one complete field mapping can be made in approximately four hours.

Circuits to regulate and monitor the probe current and the probe temperature are under construction. The IBM card punch was delivered in early June and the circuitry for the automatic read out of magnetic fields is being debugged.

3. MODEL MAGNET STUDIES

Magnetic field measurements for several proposed spiral shim configurations have been made for us by Professor Blosser at Michigan State University using a 1/8 scale model of our 83-inch magnet. The measurements indicate that improved radial stability may be achieved by using shims with radial sectors in the central region to extend beyond the 3/3 resonance traversal point and thereafter using a spiral angle which is just sufficient to keep the vertical tune at approximately 0.15. New shims of this form are therefore being prepared. The flutter will be the same as for previous model tests, approximately 23%.

Measurements with the earlier shim designs also indicated that due to severe fall-off of the field it would be difficult to maintain the isochronous field to the extraction radius. To correct this difficulty, the flare of the spiral shim is being increased, the outer edges will be beveled, and Rose shims will be added at the outer edge of the poles.

Due to the uncertainty in the final shape of the field, little effort has been put on the gradient coil design since the last report. Further work will be postponed until measurements on the actual magnetic field are available.

4. THE R.F. SYSTEM

The full-scale mock-up of the half-wave two-dee system was pictured in the last report. Measurements on the mock-up indicated that as first designed the maximum frequency that could be obtained was 12.3 mc/sec rather than the required 15 mc/sec. As a result, extensive changes have been made in the details of the system, but the principal features, namely, the half-wave line, "silo" resonators, and alumina insulators at the tank wall, have been retained. In the process of making the changes, information has been obtained on the influence on the resonant frequency of the geometry and characteristic impedance of the several parts of the system. The present design, which is close to being final, has a resonant frequency of 15.1 mc/sec with the shorting diaphragms insulated from the walls of the "silos" and 15.6 mc/sec with the diaphragms shorted to the "silos." Further, the R.F. power loss in the skin was dropped from 125 kw to less than 50 kw, and the insulator design was simplified. A few additional modifications will be tried before making the final mechanical design.

5. THE VACUUM SYSTEM

The preliminary design of the vacuum system is complete and the component parts are out for pricing. The main vacuum chamber is of simple design and will be relatively inexpensive to fabricate. A preliminary version will be constructed within the next three months in order to test the R.F. system at high power and study in some detail the ion source and extractor.

6. ION SOURCE

The detailed design of the ion source is complete, and fabrication of the parts will be started during July.

7. FOCUSING MAGNETS

The characteristics of the external beam preparation system were described in the last quarterly report. Since that time the engineering design of the two magnets has been completed and bids have been obtained for the fabrication of the magnet frames and for the coils. Delivery time on these items is five months from award of contract.

8. ANALYZER MAGNETS

The reaction-products analysis system which contains three (3) wedge-type magnets each of 180° with $n = 1/2$ and a radius of curvature of 133 cm is still in the design stage. A rather complete study is being made of the magnets since they are the key elements in the high-resolution system. Computer studies of the ion-optical properties have been completed through first-order theory to determine the gross features of each, and second-order corrections are now being studied. The over-all system will have a resolution $E/\Delta E = 8 \times 10^3$. The first magnet will cover a range of 10% in momentum, the second 4%, and the third 1%. Thus the radial aperature $\frac{\Delta\rho}{\rho}$ will be different for each. Experience with the analyzer magnet used with the 42-inch cyclotron indicates that with $\frac{\Delta\rho}{\rho} = 0.1$ the $n = 1/2$ field can be obtained by using flat pole tips and good ion-optical properties obtained by empirical shimming using the stretched wire technique. However, the radial width of the first analyzer magnet in the 83-inch system is approximately 0.32; thus first-order theory is inadequate. The field must be adjusted to eliminate radial aberrations for rays close to the optic axis, and at the same time maintain a satisfactory focus for particles of momentum $p_0 \pm 5\%$, which therefore deviate considerably from the optic axis.

Calculations are being made to determine the second-order corrections to the field shape to reduce radial aberrations for particles of a given momentum, and to determine how serious the aberrations are for particles differing in momentum by ±5%. The aim is to determine the optimum profile of the poles and of the entrance and exit faces so as to minimize the empirical shimming.

The engineering design of the analyzer magnets is essentially complete. The design of the vacuum ducts and the carriage for moving the analyzer is in progress.

Fig. 1. View of building looking to the southwest.

Fig. 2. View of south exterior of office and laboratory building.

Fig. 3. Interior of the 83-inch-cyclotron building.

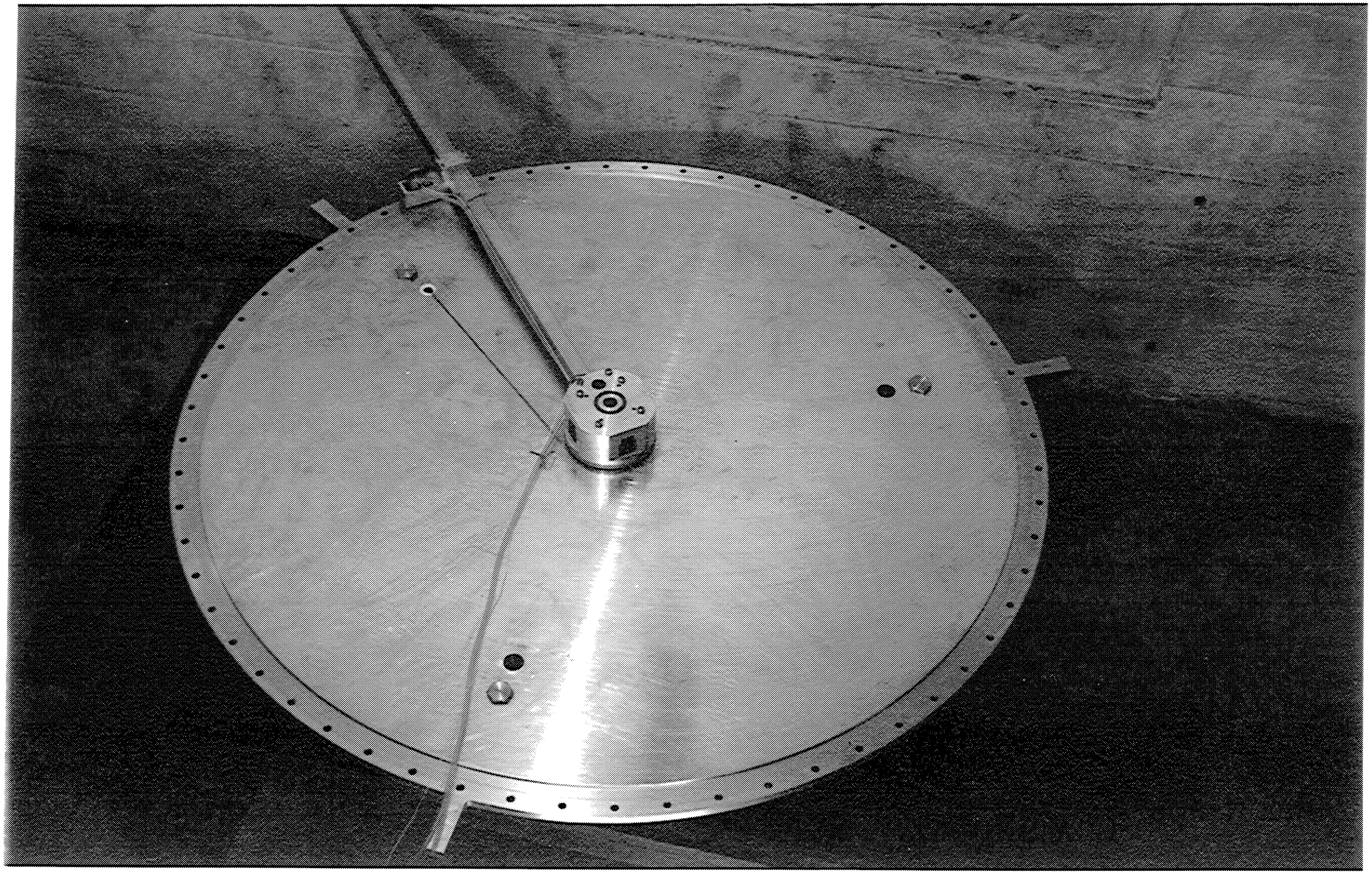

Fig. 4. Mechanical rig for precise magnetic field measurements.