TARGETRY USED ON THE BEVATRON TO
EXTRACT SECONDARY EXPERIMENTAL BEAMS*

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## Summary

This paper briefly covers development of tar-
get drive mechanisms at the Bevatron, with the
final evolution of the present high-speed mechan-
ism. The early target drives, used in the main
circulating beam channel, could raise a 1-lb tar-
get 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 accelerat-
ing 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 accomplish-
ment was a 1-lb target in 100 ms. Ultimately a
higher-speed mechanism was requested for the
external beam channel. This resulted in a mech-
anism 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-opera-
ted 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 sev-
eral 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 satisfac-
tory except for the high shock at the end of the
stroke, and the very poor bearing materials avail-
able 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 alumi-
num 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., short-
ing 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 experi-
menters target heads of fragile materials or con-
figurations without fear of damage from shock.
Figure 2 shows the early MK VII double-coil ver-
sion, 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 experi-
menter 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 ex-
perimenter's requirements. Radial adjustment
was made by using the proper length drive shaft
from the drive coils to the target head. Verti-
cally the target head was simply raised to the
centerline of the magnet gap.

In order to install the targets, it was neces-
sary 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 pres-
sure 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 pot-
ting shows little effect from the shock. The tar-
get 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 tar-
gets, 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 pro-
gram 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. re-
quired. It is proposed to overcome this limita-
tion by using a second coil, to be energized after

initial beam acceleration, to raise the smaller
fast mechanism 4 in. into its final operating posi-
tion. 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

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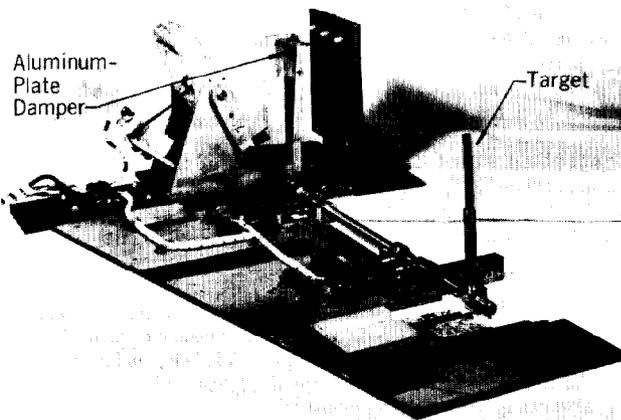


Fig. 1.  Mark VI single-coil, fixed-target drive
         mechanism with aluminum-plate damper
         (circa 1956).
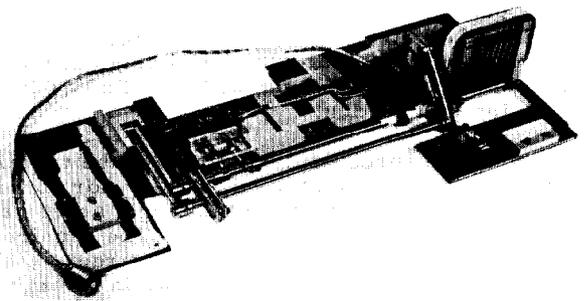


Fig. 2.  Mark VII double-coil, fixed-target drive
         mechanism (circa 1957).
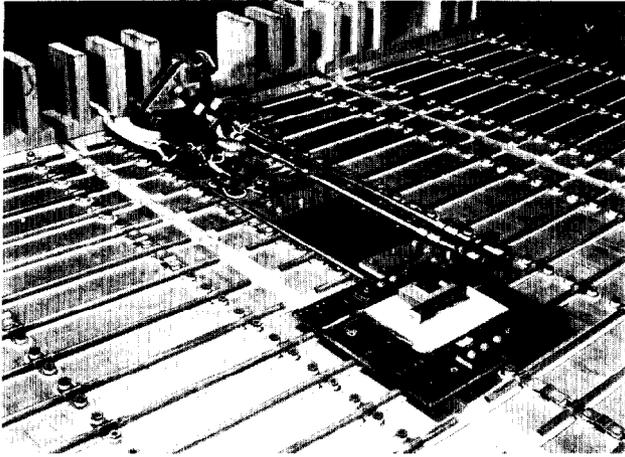
Fig. 3. Mark VIII double-coil, fixed-target drive mechanism positioned on dummy pole tip (circa 1959).
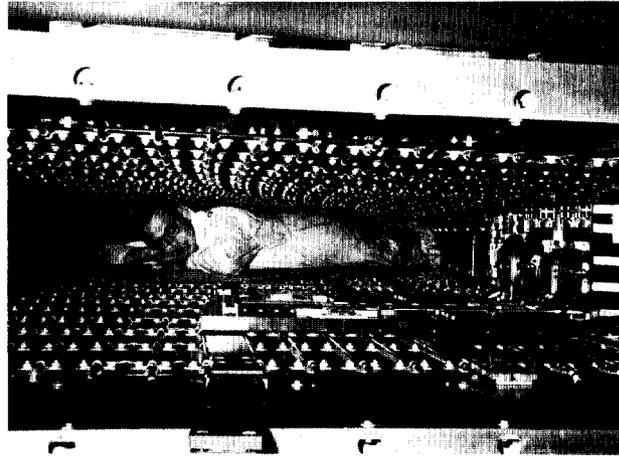


Fig. 4. View into the 1-by-4-ft space between the poles of the Bevatron magnet. Because of this limited space, installation and repair of target mechanisms such as that in the foreground are difficult.
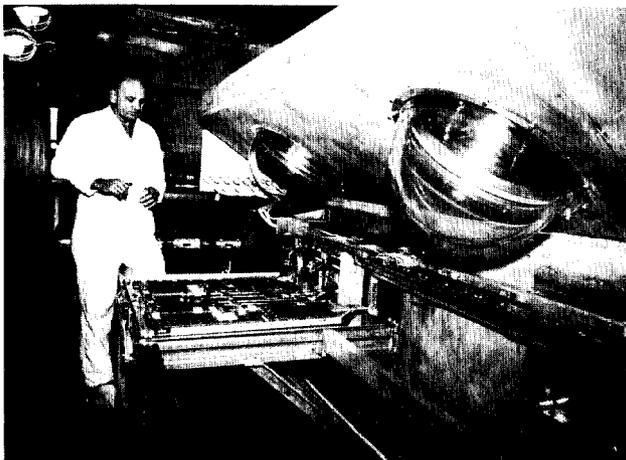


Fig. 5. Traveling target mechanism in the west tangent tank, ready to run in on the Bevatron's pole tip to its operating position.
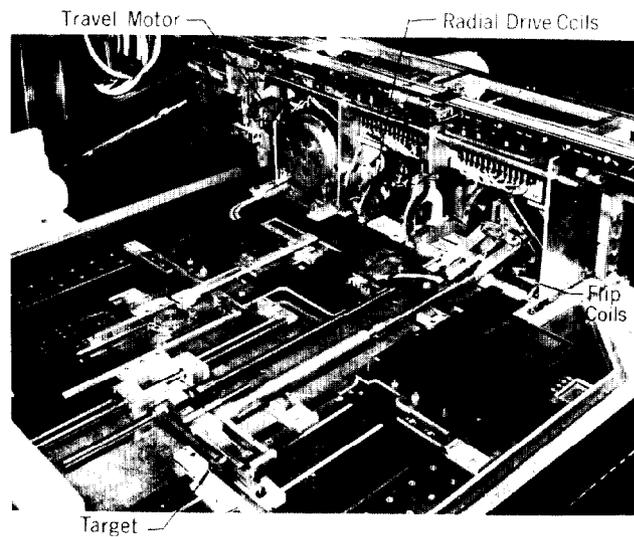


Fig. 6. Radial-motion target mechanism mounted on traveling base ready to be installed in air lock.
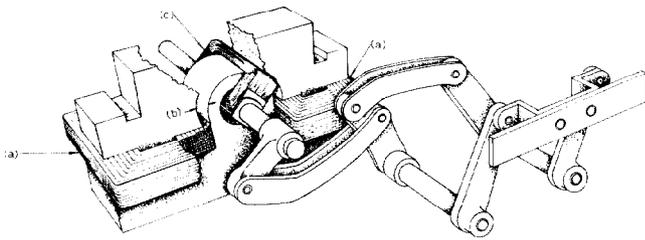
Fig. 7. Schematic of high-speed target mechanism for the Bevatron's external-beam channel.
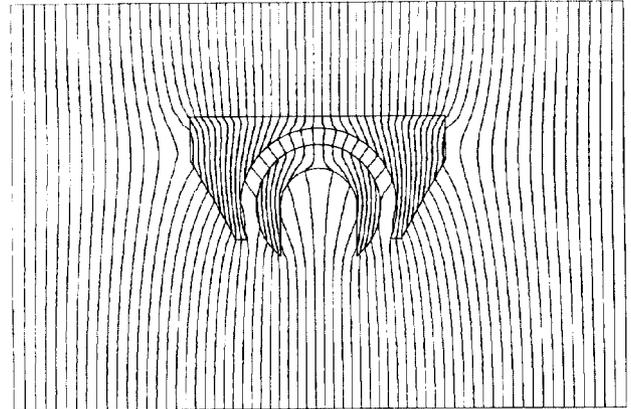


Fig. 8. Computer-derived lines of magnetic flux when a shaped iron core is placed in the otherwise-uniform, vertical, 16 kG field of the Bevatron.