

**XXIV. THE MEASUREMENT OF SMALL CAPACITIES
BY THE CONDENSERS-IN-PARALLEL METHOD**

William Schriever,

Department of Physics, University of Oklahoma

Capacities of a few thousand micro-microfarads or larger may be measured relatively accurately by the condensers-in-parallel method because the unknown capacities introduced by the connecting leads form a very small part of the total capacity. However when the capacity to be measured has a magnitude between 5 and 50 micro-microfarads, such as that of an electrometer, the capacity of the connections becomes quite appreciable and must be taken into account.

Many books on Radioactivity, Conduction of Electricity in Gases and laboratory manuals for such courses, describe the simple method for measuring the capacity of an electrometer. The standard condenser suggested is made of two concentric cylinders, the capacity of which is calculated by a formula which is applicable to infinitely long cylinders only. Thus this formula neglects the fact that the lines of induction near the ends of the condenser are not radial. The inner cylinder must be insulated

from the outer and the extra capacity due to the higher dielectric constant of the insulators is not taken into account. The third source of error is the failure to take into account the extra capacity introduced by the connecting leads. All three of these together may be called the "end-effects" of the condenser.

It is possible to take these end effects into consideration and to determine the capacity of the electrometer accurately. First it will be necessary to have two concentric-cylinder condensers alike in every respect except length; the shorter of the two should be, say, ten times as long as the difference of the radii of the cylinders so that any increase in length will not tend to change the end-effects. The capacity per unit length of the two condensers is the same for portions sufficiently distant from the ends and is given by the formula referred to above. The capacity of each condenser is therefore equal to the product of the length and the capacity per unit length plus the end-effects. A constant source of ions is supplied to the electrometer alone for a definite time and its deflection indicates the potential of the insulated system. Each of the condensers in turn is connected in parallel with the electrometer and the same source of ions is supplied for the same length of time as before, and the deflections are observed. Three equations may then be written. The first will contain a charge Q , the capacity of the electrometer K and the deflection a ; the second will contain Q , K , the calculated part of the capacity of the shorter condenser, the end-effects A , and a deflection b ; the third will contain Q , K , A , the calculated part of the capacity of the longer condenser, and a deflection c . From these three equations it is possible to eliminate Q and A and thus get K in terms of observed quantities. It is of course also possible to determine the values of Q and A .

In a certain piece of research work the capacity of an electro-scope was required. Four condensers were made alike in every respect except in length and each was connected in parallel with the electro-scope by exactly the same piece of wire. Since Q and A could be eliminated by observations made with any pair of condensers it was possible to get six values of K from the five observed deflections. The calculated values of the capacity of the electro-scope, K in C. G. S. electrostatic units are 12.40, 12.62, 12.65, 12.68 and 12.68; the average is 12.647.

Six values of the end-effects for a condenser were calculated: they were 3.81, 3.93, 3.91, 4.40, 4.32, and 3.99 C. G. S. electrostatic units, the average of which is 4.06.

The capacities of the four condensers as calculated in the ordinary way were found to be 4.15, 8.13, 10.36 and 12.25. When the end-effects are taken into account these become 8.21, 12.19, 14.42 and 16.31, C. G. S. electrostatic units. It should be observed that the end-effects in the case of the smallest condenser were as large as the capacity calculated in the ordinary way.

The capacity of the electrometer was also calculated without taking into account the end-effects, i. e., by the simple method suggested in many text-books. The values which were obtained are 4.03, 5.28, 6.20 and 6.63. Here it should be noticed that the actual capacity, 12.647, is more than three times as large as the smallest value and more than twice as large as the largest.

The method suggested in this paper is applicable to all sorts of capacity measurements. The end-effects need not be made small; it is only necessary that, for a given apparatus, they remain constant and that they be of the same order of magnitude as the capacity to be determined. Standard condensers can be constructed in any shop which has a lathe available to turn the insulators which may be made of sulphur.