makes it possible to demonstrate the three units in rapid succession. One reversing switch serves to change the direction of the current in any unit. An inclined plane mirror clamped above the apparatus makes the effect visible to a large class.

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AN INEXPENSIVE APPARATUS FOR THE MEASUREMENT OF BODILY ACTIVITY

IT is at times important to obtain objective records of the bodily activity of animals without great expense and yet by means of a sensitive instrument. The following apparatus has been used successfully with young puppies and may be adapted to larger or smaller animals.

A small light aluminum baking pan 11″ × 7″ × 1½″ (see a in Fig. 1) was suspended within a packing box

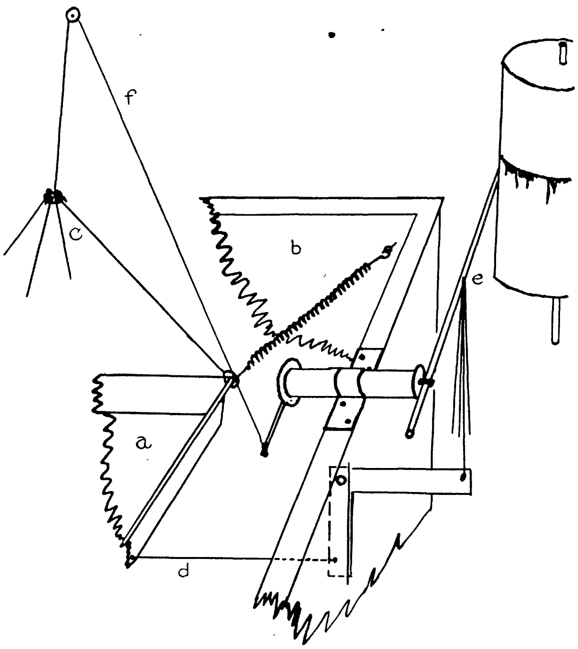

FIG. 1. Detail showing method of wiring used in apparatus for measurement of bodily activity: (a) aluminum pan; (b) packing box; (c) wire rods from corners of pan; (d) thread from side of pan to lever; (e) writing arm with threads attached; (f) thread from upright wires, leading to writing arm.

(b) (approximately 2 feet long, 16 inches wide and 1 foot deep) by means of small springs, one attached at each corner of the tray, and to eyes screwed in the corners of the box. These eyes were so arranged that they could be adjusted to various heights, depending on the weight of the animal. Four light wire rods (c) projected from each corner of the tray to meet above its center.

In order to secure a single record from all movements of the tray, heavy threads (d) were attached to it, one on each side. By means of pulleys these threads converged at a series of levers amplified 3/2, and from the levers threads were connected to a writing arm (e) bolted to a bicycle bearing.

A thread attached to the upright wires from the corners of the tray, which converged above it, was arranged by pulleys in such a way (f) as to pull downward on a lever attached to the bicycle bearing opposite to the writing arm. This lever was bolted so as to make it adjustable to the weight of the animal. Thus, with the tray under slight tension on all sides and with respect to gravity, movement in any direction resulted in a downward pull of the writing arm.

If the animal studied is very active, it may be confined within a ventilated box, which may be placed in the tray, or the box itself may be wired in the way described.

The apparatus has proved sufficiently sensitive in the case of puppies to record practically all movements of skeletal musculature.

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A SENSITIVE A-C VACUUM TUBE RELAY

A VACUUM tube relay possesses numerous advantages in the temperature control of laboratory apparatus which outweigh the slight increase in the complexity of the system. The reduction of the current which passes through the mercury regulator from ten or a hundred milliamperes to the few hundredths of a milliampere required by the vacuum tube practically eliminates all sparking at the mercury contact and makes the presence of moderate amounts of dirt or oxides in the mercury surface a matter of no consequence. This results in a twofold advantage: first, special precautions as to purity of the mercury are unnecessary, and second, the regulator will in general give trouble-free service for longer periods of time.

A vacuum tube relay circuit is described by Rosenbohm[1] requiring a storage battery for the vacuum tube filament current supply and dry batteries for plate and grid voltages. Korpiun and Geldbach[2] show a circuit for operating a similar device with batteries or 220 volt alternating current supply, using two triodes. Both of these systems have certain disadvantages, the first requires a relatively large investment in batteries

[1] E. Rosenbohm, *Proc. Acad. Sci. Amsterdam*, 35: 876, 1932.

[2] J. Korpiun and Alfred Geldbach, *Z. Electrochem.*, 39: 755, 1933.

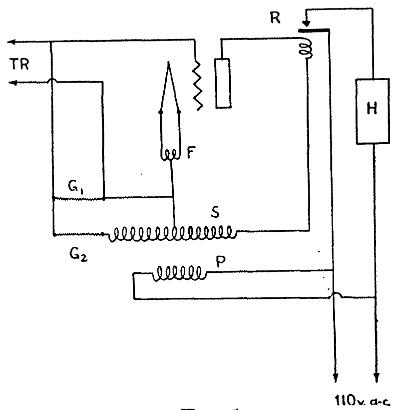

FIG. 1

and occasional interruptions of service for recharging the storage cells, and the second is relatively complex and requires the manufacture or purchase of a number of special resistances.

The author feels that a description of the simple a-c relay developed in this laboratory will be useful to others requiring a sensitive relay for temperature control or other purposes. The circuit is shown in the accompanying diagram. The relay consists of a "45" power amplifier vacuum tube, a Leach No. 1305 a-c relay (R), two resistors (G_1 and G_2) and a transformer with a 110 volt primary (P), a 660 volt center tapped secondary (S) and a 2.5 volt center tapped filament supply winding (F) (Inca transformer, type C-31). TR is the mercury thermoregulator and H is the thermostat heating element. The only electrical supply required is 110 volts a-c. The power consumption (exclusive of H) is 35 to 40 watts. The resistors G_1 and G_2 have the values 2 and 7 megohms, respectively. The parts for the relay are commercially available and inexpensive.

A relay similar to the above has given nearly two years of trouble-free service, regulating the temperature of a covered water thermostat to ± 0.002° C. and another is controlling the temperature of an open stirred water bath at 25° ± 0.01° C.

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SPECIAL ARTICLES

ON THE GRAPHIC REPRESENTATION OF IONIC EQUILIBRIA IN BLOOD SERUM

DURING the session of 1915–16 I made a study of ionic equilibria in sea water of 2.3 millimols per liter alkaline reserve, and plotted the results on log-log paper.[1] Log $[H^+]$ was measured on the x axis and log. CO_2 pressure (later reduced to mm of mercury) on the y axis. During the session of 1916–17 I plotted similar values for blood serums, but in this case the alkaline reserve (bicarbonate), titrated in a rotating hydrogen electrode vessel, varied from sample to sample, so distinguishing marks were used for each sample in marking the values on the log-log paper and it was found that the values of bicarbonate formed a logarithmic scale on an axis at 45° to the x and y axes.[2] Later I learned of the mathematical treatment of this subject by Hasselbalch[3] and applied the equation

$$[H^+] = k_2 \frac{pCO_2}{[BHCO_3]}$$

to that point on each graph where $pCO_2 = [BHCO_3]$ and hence $[H^+] = k_2$ and $pH = pk_2$ (denoting log of reciprocal of k_2). It was found that pk_2 of sea water was 7.08 at 0°, 7.20 at 10°, 7.32 at 20° and 7.44 at 30° at the points where $[BHCO_3] = pCO_2$, but inspection of the graph showed that k_2 varied slightly with CO_2 pressure. Whether this was due to partial change of $BHCO_3$ to B_2CO_3 with fall of CO_2 pressure or due to experimental errors was not determined. In case of blood serums it was thought that errors in titrating $[BHCO_3]$ would be greater at lower values, and with the higher values $pk_2 = 7.5$ at 20°. From the data on sea water it seems evident that pk_2 of blood serum would be at least 0.12 higher at 38° than at 20° and so a value of $pk_2 = 7.62$ might be guessed at. Preliminary attempts at determination of k_2 at 38° showed varying results and were interrupted by my entrance into military service, and after the war I constructed log-log-pH graph paper on three axes at angles of 60° with each other and posted it in the laboratory for the class in physiological chemistry. Since then many papers have appeared on ionic equilibria in blood and new values of the standard hydrogen electrode higher than those used by Sörensen have been used.

Hasselbalch and most later workers instead of titrating $[BHCO_3]$ of serum, added acid and pumped out the CO_2 and measured it and calculated $[BHCO_3]$ and, instead of using pCO_2 in an equation, first calculated the CO_2 physically dissolved in the serum, calling it "H_2CO_3," using two constants k' and c where $k'c = k_2$.

$$[H^+]_s = k'c \frac{pCO_2}{[BHCO_3]_s}.$$ [4]

where $c = 0.0591\alpha$.[5]

[1] Publication No. 251, Carnegie Institution of Washington, p. 36, Fig. 6, 1917.
[2] *Jour. Biol. Chem.*, 519: 522, Fig. 1, 1917.
[3] *Biochem. Z.*, 78: 113, 1917.

[4] L. J. Henderson, "Blood," New Haven (1928) equations 6–7, p. 42.