Title
A Device for Determining the Direction of Flux Lines in the Time Varying Magnetic Field of a Particle Accelerator

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The stable particles in the beam of an accelerator such as the synchrotron oscillate about a surface which is near the median plane of the magnet gap.[1]

1. M. E. Rose, Phys. Rev., 53, 392 (1938)
   Robert R. Wilson, Phys. Rev., 53, 408 (1938)

The position of this surface can be determined if the direction of the magnetic flux lines near the median plane of the gap is known and if the variation of the magnetic field with radius in the median plane is known. The flux lines are vertical near the median plane of the gap in a magnet with the usual horizontal gap - these lines are vertical at the median plane in the ideal case. This paper describes a device for determining in a time varying magnetic field the position where the magnetic flux lines are vertical.

The method is a null method. A coil is suspended vertically in the magnet gap with the axis of the coil horizontal and perpendicular to the beam path. The magnet is pulsed with the coil at various vertical positions in the gap. The voltage induced in the coil, which is proportional to the rate of change of net horizontal flux through the coil, is viewed on a cathode ray oscilloscope. When the center of the coil is at a point where the flux lines are vertical, there is no net horizontal flux linking it, and the induced voltage is zero. 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 observed.

This method has been used on a pulsed electro-magnet which has a time-rate of change of magnetic field of approximately 5000 gauss per second and in which the radius of curvature of the flux lines is approximately 19 feet. The coil for this test was wound with approximately 3,000 turns of #38 Formvar covered copper wire on a 1.6 inch square core of linen-base bakelite. The axial thickness of the winding was 1/4 inch, and its width was approximately 1/2 inch. To the top of the coil were attached knife-edges by which it hung from its supporting frame (see Figure 1). The knife-edges were formed from Lavite "A", which was baked after forming to give it hardness. They were ground to their final sharpness after baking. The knife-edges rested upon Lavite blocks that were mounted in the supporting frame. The supporting frame pivoted on a pin about a vertical axis through the center of the coil. A Lucite balancing weight was threaded on a screw protruding from the side of the coil. This was used to adjust the balance of the coil until its axis was horizontal. A tightly and uniformly twisted pair of #38 wires which was left very slack in order that it would exert no torque upon the coil was used to take the signal from the coil. The bottom edge of the coil carried two vanes which moved in oil baths for the purpose of damping out mechanical oscillations. A Lucite box around the coil assembly protected it from air currents. The box was painted with a colloidal silver preparation to provide a thin film of silver which was grounded and served as an electrostatic shield. Lines were scribed in the silver film to minimize eddy current disturbances. The signal was taken to the oscilloscope through a shielded two-conductor microphone cable. A one megohm series resistor was included in the circuit in order that the induced current in the measuring circuit would not be great enough to produce a perceptible torque on the coil.

The coil can be balanced in the field that is being tested. When the coil is properly balanced, it can be rotated through 180° about a vertical axis and the polarity of the signal will reverse, but its magnitude will not change. The balancing weight is moved on its supporting screw until this 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 be properly aligned whatever its location.

To make the measurements the coil is moved to various positions in the field until a zero signal is obtained when the magnet is pulsed. A zero signal indicates that the flux lines are vertical at the center of the coil.

The measurements were made with a Tektronix Type 512 oscilloscope using 0.3 sec. per centimeter triggered sweep and a vertical sensitivity of 0.05 volts/cm.

With continuously variable vertical positioning for the coil it was possible to determine the positions where the magnetic flux lines were vertical to within a sixteenth of an inch. This means that this equipment can detect a 0.0006 radian change in the direction of the flux lines. Only a small reduction in signal is introduced if the axis of the coil is not exactly perpendicular to the beam path, for the voltage induced is proportional to the cosine of the angle between the axis of the coil and the perpendicular line. It was found that this alignment could be made accurately enough by eye.

The work described in this paper was performed under the auspices of the Atomic Energy Commission.

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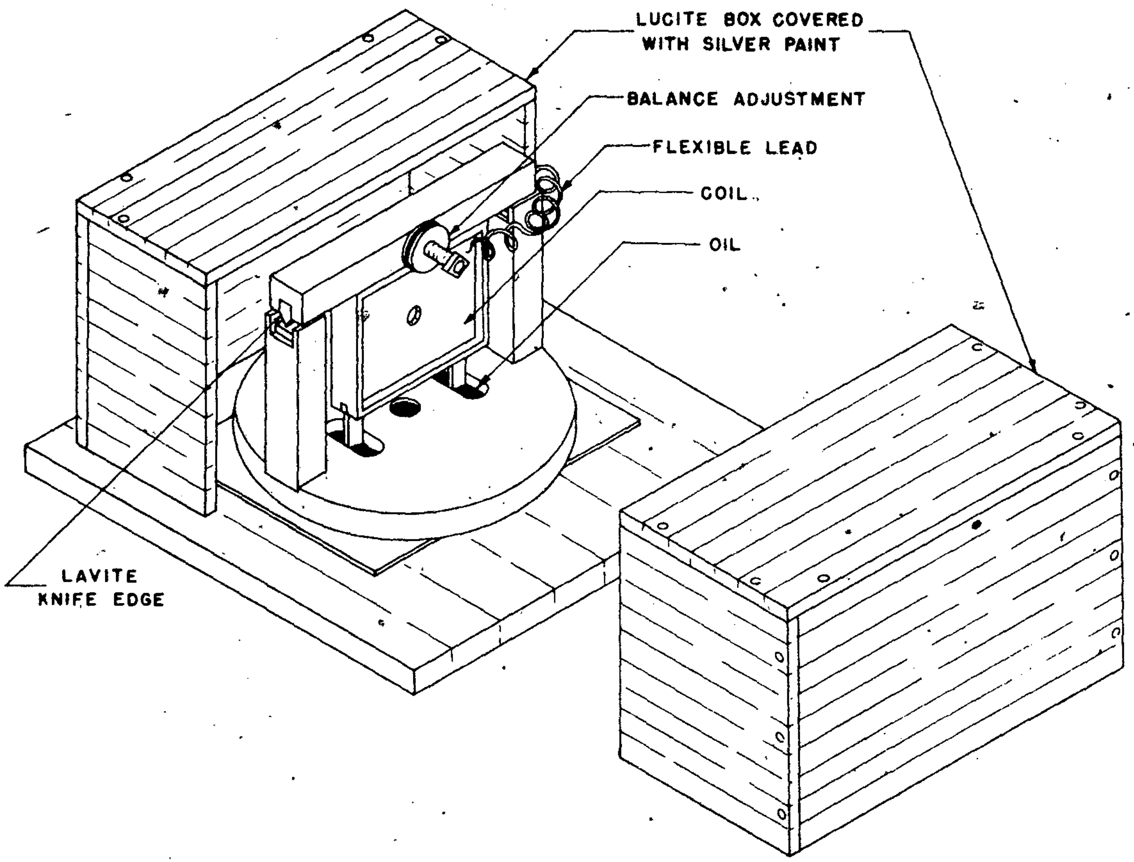
LUCITE BOX COVERED
WITH SILVER PAINT
BALANCE ADJUSTMENT
FLEXIBLE LEAD
COIL
OIL
LAVITE
KNIFE EDGE

FIG. 1