the microfluorimeter have increased the versatility of the apparatus for future biochemical work and may in time contribute to the study of enzyme-substrate reactions in various intracellular compartments.

This work was supported by the U. S. Public Health Service Grant No. GM 12202-01. The authors are indebted to Professor B. Chance, Dr. A. Mildvan, Professor M. J. Kopac, and Dr. R. Zuzolo.

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Miniature Rogowski Coil Probes for Direct Measurement of Current Density Distributions in Transient Plasmas*

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(Received 23 June 1965; and in final form, 20 August 1965)

The conventional technique for determining current density distributions in transient plasmas involves mapping the magnetic field distributions via small magnetic probes,[1] and then computing the associated current distributions from Maxwell's relations. This procedure can become tedious if steep gradients are encountered because of the need for spatial differentiation of the magnetic field profiles. The differentiation process can be circumvented, however, if the magnetic probe is protracted into a closed solenoid, i.e., is constructed as a miniature Rogowski coil.[2,3]

The basic measurement made by a Rogowski coil is the rate of change of magnetic flux interior to the windings of a many-turned closed coil. This flux change is directly related, via Maxwell's equations, to the total current passing through the aperture of the closed coil, irrespective of the detailed spatial distribution of that current or of the shape of the coil perimeter. In particular, the emf induced in the coil by the flux change, when temporally integrated, is directly proportional to that total current enclosed,

$$\int Vdt = 4\pi \times 10^{-7}(nA/s)I,$$

where V is the voltage induced on a closed coil of centerline perimeter s, having n evenly spaced turns of loop area A, when a total current I passes through the aperture (mks units).

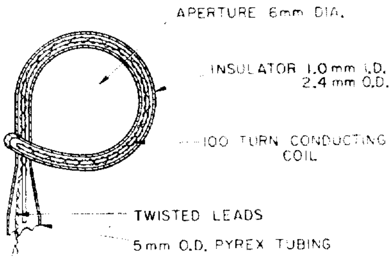

Fig. 1. Sketch of miniature Rogowski coil.

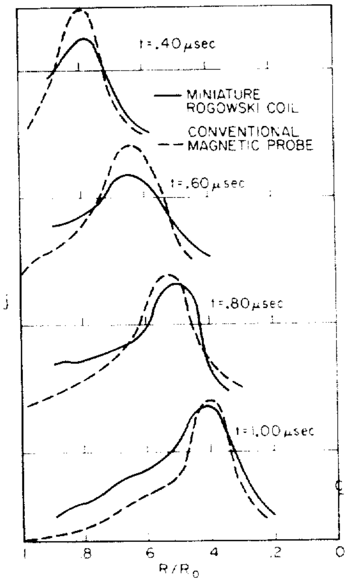

Fig. 2. Comparison of measured current density distributions in large radius pinch discharge.

The experimental technique involves the construction of a closed coil of sufficiently small dimensions that it can adequately resolve the current distributions under study, but still return signals large enough to permit their passive integration.[4] For purposes of probing the interior of a large radius linear pinch discharge,[5,6] this has been accomplished by winding 50 evenly spaced turns of #40 Formvar wire in each direction around a core of 3.6 kg test monofilament nylon fishing line. This flexible coil is then inserted inside a 2.4 mm o.d. Pyrex tube insulator terminating in a 6 mm diam circular bend, which forces the coil into a nearly toroidal shape (Fig. 1). If care is taken that no spurious wiring loops are introduced at undesired locations in the coil or its leads, and that the winding gap at the point of overlap is minimized, the probe responds only to flux changes caused by currents passing through its aperture. The emf thus generated may be integrated by an RC circuit at the input to the oscilloscope which displays the signal.

Current density distributions determined by this type of probe are found to correspond well with the results of more detailed magnetic probe mapping over the major portions of the linear pinch discharge studied. In particular, current rise and position of current maxima in the propagating current sheets are found to be practically identical, whereas some variation is noted in the current sheet widths and amplitudes, and in profiles measured close to the chamber walls (Fig. 2). More extensive results obtained with many probes of this type, and further details of their construction are presented elsewhere.[7]

The use of miniature Rogowski coils thus seems justified for rapid semiquantitative surveys of current density distributions in various transient plasmas, and in some cases may completely replace the more tedious magnetic probe technique.

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* Work supported by NASA NsG-306-63.

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Magnetic Support for Nonferromagnetic Bodies*

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(Received 4 August 1965)

MAGNETIC support systems have been used for freely suspending ferromagnetic bodies in air, in a vacuum and under liquids.[1,2] Such systems when properly designed are almost friction free supports for rotors.[3] Also they are found to serve as sensitive microbalances, densitometers, etc.[2] In all cases the temperature of the supported body is not changed by the support. However, in some experiments it is desirable to have the magnetically suspended body free of ferromagnetic material. In the past this has been acomplished by the electromagnetic generation of eddy currents in the suspended body which in turn interact with the inducing alternating field to support the body.[4,5] This type of support drastically heats the body and, in fact, has been used for simultaneously levitating and melting of specimens in metallurgical research.[5] A magnetic support is described in this note which does not excessively heat the suspended nonferromagnetic body.

Figure 1 shows a schematic diagram of the apparatus.

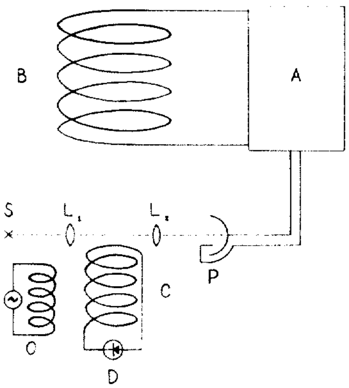

FIG. 1. Schematic of magnetic support for nonferromagnetic bodies. The oscillator coil O is considerably larger in diameter and concentric with C.

The coil C is freely supported magnetically by the solenoid B which may or may not have an iron core. The magnetic moment M of the coil C is produced by a direct current which is generated by the rectification by the diode D of the ac induced in C by an oscillator O. The upward force F on C is given by $F \sim M\partial H/\partial z$, where H is the magnetic field of B and z is the vertical distance. As C moves upward it reduces the light intensity which falls upon the photoelectron multiplier or photodiode P. This causes the servo circuit A to reduce the current in B in such a way as to stop the upward motion of C. If C starts downward the P-A system stops it. It is found that no vertical motion of C is observable. The maximum magnetic field H is along the axis of the solenoid so the freely supported coil C will seek a stable position along this axis. This apparatus is identical to that previously described[1–3] in detail for supporting ferromagnetic bodies except that the magnetic moment of the suspended body is produced by a direct current in a coil instead of being induced in the body by the magnetic field of the solenoid. In these experiments C contains from 100 to 1000 turns of No. 35 copper wire and D is a nonferromagnetic solid state diode rectifier. The suspended body is attached to the coil. Since both the magnetic field H and its gradient may be made large, the current in C can be made small. This greatly reduces the heat generated in C and D. It is clear that D and O may be replaced by a small battery, solar cells, or any means of producing a direct current in C. Also P may be replaced by other types of height sensors. This suspension was devised primarily for use in a magnetic densitometer where the float is almost supported by the displaced liquid and where the current in C is so small that heating is not a troublesome factor.

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* Work supported by the U. S. Army Research Office—Durham and Subcontract APL/JHU No. 230533 Bureau of Naval Weapons.

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