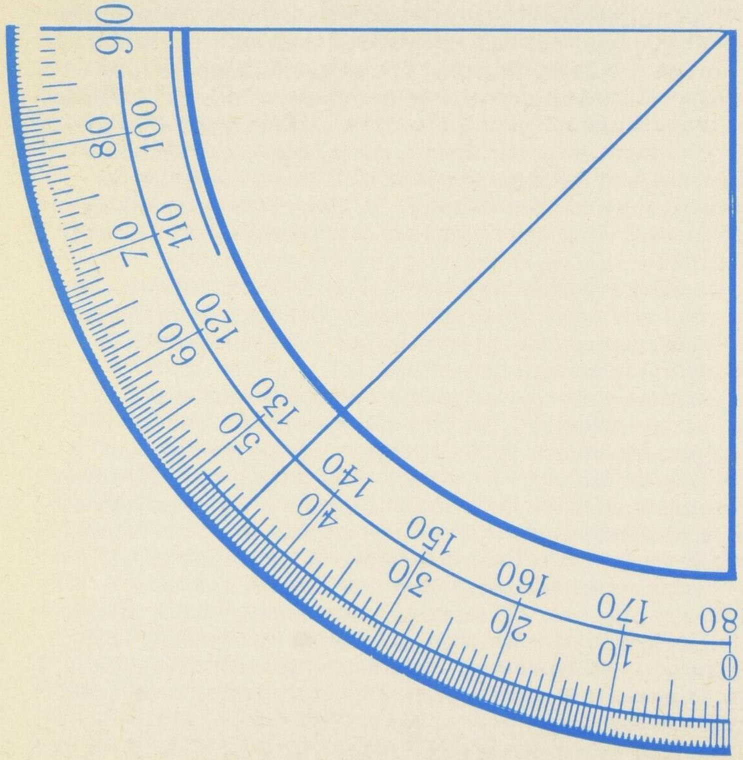
Splitting seconds with CIRCAP–

A novel method for measuring angle

A capacitor is a device that stores electric charge, falling into the same category as resistors, voltmeters and other devices connected with electrical circuitry. A protractor, on the other hand, is a device used to measure and lay down angles, and is normally associated with geometrical measurement. On first consideration, any connection between these two very different instruments, particularly one as unrelated as using a capacitor to measure angles, would seem to stretch the imagination to the limits of credulity. However, this imaginative linking of apparently far-removed concepts has resulted in CIRCAP (Circular Capacitor), a new instrument for precision measurements of angle.

Dr. David Makow of the Photogrammetric Research Section of the National Research Council of Canada's Division of Physics had originally developed an instrument for the precise measurement of length (LINCAP) and reasoned that the same principle could be used for angular measurement. The principle underlying the LINCAP, and ultimately the CIRCAP, is based on an extremely stable, self-compensating capacitor.

The simplest type of capacitor consists of two parallel, conducting plates separated from each other by an insulator; this insulator can be air, a vacuum, or any other non-conducting dielectric material. If the two electrodes (the plates) are connected to a battery, they will become charged, one positive and the other negative. Disconnect the plates from the battery and bridge them with a copper wire, and electrons will flow from the negative to the positive plate until the capacitor discharges. If a capacitor is placed in a direct current circuit, it blocks the current flow since the dielectric material sandwiched between the plates is not a conductor; flux lines reflecting the strength of the electric field are nonetheless present across the



dielectric. If the current is alternating, the capacitor can charge and discharge at the frequency of the applied current which will flow in the circuit. The capacitor acts like a resistor in a direct current circuit and there is a voltage drop across the capacitor.

A capacitor's ability to store charge is called its capacitanc (C), a unit that depends upon the dielectric, the area of the conducting plates and their distance of separation. If the area is increased or the separation distance decreased, the capacitance increases; the reverse of these changes causes the capacitance to decrease. For a given capacitor, the maintenance of a stable capacitance will depend crucially on the stability of the dimensions. If they change, even fractionally, the capacitance will change as well. Historically then, the effort to provide a standard of capacitance has been related to the construction of a capacitor with stable dimensions. Since all materials are affected to varying degrees by changes in temperature and humidity, as well as internal stress relaxation, achieving dimensional stability has been a problem.

Because an invariant capacitance is important to Dr. Makow's concept for measuring angle, he first needed a stable capacitor. He achieved this by using an electrode configuration in which *the value of capacitance is maintained by the structure's inherent self-compensation to dimensional change.*

Basically this unique capacitor consists of four toroids (circular rings) arranged in pairs and concentric about an internal vertical axis. (Figure 1). Originally made of quartz coated with conductive aluminum, the toroids also can be mad from metal coated with gold to prevent corrosion. The capacitor electrodes are represented by diagonally opposite toroids, a-b or c-d; in other words, the structure actually consists of two capacitors. At any given time, one pair of diagonally-opposite toroids form the capacitor while the other pair are grounded, serving as guard electrodes. By simply switching the electrical leads, the capacitor and guard toroids can be interchanged. The capacitance of the structure will not only depend on the distance between the diagonally-opposite toroids, but also on the opening through which the toroids can "see" each other.

"It is this configuration that contributes to the very special properties of the system," explains Dr. Makow. "Although neither one of the diagonal capacitors is particularly constant the mean value of the two remains very stable, and largely independent of dimensional change."

The self-compensating nature of the system results in a constant value for the mean capacitance.

"Suppose," says Dr. Makow, "that the toroid "C" in Figure 1 has been machined with a slightly smaller diameter, or is disturbed in some manner and moves upward. The capacitance will then decrease for this pair since the separation distance has increased. When this occurs, however the opening through which the other set of toroids can "see" each other increases, with a consequent increase in capacitance. Thus a decrease in one set leads to a commensurate increase in the other, and the sum or mean capacitance of the system remains almost unchanged. Another important instance of self-compensating change occurs when one or other of the toroids is moved sideways from its position of concentricity with the vertical axis. For one half of the toroid the separation with its diagonal will increase, while for the other half it will decrease, thus affecting the capacitanc of the diagonal capacitor very little. A change in dimension of