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SHAPE OF GRADIENT MAGNETS FOR 200-GEV ACCELERATOR

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May 4, 1967

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The factors leading to the choice of a "C"-shaped iron core for the gradient magnets of the 200-GeV ring are given in Chap. V of the "200-BeV Design Study".[1] In my opinion this choice should be reconsidered; an "H"-shaped core is technically superior and of lower cost.

A sketch of an H-magnet section with the same pole-face dimensions as used for the C-magnet is shown in Fig. 1. The laminations are die-stamped and held together with longitudinal bars welded to the laminations and stainless steel endplates. The coils will be wound in four layers which can be installed through the gap between pole faces. Coils will have the same total copper cross-section as for the C-magnet; the coil window is enlarged relative to the C-magnet for this purpose.

The significant factors affecting the choice are:

1. Accessibility. The original justification for the C-magnets of existing AG synchrotrons was to provide access to the vacuum chamber for modifications or installation of special devices. By now the simple stainless steel vacuum envelope of the AGS provides a chamber for which maintenance is negligible and modifications unlikely. Such vacuum chambers can be fitted into H-magnet sectors before installation in the 200-GeV ring, with permanently welded connections to bellows and

manifolds. With 12 long straight sections and 480 shorter spaces between magnets, it seems quite unlikely that the magnet sectors themselves will be needed for installing special devices.

2. Beam Extraction. In the past C-magnets have been used to advantage for extraction of beams from targets located upstream; the bending and focusing magnets needed can be placed closer to the orbit on the open side of the C-core. However, in the 200-GeV machine all presently planned emergent beams originate in straight sections. If a need arises for a special target in the ring, the few special magnet units required can be provided.

3. Field Uniformity. Thy symmetry of the flux-return circuit in the H-magnet yoke will extend the useful maximum field at the orbit to higher fields. Distortions due to remanent effects will be smaller, and magnet efficiency will be slightly higher. I estimate an increase in the usable maximum field from 15.0 to 15.5 kilogauss (this needs confirmation by analysis). If so, the magnetic radius at 200 GeV and the circumferential length of the magnet ring will be decreased by 3.3%.

4. Precision of Assembly. A criticism of the H-magnet in the Design Study was the engineering difficulty of achieving precise register between top and bottom subassemblies, assuming the magnet would be formed in two parts. However, if the H-yoke is die-stamped in one piece this precision is assured.

5. Radiation Shielding. Studies with the AGS C-magnet at Brookhaven show that the residual radioactive intensity behind the yoke is only 10% of that opposite the C opening. With the proposed H-magnet yoke shielding will be available on both sides of the magnet. This should reduce the average level of radiation in the tunnel. It is also possible to install compact shields of high-Z material around the vacuum chamber to reduce the induced activity still further.

6. Measurements and Inspection. Inspection following construction, and magnetic measurements, will be assembly-line processes using special tools, long coils, etc., through the end openings of the H-magnet. The need for measurements in the ring following installation is highly unlikely.

7. Cost Reductions. The gross weight of iron for the H-magnet is 10% less than for a C-magnet. Weight of copper in the coils will be unchanged. However, the lower total magnet weight will reduce costs for cranes, foundations and supports. The width of tunnel occupied by an H-magnet is about 1-ft less than for the staggered C-magnets. And if maximum field is increased to 15.5 kilogauss, the length of magnet tunnel can be reduced by 400 ft. Estimates based on incremental unit costs obtained from the Design Study give:

Magnet iron, 10% of $15,000,000	-$ 1,500,000.
Cranes, foundations, etc., 5% of $3,200,000	- 160,000.
Tunnel width, 1 ft at $440,000/ft	- 440,000.
Tunnel length, 400 ft at $1000/ft	- 400,000.
Estimated cost reductions	-$ 2,500,000.

Still other reductions may follow from this change in shape. For example, the symmetry of the H-magnet may allow redesign of a remote handling system using a Shielded Manipulator Vehicle on one side of the tunnel only; if so, tunnel width could be reduced by an additional 3 to 4 ft.

If further study confirms these conclusions and estimates, I recommend that the gradient magnet cores be changed to the H-shape.

FOOTNOTE AND REFERENCE

*Work done under auspices of the U.S. Atomic Energy Commission

[1] 200 BeV Accelerator Design Study, University of California, Lawrence Radiation Laboratory Report UCRL-16000, June 1965.

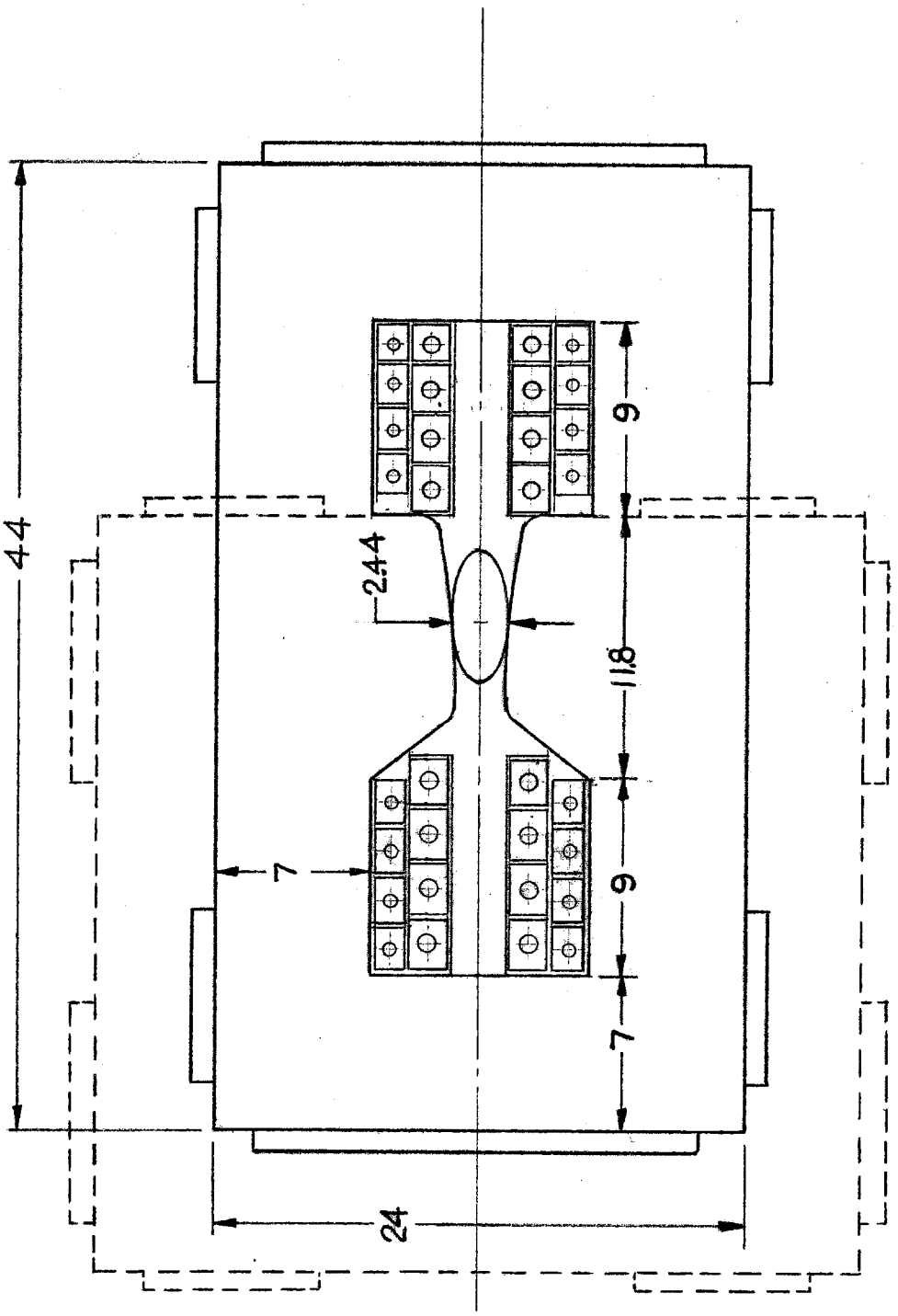

Fig. 1. Cross-section of H-magnet.