The UCLA 50-Mev Spiral-Ridge Cyclotron

B. T. Wright

This talk will deal with the magnetic field measurements we have made. As Richardson said yesterday, we had a magnet which was to have been used for a 50-Mev synchrocyclotron, and just over a year ago we decided to convert to the spiral-ridge type. The first emphasis was placed on trying to get high energy. After considerable discussion and various ideas, including a few wild schemes like putting iron inside the dees and that sort of thing, were thrown out, it was apparent that to approach the same energy that we and previously expected, we would have to have dees in the valleys only, and make full use of small gaps over the hills.

Figure 116 is a picture of the pole tip with some shims. This is a 46.5 in. dia. pole tip with 4-fold symmetry. The central region is made up on one piece. The iron cross can be easily removed for last minute shaping of the field in the central region. The main shims are at the present time 1.5-in. plate, mounted at only three points. We have pure Thomas focusing out to about a 9-in. radius. The final working radius is 21.5 in., and the required mean field is 19.7 kilogauss. The hills are 33.3° wide.

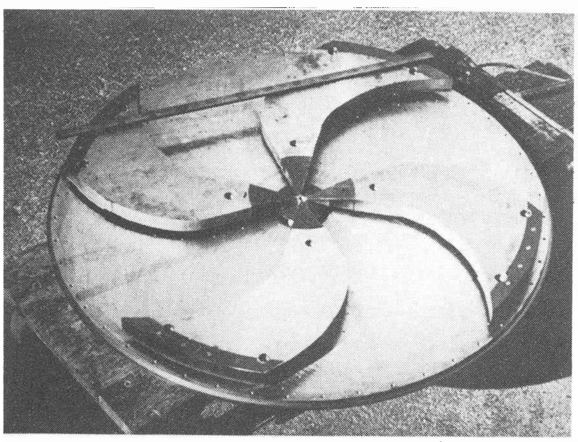

Fig. 116.

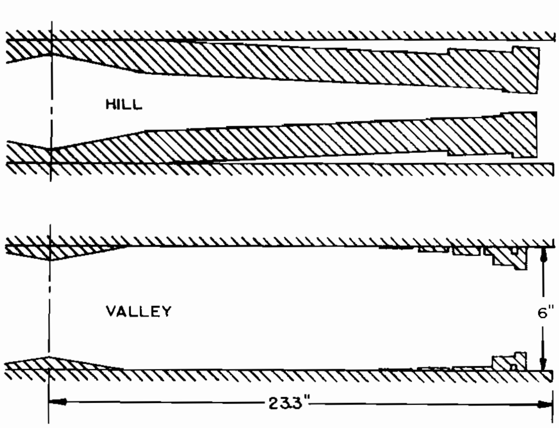

Fig. 117.

Figure 117 shows sections through the hills and valleys. This is a 6-in. gap. It is available for the shimming. The 1.5-in. plate being mounted at three points on some spacers could be conveniently tipped various degrees for getting the required 5% field rise. This type of mounting is rather convenient; if you want an increase in the field over a rather wide range of radius, additional iron can be put on the bottom of the shim. If you want to try to get an important local effect, you can put your shimming iron on the top. The main shims are removable, although they weigh about 80 lb. apiece, I think, and it takes a little struggling to get them in and out of the machine. This is about as large a model magnet, I think, as people would ever want to work with.

In the valleys the gap available for the r-f system is 4 inches. Our trimming coils will just be flat circular coils mounted directly against these pole tips. There are 8 of them, the first one at about 7-in. radius.

Some preliminary measurements were made with just some rectangular

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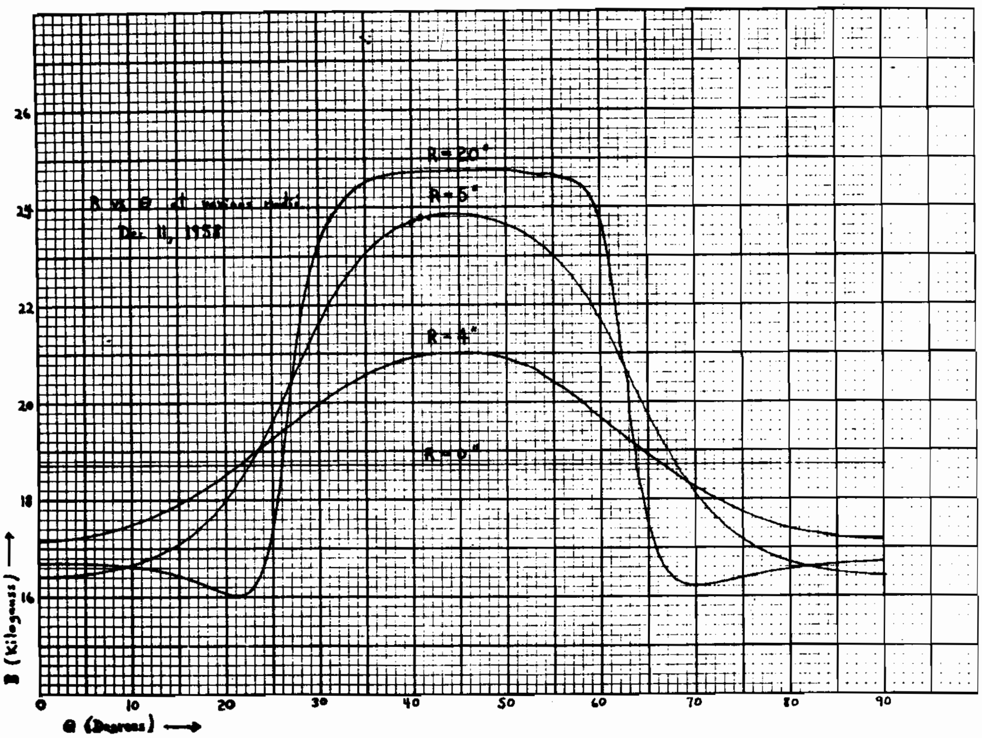

Fig. 118.

bars in a magnet, and from these measurements it was indicated that we could get variations of field from 18 to 24 kilogauss, or 18 to 25 or 26 kilogauss, with reasonable amounts of steel. We have a 6-inch gap. We put 1.5 in. of steel on either side of the gap, and we could get variations in fields of that magnitude. Then Richardson drew up a design for the desired magnetic field configuration.

We next used 1.5-in. bar stock. We torch-cut bar stock and welded it together to make up shims of extremely rough shapes. Then we put in sets of four of those and made some additional preliminary measurements. Everything looked all right. The next step was to get some steel plate and torch-cut the plate over-size purposely. We put those in the gap and made additional measurements. Next the plate was surface ground and cut to a smaller size. We put those in and made additional measurements, and finally the plates were removed and machined in sets of four to the shape that was used for the results which I will present today.

Figure 118 shows the raw data that we get in making the measurements. The measurements are made through the use of Hall plates. There is a large circular disk about 46 in. in diameter which is mounted on three carriages, 120° apart on the outer radius and supported at the center just to prevent a large amount of sag. This disk can be easily removed from the machine. You can take off one carriage and remove it from the machine. The pole tip has one accurately machined diameter, 46.6 in. (-0, + .010"), which these carriages are fitted up against.

We determined the temperature coefficient of the Hall effect. It turned out to be about 0.0008/°C or roughly 0.1%/°C. In making the measurements the Hall plate temperature is determined by simply using a thermometer which is attached near the Hall plate on the same base. The current flowing to the Hall plate is then adjusted so that the Hall plate is giving the correct field in kilogauss. The output from the Hall plate then gives one coordinate and the field comes out directly in kilogauss. The other coordinate is obtained by having a wire wrapped around the periphery of this disk; as the disk is rotated you simply pick off a potential from the wire which is proportional to the angular position of the disk. Figure 118 gives a typical set of curves at r = 0, 4, 6, and 20 inches. The maximum field at the 20-in. radius is about 24.8 kilogauss and goes down to about 17 kilogauss in the valleys.

To determine the mean magnetic field, we simply take a planimeter and integrate the area. Now, once the system is in satisfactory operation we can take a complete set of data, say, from the center out to 21 in. at 1-inch intervals, in one day. Then, in an additional day one person with a planimeter can determine all these areas. We can get the mean field as a function of radius in, say, two days. I don't think it has ever been done in that short a time, but it could be, granting that everything is going all right and that the graduate students arrive before ten o'clock in the morning. (Laughter)

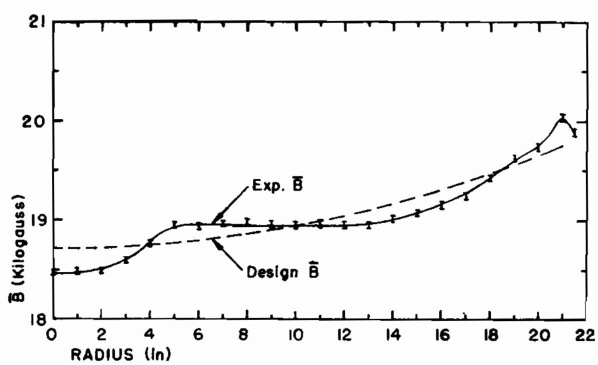

Fig. 119.

I would like then to show some results of the present shimming program. Figure 119 shows the mean field vs radius at the moment. This is the desired mean field vs radius. We wished to hold the field up to this contour out to about 21.5 inches. You can see that we are within 1% of the desired field at all radii except near the center. We haven't worked so much on the central region. This is the transition region from the iron cross to the other shim. Some additional steel will have to be removed, the central field will have to be brought up a little. Our aim in a general way is to shim the field to about 1/4%, and then to use the trimming coils to adjust the machine operationally. That is, turn on the beam, see how far out it comes, and twiddle a knob, bring it out further and twiddle another knob, if necessary, for a couple of days to get the beam out.

We are not facing the problem of variable energy. This machine will be operated initially at only one energy, so that from that point of view it should be rather a simple thing to adjust the 8 trimming coils to the proper currents.

Figure 120 shows the hill and valley fields; of course, the focusing depends on the hill and valley fields, the rapidity of change from hill to valley and the amount of spiral. The dashed lines show the required hill and valley fields to give zero focusing.

Figure 121 shows our measured flutter factor as defined by Richardson in the first paper. I have just put three blobs on here to show the flutter factor that was demanded. The flutter factor that was used in laying out the design of the field would have values along a line connecting the blobs; our measured flutter factors are somewhat larger than that. Here again is indicated stronger focusing than was demanded in the initial design.

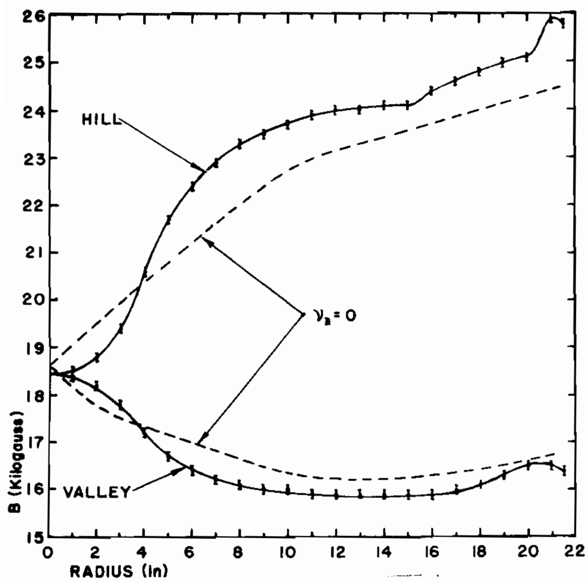

Fig. 120.

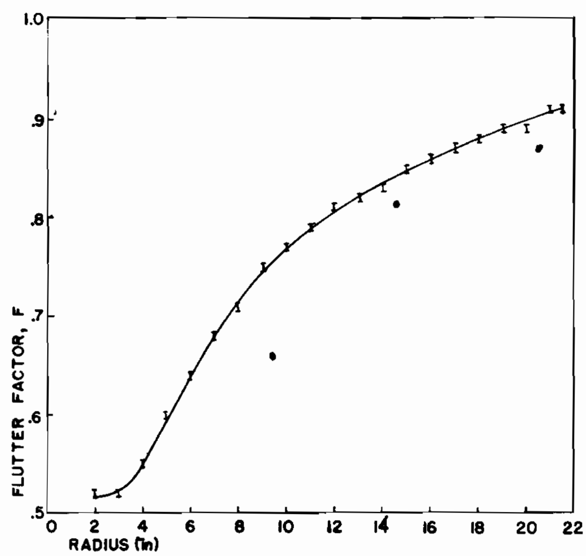

Fig. 121.

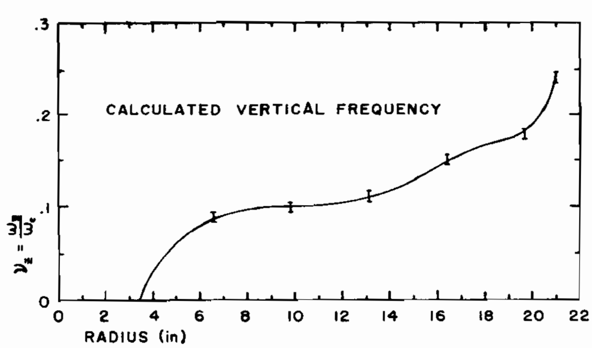

Fig. 122.

Figure 122 gives the calculated axial frequency. We don't have an indication of the stability inside of 3 inches. We undoubtedly will put some kind of a spike in the field at the center. We don't anticipate any difficulty there.

Figure 123 shows the effect of trimming coils. We made a measurement with a pair of trimming coils at 13 inches. The ampere turns in the trimming coils were 0.6% that in the main magnet. We get a bigger effect in the valleys, because the coils run under the hills. The field change at the center is 0.5%. For the above number of ampere turns in the trimming coil we obtain about 0.5% field differential in crossing the coil. We get at this particular trimming coil location a very good effect, about as much as we could hope for. David Clark was responsible for most of these field measurements.

The next thing we plan to do is to measure the harmonic content of the field. We plan to mount two Hall plates 90° apart at the same radius and adjust them so that their voltages are bucking. The system then acts as a filter for the fourth harmonic. We will rotate the pair of Hall plates and observe the angular distribution of the output voltage with position and then extract the first and second harmonic components of the field.

RICHARDSON: I want to say just a word again about the Hall plates. The Siemans people from whom we got the Hall plate say that the temperature coefficient is 0.02%. Our measurements were 0.07 or 0.08%, and we wrote to them about it. They said that as mounted in the plates they thought it was 0.04%.

WORSHAM: Has anyone considered the use of magnetoresistance

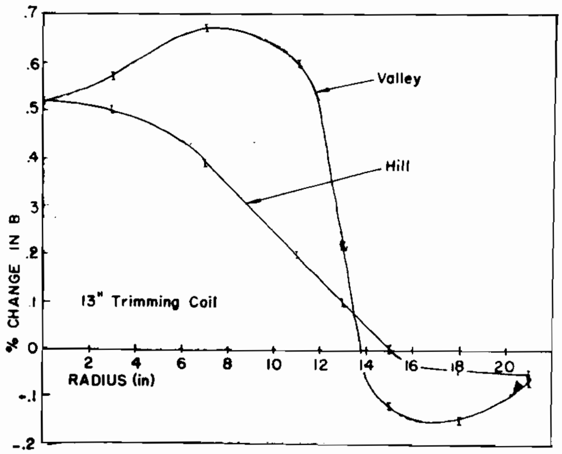

Fig. 123.

rather than the Hall effect? You can get tremendous variation in magnetoresistance under certain conditions.

DOLS: You know, of course, that the resistance effect of this bismuth spiral we are using has its limitation, but apparently all of these devices have some limitation if the temperature coefficients are high enough to be bothersome; magnetoresistance is much worse than the transverse Hall effect.