Title
A MAGNETOMETER FOR MEASURING FIELDS TO 300 GAUSS

Authors
Voelker, Ferdinand.
Leavitt, Minard A.

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Summary

This instrument was developed for measurement of magnetic field in an electron cyclotron where the following requirements were to be met:

(a) accuracy of 0.1 % to fields of 100 gauss;

(b) continuous monitoring of magnetic field to allow automatic plotting of field versus position of the probe;

(c) quadrupole probe construction, minimizing the effect of near-by iron on the measurements.

Two newer versions of the probe have been built, one --for measurement of the earth's field --which sacrifices field range above 10 gauss for small size, and the other --for fields to 300 gauss --which sacrifices quadrupole construction.

Sensing Probe

The sensing probe for this instrument is a small specially constructed transformer consisting of three windings with a permalloy strip, 0.001 by 0.005 by 0.25 inch as a core. The primary of the probe consists of an inner and an outer winding constructed so that the inner winding has twice as many turns and one-half as great a cross-sectional area as the outer winding. The windings are in a series bucking connection so that magnetic flux through the inner winding is returned inside the outer winding. This quadrupole-like construction keeps the magnetic flux due to current in the primary within the region of the probe and thus isolates the probe from near-by magnetic materials. Figure 1 shows the probe, drawn to scale.

For 300-gauss measurements the primary windings are connected in series aiding. This gives effectively three times as many turns on the primary, but sacrifices the quadrupole feature. The maximum field for which a probe can be used depends on the heat developed in the windings. These are wound from No. 40 formex-covered copper wire and we have arbitrarily set 300 milliamperes as the upper limit for a conduction-cooled probe. Dow-

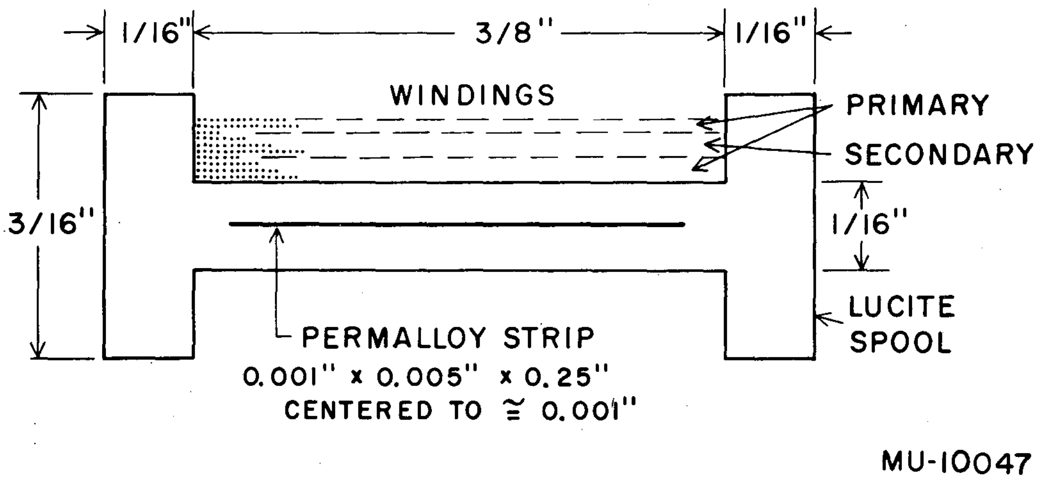

Fig. 1a. Sensing probe.

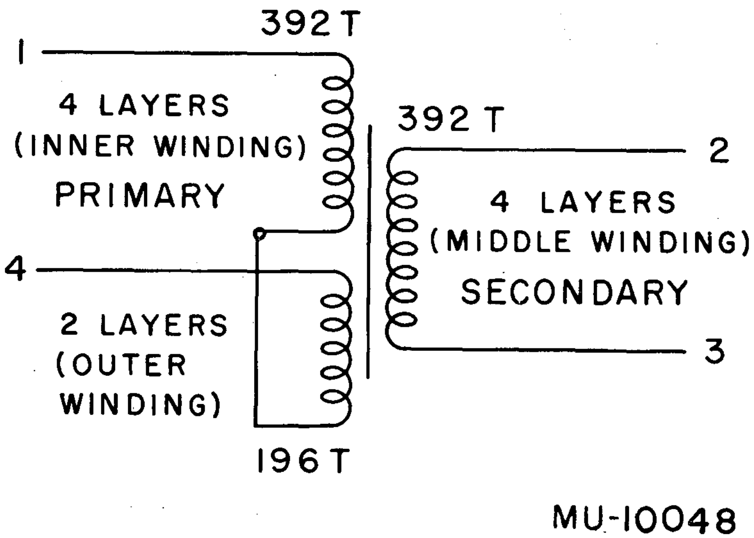

Fig. 1b. Transformer connections.

Corning silicone compound X2452 is used to conduct heat to a split copper sleeve which surrounds the probe. At 300 ma the Lucite temperature is just approaching the softening point.

Where a larger probe can be tolerated and better cooling effected, the instrument can be used for field measurements for more than 300 gauss.

Principle of Operation

The permalloy sample has a magnetization curve that is approximately as shown in Fig. 2. The primary winding is excited with an ac voltage which is sufficient to just work the permalloy over the knee of the magnetization curve. (In this instrument an ac voltage of 162.5 kc was used.) The voltage induced in the secondary in this case is very rich in harmonics, but owing to the symmetry of the magnetization curve, these are all odd harmonics if there is no dc magnetic field present. A small dc field, however, causes the exciting flux to be unsymmetrical. The induced voltage in the secondary then contains even harmonics, of which the second is the largest.

A bridge-tee filter network is used which removes the first, third, fifth, and seventh harmonics from the secondary voltage. An appreciable amount of second harmonic will be left with dc fields as small as 2 millioersteds. This second-harmonic signal is amplified to a level of several volts and is compared to a second-harmonic signal obtained by doubling the frequency of the oscillator output. A standard phase detector is used which gives an output dc voltage that is roughly proportional to the amount of dc magnetic field and is positive or negative depending on the direction of the magnetic field.

This dc voltage is further amplified by a stage of dc amplification and is then applied to the grids of four series regulator tubes. These control a dc current that can flow through the primary of the probe.

With careful design of the electronic circuitry, the instrument can be made to servo the dc current through the probe so that the dc magnetic field on the permalloy strip is maintained at a zero field ± 2 milligauss. Since the permalloy is in an essentially zero field the current through the primary coil is linear with the external magnetic field impressed on the probe. A block diagram of the system is shown in Fig. 3.

This work was performed under the auspices of the U.S. Atomic Energy Commission.

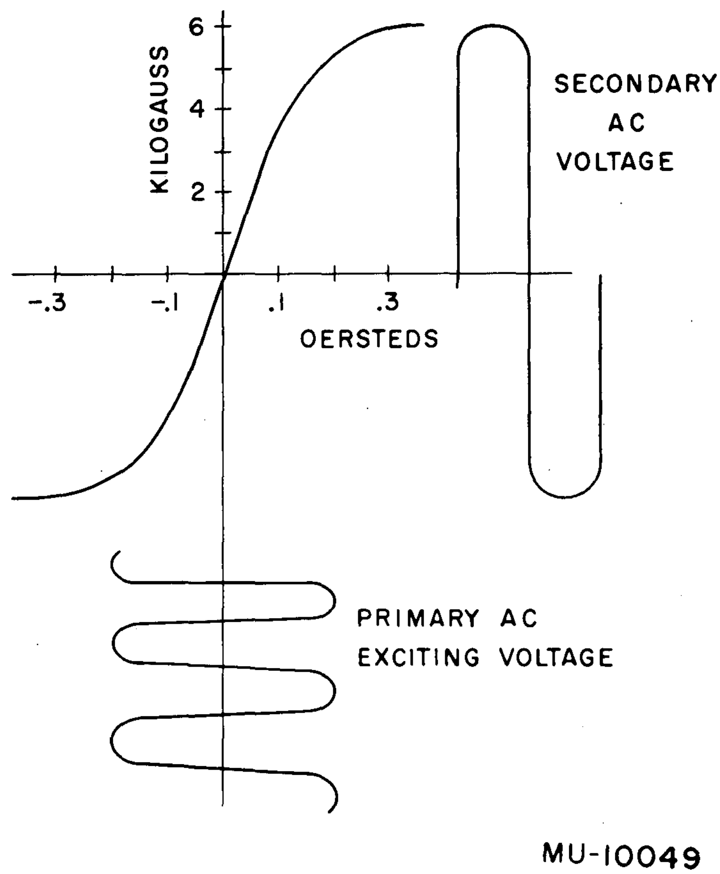

Fig. 2. The operating region on the magnetization curve.

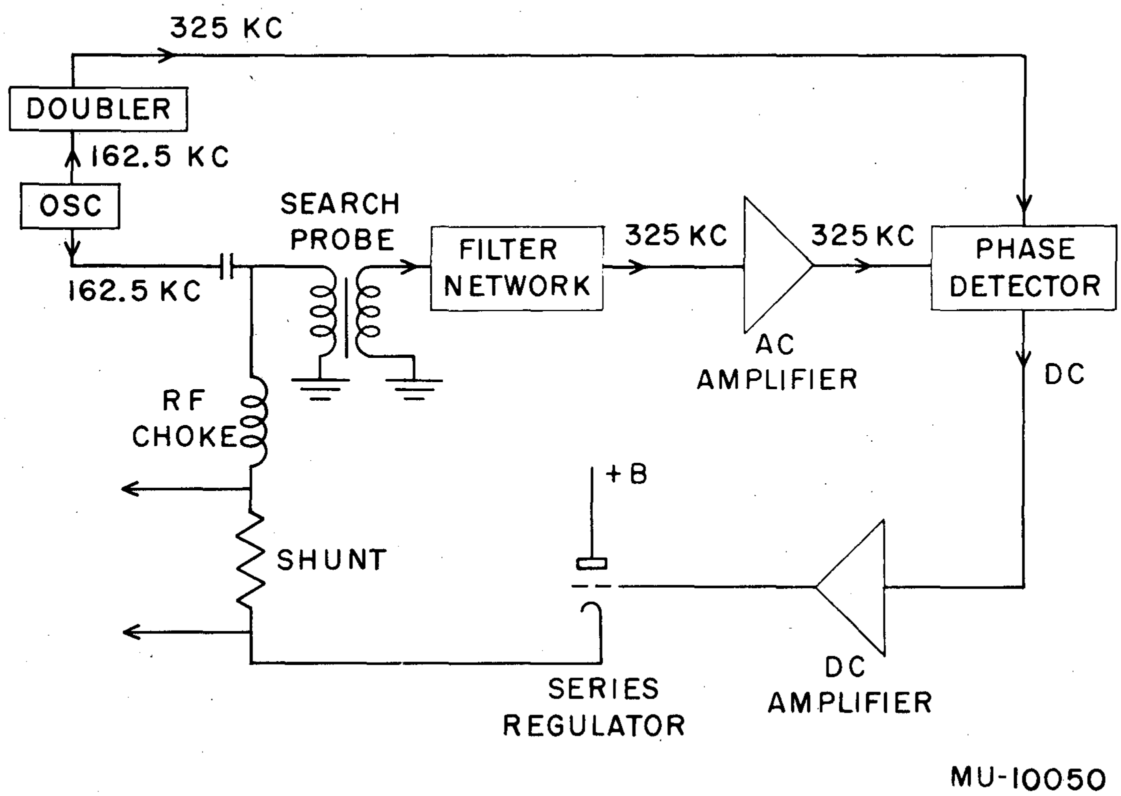

Fig. 3. Block diagram.

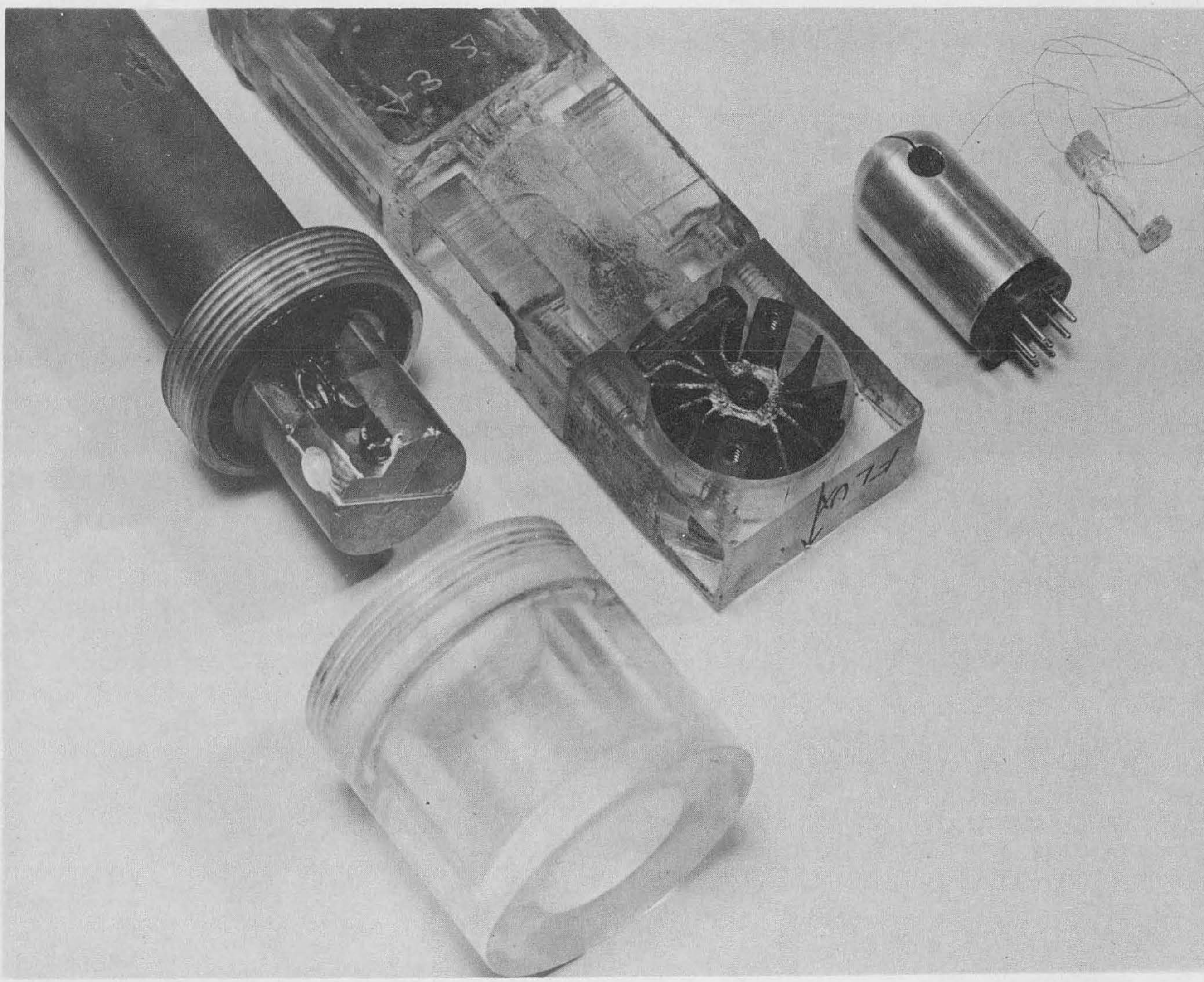

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Fig. 4. Search coil and mountings.