

During the course of our investigation we observed five eclipses of the white dwarf by its companion and found that, in every case, the time of eclipse was later than that predicted by Walker's carefully derived elements for the system. Walker had observed a small discrepancy in this same direction in 1960, amounting to an average of 0.0009 days. By the time of our measurements this discrepancy had grown to 0.00456 days. Walker's measurements in 1960 were made 2224 days after his original epoch for elements, while our measurements were made after 5117 days. If we assume that this discrepancy is due to an error in the original elements, and is accumulating linearly as a result of this error, we can calculate the discrepancy Walker should have observed in 1960. This amounts to 0.0020 days, a value not in agreement with his observation. If the period of the binary system is actually changing linearly with time, however, then the observed phase discrepancy accumulates according to a quadratic formula, slowly at first and then more rapidly. Using our data in this way to compute the value for 1960 gives 0.00086 days, a figure in excellent agreement with Walker's observation.

A lengthening period in a binary system implies a loss of mass from the system, and we can compute the amount of mass lost in a year of this "leakage" as  $1.0 \times 10^{-7}$  solar masses, which must be taken as a lower limit because mass transfer between the components of a binary can shorten the period and mask the loss of mass from the system. It is known that mass transfer occurs in the system, but the amount is not readily determined.

The revised elements for the binary system, which predict the times of eclipse minimums and take into account the changing period, are:

$$T_{\min} = 2434954.94475 + 0.19362070E + 6.529 \times 10^{-12} E^2 \text{ days}$$

where  $E$  is the number of eclipse cycles since the original epoch (term 1).

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#### References and Notes

1. M. F. Walker, *Publ. Astron. Soc. Pac.* **66**, 230 (1954); *Astrophys. J.* **123**, 68 (1956).
2. W. A. Clark, *M.I.T. (Mass. Inst. Technol.) Res. Lab. Electron. Quart. Prog. Rep.* **114** (1968).
3. M. F. Walker, *Astrophys. J.* **134**, 171 (1961). 24 January 1969

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## Magnetic Flux-Trapping Experiment with a Moving Conductor

**Abstract.** An aluminum conductor moving into and out of a magnetic field of 75 gauss traps within itself for varying lengths of time a detectable fraction of the encountered flux, which subsequently decays. A time constant of about 0.005 second, which is the order of magnitude predicted by classical electrodynamics, is measured. The result is of interest in connection with the "frozen-in field" concept of Babcock's sunspot model.

All theories of sunspot formation which depend on the nonuniform rotation of the solar photospheric plasma, such as that of Babcock (1), use the concept of the "freezing-in" of a magnetic field which occurs detectably in a moving conductor of sufficiently large linear dimensions and conductivity (2). Babcock assumes the infinite conductivity of the photospheric plasma; if the conductivity is finite, a diffusion of the field competes with flux-trapping (3). The evidence for flux-trapping and diffusion from a controlled laboratory experiment has not been reported as far as I have been able to determine; thus I attempted to detect the flux trapped in a metallic conductor (aluminum) after it had passed between the pole pieces of an electromagnet.

An aluminum disk (38 cm in diameter by 0.63 cm thick) with a conductivity of  $3 \times 10^7$ /ohm-m is rotated between the pole pieces, where the magnetic field is about 75 gauss. Embedded in the disk is a coil of fine wire; the electromotive force induced across the coil by its encounter with, and departure from, the magnetic field is recorded (through slip rings) on a fast-response recorder.

The experiment demonstrates the temporary freezing of a magnetic field in a conductor and also demonstrates the requirement for nonzero conductivity for the effect to occur. In the aluminum sample used, the flux that was trapped decayed in about 5 msec. This value is supported by theoretical considerations.

The data appeared in the form of voltage readings, from the pickup coil, recorded optically on a print-out chart moving at a rate of 64 inch/sec, with a calibration of 0.1615 volt/inch. Representative peaks, which occurred approximately every 0.04 second at a disk rotational speed of about 1500 rev/min, were enlarged  $\times 2$  onto graph paper (1/20-inch squared) for analysis.

The physical significance of the areas under the curves may be described as follows. Each curve, generated as the pickup coil passes be-

tween the pole pieces, is divisible into a part due to encounter with the flux  $\phi$  and a part due to departure from the flux (Fig. 1). These two sections of the curve display opposite voltage polarity, since the voltage is proportional to  $(d\phi/dt)$ . Furthermore, the encounter and departure fluxes are equal in the case of a nonconducting Textolite disk used as a control. In the latter case, the symmetrical curve reflects merely the shape and magnitude of the field. In the case of the aluminum disk, the encounter and departure fluxes, proportional to areas between the curves and the time axis, still are equal to within less than 2 percent. However, in this case the curves for the encounter and departure fluxes themselves are not similar. Their asymmetric character—if we neglect the electrical impedance characteristics of the pickup coil circuit—is determined entirely by (i) the flux encountered, as in the control case, (ii) the counterflux generated in the moving aluminum in accordance with Lenz's law, and

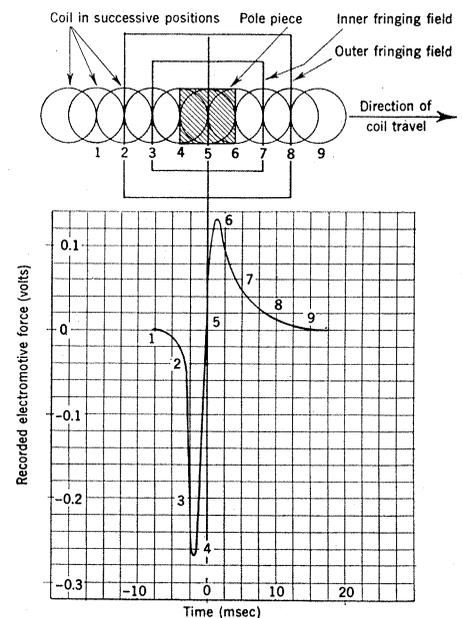


Fig. 1. Coil passing through pole pieces, accompanied by frozen-in field (schematically represented), with corresponding recorded voltage wave form.

(iii) the freezing-in of the field, which, during departure, inhibits ( $d\phi/dt$ ) and therefore depresses the recorded voltage, meanwhile extending the record well outside the region where the pole-piece field had ceased to affect the pickup coil in the Textolite disk.

If, in the case of the curve for Al, the encounter part of the curve is rotated 180° and superimposed on the departure part, the integrated difference between the encounter and departure curves gives the anomalous flux not accounted for by the magnet and by back electromotive force.

The decay of the frozen flux is approximately exponential, vanishing after about 10 msec. To assess the exponential character of the decay, a semi-logarithmic plot was made of the data in Fig. 1. The linear region of this plot has a slope indicative of a decay time constant of 0.0052 second. This

is in good agreement with the theory, which predicts a decay time constant of about 0.003 second.

The general conclusion for sunspot theory is that the frozen-in magnetic field is in fact a valid starting point, once a high-conductivity plasma is assumed to constitute the photosphere. Near a sunspot, the decay time constant [if we assume a conductivity of 100 ohm-m (4)] would be about 10<sup>20</sup> seconds.

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#### References

1. H. W. Babcock, *Astrophys. J.* **133**, 572 (1961).
2. S. Lundquist, *Ark. Fys.* **5**, 298 (1952).
3. H. Alfvén and C. Fälthammar, *Cosmical Electrodynamics* (Oxford, London, 1963), p. 100.
4. R. J. Bray and R. E. Loughhead, *Sunspots* (Wiley, New York, 1965), p. 126.

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## Microparticulates: Isolation from Water and Identification of Associated Chlorinated Pesticides

*Abstract. Microparticulates suspended in lake water were collected by continuous centrifugation and either examined directly or placed on a linear sucrose gradient. Total residue as well as fractions of the centrifuged gradient were extracted with hexane and examined by gas chromatography for the presence of chlorinated hydrocarbon pesticides. Hexane extracts of total residues were also examined by thin-layer chromatography. Lindane and endrin were shown, by gas-liquid chromatography and thin-layer chromatography, to be associated with microparticles. These and other pesticides appeared to be selectively associated with microparticles of different densities, when gas-liquid chromatography was used, although concentrations were below the detection limits required for confirmation by thin-layer chromatography. Samples taken at different times from different locations in Lake Erie revealed different associations with hexane-soluble electron-capturing compounds.*

The ubiquity of pesticides and the significance of their presence in the aquatic habitat has been established. Techniques for identification of pesticides in natural water usually involve extraction from water by adsorption on activated carbon. This particular method has been included in the 1962 USPHS drinking water standards as the method for the determination of organic substances in water (1). In this procedure, up to 5,000 gallons (about 19,000 liters) of water are passed through a column of activated carbon 18 by 3 inches (45.7 by 7.6 cm). The column is extracted with chloroform to remove adsorbed pesticides, and the extract is analyzed by gas chromatography. It is possible to obtain analyses by extraction of small volumes of water (for example, 1 liter) where

concentrations of pesticides are high enough to cause a detector response at that level. Water samples containing pesticide concentrations below limits of detection are usually extracted by a countercurrent batch process or by liquid-liquid extraction processes to increase sensitivity of the method (2). Combinations of these methods have been useful for detection of extremely small amounts of contaminants but are quite time-consuming.

We have investigated the association of chlorinated hydrocarbon pesticides with microscopic particles suspended in Lake Erie. Water was collected in the vicinity of the Bass Islands in the western basin of Lake Erie from 15 feet (4.6 m) below the surface. A 5-gallon sample was centrifuged in a Sorvall RC-2B Szent-Györgyi and Blum con-

tinuous flow centrifuge at 27,000g at a flow rate of 11 ml/min. The particulates from this fraction (0.15  $\mu$ m in diameter and above) were placed on top of a preformed linear gradient of sucrose (0 to 65 percent) and centrifuged at 1500g for 60 minutes. The tube was divided into four fractions, each of which was extracted with hexane. Raw water samples (2 liters) have been extracted by using the liquid-liquid extraction procedure. No detectable chlorinated pesticides were found. Analysis of the hexane extracts for presence of chlorinated hydrocarbon pesticides was made by using an Aerograph 200 gas chromatograph equipped with an electron-capture detector [250 mc of titanium tritride, column temperature 190°C, detector 200°C, injector port 230°C, 5-foot glass, 1/8 inch (internal diameter) column packed with Chromosorb W 60/80 mesh, coated with 5 percent Dow silicone SE-30, high-purity N<sub>2</sub> carrier gas 60 ml/min].

Because gas-liquid chromatography (GLC) retention time and reinforcement of peaks are analytically inadequate for identification purposes, the presence of specific pesticides must be regarded as presumptive. The data suggested, however, that concentrations of specific pesticides associated with individual particulate fractions were below the level of detection by thin-layer chromatography (TLC) (3). Therefore, the use of confirmatory TLC on particulates from larger water samples was employed. For this purpose, a 20-gallon water sample was centrifuged as previously described. The total particulate residue was extracted with hexane and concentrated to 0.5 ml by evaporation. Aliquots (2  $\mu$ l) were injected into the gas chromatograph and the remaining volume was added as a single spot onto Eastman Chromogram 6061 TLC sheets. The TLC sheets were preconditioned and developed by the methods of Kovacs (4), and sprayed with 0.05 percent Rhodamine B (3); 5- $\mu$ g and 50- $\mu$ g spots of control pesticides were chromatographed on the same TLC sheet.

The TLC sheets indicated the presence of spots with  $R_F$  values identical to lindane and endrin. The GLC recordings verified the presence of lindane and endrin as well as several additional peaks from this particular sample.

Pesticides which have been tentatively identified from GLC recordings taken from particulate fractions are lindane, heptachlor, aldrin, and endrin; there were also several unidentified peaks.