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Ernest O. Lawrence Radiation Laboratory

TARGETRY USED ON THE BEVATRON TO EXTRACT SECONDARY EXPERIMENTAL BEAMS

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Errata

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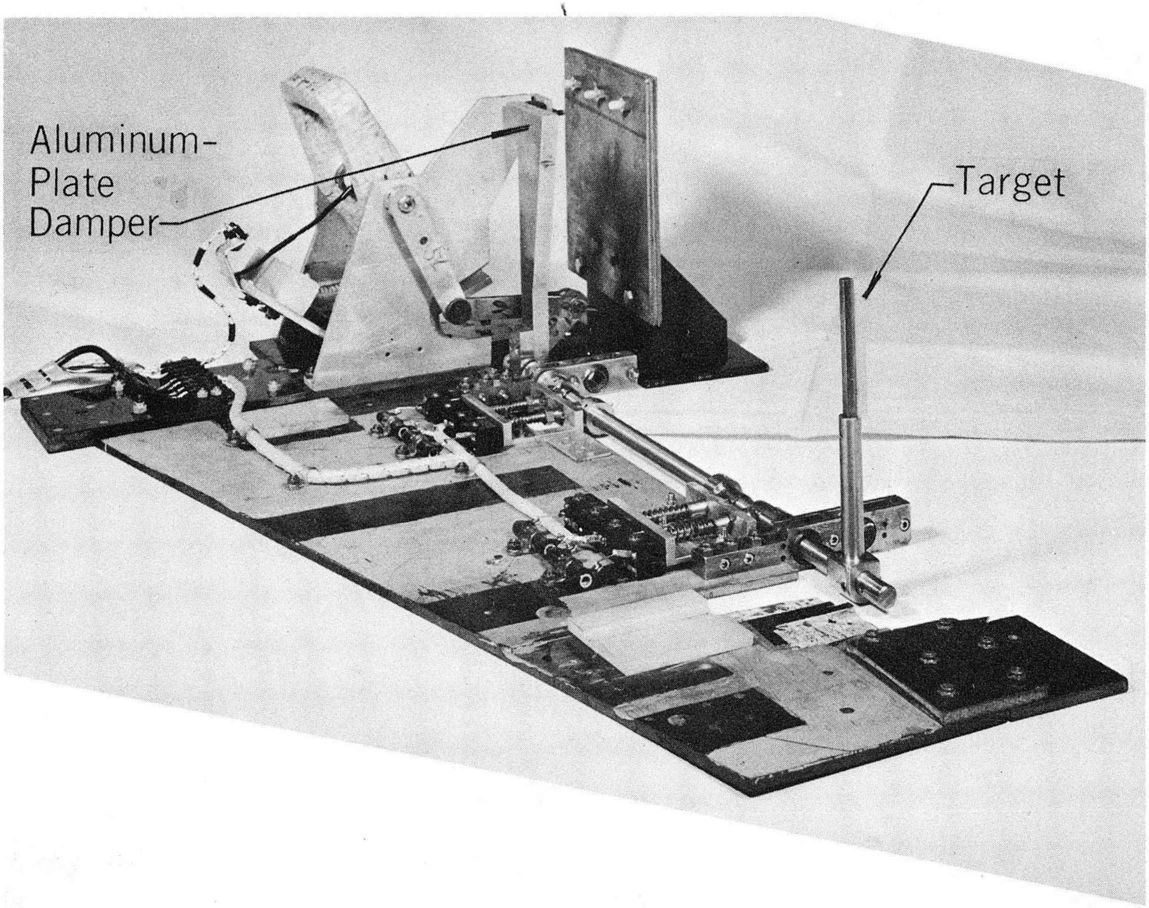
ERRATA

TO: All recipients of UCRL-17278

FROM: Technical Information Division

Subject: UCRL-17278 "Targetry Used on the Bevatron to Extract Secondary Experimental Beams," Kenneth F. Stone, November 10, 1966

Please replace pages 5, 6, 9 and 10 in subject report.



BEV 1400A

Fig. 1

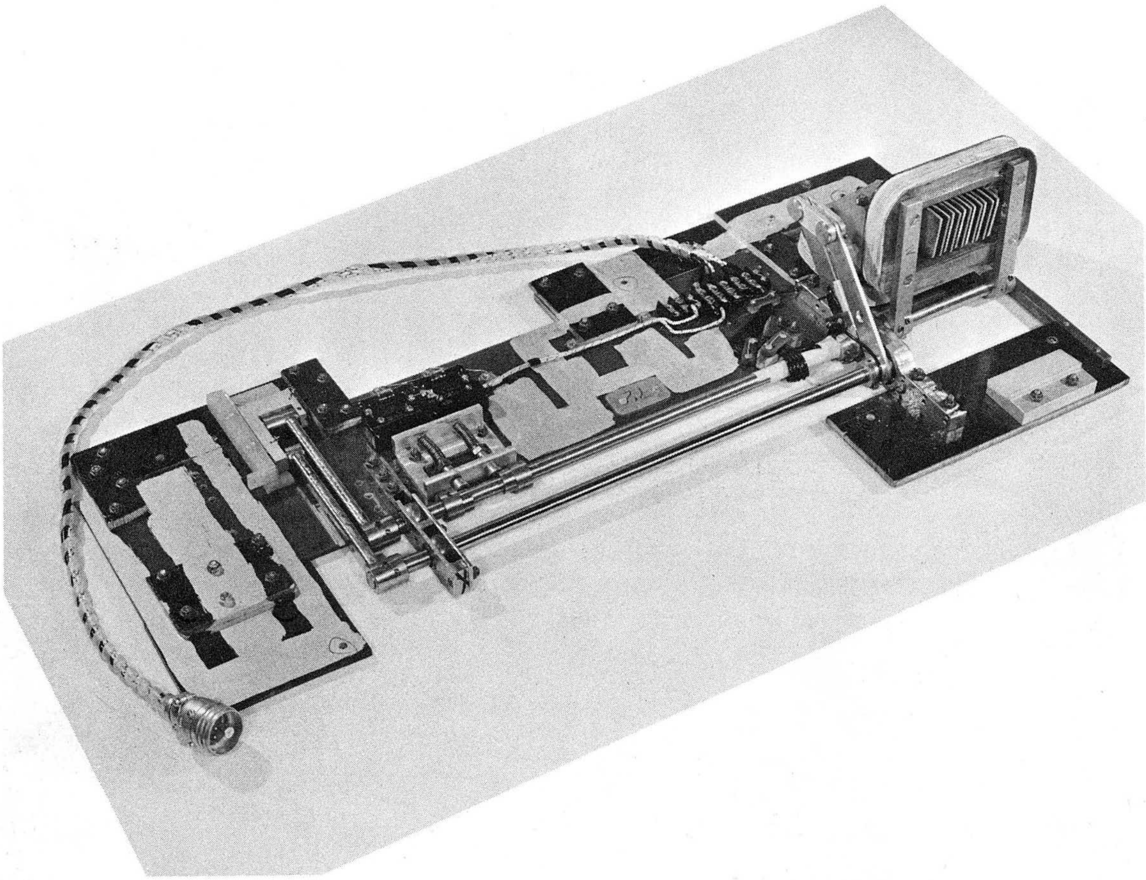


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Fig. 2

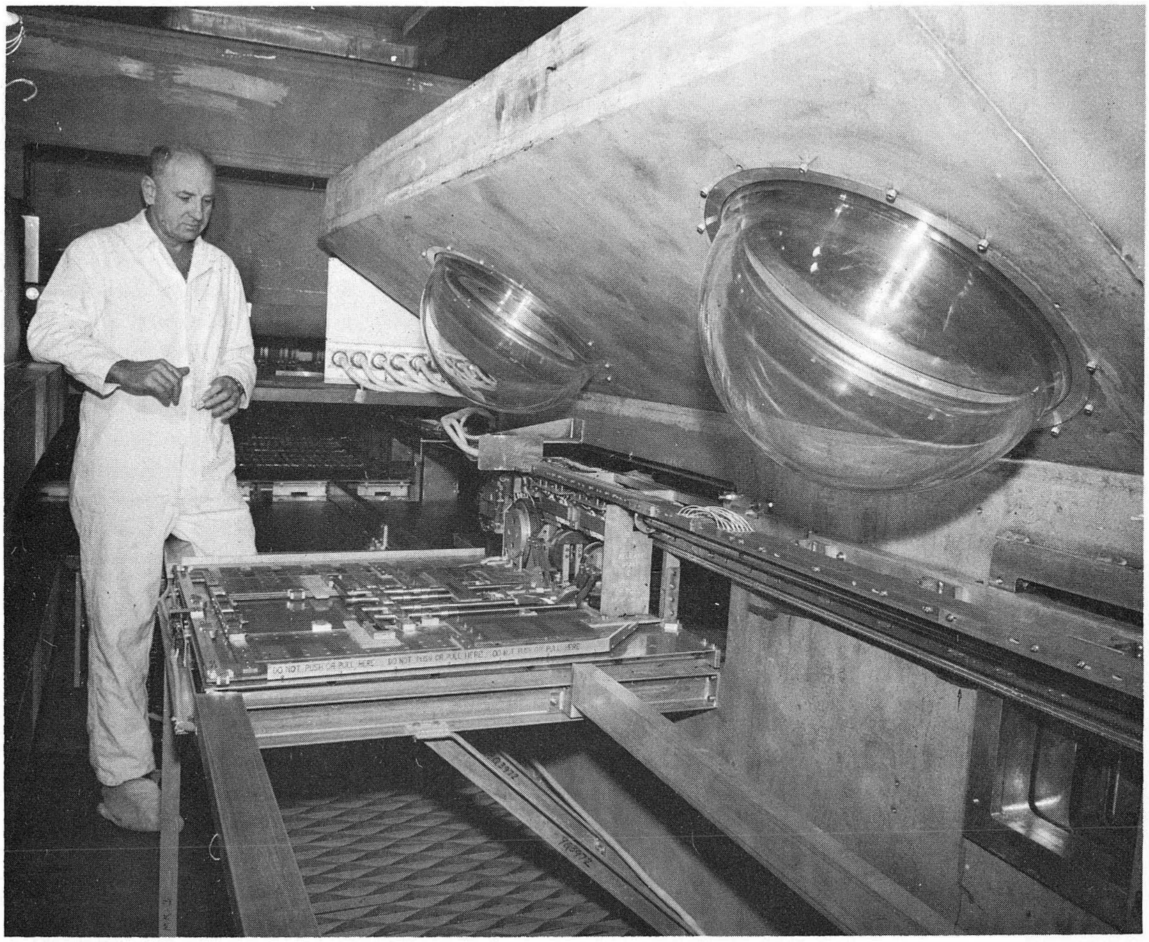

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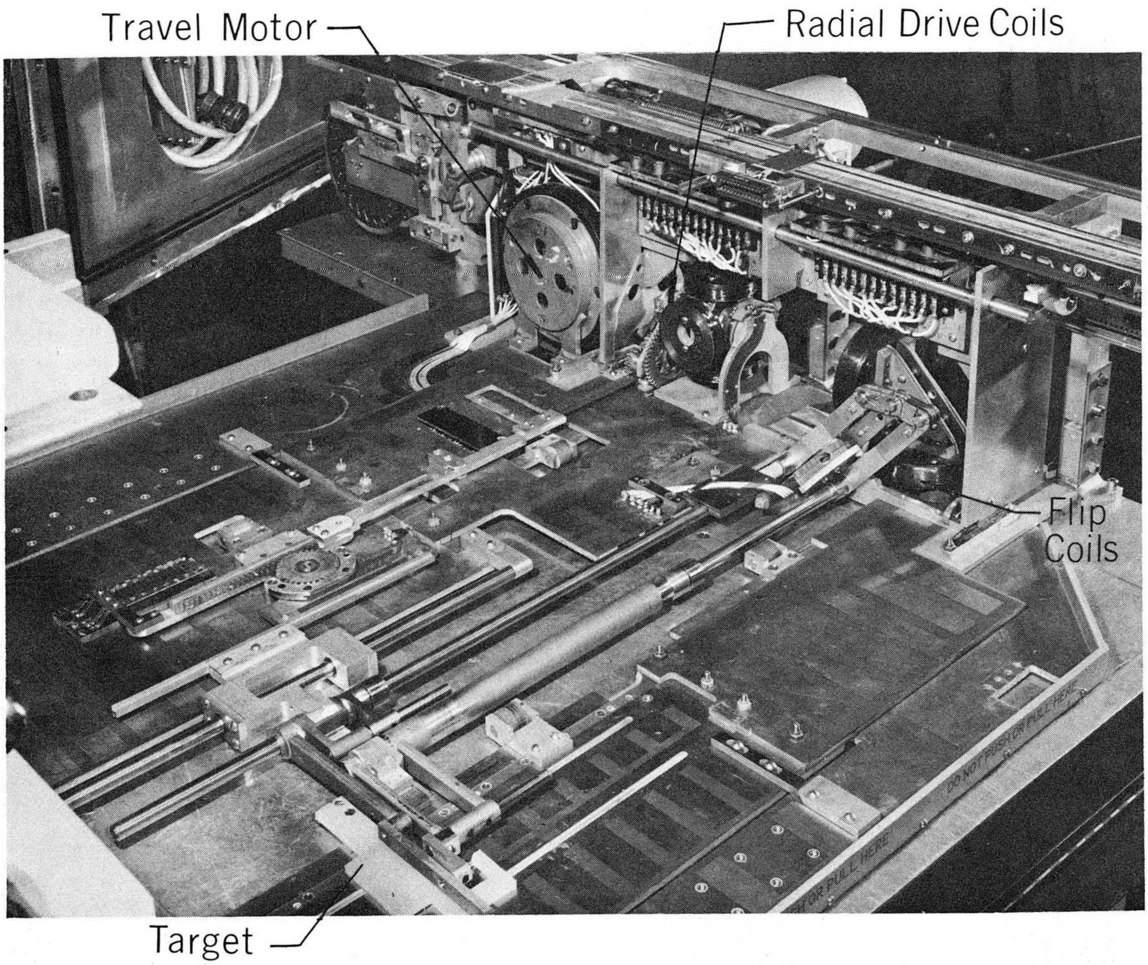
Fig. 5



BEV 4024A

Fig. 6

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Kenneth F. Stone

November 10, 1966

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Abstract

This paper briefly covers development of target drive mechanisms at the Bevatron, with the final evolution of the present high-speed mechanism. The early target drives, used in the main circulating beam channel, could raise a 1-lb target head 5-1/2 in. in 100 ms. The present high-speed target drive is designed to raise a 1/2-lb target head 1-1/2 in. in 10 ms. The higher-speed mechanism became desirable with increased beam control, allowing for flat topping and splitting individual Bevatron beam pulses between two or more experimenters. All designs are intended for performance in the high vacuum of the accelerating chamber.

Introduction

Targetry in the Bevatron, Lawrence Radiation Laboratory, has progressed through several phases. At first, the effort was to place a 2-lb target into the internal beam in 100 ms. Actual accomplishment was a 1-lb target in 100 ms. Ultimately a higher-speed mechanism was requested for the external beam channel. This resulted in a mechanism to raise a 1/3-lb target into the beam in 10 ms.

History

In the initial operation of the Bevatron the only target mechanisms available were air-operated plunging devices in the straight sections only, except for one unit at about the 70-deg position in Quad II. The latter unit, mounted on the inner-radius tank wall, was driven by an air cylinder located on top of the west straight section.

During the first two years of operation several types of mechanisms were considered, but the only dependable units used in the magnetic field of the beam channel were flip-coil drives. The early models consisted of a coil placed at approximately 45 deg to the field and rotated through 90 deg by an electric current through the coil, reacting with the magnetic field (Fig. 1). These early flip-coil drives were very satisfactory except for the high shock at the end of the stroke, and the very poor bearing materials available for vacuum operation.

The shock was reduced, while the target was being raised, by swinging an aluminum plate (see Fig. 1) from the horizontal to vertical position, thus letting the eddy current formed in the aluminum plate act as a damper. This worked in one direction only—the target banged as hard as ever on the down stroke. The final solution to the high shock was not found until 1957 when the double coil mechanism was built.[1,2] The first coil was used to drive the target up, while a second coil, located approximately 90 deg to the first, was shorted. The second coil then acted as a damper on the up drive. By reversing this, i. e., shorting out the first coil and driving with the second, there was effective damping on the down drive. With this design it was possible to give the experimenters target heads of fragile materials or configurations without fear of damage from shock. Figure 2 shows the early MK VII double-coil version, and Fig. 3 is the later MK VIII model.

The bearing problem was solved at about the same time with the introduction of porous bronze with the bearing surface impregnated with teflon, a product of the Glacier Metal Co. Ltd. of England. Where magnetic materials could be tolerated, ball bearings lubricated with Apiezon M or L were found to be very dependable.[3]

Early versions of the flip-target mechanisms were all for fixed installation, i. e., the experimenter calculated the required location, both azimuthally, (along the beam) and radially (across the beam). Then, by using a dummy pole top (Fig. 3), the target mechanism base was made up and drilled to properly locate the unit to the experimenter's requirements. Radial adjustment was made by using the proper length drive shaft from the drive coils to the target head. Vertically the target head was simply raised to the centerline of the magnet gap.

In order to install the targets, it was necessary to bring the entire Bevatron vacuum chamber up to air, carry the target mechanisms in on the pole tip to the specified position and then bolt them in place. Because the gap is only 12 in. high and 4 ft. wide, installing the targets was very tedious (see Fig. 4). In addition, it was costly, because it meant shutting down all operations for about 2 days. Naturally, as many targets as possible were installed each time the vacuum chamber pressure came up to air.

In all, 26 mechanisms of this type were built; all were used at one time or another. Operation proved to be very dependable, with only about five failures recorded out of perhaps 10 million target operations. None of these failures completely shut down the Bevatron, and only two seriously affected the progress of the experiment.

As the beam intensity increased, it became very evident that sending men into the gap to install targets would eventually have to end because of the high radiation they would absorb from the pole tips. A program was started in 1958 to build a mechanism that would remotely position a target at any point in the machine where an experimental beam might be required. The target position was to be repeatable within 1/4 in. along the beam channel. There were to be four separate operating positions, i.e., four targets could be in operation at one time. Furthermore, targets were to be changeable without letting the vacuum chamber up to air.

This required building a track through the vacuum chamber for 133 feet. Operating power and controls were taken in on 15 copper bus bars with palladium alloy brushes to pick off power and position signals. Each of four operating and four storage sections had to be separated electrically and independently controlled. This design was completed and installed by the fall of 1962 and has been in very successful operation ever since. It uses the same double coil system, described above, to raise the target head and an 8-pole, 400-cps eddy-current motor to position the mechanism along the beam line. (See Figs. 5 and 6.) A three-coil, double-acting solenoid is used to operate a lock mechanism to hold the target in position.

To avoid bringing the entire Bevatron vacuum system to atmospheric pressure when changing targets, a 14-in.-high by 54-in.-wide and 42-in.-deep air lock was built into the west-tangent-tank inner-radius wall. The target mechanism can be remotely driven onto a cart which then can be brought out into the air lock and then out to air for service, repair or change. Figure 5 shows the target mechanism located on the cart ready to be moved into the air lock.

In the four years the traveling target mechanism has been in service there has been an apparent saving of 1244 hours of vacuum down-time. Since only about half of this saving can be attributed to the traveling target, this means a saving, to date, of about $622,000. The original traveling mechanism cost on the order of $500,000 including installation.[4]

With the successful operation of the traveling target, the experimenters then asked for some means to remotely position the target across the beam, or in the radial direction. The requirement was to be able to position the target ±1/8 in. from any position approximately ±5 in. from the horizontal centerline of the magnet gap. To get the full 10-in. adjustment by remote control proved to be too costly, but it was possible to give the experimenter 2 in. of remotely controlled movement with the remaining 8-in. adjustment available by pulling the target mechanism out of the vacuum chamber and moving to a new operating range (see Fig. 6). Removing the unit from the vacuum chamber, changing the radial operating position and reinstalling it in the vacuum chamber requires about 1-1/4 hours. This includes time required to pump down the air lock and run the target back into its operating position. Four of the radial-motion target mechanisms have been built to date. The first one was put into service in February 1965. Since then these units have had 5.4 million strokes without failure.

Present Status of Bevatron Targetry

In order to split the beam pulses between more experimenters, there has been a continuous effort at Berkeley to devise improved methods of high-speed targetry. The first specifications called for raising a 2-lb target head 5-1/2 in. in 100 ms. Although later considerable effort was put into decreasing this rise time to 35 ms, the best operation achieved was raising a 1-lb target 5-1/2 in. in 75 ms. Now, by taking a slightly different approach to the problem, we have found a satisfactory solution.

Figure 7 shows the 10-ms target mechanism built for use in the Bevatron external-proton-beam channel. For this model, designed to operate where there is no magnetic field, there are two field coils (a) on either side of the gap (b). The field coils create a magnetic field approximately radially across the semicircular gap. When an electric current is passed through the armature coil (c) a reaction drives the coil through 180 deg. Reversing the current direction causes the armature coil to return to its starting point.

The two factors that most affect the speed of operation on this type of equipment are the circumference through which the driving leg of the armature coil must travel, and the inertia of the coil and other moving parts. By using a small coil and driving it with high electric current, torque is maintained with minimum coil inertia. The inertia of the remaining parts is minimized by using magnesium wherever possible. One can consider the drive unit as a series-wound motor cut in half with iron removed from the armature and used as the lower pole tip.

In operation, first the field coils are energized and then current is passed through the armature coil. This results in a faster and better controlled start because the magnetic flux builds up relatively slowly in the iron. Energy builds up fast in the armature, because there is no iron and the coil is wound with only a few turns of heavy wire.

Damping has been a somewhat larger problem than on the double-coil target drives designed for use in the full Bevatron field. There, with a 16-kG field, more than enough damping was derived by shorting out the second coil. With this smaller mechanism the highest measurable field was about 2 kG, which was not enough to generate any noticeable damping action. After many attempts at damping, first with a shorted coil and then by feeding a reverse current into a damping coil, it was found that by holding the armature coil and drive arm to a minimum mass, the natural harmonic damping of the four-bar drive mechanism is sufficient. This allows the coil to hit its stop hard, but a coil wound with continuous epoxy potting shows little effect from the shock. The target head, on the other hand, is relatively shock free.

Conversion to External Magnet

Earlier in the paper we mentioned the efforts to find a high-speed target drive for internal targets, i.e., targets located in the magnetic field of the main Bevatron beam channel. With the development of the high-speed unit described above, it seemed possible to adapt it to internal operation. Figure 8 shows the computer-derived lines of magnetic flux that may be expected from placing shaped iron cores in an otherwise even vertical magnetic field. In particular, this program was written around the Bevatron field at 16 kG and 1 in. from the inner-radius stanchion. The effort is to bend the field across the radial gap enough so an armature coil will react in a similar manner to that described above for the external beam channel.

Because the small coil delivers relatively low torque and therefore can be expected to raise a target head no more than the 1-1/2 in. used in the external beam channel, some other means must be used to raise it the additional 4 in. required. It is proposed to overcome this limitation by using a second coil, to be energized after initial beam acceleration, to raise the smaller fast mechanism 4 in. into its final operating position. This would allow 1-1/2 in. clearance for the fully accelerated beam until the little high-speed unit brings the target head up into the proton beam.

This same device could be used where a high-speed drive is required for a target located inside a steering magnet. However, the magnet gap would have to be somewhat wider than otherwise required, because of the disturbing action of the iron target core located at the edge of the pole tips.

References

*This work was sponsored by the U. S. Atomic Energy Commission.
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2. W. D. Hartsough, "Bevatron Operation and Development XIV, May-June 1957," Radiation Laboratory report UCRL-8022, Oct. 24, 1957.
3. K. F. Stone, Lawrence Radiation Laboratory Eng. Note M3732, April 21, 1966 (unpublished).
4. K. F. Stone, Lawrence Radiation Laboratory (Berkeley) Eng. Note M3836, Oct. 28, 1966 (unpublished).

FIGURE LEGENDS

Fig. 1. Mark VI single-coil, fixed-target drive mechanism with aluminum-plate damper (circa 1956).

Fig. 2. Mark VII double-coil, fixed-target drive mechanism (circa 1957).

Fig. 3. Mark VIII double-coil, fixed-target drive mechanism positioned on dummy pole tip (circa 1959).

Fig. 4. View into the 1-by-4-ft space between the poles of the Bevatron magnet. Because of this limited space, installation and repair of target mechanisms such as that in the foreground are difficult.

Fig. 5. Traveling target mechanism in the west tangent tank, ready to run in on the Bevatron's pole tip to its operating position.

Fig. 6. Radial-motion target mechanism mounted on traveling base ready to be installed in air lock.

Fig. 7. Schematic of high-speed target mechanism for the Bevatron's external-beam channel.

Fig. 8. Computer-derived lines of magnetic flux when a shaped iron core is placed in the otherwise-uniform, vertical 16 kG field of the Bevatron.

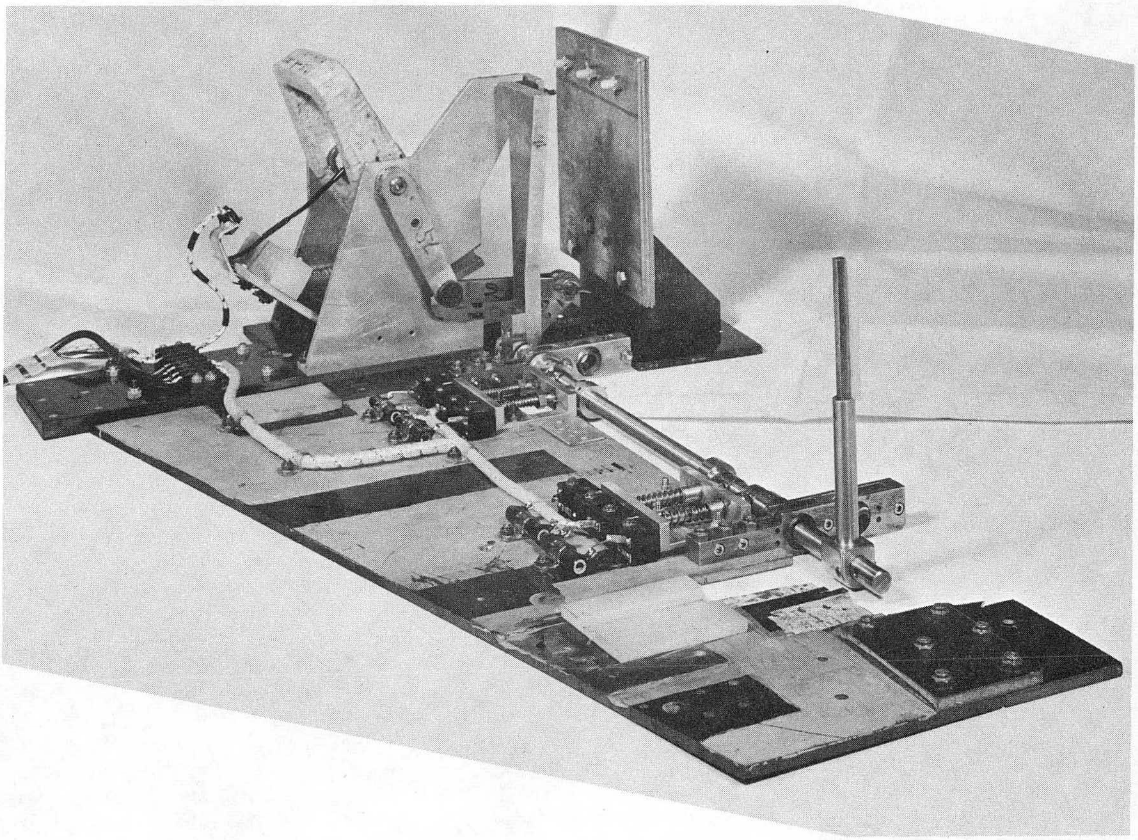

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Fig. 1

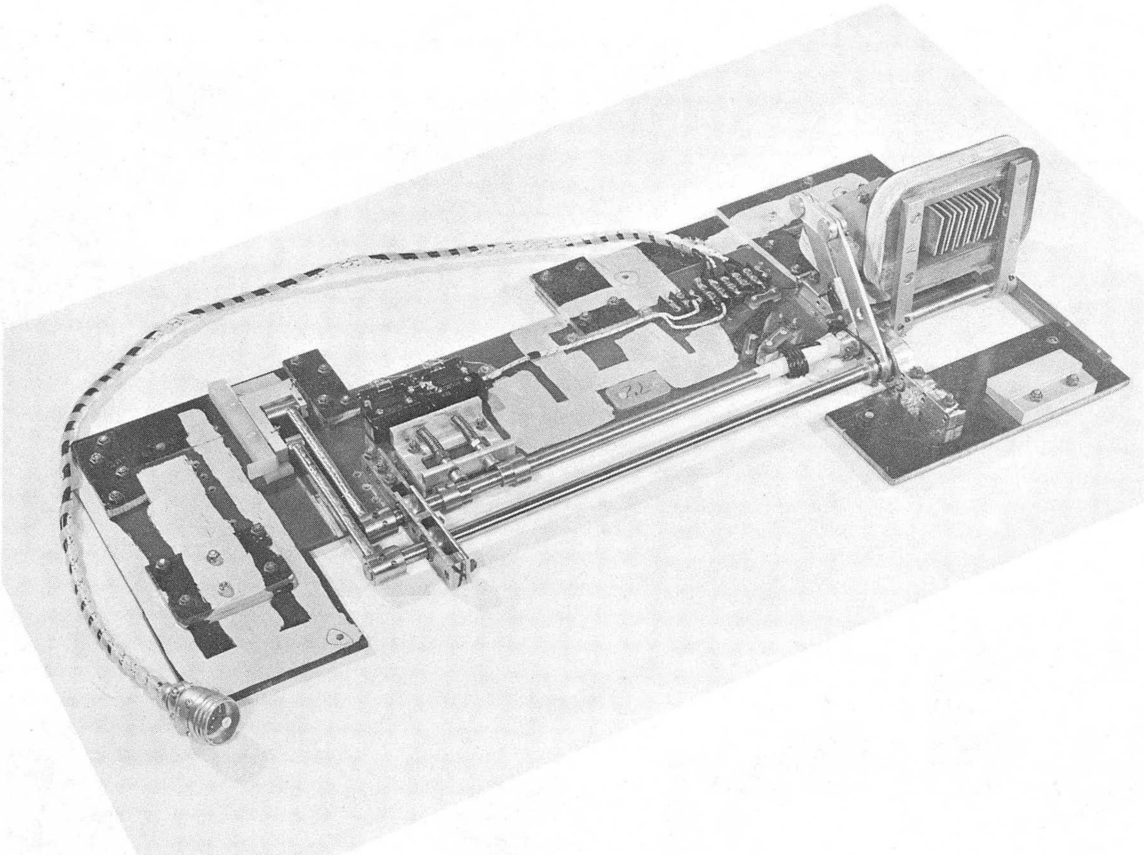

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Fig. 2

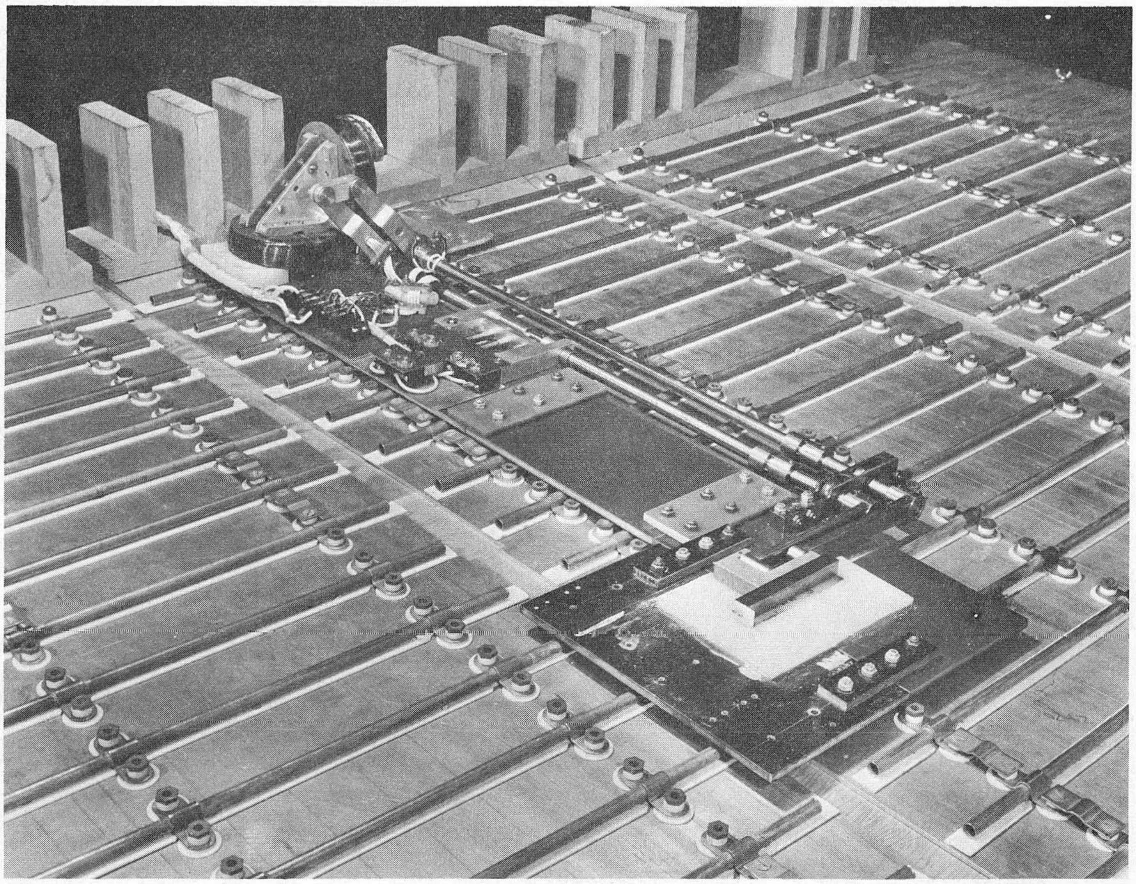

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Fig. 3

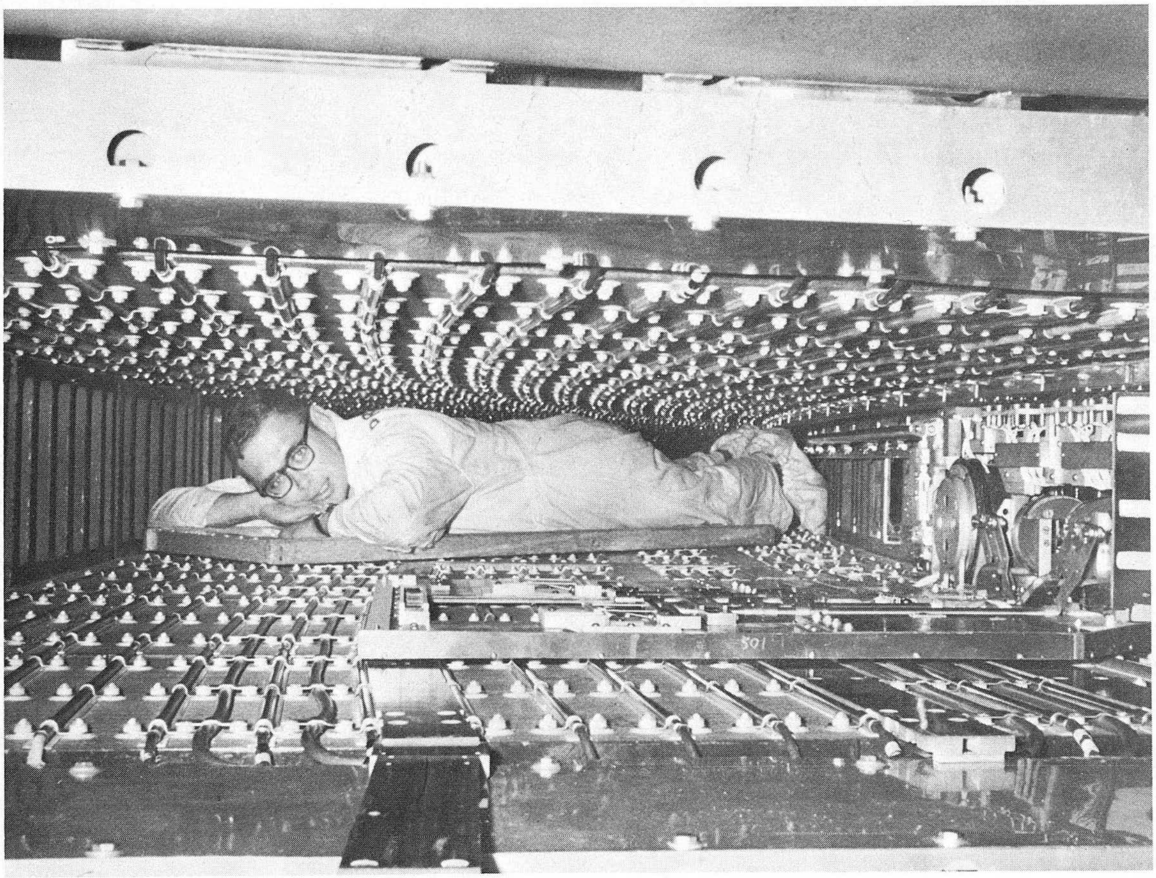

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Fig. 4

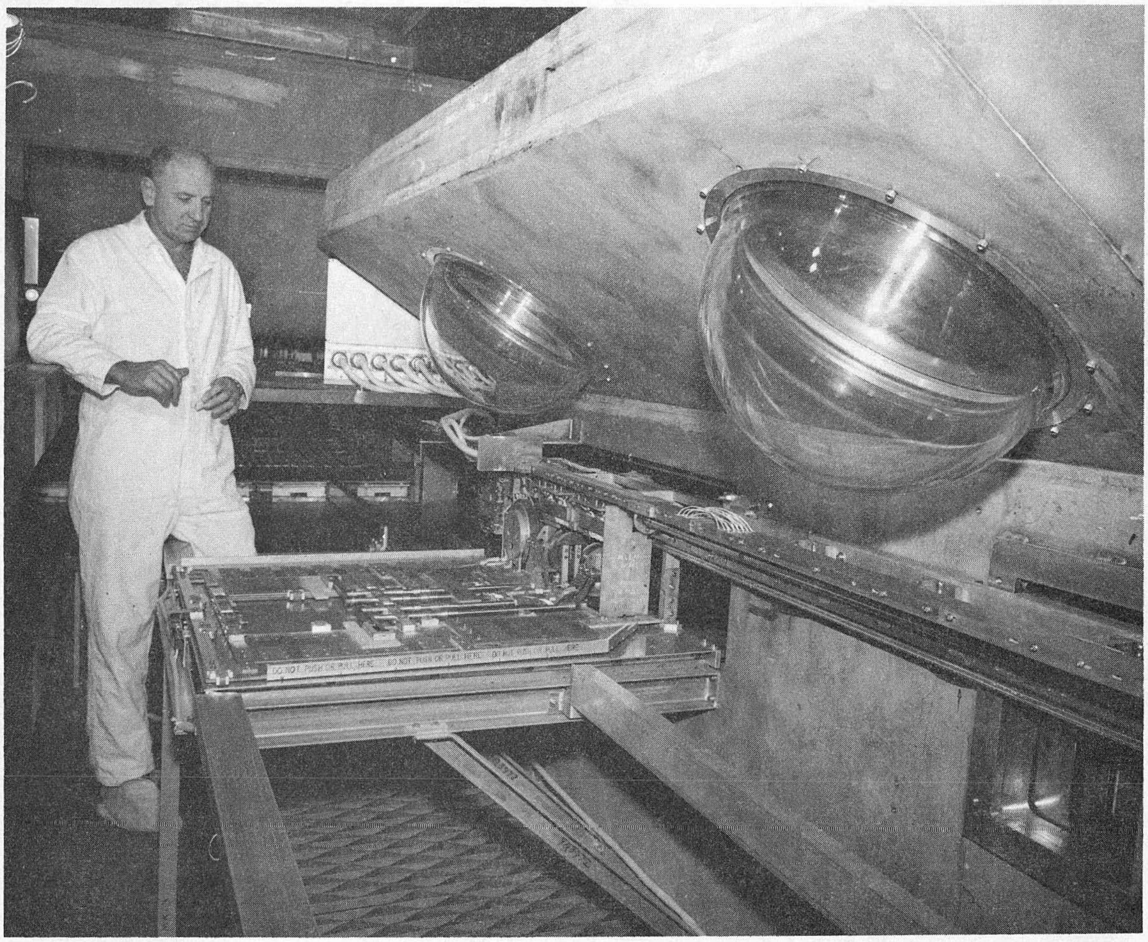

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Fig. 5

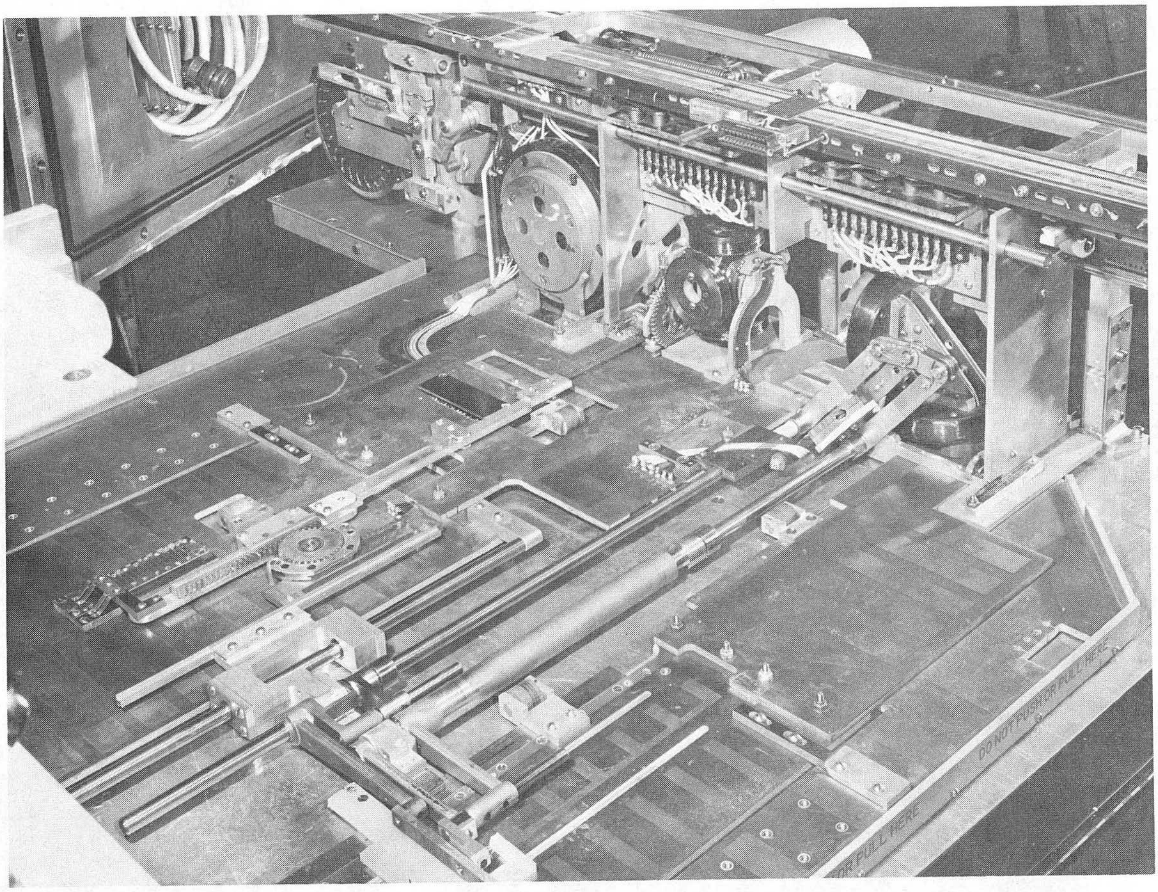

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Fig. 6

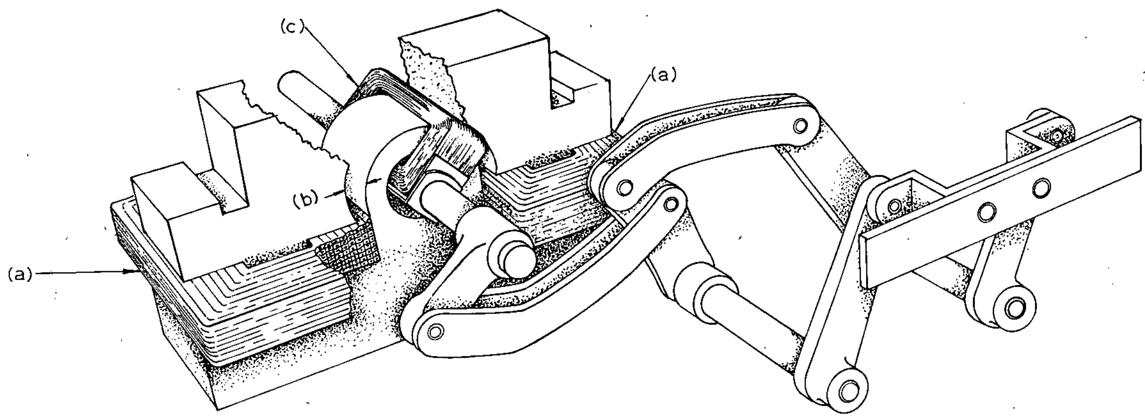

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Fig. 7

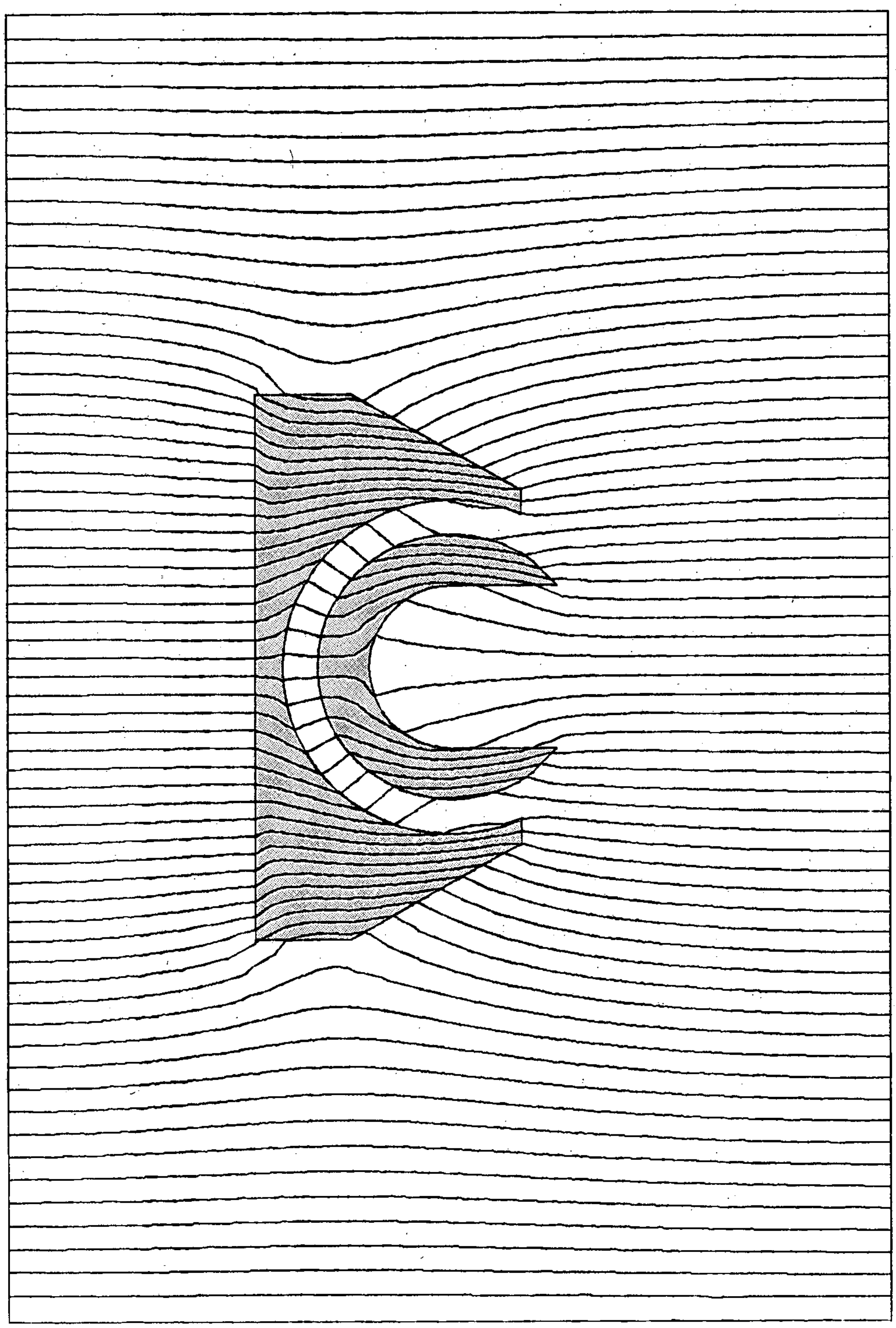

Fig. 8