also a report on "Data Relating to X-Ray Spectra" by William Duane, published by the NATIONAL RESEARCH COUNCIL.

[3] Blake and Duane, *Physic. Rev.*, Dec., 1917, p. 624.

[4] See E. Wagner, *Jahrbuch der Radioahctivität*, 1919, also *Physik. Zeit.*, Nov., 1920, p. 621; and C. Zecker, *Ann. Physik. Leipzig*, Sept., 1920, p. 28, also a note by D. L. Webster, presented to the American Physical Society at the same meeting at which the authors presented a note on this research, April, 1921.

THE U-TUBE ABSOLUTE ELECTROMETER

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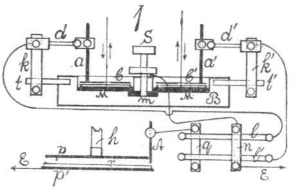
Communicated May 25, 1921

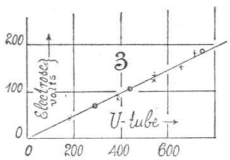
1. *Electrical Condenser.*—Adjusting the wide shank of the shallow U-tube heretofore described (these PROCEEDINGS, **7**, 1921, p. 71) with the top plates removed, so as to admit a metallic disc above the earthed mercury surface and parallel to it, the device becomes an absolute electrometer. The disc is perforated at the middle so that the component rays of the interferometer may reach the mercury. This instrument is chiefly useful in measuring electrostatic potentials. If p is the electric-pressure below the disc charged at potential difference V and h is the head of mercury resulting

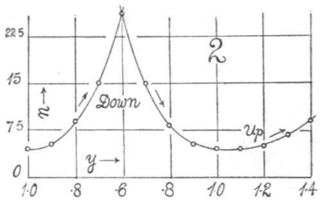
$$V = d\sqrt{8\pi p} = d\sqrt{8\pi h\rho g} = d\sqrt{4\pi\lambda\rho g.n}$$

where d is the distance between disc and mercury, ρ the density of mercury and λ the wave-length of light when n fringes correspond to V. Hence if $d = 1$ millimeter, $V = .315\sqrt{n}$ els. units; or $= 95\sqrt{n}$ volts.

2. *Improved Apparatus.*—The electrometer eventually took the form shown in figure 1 which gives the apparatus in connection with the electrophorus







and a commutating key similar to Mascart's. To put the mercury M to earth, a steel screw, S, which also carries a flat clamp for fastening one end of the earthed wire, has been inserted. This screw, S, has the further important purpose of damping the oscillations of the mercury M or M', by adjustably closing the channel m. The deflections can thus be made quite dead beat, which is an advantage. To level the electrodes C, C' (using a small spirit level placed on them) each has connecting rod d, which carries a clamp at one end, allowing the rod a, a' to slide up and down, rotate around a, a' and d, d' and admitting of small displacements along d. At the other end of each rod is a flat vertical plate which is received in a fissure at the top of the corresponding hard rubber post k, k' and clamped. This gives a horizontal axis at right angles to the preceding. The lower ends of the posts k, k' are suitably clamped to the tubes t, t', attached to the body B of the electrometer. Here further motion along the tubes t, t' and rotation around them is possible. In this way it is not difficult to place C, C' symmetrically above the mercury pools and parallel to their upper faces, for experimental purposes. It is not sufficient, however, if precision is required.

Figure 1 shows the Mascart key below on the right, which consists of the elastic brass strips l, l', the earthed cross bar n above them and the cross bar q below. Thus the whole U-tube is earthed when not in use. The bar q is connected by wires with the brush A of the electrophorus shown on the left, so that when l or l' are depressed into contact with q, C or C', respectively, receives a positive charge while the other electrode and the mercury is earthed. This affords a very satisfactory means of commutation; for since $\Delta V = C\sqrt{n} = C'\sqrt{n'}$, the electrodes are so adjusted that C and C' are nearly equal.

Tests were made with this apparatus and a known $\Delta V = 173$ volts. For example, the scale readings in the ocular on commutation were $x = 34$, $x' = 17$ so that $(x - x') = .7\,(n + n')$, as the fringe breadth was .7 scale parts. Thus $\Delta V = A\sqrt{24}$, or $A = 35.3$ volts per fringe, initially. With large fringes and under quiet surroundings 3 or 4 volts could have been detected.

The upper face of the electrophorus p is on a vertical micrometer screw, insulated by the hard rubber connector h. The distance apart of p, r and p' (to be denoted by d' and d'') or any change of this distance (Y) are thus closely measurable in turns (mm.) of the screw. In a dry room this apparatus retains its charge Q very well and a great variety of fields are producible.

3. *Equations.*—If we treat the case of the electrophorus as a closed cylindrical field of cross section A, and if V_0 is the potential of the charged hard rubber surface, we may write

$$Q' = \frac{AK'}{4\pi d'}(V' - V_0)$$

where Q', V' are the positive charge and potential in the top plate at a distance d' from the charged rubber surface at potential V_0 and K' the specific inductive capacity of the dielectric medium. A similar equation holds if Q'', V'' are the charge and potential of the lower plate at a distance d'' from V_0 with a layer of specific inductive capacity K'' between.

If the two plates are put in contact, $V' = V''$.

If the two plates thus charged are then insulated and the top plate is moved normally towards the lower, a distance of y, the equations reduce to

$$-\Delta V = 4\pi Q d'' y / A(K''d' + K'd'') = \text{const.} \sqrt{n},$$

ΔV being the potential difference thus produced and measured at the U-tube electrometer taken as small in capacity in comparison with the electrophorus.

$Q = Q' + Q''$. Hence, as a first approach, the y, n locus is a parabola. For instance in the following example the insulation loss amounted to not more than 2 fringes in 10 minutes at full charge. The pitch of the micrometer screw being .1 cm., the upper plate was conveniently discharged when $d' = 1$ cm. above the hard rubber surface. Large fringes (about 1.5 scale parts) were installed. The fringe displacements (n) observed on lowering and raising the plate are shown in figure 2. The outgoing and incoming series practically coincide.

4. *Specific Inductive Capacity.*—In equation (7) if the space d' is filled with air, $K' = 1$. On the other hand if a plate of some insulator like glass is inserted of thickness d'_g

$$d' = d'_g + d'_a$$

where d'_a is the thickness of the air layer. Moreover if K_g is the specific inductive capacity of the insulator

$$d'/K' = d'_a + d'_g / K_g$$

If, therefore, in the absence of the insulator, y is the downward displacement of the upper plate which gives the same fringe displacement n, and hence the same V as the insertion of the insulator plate, the resulting equations eventually reduce to

$$K_g = d'_g / (d_g - y)$$

To determine the specific inductive capacity of a given insulating plate, the electrophorus is discharged at a convenient distance, d', between plate and hard rubber face. The insulator (K_g) is then inserted (noting the fringe displacement n) and withdrawn. The fringes must return to zero, showing that no charge has been imparted by the friction of the insulator. The upper plate is now depressed (y) on the micrometer screw until the same fringe displacement n is obtained. The operation is quite rapid; nevertheless the results so obtained were usually too large. Dielectric hysteresis was looked for, but could not have exceeded a fringe breadth.

5. *Absolute Values.*—The comparison of the U-tube with three different Elster and Geitel Electroscopes, the latter all standardized in volts, is given in figure 3 and is as linear within the reading error. The U-tube results were computed by equation A, measuring d from the mercury surface M' in figure 1 to the electrode C', with allowance for the K of glass plate. They are about four times too large. When, however, the measurement of d was made from the top of the glass plate to the electrodes, the results of the two instruments practically coincided. Hence the thin glass plate here acts like a conductor. The charge is transferred to its top face.