Title
A Device for Determining the Magnetic Plane of Symmetry in a Time-Varying Electromagnetic Field

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A DEVICE FOR DETERMINING THE MAGNETIC PLANE OF SYMMETRY IN A TIME-VARYING ELECTROMAGNETIC FIELD

Bevatron Quarter Scale Operating Model

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Purpose of Test:

In the magnet of a particle accelerator such as the betatron, the synchrotron, and the bevatron it is desirable that the magnetic flux lines be curved outward in order that there be forces acting to keep the beam within a defined region. The ions in a stable beam oscillate about a surface normal to the flux lines, defined as the magnetic "plane of symmetry." In the ideal case this is actually a plane, and is horizontal. The flux lines are then vertical at the "plane of symmetry." Particles not in this region are forced toward it by the magnetic focusing forces. In construction of a magnet for an accelerator, tests are made to determine the plane of symmetry before attempts are made to obtain a beam. Deviations from design characteristics, which may be caused by lack of uniformity in the magnetic characteristics of the material used, may thus be detected. Near the plane of symmetry the flux lines approximate circular arcs. The determination of the region in which the flux lines are vertical makes possible the calculation of the magnetic plane of symmetry.

General Method:

This is essentially a null method. A rectangular coil is suspended vertically in the gap (axis of the coil is horizontal). The plane of the coil is tangent to the beam path. The magnet is pulsed with the coil at various vertical positions in the gap. A voltage is induced in the coil which is proportional to the rate of change of net horizontal flux through the coil. Since the flux lines are circular, there is no net horizontal flux when the center of the coil is at a point where the flux lines are vertical. There is then no induced voltage in the coil. If the coil is above this point there will be a voltage induced, and if the coil is below the point a voltage of opposite polarity will be induced.

Description of Apparatus:

The coil is wound with approximately 3,000 turns of #38 Formvar covered copper wire upon a 1.574" square core of linen-base bakelite. The axial thickness of the coil is 1/4", and its "radial" thickness is approximately 1/2". To the top of the coil are attached knife edges by which it hangs from its supporting frame. There is a Lucite weight on a balancing screw to adjust the coil to a vertical plane. The knife edges are formed from Lavite "A", which is baked after forming to give it hardness. After baking, they are ground to their final sharpness. The knife edges rest upon Lavite blocks mounted in the supporting frame. The supporting frame pivots on a pin, about a vertical axis through the center of the coil. The signal is taken from the coil through a twisted pair of #38 wire which is left very slack in order that it will exert no torque upon the coil. The bottom edge of the coil carries two vanes which move in oil baths for the purpose of damping out mechanical vibrations. The coil assembly is housed in a lucite box to protect it from the motion of the air, which might set up vibrations. This is particularly necessary since the magnet is air cooled and preliminary tests are made before the vacuum tank is in place. The box is painted with a colloidal silver preparation to provide a thin film of silver which serves as an electrostatic shield. Lines are scribed in the silver film to prevent the setting up of eddy currents when the field comes on. The signal is taken to the oscilloscope in a shielded twisted pair. A series resistor is included in the circuit in order that the induced current will not be great enough to give a perceptible torque.

Procedures of Test:

Aligning the coil:

When the coil is vertical, rotation of the coil through 180° about a vertical axis will reverse the polarity of the signal, but will not change its magnitude. The coil is placed in the gap and oriented approximately tangent to the proposed beam path. Its signal is noted, then the coil is rotated. If the signal is not of the same magnitude and opposite polarity, the weight is moved upon the balancing screw until the vertical condition is obtained. Since the only forces acting upon the coil are those of gravity and the reaction of the support, the coil will now hang vertically whatever its location.

Determining the median plane:

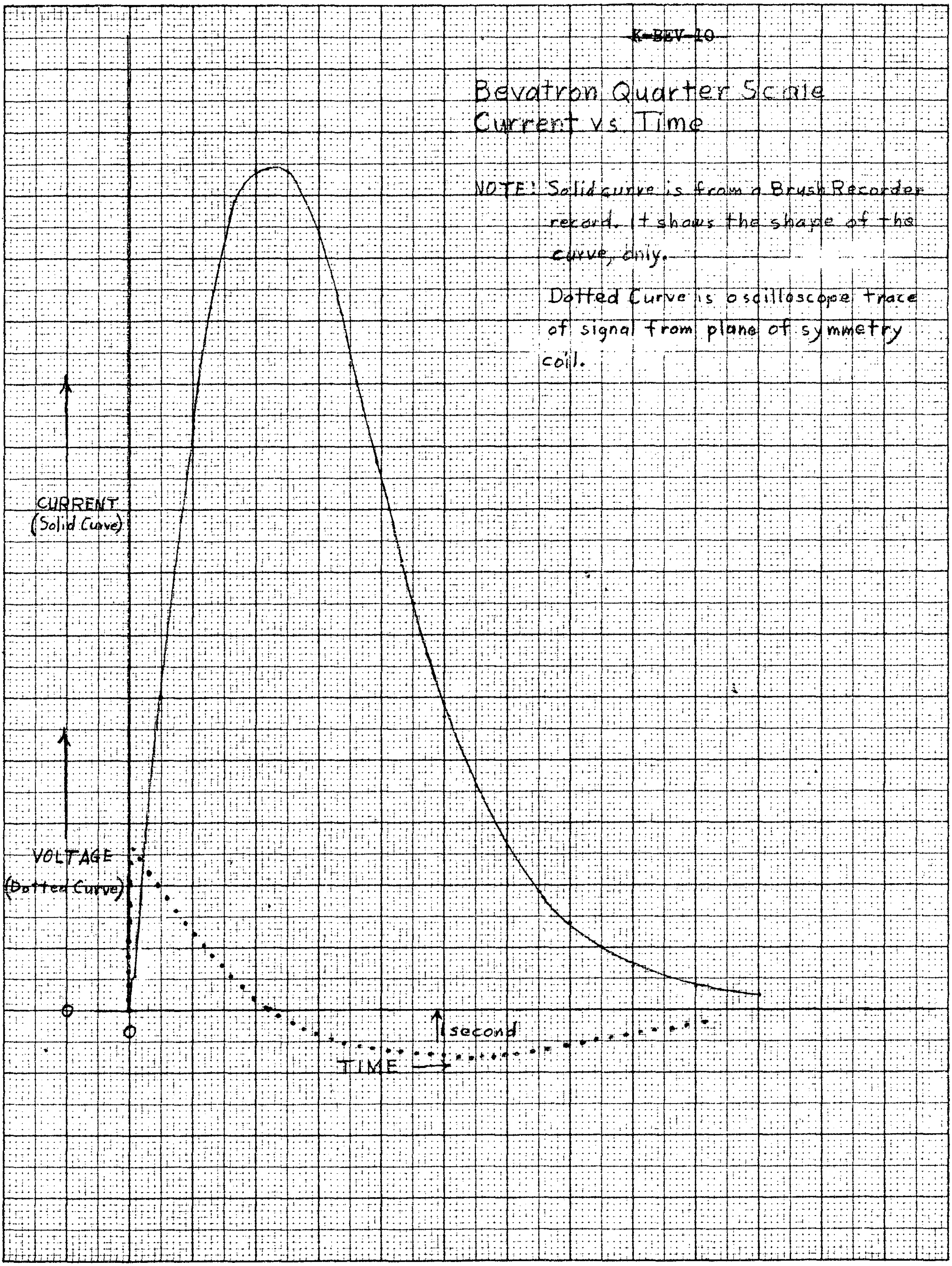
When the coil has been aligned, the support is moved to various vertical positions and the induced voltage viewed upon the oscilloscope. In this test the coil was moved in quarter inch vertical jumps. Thus the region of vertical flux lines could be localized only as lying between two such positions.

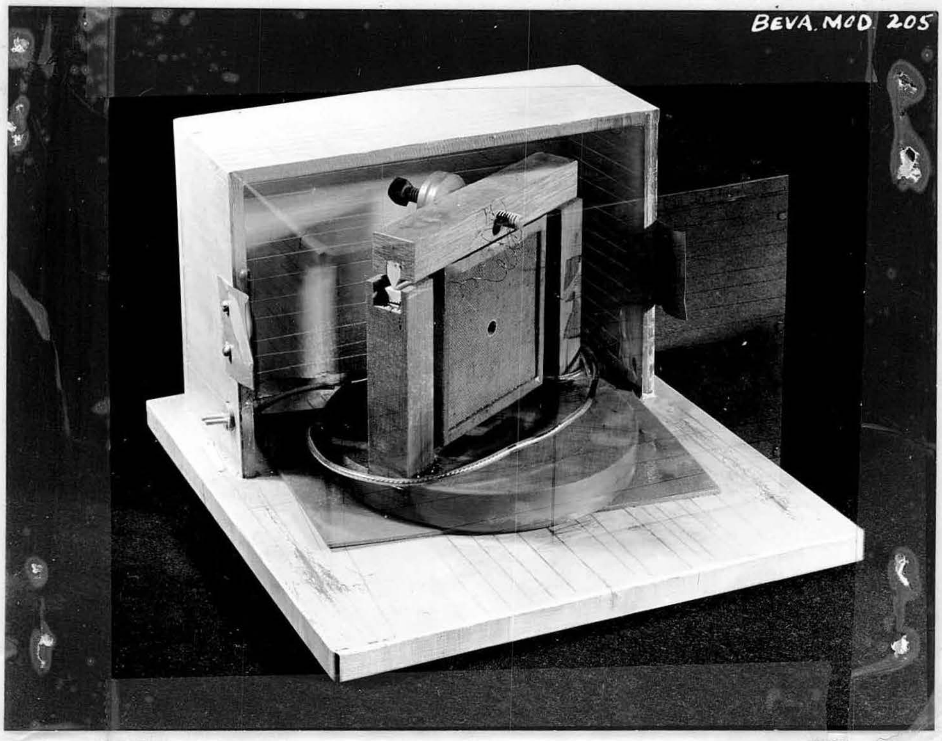
Results of Test:

It was found easy to detect the positions between which the flux lines were vertical. From the ratio of amplitudes of the two "bracketing" signals, it was possible to estimate the location to within less than a quarter of an inch. With a continuously variable vertical positioning for the coil, it should be possible to determine the plane of symmetry of the quarter scale model to within a sixteenth of an inch. Since the full size bevatron will have magnetic flux lines with only one-fourth of the curvature of those in the quarter scale, this would correspond to a determination of the plane of symmetry to within one-quarter inch in the full scale.

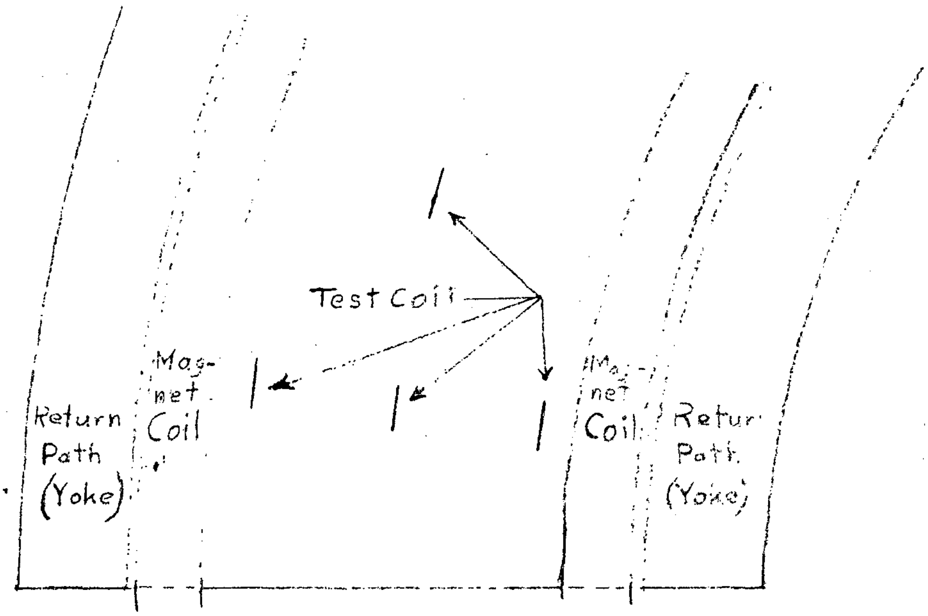
The plane of symmetry of the quarter scale model was found to coincide with the geometrical median plane to within the accuracy of this apparatus. Determinations were made at four positions in the GH quadrant, as shown in accompanying sketches. The quarter scale model has a time-rate of change of flux of approximately 5,000 gauss per second; n is 0.6; radius to center of tank is 11.5 feet. Measurements were made with a Tektronix Type 512 oscilloscope using the slowest sweep provided.

Note: In the accompanying photograph, the line joining the pins of the output plug is horizontal. During the actual test, this line was vertical in order that the loop formed by the pins would link a minimum of flux.

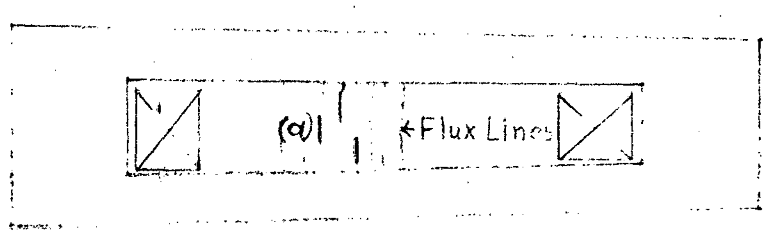

K-BEV-10
Bevatron Quarter Scale
Current vs. Time
NOTE: Solid curve is from a Brush Recorder record. It shows the shape of the curve, only.
Dotted Curve is oscilloscope trace of signal from plane of symmetry coil.
CURRENT
(Solid Curve)
VOLTAGE
(Dotted Curve)
0
0
1 second
TIME



Plane of Symmetry Coil and Mounting



Plan View Showing Positions at Which Determinations Were Made.



Elevation Showing Coil in Null Position (a), and in Two Non-Balanced Positions.

Curvature of the flux lines is greatly exaggerated.