which accompanies pituitrin injections. Recently, however, Rey[5] reported that the hydrating response in frogs to pituitrin is not alone due to the increased absorption through the skin, but that the decreased kidney output and an increased water retention by certain tissues play an important rôle in causing the increase in body weight. The work of Novelli[6] with skin pouches in which the circulation was left intact indicates that the skin permeability is in some way affected by pituitrin to allow an increase transfer of water.

Although it is admitted that the exact nature of the transfer of water in amphibians after the injection of pituitrin is still obscure, it can be concluded from the above experiments that there is a definite correlation between the amount of water interchange and the natural habitat of the animal.*

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An Ensemble for Determination of Circulation Time of Blood By an Ionization (Geiger Chamber) Method.

EARL C. MCCRACKEN,* CHARLES SHEARD AND HIRAM E. ESSEX.

From the Division of Physics and Biophysical Research and the Division of Experimental Surgery and Pathology, The Mayo Foundation, Rochester, Minn.

A decade ago there appeared the first of a series of publications by Blumgart and his associates[1] concerning the use of injections of the disintegration products of radon (radium emanation) for the determination of the time elapsing between the introduction of the radioactive material at a given point in the blood-vascular system and its arrival at some other point in the system as detected by a shielded ionization chamber.

In the early investigations the radioactive material was injected into the cubital vein of one arm and detection of its arrival in the radial artery of the other arm was accomplished by means of a modi-

[5] Rey, P., *Comp. rend. Soc. de biol.*, 1935, **118**, 949.

[6] Novelli, A., *Rev. Soc. Argent. Biol.*, 1936, **12**, 163.

* These experiments were begun at the University of Michigan Biology Station at Douglas Lake.

* Fellow in Biophysics, The Mayo Foundation. Now associated with the Department of Physics, Iowa State College, Ames, Iowa.

[1] Blumgart, H. L., and Yens, O. C., *J. Clin. Invest.*, 1927, **4**, 1. Blumgart, H. L., and Weiss, Soma, *J. Clin. Invest.*, 1927, **4**, 389.

fication of the cloud-chamber devised by Wilson.[2] In the later studies Blumgart and his coworkers used ionization chambers of the type designed by Geiger[3] and a mechanism for recording the time of passage of the active material between the chosen points. The ensemble of apparatus was somewhat cumbersome, unwieldy and expensive. A compact, portable and relatively inexpensive type of equipment has been assembled and used by us in investigations concerning the circulation time of the blood between 2 points (in general, between the left jugular vein and the right femoral artery, lying in the adductor canal) and as an adjunct in the series of investigations concerning blood flow in dogs by Herrick, Essex, Mann and Baldes.[4] The apparatus and method have the advantages of absence of trauma, utilization in trained animals, deletion of reaction times and of immediate and positive detection of the injected radioactive material. By reason of the desire expressed by various investigators for information concerning the experimental ensemble and procedure, we are presenting the essential features.

The ensemble of apparatus for the detection and recording of the radioactive material at the time of its arrival at the chosen point in the blood-vascular system consists essentially of 4 parts: an ionization (Geiger) chamber and attached insulated cable, a supply of power of high voltage for the ionization chamber, three stages of amplification with power supplies, and a mechanism for recording the receipt of ionizing energy or changes in ionization in the Geiger chamber. The unit is operated from a 110 volt, 60 cycle, source of alternating current through a voltage stabilizer; the recording circuit requires, in addition, a supply of direct current of about 120 volts.

The wiring diagram of the amplifying system and power supplies is too complicated to be suitable for reproduction. This portion of the apparatus was assembled for us by the General Radio Company, Cambridge, Mass., under the designation of Type GR-P-361 Geiger Counter; diagrams and details of construction and operation may be obtained from them or from one of the authors (C.S.) of this communication.

The ionization chamber is attached to a flexible cable which, in turn, is so constructed as to prevent leakage and to obviate the discharges caused by changes in capacity due to movements of the cable. The cable is 8 feet in length in order that the ionization

[2] Wilson, C. T. R., *Proc. Roy. Soc. Med.*, Series A, 1911, **85**, 285.

[3] Geiger, Hans, and Rutherford, E., *Phil. Mag.*, 1912, **24**, 618. Geiger, Hans, *Phys. Z.*, 1913, **14**, 1129.

[4] Herrick, J. F., Essex, H. E., Mann, F. C., and Baldes, E. J., *Am. J. Physiol.*, 1934, **108**, 621.

chamber may be conveniently and advantageously placed in any desired location during the investigations of the time of circulation of the blood. The ionization chamber (Fig. 1), designed for ease

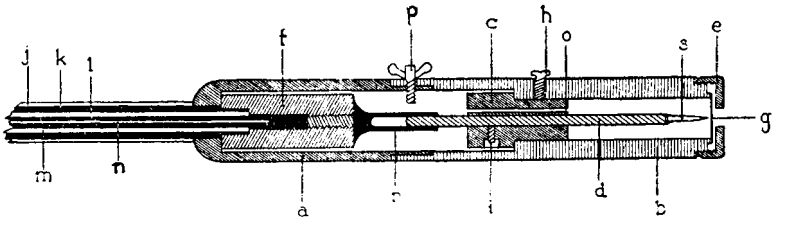

FIG. 1.

Details of construction of the ionization chamber and attached cable. The significance of the letters is indicated in the text.

of replacement of the needle point (s) or aluminum window (g), is made of a cylinder of brass. The window of aluminum foil (0.0125 mm. thick) is protected by a screw cap (e) containing an aperture 3 mm. in diameter; the needle (a polished phonographic needle with a tempered point) is fastened into a brass rod (d) mounted in the axis of the cylinder. The two portions (a, b) of the chamber may be separated by removing the wing nut (p). The rod carrying the needles is held in its retaining bushing (c) of hard rubber by means of a set screw (i). The point of the needle is placed about 1 mm. from the aluminum foil.

The center of the *flexible cable* consists of a 7 mm. high-tension cable (l, n), the core (n) of which is soldered to the holder (r) of the rod carrying the needle. Rubber tubing (m), of 7.5 mm. internal diameter, is forced over the central cable. Flexible copper shielding (k) is stretched tightly over the rubber tubing and soldered to the ionization chamber. An outer layer of machinists' tape completes the construction of the cable. These details regarding the construction of the ionization chamber and cable have been given because of the difficulties encountered in eliminating fairly frequent and relatively prolonged discharges from the needle point (charged positively and just under the break-down potential of about 2500 v.) to the window of the ionization chamber. Following the plan of construction as outlined, we found that a sharp, decisive blow to the cable was necessary to change the capacitance enough to cause momentary discharges in the chamber.

The *output* from the amplifying system is impressed on a *recording system* which is shown in diagrammatic form in Fig. 2. The relay (y) acts as a vibrator switch; its period is longer than the time required for the deionization of the thyratron tube (t) or of the ionization chamber. Activation of the relay motivates the

recording point (p). Records of the to and fro movements of the point (p) which occur during the receipt of ionizing energy in the Geiger chamber are made on a strip of paper moving with a constant known velocity. For reasons which will be obvious from the data to be presented in other communications regarding the circulation time of the blood as influenced by various physico-physiological agents and by drugs, we found it desirable to employ gears giving, respectively, 1, 2, 4 and 8 cm. of travel of the paper in one second. In Fig. 2, S_3 indicates the insertion of the leads from a switch, of

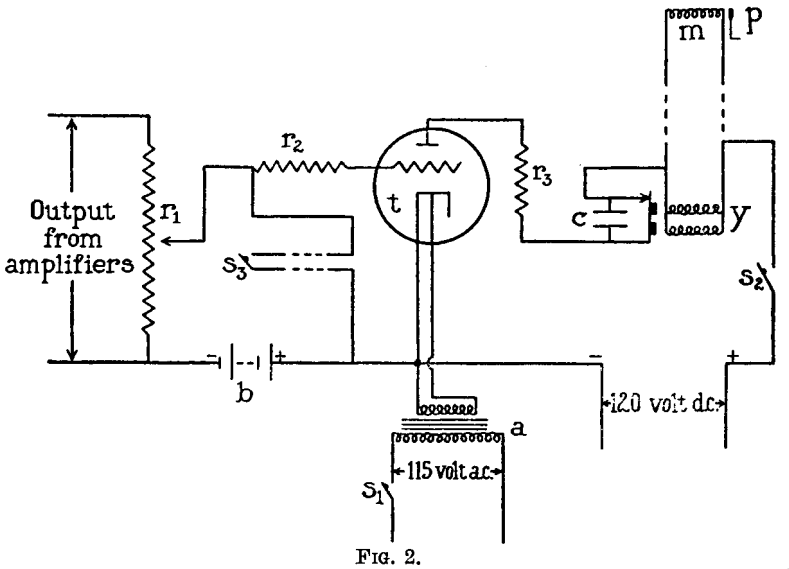

FIG. 2.

Diagram of recording circuit. The significance of the letters is indicated in the text.

spring brass, attached to the plunger of the syringe used for purposes of injection; when this switch is closed, a record of the commencement and the duration of time of injection of radioactive material is made on the moving strip of paper.

The *radioactive material* which is used as the ionizing agent and which is injected into the animals consists of a solution of the disintegration products of radium emanation (radon). One of these active products, radium C, has a marked emission of gamma rays. Since gamma rays are highly penetrating and active ionizing agents, they serve as the principal source for the production of discharges in the Geiger chamber. The transformation of radioactive products proceeds very rapidly to radium D. In about 2 hours the activity of the injected material has decayed sufficiently to allow of the use of the same animal in other tests. The injection of a solution of

the radioactive material obtained from 3 to 5 millicuries of radon gives satisfactory records of the circulation time.

Satisfactory *shielding of the ionization chamber* is accompanied by the use of cubical lead blocks about 7.5 cm. on a side. These blocks are mounted on suitable rods and supports and so arranged that 2 of them, in the shape of a V, are placed as close to the body of the animal as possible. The ionization chamber is placed in the crotch formed by the lead blocks. Additional screening is secured by lead plates 0.5 cm. thick, 10 cm. wide and 25 cm. long, placed over the abdomen and just in front of the lead blocks, respectively. This procedure reduces the number of extraneous discharges to an occasional one only.

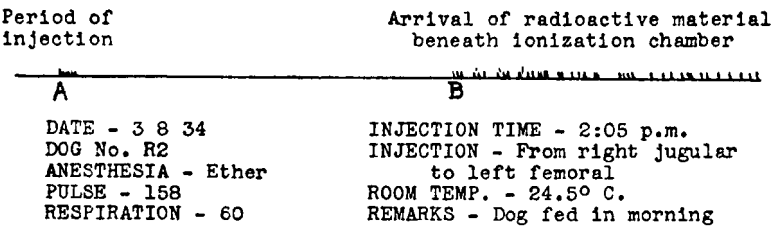

FIG. 3.

Reproduction of a photograph of an original record (reduced about a third). The circulation time of the blood in this case was 5.5 seconds. The distance A to B represents the time between injection of radioactive material in the jugular vein and its arrival in the femoral artery.

Fig. 3 is the reproduction of a record (reduced about one-third) obtained for use in determining the time of circulation of the blood between the right jugular vein and the right superficial femoral artery of a dog under light ether anesthesia. The circulation time of the blood between these two points is determined from the known velocity of the recording paper and the distance between the commencement of injection and the first indication of the arrival of the radioactive material beneath the window of the ionization chamber.[5]

[5] Sheard, Charles, McCracken, E. C., and Essex, H. E., *Am. J. Physiol.*, 1934, **109**, 96.