CONTRIBUTIONS

TO

PRACTICAL PHYSIOLOGY AND PHARMACOLOGY

BY

CHARLES CLAUDE GUTHRIE

Professor of Physiology and Pharmacology
University of Pittsburgh Medical School

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INTRODUCTION

As all are aware of the limited amount of time provided for Physiology and Pharmacology in the modern medical course, and also, of the nature and aims of such courses, it is unnecessary to give lengthy reasons for the view that time-saving laboratory methods are desirable.

By providing the student with simple, efficient and sturdy apparatus designed especially to meet the requirements of the courses, I believe much time now devoted to the purely mechanical side of the experimental work may be saved, thereby enabling him to perform more experiments in the allotted time. Also, his results will be more certain and accurate, and being less burdened with mechanical details, his mind will be freer to contemplate the physiological or pharmacological phenomena revealed during the time of the experiment, a point I would strongly emphasize. Finally, I believe that under such conditions the courses would have larger pedagogic values.

The view has been held that by assembling, adapting and devising all of the separate pieces of apparatus for each experiment the student gains valuable practical training, both manual and technical. I believe the value of this feature of such courses has been overestimated in the past; and with modern preliminary requirements for medical students, I see no reason why the Physiologist or Pharmacologist should deem it a part of his duty to teach manual training or elementary physics. Only a very small percentage of such students become teachers or investigators in these fields, and the course with time-saving apparatus is not less stimulating—in fact, it is more so.

From a purely technical standpoint, physiology has not kept abreast of her sister science physics, save in certain special fields. Even in muscle-nerve physiology there is no uniformity of methods in different laboratories. In general, the student is obliged to adapt apparatus to particular ends. Therefore, results are secured at the expense of much time, and the results themselves are prone to be inaccurate. The mechanical errors are great and imperfectly known, since for the most part such apparatus is not standardized. Also, time and the limitations of the apparatus render study of the finer and more ultimate phenomena impracticable. Pedagogically, for the time expended, the result is unsatisfactory.

I believe that much can be done to remedy the condition, both by individual teachers and by co-operation between schools. The material presented in the succeeding pages is offered from this standpoint. Though the task has been very time-consuming, the improvement in the students' results and the very marked extension of the experimental work rendered possible in the laboratory is abundant justification. I shall be glad if others can in any way profit by it.

All of the apparatus has been thoroughly tested, both directly for mechanical faults and by use in experiments for which it is designed. Much of it has been used as regular student equipment for one or more terms, which is, perhaps, the severest test to which apparatus is subjected. In designing and constructing, the purposes and conditions of its use have been primary considerations. Simplicity and durability of design have been retained at the expense of accuracy when the difference in the latter has been largely of theoretical importance. Absolute perfection is desirable, but difficult of achievement, even in the most highly specialized instruments and to have striven for this at the expense of simplicity, durability and cost would have conflicted with the plan under which the work was undertaken. Therefore, although recognizing its imperfections, I am convinced that when used for the purposes for which it is designed, the apparatus gives credible results which, from a practical standpoint, are satisfactory. The probable errors and practical limitations are given in most cases along with the descriptions.

It is planned for the second number of this contribution to deal with the working directions based upon laboratory experience with the apparatus. The value of such directions is enhanced by their actual employment in the laboratory and for this reason they may not be printed until they have been further tried out in the regular course during the approaching session.

I shall welcome suggestions both in the way of criticisms and in the way of improvement of the apparatus.

The drawings reproduced were made to scale so that with the descriptions and specifications any competent mechanic can construct the apparatus.

It is a great pleasure to acknowledge the helpful suggestions of past and present members of the departmental staff and particularly the painstaking work of Mr. Robert Tontrup, mechanician, and the patient and skillful testing and drawing of Miss Marian Lee, research assistant.

Private publication was decided upon owing to the policy of appropriate journals of barring or restricting purely technical material. It seemed most desirable to publish all of the material at one time and in one place.

July 31, 1915.

CONTRIBUTIONS TO PRACTICAL PHYSIOLOGY AND PHARMACOLOGY

PART I—APPARATUS

Myograph

This form of myograph is designed primarily for recording contractions in isolated skeletal, cardiac and plain muscle, but it is also convenient and efficient for studying muscle *in situ*, Figs. 1, 2, and 3.

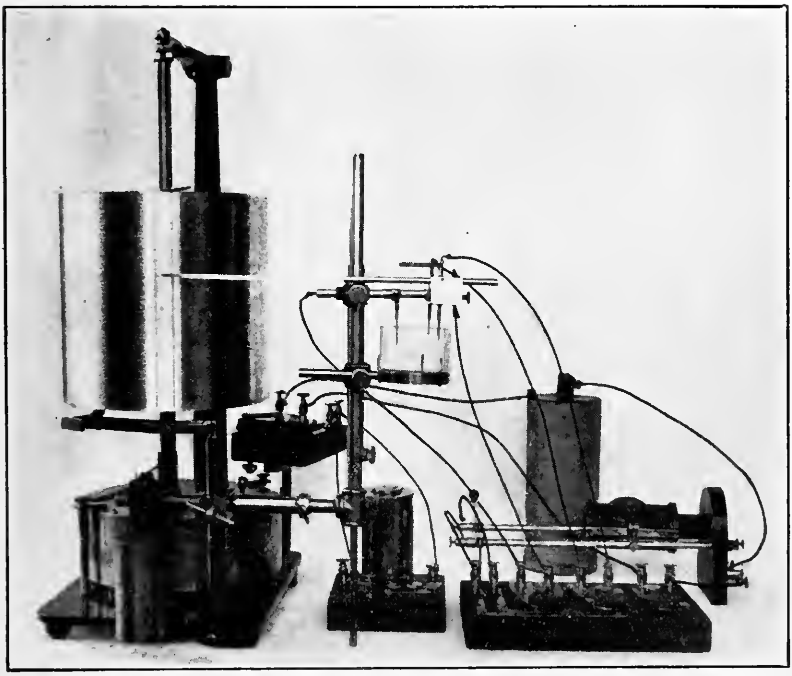

Fig. 1. Myograph assembled with drum stand, automatic stimulating key and rheocord, hand primary key and secondary cut-out key and switch, coil, and battery.

It has but slight inertia. The frame is of brass. It is pierced by holes and threaded sockets for various attachments. The lever may be used as a simple lever with both arms horizontal or as a right angle lever, the recording arm being horizontal and a short arm to which the force is applied, perpendicular. The lever is made of thin brass tubing rigidly attached at the fulcrum, Fig 4. This point is transversely pierced with a tube which firmly holds the axle which turns in bearings in the frame. The entire construction is such that, though light, the instrument is very rigid and compact. All parts are readily accessible.

The horizontal arms of the lever are pierced with perpendicular holes at intervals of one centimeter from the fulcrum. These holes serve to mark centimeter intervals, and as points of attachment for the

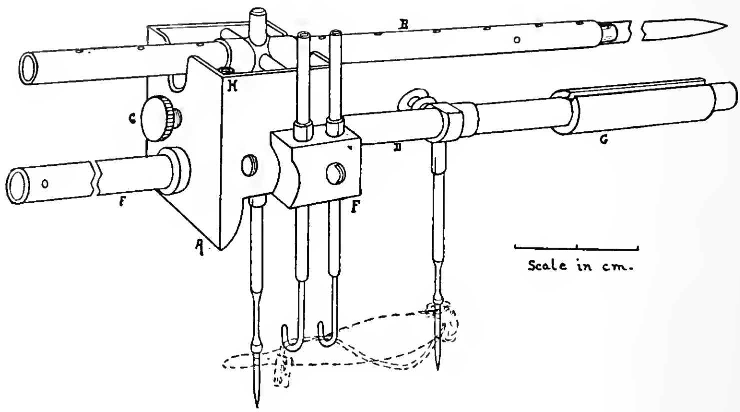

Fig. 2. Myograph. Posterio-lateral view.

A. Frame.
B. Lever.
C. Lever rest or after-loading screw.
D. Anterior support rod.
E. Detachable support rod. A side socket for E is shown in the frame.
F. Nerve electrodes.
G. Insulating sleeve. The method of mounting a muscle-nerve preparation is shown by the dotted lines.

weight pan and other accessories. The openings in both ends are taper reamed to facilitate attachment of extensions. The forward arm to which the writing point is usually affixed is transversely pierced about two centimeters from the end by a pin which is permanently soldered in place, so that when a straw is forcibly thrust into the tube it is split, and thus expanded; or if the end be cut obliquely, it is compressed firmly between the pin and the side of the tube, thus providing a simple means of instantly and rigidly affixing straws of various sizes.

The perpendicular arm is a tube which forms a spring socket into which extensions are thrust. These extensions are of various lengths;

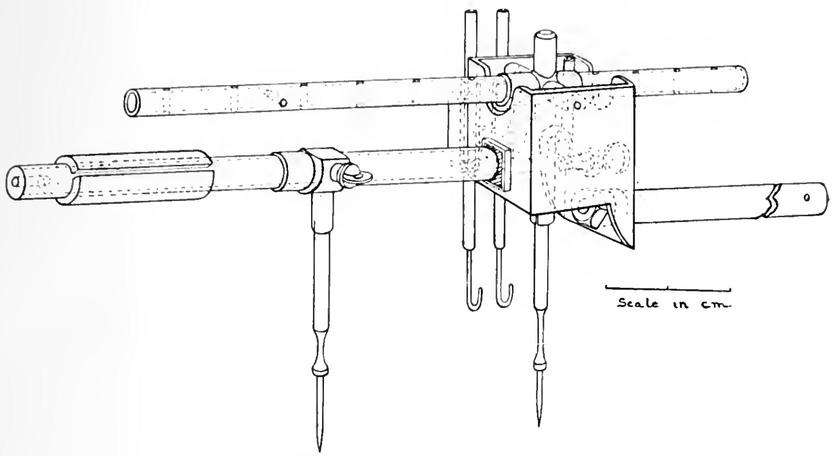

Fig. 3. Myograph. Anterio-lateral projection.

they consist of a brass tube into one end of which a solid metallic point is fixed. The point serves to attach one end of the muscle to the lever by transfixing it. A collar on the point serves as a stop to the tissue, and its lower surface is at a known distance from the fulcrum, usually

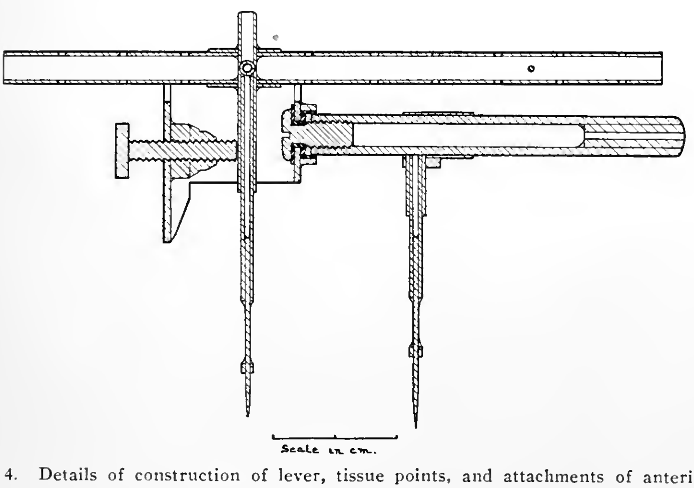

Fig. 4. Details of construction of lever, tissue points, and attachments of anterior support rod to frame and insulation.

three to five centimeters, depending upon the length of the extensions employed. Backward excursion of the arm is limited by an adjustable stop or rest screw which pierces the posterior wall of the frame.

A fixed support for the other end of the muscle is carried on a horizontal rod which is firmly attached to the anterior surface of the frame. It consists of a spring socket similar to that of the perpendicular lever arm into which are inserted similar pointed extensions. The point of the socket on the horizontal support rod is adjustable by means of a set screw conveniently placed, thus permitting adjustment for tissue preparations of different lengths. The extension is of such length that the lower surface of the collar, which acts as a stop to the tissue, is somewhat above the horizontal plane of the stop on the perpendicular lever arm extension, so that the muscle contracts more nearly in the line of the circumference of the arc described by the perpendicular arm, *i. e.*, not tangentially, Fig. 5. Thus the movement

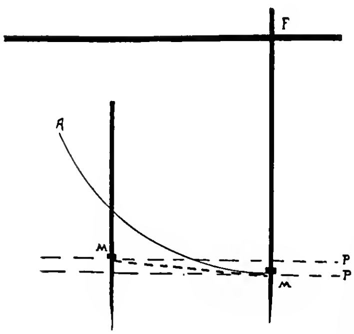

Fig. 5. Diagram to show the relation of the direction of the pull of a muscle to the arc of the perpendicular myograph lever.
F. Fulcrum.
P. Horizontal plane of movable point stop.
P′. Horizontal plane of fixed point stop.
A. Arc of perpendicular lever.
M. and M′. Longitudinal axis of muscle.

of the lever is more nearly uniform throughout the contraction. The extensions serve not only as tissue holders but as electrodes for direct stimulation of the tissue. They may be easily withdrawn from the spring sockets and replaced by others of different lengths. The adjustable socket for the fixed arm may be removed from the support rod.

The anterior support rod is immediately below and parallel to the forward arm of the lever. It is electrically insulated from the frame, and the forward end is provided with a hole for the purpose of making electrical connection in order to lead a current to the muscle through the fixed muscle point and electrode. Electrical connection to the movable muscle point and electrode is made by inserting the end of the wire conveying the current into a tube provided for the purpose, Fig. 2, H. No other form of binding post is used, as they are more cumbersome, more prone to get out of order, as through loss of parts, and they are no more effective than the form described. Besides, this method of connecting is time saving.

A nerve electrode holder for adjustable electrodes is attached to the far side of the frame, Fig. 2, F, and Fig 6. The body of the holder is of fibre and, therefore, insulates the electrodes from the myograph

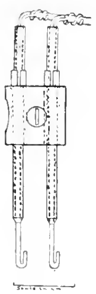

Fig. 6. Myograph nerve electrodes. Details of construction and method of making electrical connections.

frame. The electrodes consist of brass tubing, into the lower ends of which are fitted metallic points which are curved to support a nerve or other tissue laid upon them. The holes in the upper ends of the tubes of the electrodes serve for making electrical contact. The spring sockets of the holder into which they fit permit of their instantaneous removal or adjustment.

The support rod attached to the anterior surface of the frame and which carries the fixed point serves in many experiments as a support for the myograph, as it may be clamped to a stand rod without interfering in any way with the action or manipulation of the myograph, Fig. 1. In addition, the posterior and far sides of the frame are provided with threaded sockets into which a detachable support rod may be fastened as occasion indicates. The support rod is provided with a fiber collar so that it may be electrically insulated from the clamp. The collar is three centimeters long; it is split longitudinally through one side so that it may be easily adjusted to any point upon the rod or removed therefrom. It may also be used upon the support rod attached to the anterior surface of the frame. The support rod may be quickly removed by unscrewing from the frame; if tight it may be loosened by using an ordinary clamp as a wrench. In addition, it is pierced transversely near its posterior extremity by a hole through which a pin such as a nail may be thrust to facilitate its adjustment or removal. When the rod is screwed into the far side of the frame it is then fixed at right angles to the direction of the lever. This arrangement is very convenient as in recording the contraction of a frog's heart *in situ*.

Various accessory attachments greatly extend the use and value of the myograph, and, therefore, will be described in detail.

BATH

As a ready and simple means of applying solutions to isolated tissues, the adjustable bath is used, Fig. 7, A, and Fig. 1. The dish

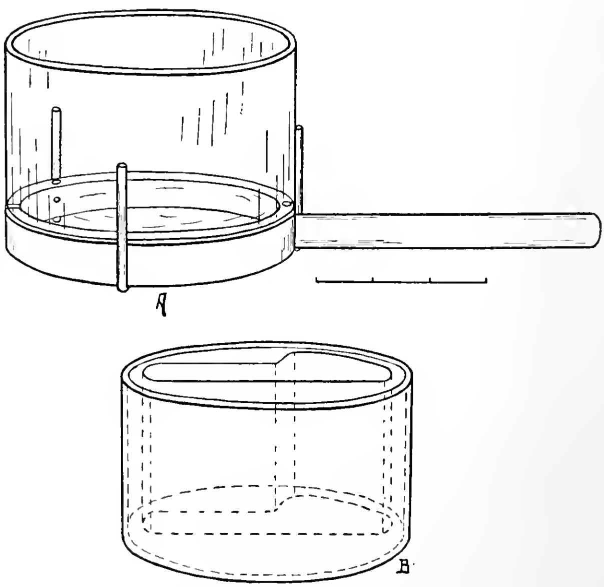

Fig. 7. A. Myograph bath holder and dish.

B. Modified form of dish requiring but 5 to 8 cc. of liquid to submerge tissue.

is of glass, circular in form. In diameter it is 52 mm. and in depth 30 mm. The walls and bottom are 1.5 mm. thick. It is firmly grasped by the spring prongs of the holder, but is instantly detachable, and, therefore, is easily cleansed. The holder is solidly and substantially

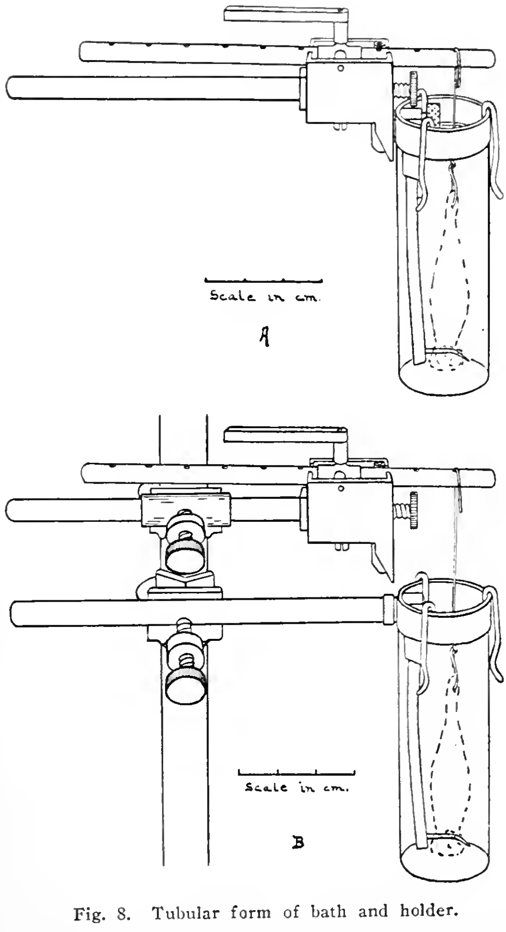

Fig. 8. Tubular form of bath and holder.

A. Holder mounted on myograph frame.
B. Holder mounted on support rod.

constructed. It consists of an open brass ring attached to a support rod and equipped with three spring fingers for holding the dish, spaced at equi-distant points of its circumference. The ring also acts as a spring owing to the fact that it is not closed. The dish is firmly held in position so that the holder may be inverted without the dish becoming displaced. When inverted, *i. e.*, when the spring prongs are directed downward, it serves as a ring support for a beaker in such experiments as require changing the temperature of the solution.

The bath renders a moist chamber unnecessary in most experiments as all of the tissues may be instantly submerged in or removed from blood or salt solutions by simply raising or lowering the dish. The large surface of liquid exposed favors gaseous exchange between the air and liquid. The tissue may be stimulated while submerged in the bath or while exposed to the air, as desired. In the latter case, undue drying is prevented by raising the bath at intervals to submerge the tissues.

A tubular form of bath and holder is shown in Fig. 8. The tissue is attached to a fixed point carried by the holder and to the posterior arm of the lever. Wire is used for attaching the tissue to the lever. After the tissue is mounted the bath tube is adjusted from below upwards and is held in place by the spring prongs. The tissue may be electrically stimulated by connecting one electrode wire to the myograph frame and the other to the bath holder.

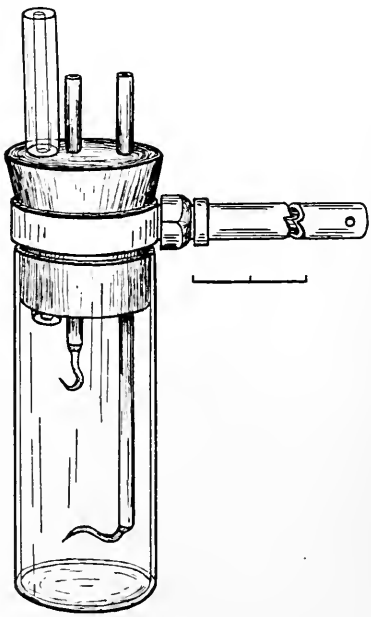

Fig. 9. Volume tube.

The chief advantage of this method is that less liquid is required to submerge the tissue than in the regular form of dish, so it is recommended only in experiments where the quantity of bath liquid is restricted, as in the case of expensive drugs. The modified form of ordinary bath, Fig. 7, B, requires less liquid than the tubular form. The ordinary form of dish requires from about 25 to 40 cc.; the modified form 5 to 8 cc.; and the tubular form 8 to 15 cc. of liquid.

MUSCLE VOLUME TUBE

A modified form of tubular bath shown in Fig. 9 serves as a muscle volume tube.

WEIGHTS

The weights are flat metallic rectangles measuring about 25 by 30 mms., Fig. 10, A. A set consists of nine, weighing ten grams each, and two, weighing five grams each. Near one extremity they are pierced by a hole by means of which they may be hung on a hook suspended from the lever, Fig. 10, B. The hook is of such dimensions and shape that the other parts of the apparatus do not interfere with the placing or removal of the weights, Fig 11. It weighs one gram. At its point of contact with the lever it is pierced with a pin by means of which it is fixed on any point on the lever pierced by the perpendicular holes occurring at one centimeter intervals. The attachment is such that the hook is free to swing with the up and down excursions of the lever.

Also a weight pan is provided for supporting the weights on the lever, Fig. 10, C. It is made of sheet metal, consisting of a base and two sides. It is of such size that the weights lie flat and fit snugly, but do not bind. At one end, the walls are bent inward slightly so that the weights cannot pass through. When adjusted to the lever, the narrow end is away from the experimenter and the pan is tilted so that the bottom slopes slightly to this end. This is to avoid displacement of the weights by the jar that occurs when the muscle relaxes. The pan is attached to the horizontal arm of the lever by means of a saddle through the middle of which a spring point, slightly longer than the diameter of the horizontal tube, projects. This point is inserted into one of the perpendicular holes piercing the lever, and when the saddle is placed in contact with the lever, the point, by virtue of its spring quality, binds it firmly into place. The pan weighs ten grams.

The forward arm of the horizontal lever being longer than the backward arm, the lever itself serves as a load to the muscle. The recording extension adds to this load. As ordinarily employed, the load amounts to two or three grams, when the muscle is attached five centimeters from the fulcrum. This being the case, in most experi-

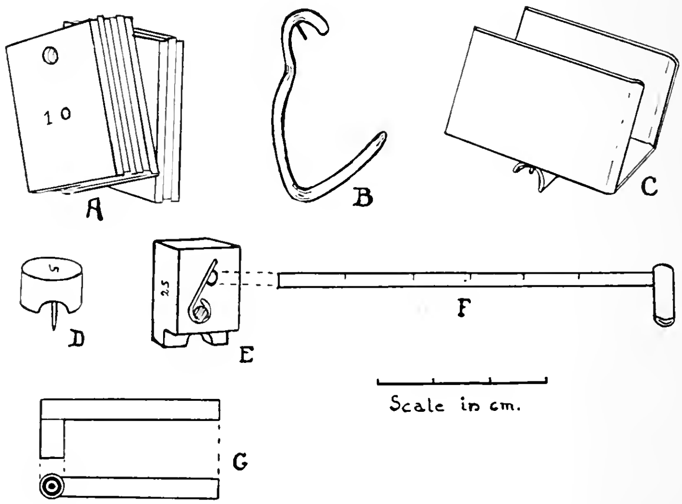

Fig. 10. Myograph attachments.

A. Weights.
B. Weight hook.
C. Weight pan.
D, E, and F. Special weights.
G. Counterpoise weight showing end-thrust socket.

ments, no additional load is required. However, two special forms of weights are sometimes found useful. One of these is very simple, consisting of a five-gram weight with a saddle and point arrangement for attaching it to the lever, Fig. 10, D. The other weight is of a sliding type, Fig. 10, E. It is supported in part by a saddle groove which rides on a horizontal lever, but chiefly by a horizontal arm, Fig. 10, F, carried about one centimeter above but parallel with the horizontal lever arm. The weight is attached to the horizontal arm by passing the arm through a hole which pierces it. The arm is encircled at centimeter intervals by shallow grooves, and to one face of the weight is attached a round straight spring which presses into the grooves, by means of which it is readily fixed at any point on the arm. The horizontal weight is attached to the end of the perpendicular arm socket which pierces the horizontal lever. Connection is made by a double friction thrust joint which secures it very firmly yet permits of instant adjustment or removal, Fig. 10, G. The weight is 25 grams and the weight arm adds one gram to the load of the lever. The horizontal arm may be directed in any horizontal direction, and thus serves as a

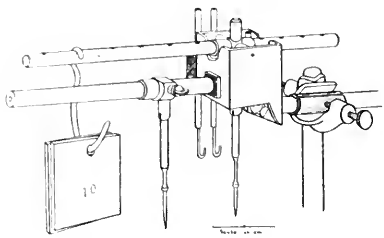

Fig. 11. Myograph with pivoted hook weight support.

counterpoise which may be desirable when very delicate tissues are used. It is particularly useful when the lever is used for recording the contractions of the hearts of small frogs, as by simply rotating it, the load is instantly and delicately adjusted.

Ergograph

The ergograph attachments consist of a coil spring, pulley, cord, and finger loop and cord holder for attaching to the myograph, Fig. 12. An L rod serves as the hand holder. The apparatus is assembled as shown in the figure. It is very easily adjusted through a wide range for tension, etc.

Gas Chamber Electrodes

This electrode accessory is designed for studying the effect of gases and volatile substances upon the irritability and conductivity of nerve. It consists of a short cylinder of hard rubber containing a longitudinal cavity, Fig. 13. It is supported on a tube. The tube communicates with the cavity and further serves for the introduction of gas. The wall of the chamber is transversely slit at right angles to the support from above downward, through about four-fifths of its extent, which provides a means for extending the nerve across the cavity. The top of the cavity and the greater part of the transverse slit are closed by a metal cap bearing a wide flange to hold it in place. The electrode points are placed horizontally in the cavity at a level slightly higher than the bottom of the transverse groove. The points are set at right angles to the holders which, therefore, are perpendicular. The holders are set firmly in the rubber, and their upper free ends serve to connect the wires from the coil or battery.

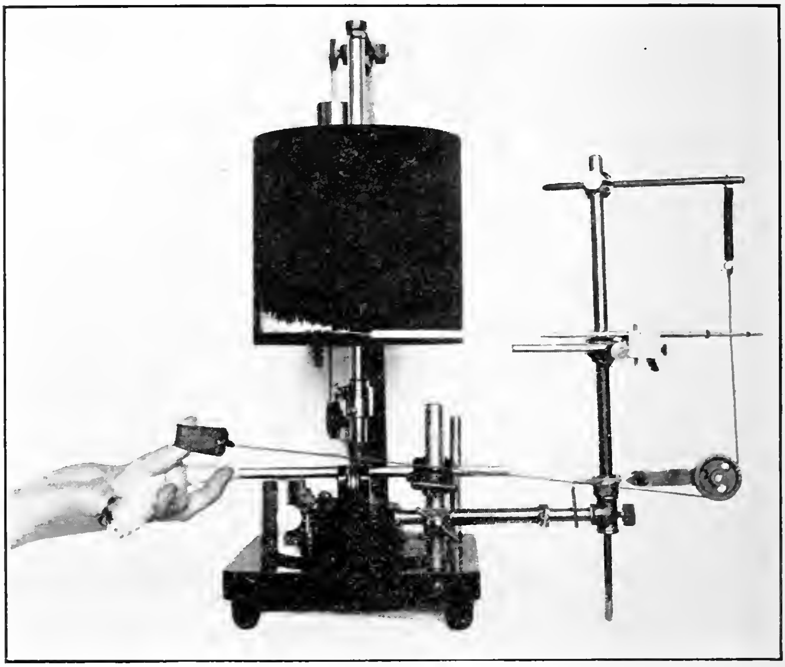

Fig. 12. Myograph with ergograph attachments.

The dimensions are such that the electrode may be adjusted to the nerve between the point of contact of the nerve on the myograph nerve electrode and the entrance of the nerve into the muscle without removing the bath from the preparation. It may be lowered so that the nerve is submerged in the bath. This is an advantage in long experiments in preventing undue drying, and also in removing any substance to which the nerve may have been exposed. During the time of passage of the gas, the electrode is raised until the bottom is free of the surface of the bath solution.

Usually observations upon both excitability and conductivity are made, Fig. 14. The stimulating current is switched at will from the gas chamber electrode to the myograph nerve electrode by means of the combined primary and secondary key, Fig. 38.

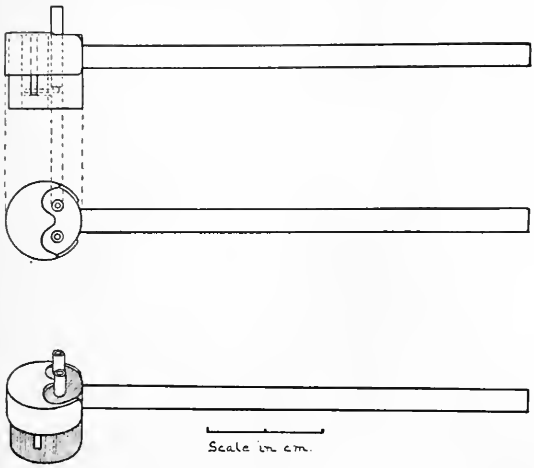

Fig. 13. Gas chamber electrodes.

Among the advantages of this form of gas electrodes is the ease and rapidity with which the nerve may be attached or disconnected from it without injury.

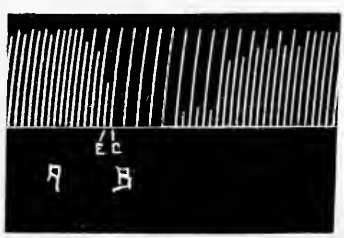

Fig. 14. Effect of ether vapor on conductivity and excitability of nerve.

A. Vapor applied.
B. Vapor removed.
C. Response to stimulation of nerve central to gas chamber.
E. Response to stimulation of nerve in gas chamber.

The gas is passed into the support tube and thus into the chamber, by a rubber tube slipped over its outer end, the other end being connected with the generator or source of supply. For chloroform, ether, alcohol, ammonia, and the like, *i. e.*, volatile liquids or solutions of gases, the substance is placed in a small glass bottle or other suitable container, and, if necessary, volatilization is accelerated by placing the container in a vessel of water, the temperature of which can be varied.

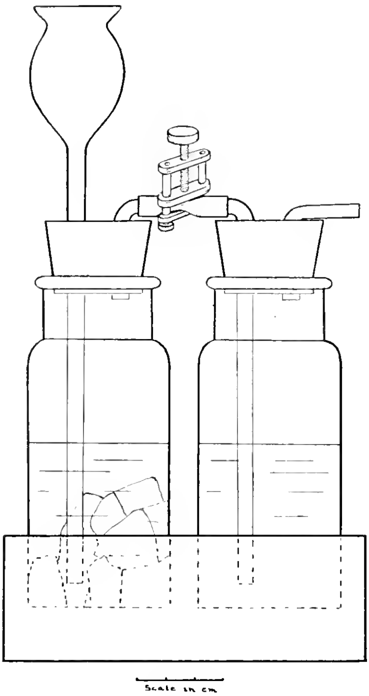

Fig. 15. Generator.

For studying the effect of gases, as carbon dioxide, a compact form of generator is provided, the parts of which are substantially mounted on a base for convenience in handling and storing, Fig. 15.

THERMAL ELECTRODES

The thermal electrodes consist of a brass box which is closed excepting for an inflow and outflow tube mounted on the back, Fig. 16. The outflow tube is left sufficiently long to serve also as a support by attaching it to a clamp. Temperature change is effected by circulating warm or cold solutions through the cavity by means of rubber tubes attached to the inflow and outflow tubes and to a reservoir, and a vessel for receiving the outflow.

A brass tube is soldered to one side of the box. The lower end is closed. Salt solution is placed in the tube and into this the bulb of a thermometer is inserted. It adequately holds and supports the thermometer since its position is perpendicular, and in diameter it is only

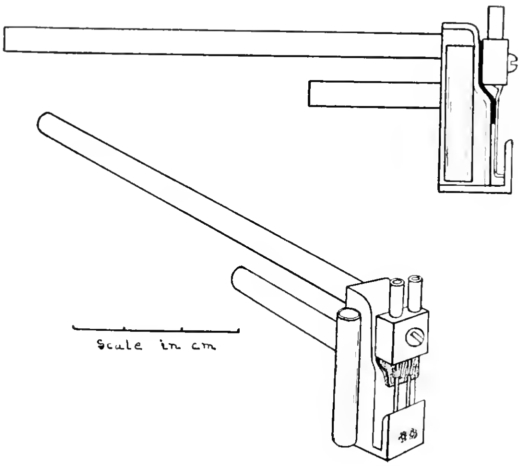

Fig. 16. Thermal electrodes.

slightly larger than the thermometer bulb. The salt solution placed in the tube forms a thin layer around the walls owing to its displacement by the thermometer and therefore its temperature quickly follows any change in temperature of the metal. And since the temperature of the metal closely follows the temperature of the solution circulating in the box, the thermometer indicates very nearly the temperature of the apparatus. The bottom of the box extends outward for a short distance beyond the front surface and then bends upward at a right angle and terminates at a distance of about one centimeter from the bottom. Thus, a broad slit bounded on three sides by metallic surfaces is formed at the lower margin of the front of the box. A pair of electrodes is fastened to the upper part of the front of the box, from which they are insulated, and extend downward. The points are insulated from the front of the box adequately to prevent shortcircuiting. Near the points and near the bottom of the groove through which they extend they are bent forward at right angles and are firmly attached by non-conducting material in holes in the perpendicular portion of the lip.

In use, the nerve is carried downward into the slot until it rests upon the electrodes. The slot is then filled with salt solution, the greater part of which it retains through capillarity. Thus that portion of the nerve resting upon the electrodes is surrounded by salt solution, the temperature of which must closely follow temperature changes as indicated by the thermometer, for relative to its mass, a large area of the surface of the salt solution is in direct contact with the metal of the box and lip.

The design and dimensions of the thermal electrode are such that it may be readily adjusted to the nerve without removing the nerve from the myograph electrode or lowering the bath. When it is desired to produce a change in temperature, the thermal electrode is raised until it is free of the surface of the bath solution; or the same end is accomplished by lowering the bath.

To lower or raise the temperature, cold or hot brine is circulated through the cooling chamber.

This form of thermal electrode presents a ready means of studying the effect of temperature and with the expenditure of but little time. In addition, the temperature is under adequate control and wide fluctuations can be produced at will.

CARDIOGRAPH

Isolated heart muscle is studied by attaching it to the fixed and movable points of the myograph. The base of the auricles is transfixed on the stationary point, and the apex of the ventricle on the movable point. Or the heart may be transfixed at the auricular-ventricular junction by the fixed point and either the apex of the ventricle or the base of the auricle transfixed by the movable point. Or the auricles and ventricles may be separately attached to the points. Tracings taken by this method are shown in Fig. 17, B and C. In the same way strips of heart tissue are attached to the points and studied.

The heart may be studied *in situ* in much the same way. After removing the anterior wall of the chest, the animal is brought upward in such a position that the points transfix the heart. By using longer points the lever may be adjusted to the heart of a cat or dog. Two levers may be attached to one heart and both auricular and ventricular contractions separately and coincidently recorded.

The lever is also adapted to studying the heart *in situ* by the suspension method. See tracing, Fig. 17, A. For this purpose the points and electrodes may be removed. The posterior support rod is removed

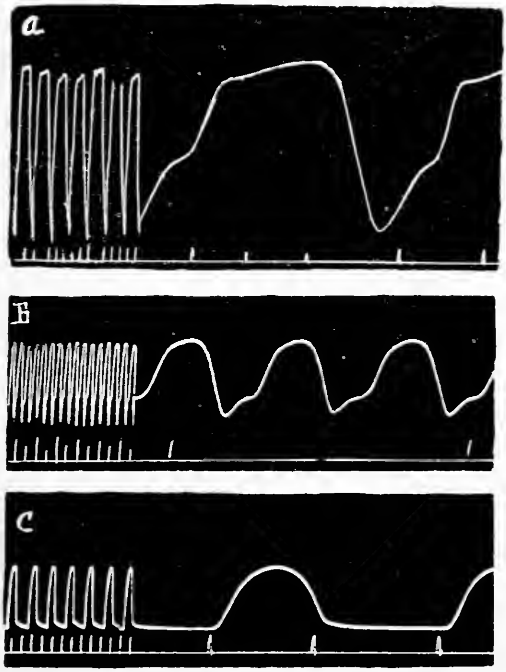

Fig. 17. Heart tracings from a 31.5 gm. frog.
A. By suspension method with regular myograph.
B. Heart isolated and auricles and ventricle attached to points of myograph.
C. Ventricle only attached to points of myograph.

and attached to the far side of the frame. Or it may be removed and the lever held by clamping the anterior support rod. The animal is placed beneath the lever and a thread attached to the apex of the ventricle or auricles is carried upward and fastened about the posterior (horizontal) arm of the lever. A holder is provided for fastening the thread. By thus employing two levers at the same time, both auricular and ventricular contractions may be recorded. This method is especially useful for turtles.

For studying the frog's heart *in situ,* a pad and support method is convenient and effective, Fig. 18. The heart is supported on a metallic finger or spoon rest which is connected through an insulation block to the frame above by means of a screw passed through the posterior support rod socket. The pad consists of a small disk of cork (which may be cut from the end of a stopper) attached to the movable point

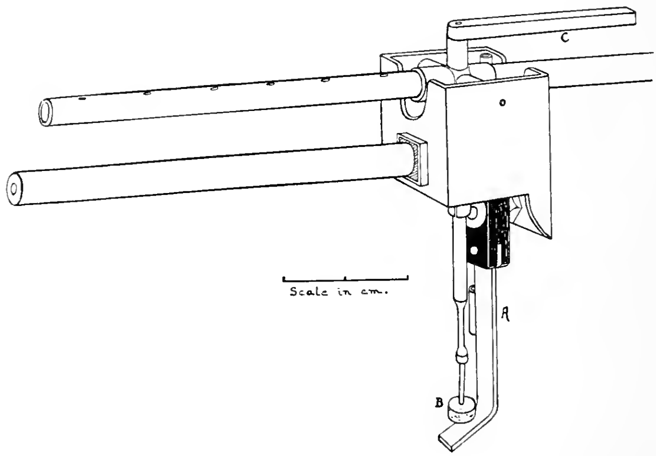

Fig. 18. Myograph arranged for studying frog's heart *in situ.*

A. Insulated heart support. Note tubular socket on side of strip for the electrode connection.
B. Cork pad on tissue point for transmitting movement of heart.
C. Counterpoise weight.

by transfixing it near the center. The point emerges from the lower surface of the disk so that it slightly penetrates the tissue and thus serves to prevent horizontal movement between the pad and the heart. The frog is supported on a board clamped to the stand support rod below the lever, Fig. 19. By a slight movement of either the lever or frog board the heart may be instantly adjusted to or removed from the lever.

In all the above experiments where delicacy of poise of the lever is an essential requirement, this may be instantly carried out by means of the right angle weight support bar, or special right angle counterpoise provided for the purpose, Fig. 10, G. Attachment between the weight and the lever is made by means of a double end-thrust contact between the socket on the weight and the tubular cup provided on the top surface of the lever on a perpendicular line through the fulcrum.

It is easy to obtain the desired adjustment of load by rotating the weight horizontally.

To stimulate the heart directly, in the pad and rest method of attachment, an electrical contact tube is provided on the metal portion of the rest, and for the other contact the tube on the frame is employed. Thus an electrical current may be transmitted between the movable point and the rest through the heart tissue placed between them.

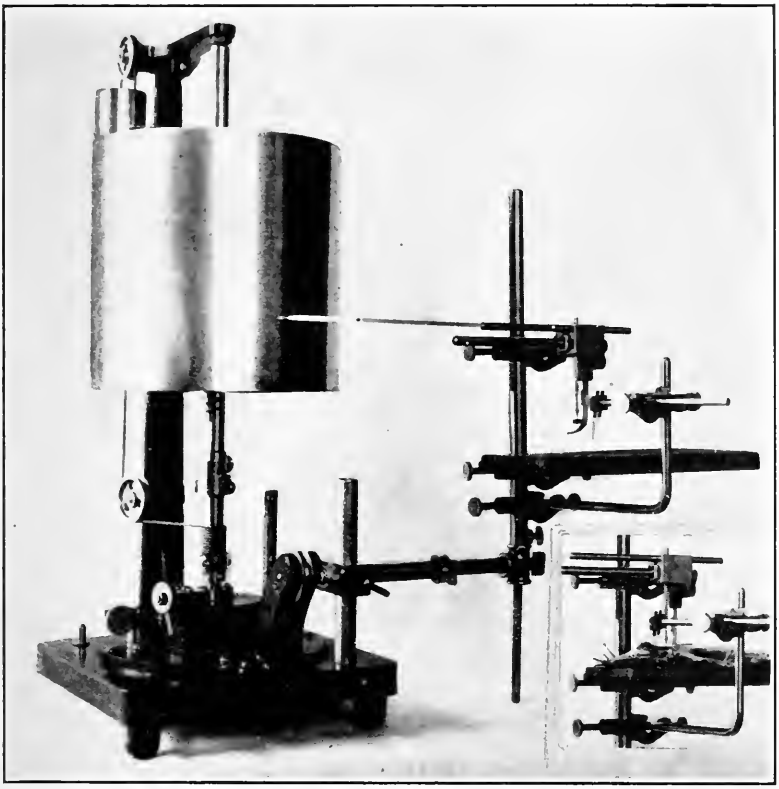

Fig. 19. Myograph arranged as frog cardiograph and mounted with frog board and detachable electrodes. Insert shows adjustment to frog.

SIMPLE ELECTRODES

A pair of adjustable, detachable electrodes is shown in Fig. 20. The electrodes consist of a support rod attached to a fibre block into which the electrode point holders are fixed. The points are sufficiently long to render adjustment easy. Near their free extremities they are bent outward at an angle to provide a rest for the nerve. Electrical connection is made by inserting wires into the top ends of the holders. In the experiments on the frog as just described, the electrodes are supported on an L rod, which in turn is clamped to the stand support rod sleeve below the clamp which holds the frog board. Thus it is possible to adjust the electrodes quickly in any position desired, and since they are rigidly supported they maintain a very constant adjustment to the nerve.

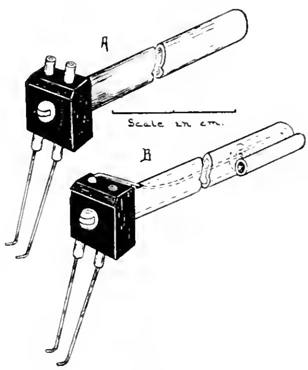

Fig. 20. Adjustable electrodes.

B. Adjustable electrodes with electrical contact surfaces in posterior end of support rod. An insulating collar similar to the one shown in Fig. 2, G, is provided.

This electrode is convenient for use on frogs and turtles, and in certain experiments on mammals. It may be used for stimulating muscle directly, as in the case of the turtle's heart, by lightly placing the lower surfaces of the bent ends against the muscle, in which position it may be held by a clamp attached to a support.

SPECIAL CARDIOGRAPH

A special form of heart lever has been designed for studying the heart by the suspension or the pad and rest method, Fig. 21. It is employed precisely as has been described for the regular lever and presents no points of superiority other than those conferred by the fact that being designed especially, it is somewhat smaller, particularly due to cutting down of the frame, and to the absence of frame accessories. The movable point is not attached at the fulcrum, but one or two centimeters in front of it. Its chief advantage lies in the fact that, due to cutting down of the frame, in the pad and rest method a shorter movable point can be employed and thus a greater magnification secured.

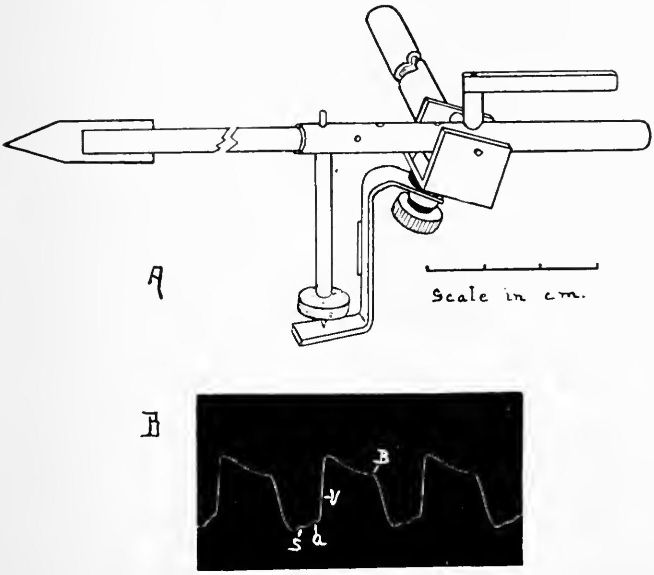

Fig. 21. A. Special cardiograph.
B. Tracing taken with above form of cardiograph.
S. Sinus. A. Auricles. V. Ventricle. B. Bulbus.

Frog Holder—Form I

The frog holder consists of a wooden base topped with a thick pressed cork pad, the two being firmly united by cement and brass brads, Fig. 22. The dimensions are 150 x 100 x 10 mm. To one side 50 mm. from one end a support rod is attached at right angles to the long dimension by means of screws inserted into holes in the broadened end of the rod and turned into the bottom of the board. This serves to support the board on the stand support rod by means of a clamp.

Form II

The adjustable form of holder shown in Fig. 23 is convenient for certain experiments as it permits of a wide range of adjustment. A threaded socket provides for the direct attaching of a support rod for mounting electrodes and a hole near the forward outer corner for microscopical observation of circulation in membranes.

Frogs are fastened to the holder by means of pins, as the method is simple, rapid, efficient—and pins are easily obtained to replace those lost. The holder when assembled is water-proofed by soaking in hot paraffine, so it is easily cleansed by wiping with a moist cloth or sponge

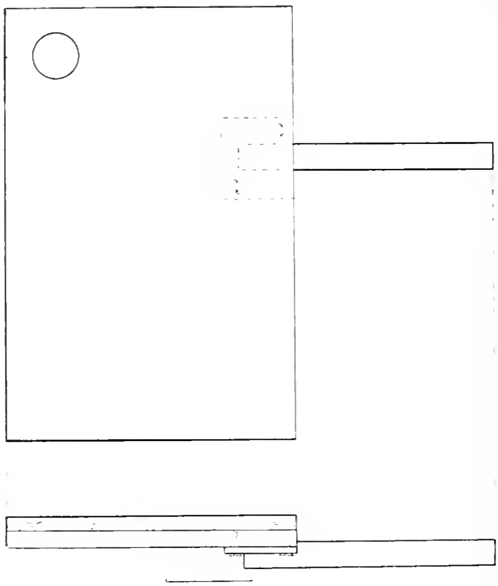

Fig. 22. Frog holder. Form I.

or washing in cold water. Obviously, hot water should not be applied to it. It is sufficiently large for ordinary frogs, and not being cumbersome, takes up but little room. It is readily adjustable to any position desired and being designed especially for use with the myograph, it meets all ordinary requirements. (See Figs. 23a and 23b.)

FORM III

This form of holder, Fig, 24, is particularly useful for graphically recording results in reflex experiments, character and site of action of drugs with the circulation intact, etc. (cf. Am. Jr. Phys., 1910, xxvi, 329). Owing to the ease with which accurate and stable adjustments can be made, and the absolute control of the current, very accurate results are obtained.

The wooden base is screwed to an iron shelf bracket, which is provided with a socket and set screw for attaching to a stand rod. The floor of the base is covered with a cork pad which is boiled in paraffine and laid while the paraffine is melted and pressed until the paraffine sets. The anterior third of the floor has a double thickness

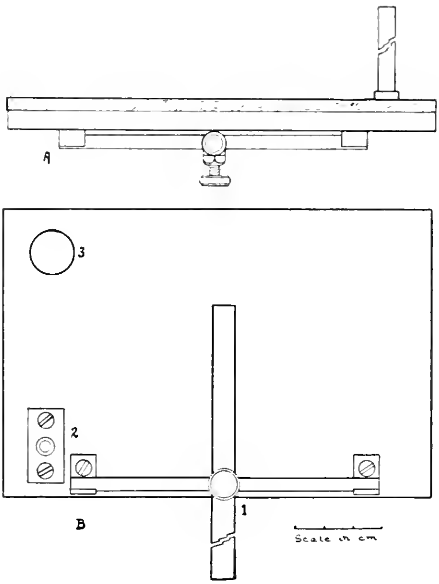

Fig. 23. Adjustable frog holder. Form II.
A. Side view. B. Bottom view.
1. Adjustable support rod.
2. Electrode support rod socket.
3. Hole for microscopical examination of frog's web.

of cork, the posterior edge of which is beveled. Owing to the treatment with paraffine, the floor is water-proof, and, therefore, is easily kept clean. And being of cork, pins may be readily thrust into it to hold the frog.

Three pairs of electrode holders with adjustable electrodes are mounted along either side. The holders are so spaced that the gastrocnemius muscle, sciatic nerve, and fore limb skin or nerves may be stimulated. Or all three pairs may be adjusted to the sciatic, as in studying the local action of reagents on the nerve trunk. A tubular metal container is provided for the electrodes when not in use. A special multiple key and switch serve to control the current to the electrodes. The construction of the key is the same as in the combined primary and secondary cut-out key, switch and commutator, Fig. 38. No unipolar stimulation can occur.

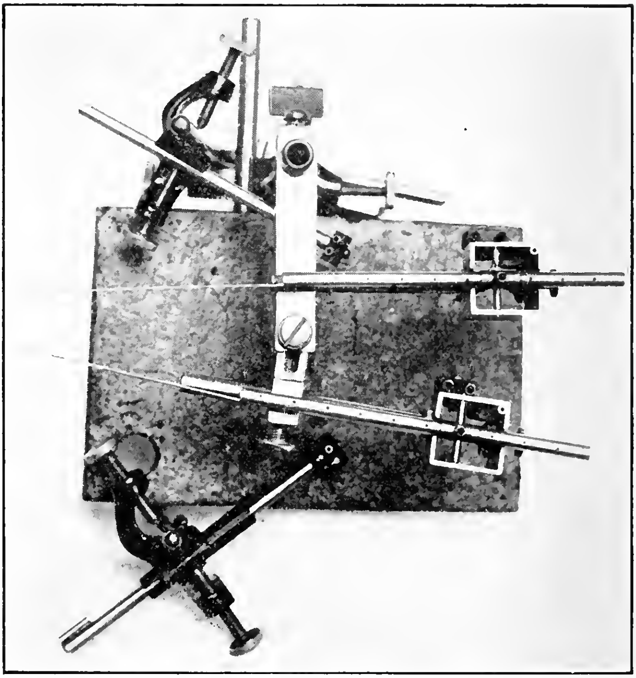

Fig. 23a. Frog holder assembled with special duplex myograph clamp and two myographs and two pairs of electrodes for simultaneous tracings from both gastrocnemius muscles *in situ*. The tendons of the muscles are connected directly to the levers by the tissue points.

TURTLE HOLDER

The holder, which is of wood, consists of a base measuring 200 x 200 x 25 mm., and two rests measuring 45 x 45 x 150 mm. The rests are attached to opposite sides of the base so that their facing surfaces are parallel and about 110 mm. apart, Fig. 25.

The central portions of the upper inner corners are concave for a distance of 110 mm. and a depth of 10 mm. in the middle. The base and rests are finished with a water-proof paint or varnish.

Two metal pins are set obliquely in one end of the base for attaching the head. A nickeled support rod 10 cms. long rising from the forward end of one of the rests provides a means of attaching electrodes, etc.

A terrapin or turtle is mounted by placing it back down upon the holder. It is held in place by pressing with one hand upon the ventral plate. A short hook formed on one end of a steel rod, Fig. 25, D, is then pressed under the "chin" and the head withdrawn and crushed

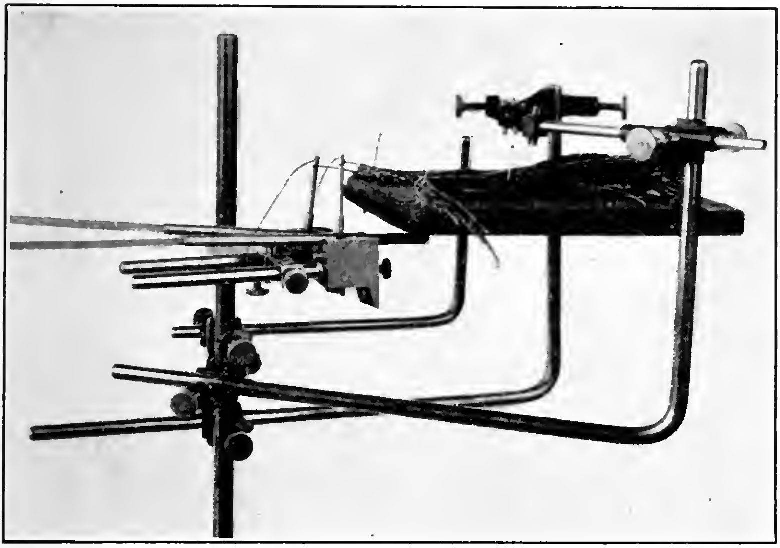

Fig. 23b. Side view of assemblage to illustrate the method of supporting the frog board and electrodes by means of L rods. The board clamp is not shown. All clamps on the main support rod should be atttached to a sleeve for convenience of perpendicular adjustment to the drum. The tendons of the muscles are connected to the myographs by means of threads and special extensions attached to the levers. The electrodes are adjusted to the sciatic nerves. (For sleeve, see Fig. 1 or 16.)

with gas pliers. A piece of wire is then bound tightly about the upper part of the neck to prevent hemorrhage and the pliers removed and the neck placed between the bars of the holder and fastened by means of the ends of the wire. The feet are then fastened to the ends of the rest block with nails. Roofing nails, which are short, thick, and sharp-pointed, are convenient for this purpose. The ventral plate is then removed with a hack saw and knife and any bleeding vessels ligated, when the preparation is ready for use.

Tuning Fork

The tuning fork made by the Harvard Apparatus Company is modified to the extent of slitting one of the ends near one side to facilitate attachment of a writing point, Fig. 26. Made of good quality of paper or of thin celluloid and fastened with sealing wax, the writing points give excellent results and rarely need adjustment.

For starting the fork to vibrate, a block of hard wood, measuring 28 x22 x 23 mm. and equipped on one side with two brass pins 4 mm. in diameter screwed firmly into the block, is used. The pins are set

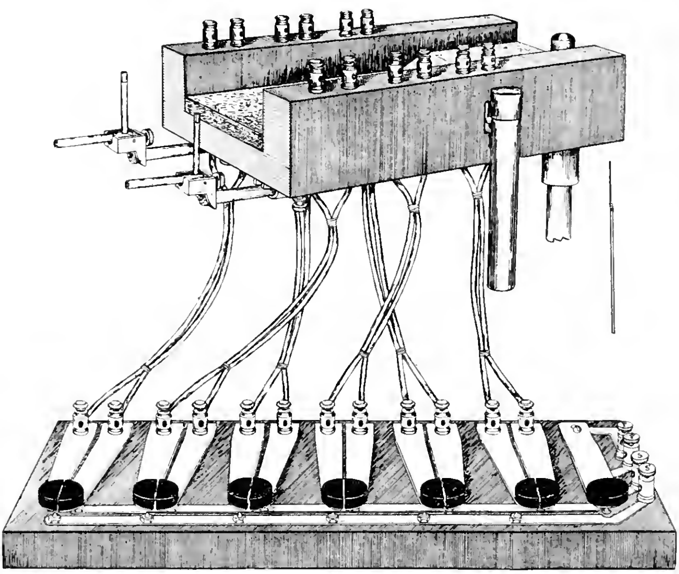

Fig. 24. Compound frog holder, Form III, and key. The frog holder is equipped with two special myographs, but the regular form can be used. The six pairs of binding posts mounted on the holder serve as electrode holders. An electrode is shown in the right of the figure. The cylindrical case attached to the side of the holder is a container for the electrodes when not in use.

On the key the binding posts marked P and P′ are connected in the primary circuit, and S and S′ in the secondary circuit of an induction coil. The battery current may be lead to the tissues by connecting to the posts S and S′.

13 mm. apart. They project 7 mm. from the surface of the block, and their facing sides are filed in a sloping manner so that their nearest point of approach is near their free ends. The appliance is attached to the fork by springing the bars together with one hand and sliding the projecting pins on the block over their outer surfaces from their free ends backward. Owing to the sloping surfaces of the pins they bind on the fork near their points only, and, therefore, they firmly hold to the bars after the hand is removed. To set the fork vibrating,

the block is removed by a turning movement from before backward. The backward edge of the face in contact with the edges of the bars is used as a fulcrum, and the points of the pins are forced to slide from the bars without jar or misplacement of the instrument as a whole.

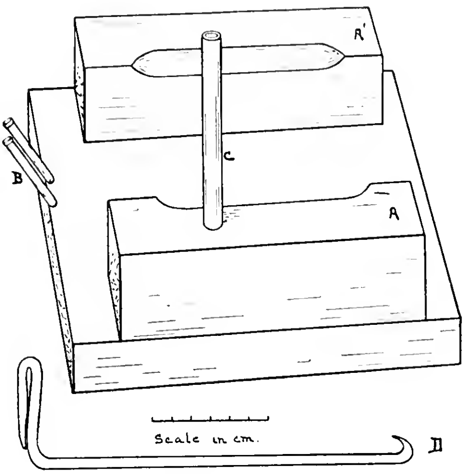

Fig. 25. Turtle holder.

A. and A′. Rests.
B. Head holder.
C. Support rod.
D. Hook for withdrawing head.

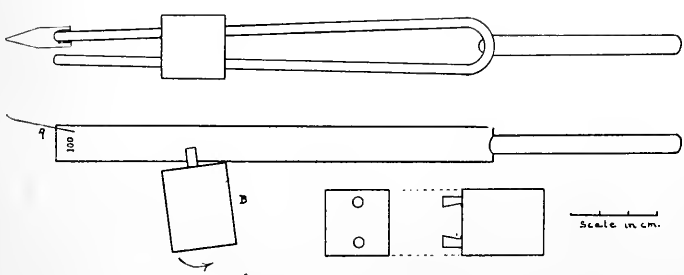

Fig. 26. Tuning fork and starter.

A. Slot in fork for writing point.
B. Method of using starter.
C. Details of construction of starter.

SIGNAL—FORM I

The electro-magnet signal is of compact form, Fig. 27. It measures in greatest diameter 8 mm. and in extreme length 112 mm. An extension holder is provided by means of which the length may be

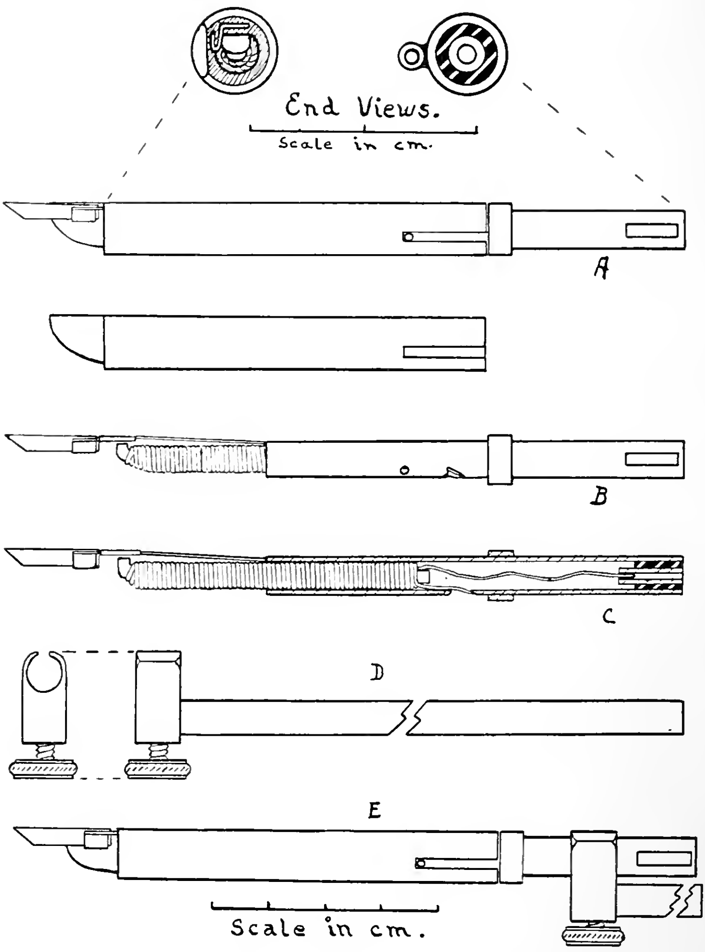

Fig. 27. Electro-magnet signal.

A. External view of signal.
B. Side view, cover removed, showing the magnet and the vibrator.
C. Cross-section.
D. Extension holder.
E. Extension holder attached. (See Fig. 68 for tracing.)

increased 150 mm., which is adequate for all purposes. The magnet is placed horizontally and is enclosed. The vibrator is of the spring type and is mounted parallel with the magnet and is enclosed, excepting its outer end, which receives the recording point. The point is protected by a guard. When not in use, the cover sleeve may be partially withdrawn from the magnet base and thus it serves to guard the recording point from accidental injury. Electrical connection is made by inserting the ends of wires into sockets provided on the posterior end of the rod.

The resistance of the signal is about 0.5 ohm. It works efficiently connected in series with a Porter coil and one ordinary dry cell. It has considerable lag, but it will vibrate efficiently a hundred times or more per second. It has some secondary vibration, but for all ordinary drum speeds this does not introduce a practical disadvantage. See Figs. 52, and 68, C and D.

FORM II

This signal has about 0.0025 second lag. It has very little secondary vibration. It is constructed with a pivot angle magnet bar and point holder controlled by a spring, Fig. 28. In this form the magnet

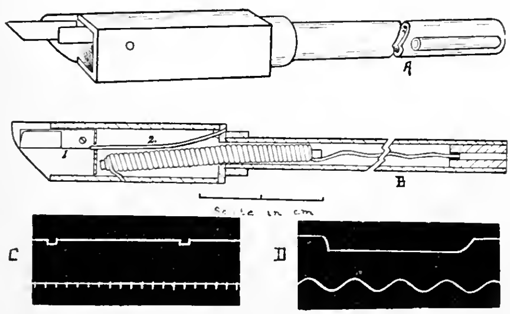

Fig. 28. Signal magnet with right angle form of vibrator.

A. External view.
B. Cross-section. 1. Right angle vibrator. 2. Vibrator spring.
C. Signal recording on slow drum.
D. On fast drum. Lower tracing is tuning fork at 100 DV per second.

cover is square and measures 9.5 x 35 mm. The support arm is round and measures 6.5 x 80 mm. As in the other form, an extension is provided. The magnet is mounted as in the other form of signal and the resistance and method of making electrical connections are the same. See also Fig. 68, A and B.

DRUM KEY—FORM I

This key, Fig. 29, consists essentially of a fixed and an adjustable contact point, A and B, in connection with the binding post, P, between which a movable arm, C, in connection with another binding post, P′, is placed in such a manner that when it is swung through part of an arc its contact surface engages successively with the contact surfaces of A and B, thus opening or closing the primary circuit. The key is used by clamping it to a stand in such a position that the free end of

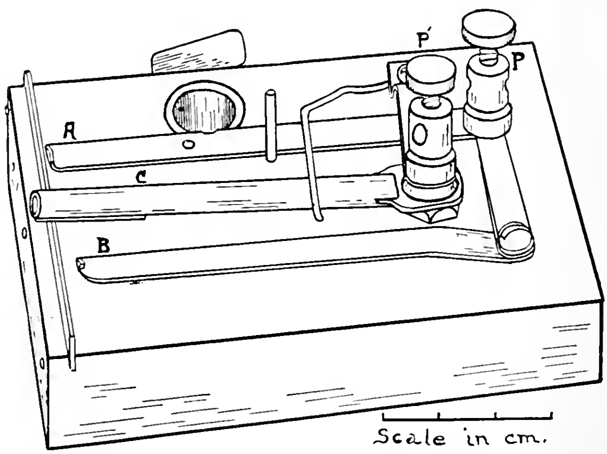

Fig. 29. Drum key, Form I. It is connected in the primary circuit and a stop on the drum acting upon the swinging bar C opens the contact with A and B. (cf. Fig. 1.)

the swinging arm, C, is acted upon by a suitable catch adjusted to a drum for that purpose (cf. Figs. 1 and 59). The key may be used for throwing in a single break shock; or by adjusting it so that the swinging arm engages with both contact points two successive stimuli may be thrown in, the interval between the stimuli depending upon the distance between the two contact points of the arms A and B and upon the rate of the drum. Closing currents from the secondary coil are reduced to sub-threshold magnitude by separating the primary and secondary coils. Though such interpolated sub-threshold stimuli introduce no practical difficulties, the key is not perfect. But it is practical and satisfactory for ordinary student use.

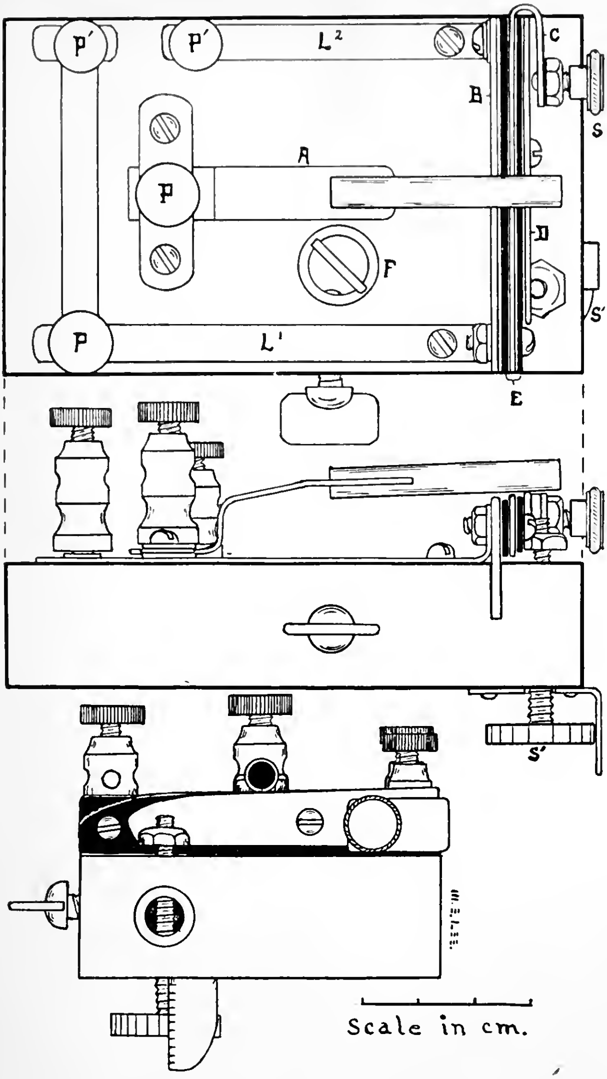

Fig. 30. Drum key, Form II.

P, P. Battery posts. P′, P′. Rheocord posts.

A. Swinging contact arm. It engages with the bars B, C, and D.

B. Bar for contact *without* rheocord. It connects with circuit only through L^1 and swinging contact arm.

C. Bar for contact *with* rheocord. It connects with circuit through L^2 and swinging contact arm. Also, contact may be made with the bar D by means of the screw S.

D. Bar for breaking circuit or reducing current. The time of circuit breaking is controlled by the calibrated screw S′.

E. Insulation.

F. Socket for attaching the key to its support on the drum base. The cross bar fits into a slot in the support and the set screw binds it rigidly in place.

(Tracings taken with this key are shown in Figs. 33 and 34.)

FORM II

The form of key shown in Fig. 30 is more nearly perfect both practically and theoretically, but it is somewhat more complicated. In this key the current is suddenly reduced from maximum to 50 per cent (or less), which causes the first shock, and from 50 per cent (or

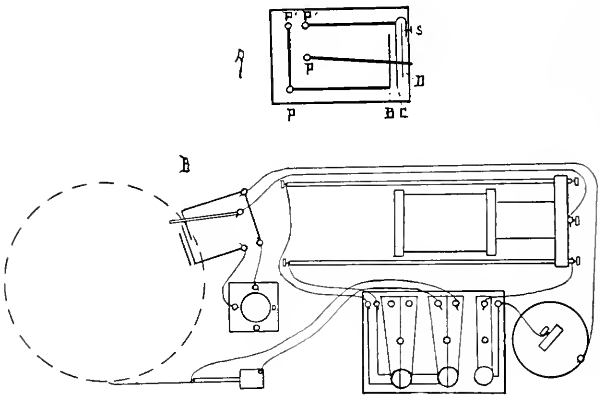

Fig. 31. Diagram of key, Form II.
A. Diagram showing circuits through key.
B. Diagram to show wiring with other apparatus.

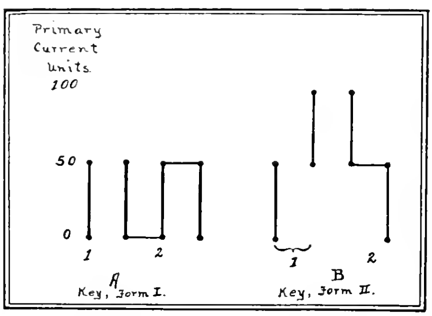

Fig. 32. Diagram of primary circuit change with the two forms of drum keys described.
1. When used for one stimulus.
2. When used for two stimuli.

less) to zero for the second shock, Fig. 32. The continuous sliding contacts are very efficient and all adjustments are simple and easily made. The resistance is adjusted with a rheocord, Figs. 31 and 35. In a special form of the key a rheocord may be mounted in the base.

The contact bars are strongly mounted and insulated. Contact is controlled by a screw having a large calibrated head. The key may be instantly adjusted for single shocks or two shocks separated by varying intervals. The interval between the shocks may be made very slight. Figs. 33 and 34 are tracings obtained with this key.

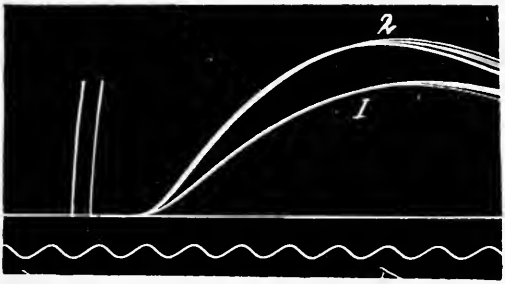

Fig 33. This tracing (summation of stimuli) indicates the accuracy of the key and constancy of the drum speed as five tracings were superposed with both one and two stimuli.

Combined Rheocord and Bridge
Form I

The instrument is of compact form, Fig. 35. The base is square and measures 90 x 90 mm. The total height is about 90 mm. It is of rotating type. The resistance is Mangan wire. It is wrapped in spiral grooves turned in a hard rubber hollow core. There are 30 turns of wire. The total resistance is 6 ohms. The lower end of the wire is attached to a binding post, which is designated zero. The upper end is carried to the base through a thick copper connection and connects with a post designated 100. The sliding contact is of spring brass and is attached to the inside of the cap, Fig. 36. The cap rotates upon a threaded rod which is solidly attached in the center of the inside of the top. The threads of the rod engage with the threads of a brass socket attached to the upper end of the rubber core. The thread of the rod and socket is of the same dimension as the thread of the rubber core into which the resistance wire is wound. Therefore, when the cap is rotated the slider very accurately follows the resistance wire. A thick brass connection unites the threaded socket with a post on the base designated S. The upper rim of the cap is milled to facilitate rotation. Around the lower margin the cap is calibrated in 20 equal divisions. A post is mounted on the base perpendicularly so that it extends upward closely along side of the cap. It carries 30 transverse calibrations, which are spaced according to the distance between the turns of resistance wire. The calibrations are numbered from below

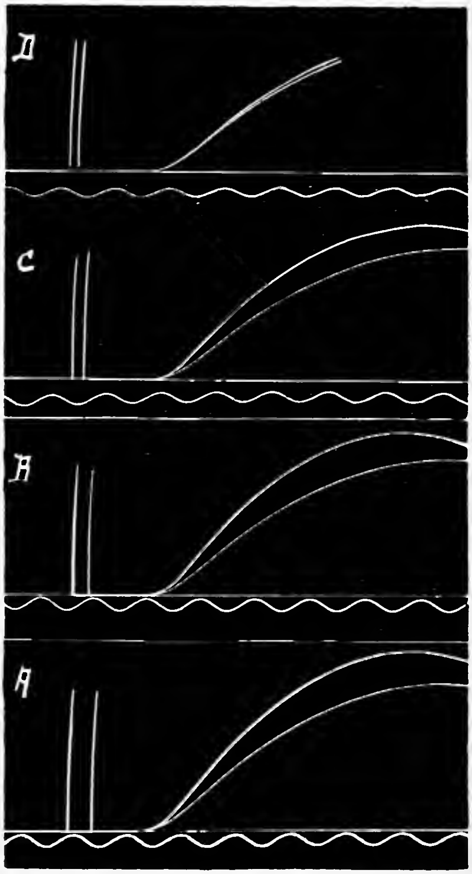

Fig. 34. Summation of stimuli by muscle and refractory period. The interval between the stimuli was progressively shortened so that finally (D) the second stimulus fell within the refractory period. Key II. employed.

upward by fives from 0 to 30. Readings are taken from the lower edge of the cap and indicate directly the number of turns of resistance wire between zero and the slider, while the calibrations around the lower end of the cap are read off against the edge of the post and indicate the fractions of turns of wire. The readings indicate directly the actual resistance. Since the 30 turns of wire have a resistance of 6 ohms, each turn has a resistance of .20 ohms, and as there are 20 divisions on the cap each division on the cap represents .01 ohm. For

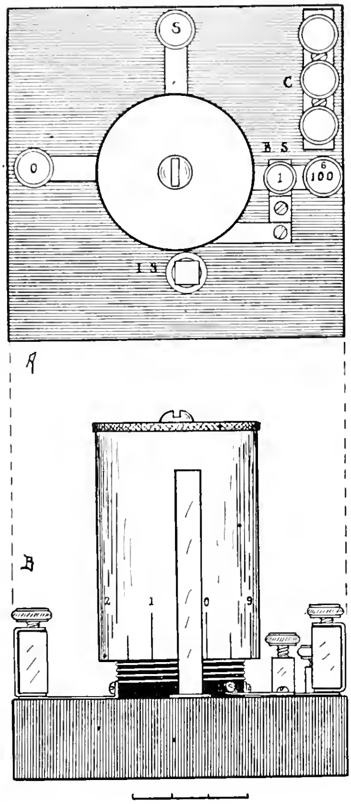

Fig. 35. Combined rheocord and bridge, Form I.

A. Top view.
B. Side view.
The post marked 0 is connected with the zero end of the wire and the post marked 100 connects with the other end of the wire.
S. Slider post.
B. S. Bridge switch.
C. Triple connector.
I. S. Indicator standard.

example, a reading of 4 turns and 7 cap divisions would be 4 x .20 ohms equals .80 ohms plus .07 ohms equals .87 ohms.

The screw designated BS is used as a bridge switch. When it is turned down it engages with the thick brass connection attached to the resistance wire 5 turns above the zero end. Thus a shorter length of wire may be used as in taking telephone readings in conductivity measurements which is advantageous as a change in sound may be appreciated more sharply. A triple connector block is mounted upon the base for convenience as in resistance measurements.

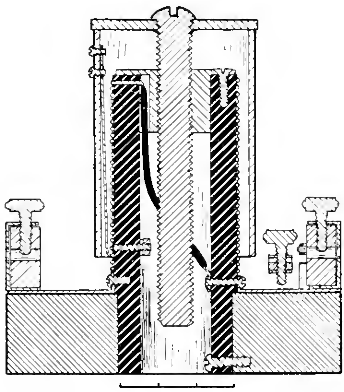

Fig. 36. Combined rheocord and bridge, Form I. Cross-section.

FORM II

In a special form additional known resistance is provided by mounting coils in the base and providing suitable connections, Fig. 37.

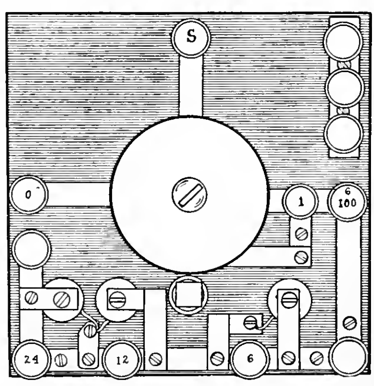

Fig. 37. Combined rheocord and bridge, Form II. Extra resistance is added by mounting coils in the base and providing suitable connections. It may be used independently.

Thus resistance up to 48 ohms may be used. The additional resistance consisting of 42 ohms is so mounted that it may be used independently of the slider resistance in multiples of 6 ohms.

The construction is rugged. There are no loose parts. The sliding contact is constantly maintained and is self-cleaning. It is very efficient and requires little or no attention.

COMBINED PRIMARY KEY AND SECONDARY CUT-OUT KEY, SWITCH AND COMMUTATOR

This apparatus is compact and substantially made. The base measures 160 mm. by 110 mm., Fig. 38. There are no concealed wires or connections, all the conductors being flat metal strips mounted on

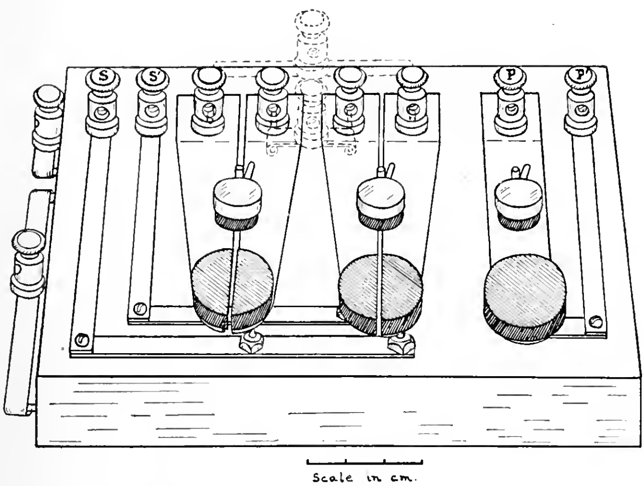

Fig. 38. Combined primary key, secondary cut-out key, switch, and commutator. The commutator attachments as in use are shown by the dotted lines.

P and P'. Primary posts.

S and S'. Secondary posts. S and S' may also be used for battery currents.

the top of the base. Essentially the primary key consists of a movable contact, which is a spring metal strip carrying the finger rest, and a blunt cone-shaped stationary contact point with which the under surface of this strip engages. Platinum or other special contact metals may be applied to the contact surface and point, but for ordinary purposes this is unnecessary, with reasonable care to avoid abuse of the key and if the surfaces are occasionally brightened. Continuous contact may be maintained by means of the screw which pierces the spring strip.

The switch consists of two double spring keys, either of which when closed leads the secondary current from two contact strips connected with the secondary coil to tissue electrodes connected with them. No unipolar stimulating effects can occur as contact with both of the leads from the secondary is broken when the key is released. The contact points are cone shaped and the surfaces the same as in the

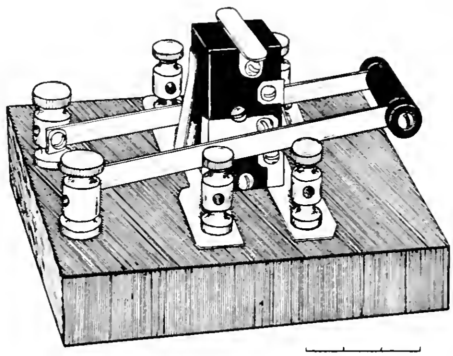

Fig. 39. Special form of universal circuit controller.

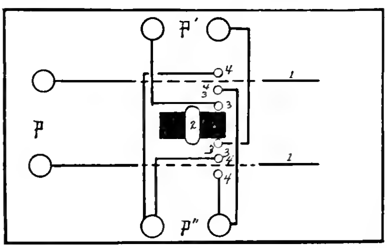

Fig. 40. Diagram of universal circuit controller. P, main current leads; 1, double sliding bar; 2, short-circuiting contact bar; 3, and 3, 4, switch contacts leading the current to posts P′ and P″ respectively; 3, 4 and 4, commutator contacts leading current to posts P″.

primary key. Each key is provided with a screw lock for maintaining contact when desired. When used for single shocks, either closing or opening shocks may be eliminated by closing the secondary keys before or after closing or opening the primary key, as the case may be. By connecting one of the secondary keys to the nerve, and the other to the muscle electrodes of the myograph, Fig. 1, a muscle-nerve preparation may be stimulated directly or indirectly by closing one or the other of the keys.

To use as a commutator, the attachments are connected to the secondary keys as shown in the figure, and the electrodes connected with the attachments. The current is then reversed through the electrodes when one or the other of the pairs of secondary keys is closed. Other currents may, of course, be reversed in the same way by connecting to the secondary lead terminals.

Combined Constant Contact Primary and Automatic Secondary Cut-Out Keys
Form I

This is a spring contact key operated by hand, Fig. 41. It is mounted on a wood base measuring 140 x 63 x 22 mm. P and P′ are binding posts connected with the insulated spring strips, P and P′ which are provided with platinum contacts. The hand, acting on the

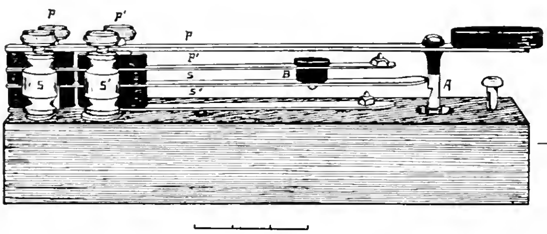

Fig. 41. Form I. Automatic stimulating cut-out key. Hand form.

end of the strip P, brings the contact surfaces of the two springs together, thus closing the primary circuit. Between the springs P′ and S is a bumper of non-conducting material B, so that after the contact between the springs P and P′ is established, the force of the hand is communicated to spring S, which carries it toward the base, thus bringing the platinum plate which it carries in contact with the platinum contact point on the spring S′. The force of the hand continuing to act, the end of the spring S is carried under the notch which serves as a catch, in the arm A, hinged to the base.

The arm passes through a slot in the spring P, and the adjustment is such that when the end of the spring S passes under the notch the arm tilts forward in response to a coil spring set in the base, and the end of the spring comes to lie in the notch. At this time the hand is raised, and the pressure against the springs is released in inverse order to which it was applied. Contact between P and P′ breaks first. Following this, the spring P, acting upon the cone-shaped, insulated upper end of the catch arm, which is tilted forward, thrusts the arm to the perpendicular position, thus releasing S from the catch, thus breaking contact between S and S′. An adjusting screw passes upward through the base and acts upon S′. Either closing or opening shock may be eliminated by reversing primary and secondary connections with the key. The tracing, Fig. 44, A, shows the efficiency of the key both as to constancy of contact and elimination of secondary shocks.

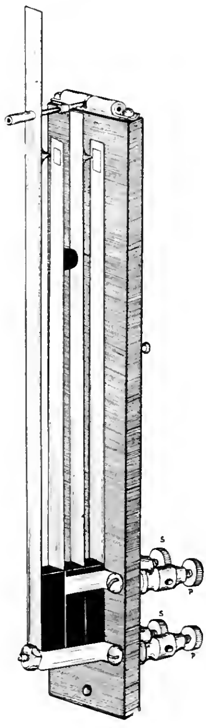

Fig. 42. Form II. Automatic stimulating cut-out key. Pendulum form. Spring contacts.

FORM II

This is a spring contact key operated by pendulum, Fig. 42. The construction is essentially the same as that of Form I. The catch arm is not provided with a spring, as gravity alone is sufficient to insure the proper working of the catch. A pendulum swinging against the projecting free end of the outer spring operates the contacts. Tracing, Fig. 44, B, was taken with this key.

Form III

This is a mercury contact key operated by pendulum, Fig. 43. The contact points P and P″ dip into mercury cups thus closing and opening the contact. Each point is carried upon an axle and each axle

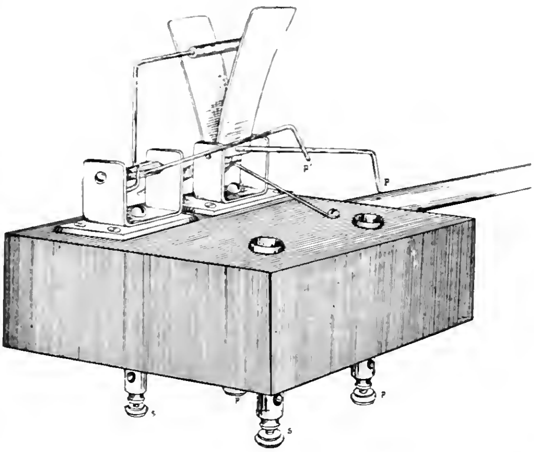

Fig. 43. Form III. Automatic stimulating cut-out key. Pendulum form. Mercury contacts.

is provided with a spring trip. In addition, one axle is provided with a metal V through which it is rocked back and forth by a pendulum. The other axle is equipped with a right angle lever which is acted upon by the inside surfaces of the V. The adjustment is such that one contact is made before the other and in opening the reverse occurs. The key is employed as Form II. Tracing, Fig. 44, C, was taken with this key.

Fig. 45 shows one form of wiring of the above keys and battery, coil and stimulating electrodes. All of these keys are well adapted for use as shown in Fig. 46 in place of the electrical controller.

Multiple Drum Stand

The base is of wood, Fig. 46. Six drum support rods are set into it perpendicularly. They are spaced so that all the drums may be driven from one belt as shown. The support rods are sufficiently tall to permit the attachment of an L support rod below the drum sleeve. Two myographs are mounted on sleeves on each L rod. The myographs are wired in series for direct or indirect stimulation or both.

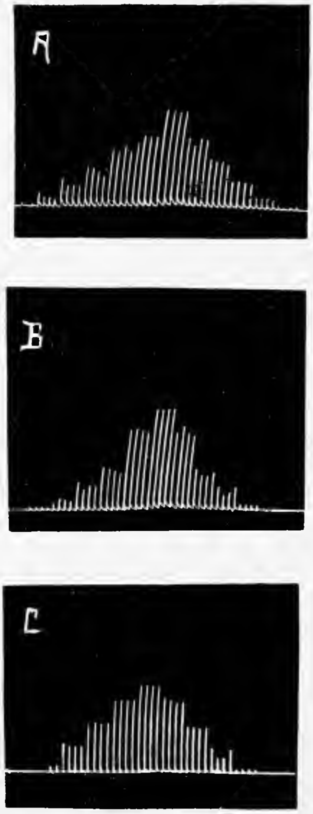

Fig. 44. Tracings taken with automatic cut-out keys. In each instance the current was gradually increased and decreased.

A. Hand form.

B. Pendulum spring form.

C. Pendulum mercury form.

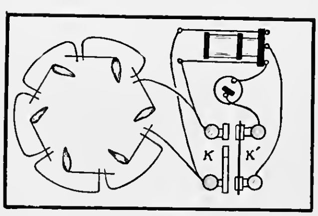

Fig. 45. Diagram of circuits in automatic duplex keys. K and K′, primary and secondary keys. A pendulum closes K′ before K, thus short-circuiting the closing induced current.

K′ is opened before K, thus permitting the opening induced current to flow through the stimulating circuit, in which the tissues are interposed in series.

A drum motor is used for rotating the drums. Any of the three forms of combined constant contact primary and automatic cut-out secondary keys described, or the electrical current controller which is shown in Fig. 70 give satisfactory results. The apparatus is especially adapted for studying the action of solutions. A sample tracing is shown in Fig. 47.

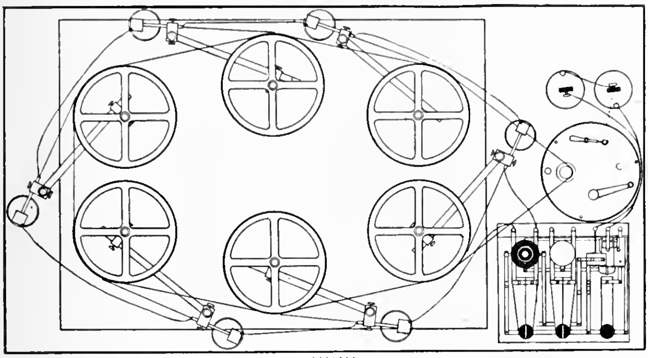

Fig. 46. Multiple drum stand and arrangement of apparatus comprising drums, motor and belt, and myographs. Wired in series with the combined coil and current controllers.

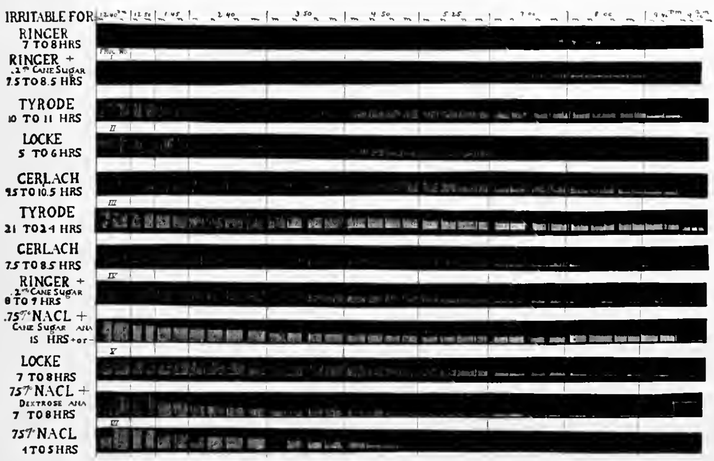

Fig. 47. Tracings from multiple drum assemblage.

Automatic Myograph Key

In principle the key, Figs. 48 and 49, is based upon Stewart's method of automatic stimulation (Stewart, Manual of Physiology, 1914, p. 724). The contact points are platinum, and adjustment is such that the current may be closed or opened at any point of contraction or relaxation of a muscle attached to the myograph. By means of the comb, Fig. 50, horizontal lines are easily run through the tracing and,

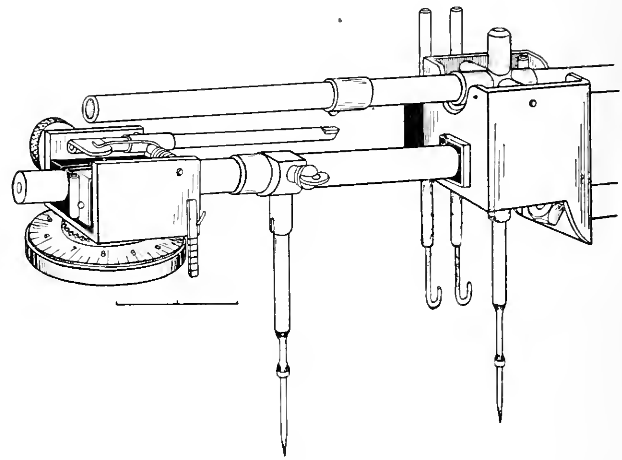

Fig. 48. Automatic myograph key attached to myograph.

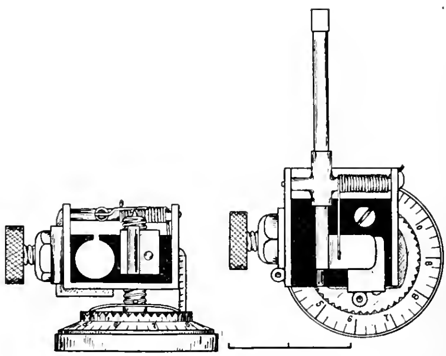

Fig. 49. Automatic myograph key. Top and end views.

since the teeth of the comb are spaced to correspond with the divisions on the head of the screw by means of which the contact is adjusted or set, the instant of closure or opening of the circuit may be determined on the tracing with accuracy and ease. The indicator scale on the screw may be turned independently of the screw and, therefore, may be readily set for zero.

Results of a calibration test are shown in Fig. 51.

The effects of a single stimulus applied to the heart in varying phases of activity by means of the key are shown in Fig. 52.

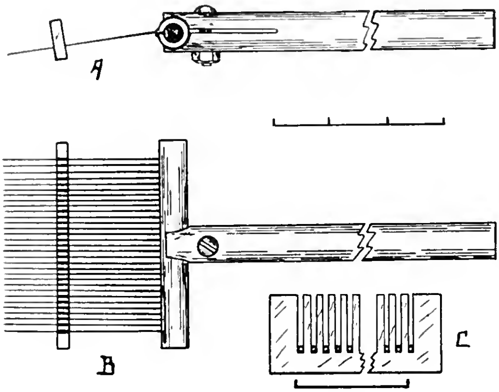

Fig. 50. A and B. Automatic myograph key comb or line-marker. C is a section of the spacer for the points.

Drum Control Stand

The stand serves as a practical and accurate means of rotating uniformly and controlling the drum at fast speeds. Also it serves to unite the drum and apparatus support to a common base, thus assuring optimum conditions for assembling and adjusting recording apparatus. The entire assemblage may be moved without danger of disturbing the adjustments. The writing points of recording instruments are simultaneously removed momentarily or readjusted to the recording surface by swinging the support rod slightly away from or toward the drum. Delicate adjustments are easily and rapidly made.

The stand is provided with a support rod for a hand drum rotator and a drum brake, Fig. 54, for controlling the drum at fast speeds and for attaching the apparatus support stand. Another support rod is provided for holding an automatic drum single and double contact key, which is worked by a combined brake and key pin attached to the under surface of the drum. This support rod further serves for holding other apparatus in certain experiments. A pulley is mounted on the base and a weight and cord, Fig. 57, are employed for rotating the drum at fast speeds. A knot holder is attached to the lower end of the sleeve. The stand is designed for the later Porter recording drum

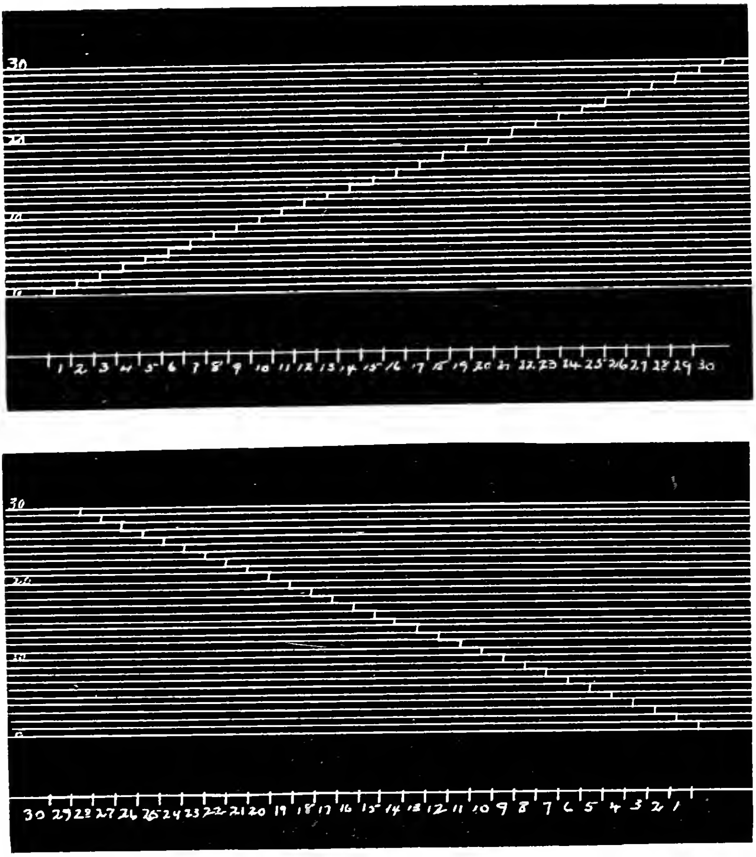

Fig. 51. Calibration test of automatic myograph key. Drum turned with hand rotator. Figures beneath signal tracing indicate screw turns in full divisions.

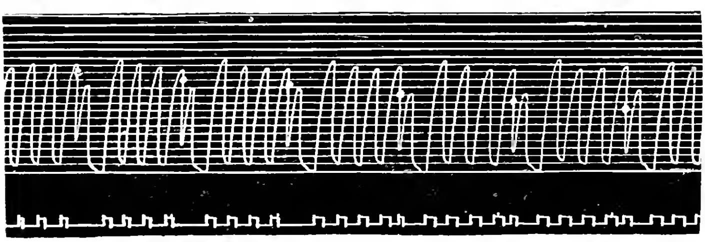

Fig. 52. Heart tracing. Automatic stimulation. Ventricle of turtle's heart. The dots on the tracings indicate the point of stimulation. The signal tracing provides a check on the efficiency of the contact.

models. With the stand and its attachments it is a simple matter and requires but little time to take accurate tracings showing the phases of a simple muscular contraction, summation of stimuli, superposition of contraction, rate of nerve impulse, refractory period, etc.

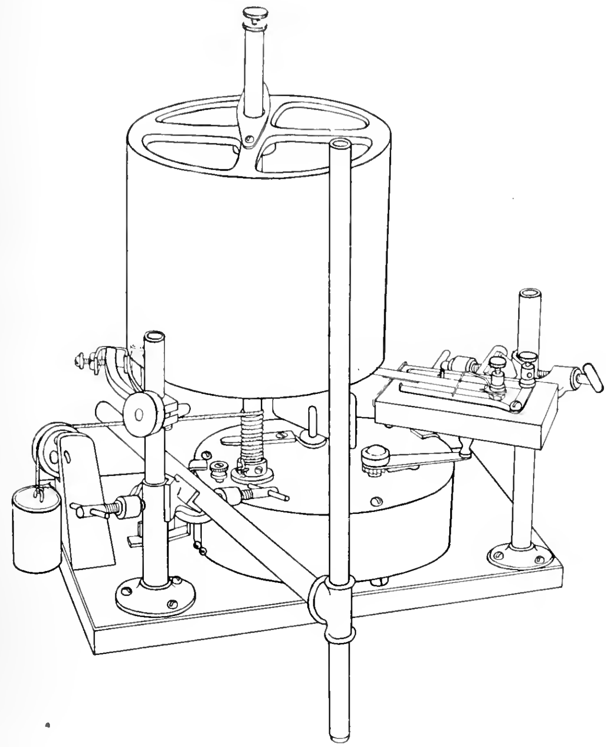

Fig. 53. Drum control stand, Form I.

Form I

The base of the stand is of wood, blackened and wax finished, Fig. 53. It measures 408 x 176 mm. and is 22 mm. thick. The bottom surface is provided with three foot pads. The upper surface is provided with depressions for the foot rests of the kymograph and two attached clamps of nickeled spring brass for holding the kymograph base. At the front margin is the wooden pulley support which is finished like the base. The pulley is nickeled brass. To one side of the pulley support is the support for the apparatus, hand drum rotator, and drum brake, Fig. 54. Behind this at the posterior margin of the base is the key support. Both supports are of heavy nickeled brass tubing screwed into bases of the same material, which in turn are firmly attached to the wooden base by heavy nickeled brass screws.

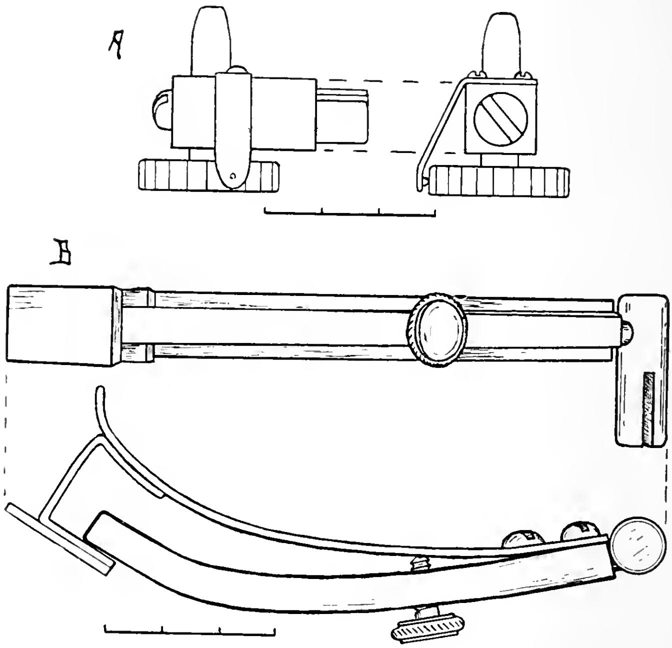

Fig. 54. A. Drum rotator; see also Fig. 71. One division of the rotator moves the drum through one millimeter.
B. Drum brake; see also Figs. 55 and 1.

FORM II

The base is of compact form, Fig. 55. It is made of iron and is given a smooth water-proof finish. It is provided with three leather-soled feet. A rigid arm rises perpendicularly from the back of the base and terminates above in an adjustable hinged extension, which carries a pointed bearing to engage in a bearing socket in the screw on the upper end of the drum sleeve. Thus, support is given to the free end of the spindle, which eliminates excessive vibration when the drum is checked and stopped at fast speeds, especially when heavy weights are employed. The base weighs 8 pounds, and this further serves to eliminate vibration. The pulley, stand and key rod and drum base clamps are nickeled brass. Two additional pulleys may be mounted on the perpendicular arm, one near the base and the other at the top so that it is not necessary for the front pulley to project beyond the edge of the table, but for ordinary purposes the additional pulleys are superfluous.

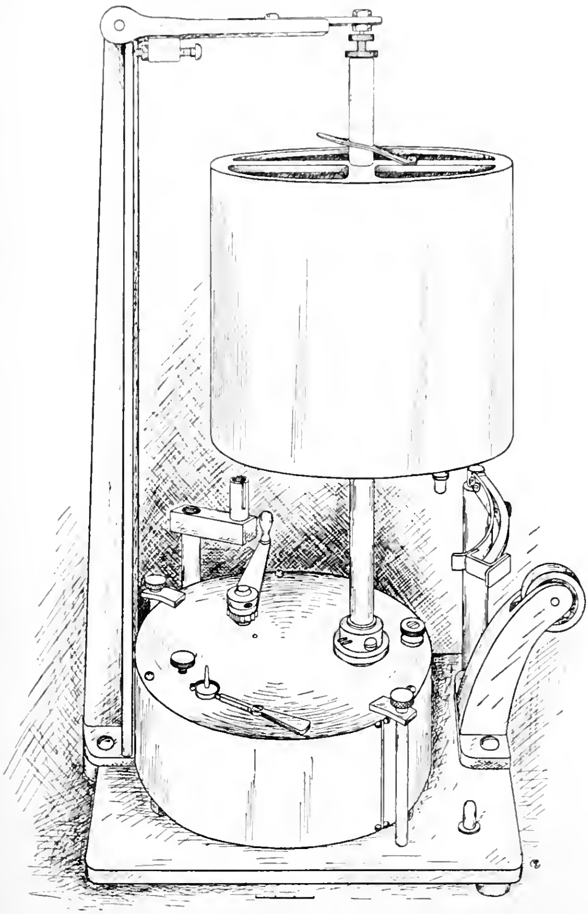

Fig. 55. Drum control stand, Form II.

Recording Drum and Controller

The drum, Fig. 56, is mounted on a substantial cast iron base. It is driven by a weight and cord, Fig. 57. Any speed from a few millimeters per minute to 500 or more per second is easily and quickly attainable. All speeds may be regulated by the weight. In addition, the slower speeds are controlled by a viscosity brake. The spindle and brake pulley comprise a single moving part. The construction throughout is rugged and designed for heavy service. The design is such that little time is required for dismounting, assembling or

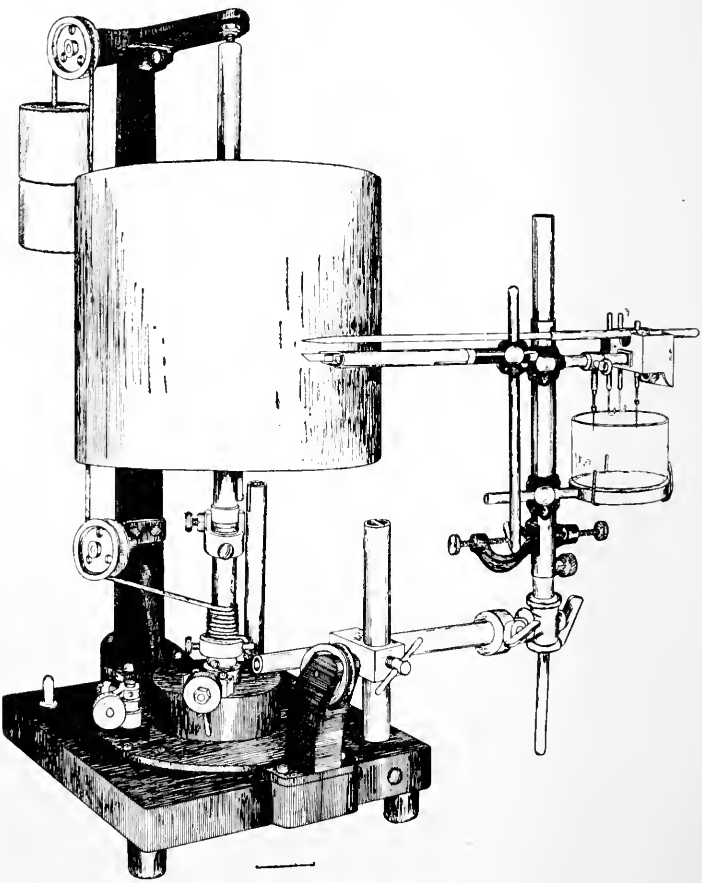

Fig. 56. Recording drum and controller.

adjusting. Simple, strong, and efficient attachments are provided for all ordinary needs. The tubular posts arising from the base provide a means of attaching a hand drum rotator and drum brake for high speed work, Fig. 54, and a drum stimulating key, Fig. 30. To the anterior of these posts is attached a universally adjustable recording apparatus stand, thus eliminating the need of separate apparatus supports. The base is smoothly finished in black and all brass parts are nickeled.

The drum itself is of the Porter cast aluminum pattern. It is mounted on a sleeve support, Fig. 59, to which it is fixed at any height by a substantial lock on the upper end. It is prevented from turning by a key on the support and a slot in the lower end of the drum. Thus

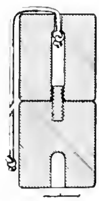

Fig. 57. Weight and cord. The weight unscrews in the middle, the connector pin remaining with the lower half.

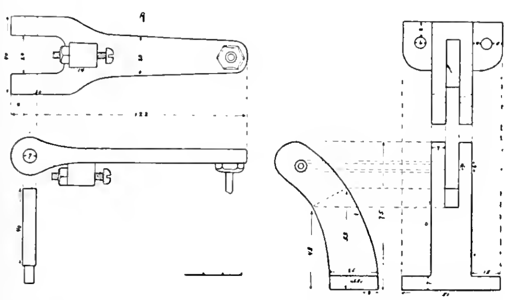

Fig. 58. A. Swinging arm and upper bearing. B. Anterior pulley support. Measurements are in millimeters.

accidental moving or creeping of the drum in any direction on the support is guarded against. Yet it is instantly adjustable to any horizontal or perpendicular plane. A combined drum brake and key pin is set, with insulation, in the lower end of the drum. The drum is mounted on the spindle of the controller. The drum support is tubular brass, Fig. 60, A. The upper end is closed and inside it is provided with a centered cone pointed, hardened steel bearing which bears on the upper end of the controller spindle. This bearing carries the weight of the support and drum. The outer surface of the closed upper end of the support is provided with a centered socket in hardened steel to receive the drill steel pin of the upper controller bearing. The inside diameter of the support is somewhat greater than the diameter of the controller spindle and near the upper end a brass ring bearing is provided, which is accurately fitted and adjusted to the spindle, which is drill steel, so that the drum may turn smoothly and not have undue "play." The

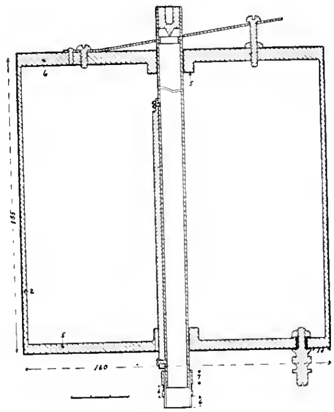

Fig. 59. Drum mounted on sleeve.

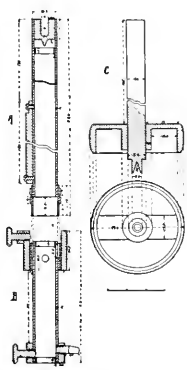

Fig. 60. A. Drum support sleeve. B. Reel. C. Spindle.

lower end of the support is open. To the outer surface near the lower end is affixed an encircling brass friction band. It is acted upon by the friction arm and screw of the reel, and thus the support and reel are united with any desired degree of rigidity. The end of the support below the friction band fits accurately into a circular slot in the upper end of the reel and serves to aid in centering and maintaining the two in position. The wall around the lower end of the support is beveled on both sides to insure its entering the slot smoothly without special attention when the support is placed on the spindle. The length of the drum support is ample to provide for all perpendicular adjustments of the drum, and for smoking the drum paper without soiling or burning the hands.

The reel, Fig. 60, B, carries the weight cord and transmits the turning force to the drum. It is of tubular brass of the same transverse dimensions as the drum support. Inside, near either end, it is provided with circular bearings accurately fitted to the controller spindle like that of the support. The upper end is provided with a slot to receive the lower end of the drum support. Also it carries a self-adjusting friction lock for connecting the reel and drum support. Owing to the extensive and accurate engagement of the lower end of the drum support and the slot in the reel and the self-adjusting feature of the friction lock, the pressure of the friction arm and of the screw to the opposite points of the friction band of the drum support is equalized and there is no danger of causing the reel and drum support bearings to bind on the controller spindle when the two are locked together. The blunt cone point of the locking screw centers on the beveled surface of the friction band, and as this surface is on the upper margin of the band, the reel and drum spindle are drawn tightly together end to end when the screw is tightened, thus causing end as well as side pressure at the joint.

A heavy collar is affixed to the lower end of the reel. In this, a knot holder, consisting of a pin terminating in two blunt parallel arms is set for instantly attaching the weight and cord to the reel.

The collar also carries a set screw for locking or releasing the reel from the controller spindle. A stop in the form of a collar on the spindle, Fig. 63, prevents the reel from being set at so low a level that an imperfect connection with the drum support might cause binding of the bearings on the spindle.

The drum is removed from the controller by (1) locking the reel to the spindle; (2) unlocking the drum support from the reel; (3) turning the hinged upper bearing arm upward and backward; (4) lifting the drum support (or sleeve) with the drum off the controller spindle. To mount the drum, the processes are reversed. To wind the reel, the drum is mounted and locked to the reel. The reel is then unlocked from the spindle, the cord of the weight placed over the pulley with the weight suspended and the knot at the end of the cord placed in the holder and the drum rotated backward, *i. e.,* anti-clockwise until the weight is raised near to the pulley, when the reel is locked to the spindle. The drum is conveniently rotated by manipulating the upper end of the reel with the fingers of one hand. The cord should be evenly wound. This is insured by slightly depressing or raising it between the reel and pulley if necessary. The weight provides an even tension during winding.

For slow and moderate speeds, *i. e.*, up to 30 to 50 millimeters per second, the viscosity brake is used. Therefore, the reel remains locked to the controller spindle and the drum is started and stopped by releasing and clamping the spindle. The rate of the spindle is adjusted by the speed regulator, or by increasing or decreasing the weight, or both.

For faster drum speeds, the drum and reel lock is released until the joint turns freely and the milled surface of the drum stop pin is adjusted to the drum brake and stop. The drum sleeve and reel are then relocked together and the reel released from the controller spindle. When released by the brake and stop, the drum and reel rotate independently of the controller spindle, *i. e.,* they rotate around it owing to the inside support bearing at the top of the sleeve which carries the weight on the end of the spindle, and the three inside ring bearings. The drum is steadied and with the spindle is held perpendicular by the socket in the top of the sleeve and with the pin carried by the hinged arm of the rigid support rising from the controller base.

For stationary work, that is, when records are made as perpendicular lines, the drum being turned slightly between such records, the reel is locked to the spindle and the drum sleeve released from the reel. If the drum is turned by hand enough friction may be maintained in the joint as may be desirable to insure the immobility of the drum while records or notes are being written on the smoked surface. If rotation is by means of the hand rotator, Fig. 54, A, the sleeve-reel lock is completely released and the sleeve raised slightly in the drum (say one millimeter), so that the weight may be carried by the rotator, thus insuring its proper action.

The controller spindle, Fig. 60, C, is of drill steel. The upper end is free when the drum sleeve is removed. When the drum is mounted the upper end forms a bearing with the inside cone-pointed bearing of the sleeve and it is centered to the pin of the upper outside bearing, that is, the bearing between the socket in the upper surface of the end of the drum sleeve and the pin carried by the hinged arm of the upper bearing support, through the ring bearings in the drum sleeve and reel. The lower end of the spindle is cupped and rests upon a hardened steel ball, which is set in a socket in the floor of the viscosity chamber of the controller base, Fig. 61. The ball rests upon a hardened steel

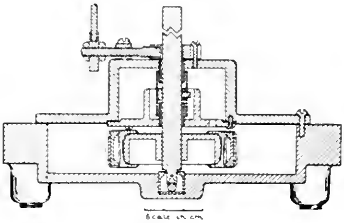

Fig. 61. Cross-section of base of drum stand. Note the lower bearing, the viscosity chamber, pulley and brake, the air chamber of the cap communicating with viscosity chamber through a hole in the diaphragm, and the double grease cup seal in the air chamber. The leather soles of the drum feet are shown.

floor. The socket is provided above with a narrow circular brass bearing surface, which is fitted to the lower end of the spindle. Just above the lower bearing the spindle carries a brass oval-faced pulley, which is set rigidly to the spindle, after which the outer face is turned and polished very accurately, as it is by means of this surface that the speed

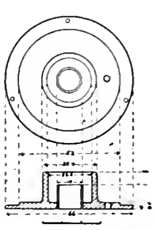

Fig. 62. Diaphragm interposed between viscosity and expansion chamber. Note lower half of grease seal and hole for expansion of glucose.

of the spindle is regulated. Above the pulley the spindle passes through a metal diaphragm, Fig. 62, but does not come into contact with it, excepting through a grease cup seal on the upper surface of the diaphragm. Passing upward the spindle emerges from the viscosity chamber cap but does not form contact with it save through another grease cup. It then passes through the garrotte clamp, Fig. 63, by means of which, at viscosity speeds, the drum is started or stopped. Just above this point the spindle carries the narrow circular stop for limiting the position of the reel.

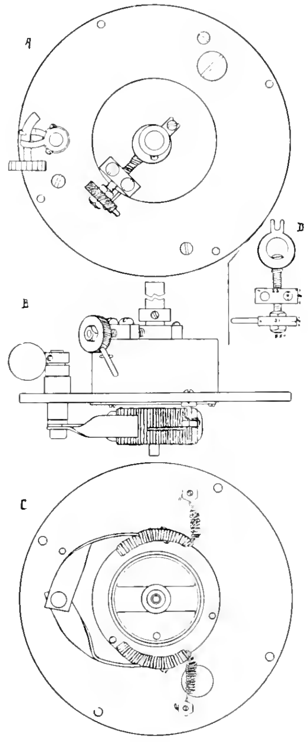

Fig. 63. Top, side and bottom view of spindle, viscosity chamber cap, and brake. To the right is a top view of the clamp for stopping the drum.

The spindle has, therefore, two bearings, the upper being of the pin and socket type, the lower being of a combined ball end thrust and annular side type. The ball end bearing carries all of the load and is subjected to the severest duty of any of the bearings, but it is capable of sustaining many times as much strain as can be exerted upon it through the use to which it is here put without danger of appreciable wear or damage. The edge bearing surface of the annular part of the lower bearing has only to withstand the pull of the weight which is applied to the spindle at the level of the reel, and this only at the viscosity speeds. Therefore, it is subjected to but little wear. At fast speeds, that is, when the drum is rotated upon the spindle, the garrotte clamp rigidly holds the spindle and thus relieves the lower bearing of all duty. All bearings possess a very large margin of surplus strength and are capable of unlimited usage without material wear. Occasionally a drop of oil or a very little vaseline should be applied to the top and side of the spindle and to the outside top bearing to insure constancy of rate at high speeds, but no appreciable damage will result from failure to do this. Of course, if the parts are allowed to rust, perfect performance cannot be expected.

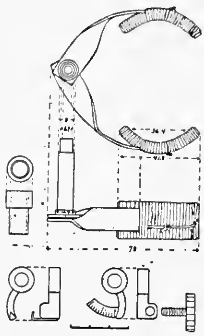

Fig. 64. Drum viscosity brake. Dismounted to show construction. The regulator is shown below.

The speed of the spindle is regulated through the viscosity brake, Fig. 64, and by means of the weight. The brake pulley is embraced at opposite points of its face by brake shoes faced with wool yarn.

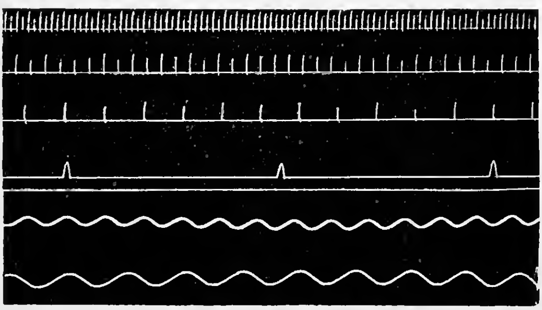

Fig. 65. Drum test. The upper four tracings are of a Jacquet time marker recording seconds on a drum controlled with a viscosity brake. The speed may be set for one revolution in 30 minutes or longer. By adding weight a much faster viscosity regulated speed than that shown in the fourth tracing may be obtained.

The two tracings at the bottom are of a tuning fork giving 100 D. V. per second. The drum sleeve rotated on the spindle. A wide range of speed may be obtained by this method by altering the weight.

The yarn is wrapped transversely. The faces of the shoes next to the pulley are doubly concave, so the yarn surface that acts upon the pulley is elastic as it extends between the edges of the horizontal concavity. Also, this permits of automatic adjustment of each yarn strand to the pulley without binding and insures an even and constant distribution of glucose to the surface, the cavity between the yarn and metallic surfaces being occupied by this substance. The shoes are mounted on a pair of self-adjusting U-arms. The arms are approached or separated by a quadrant lever and calibrated screw on top of the base which are provided with indicator scales. The faces of the brake shoes but lightly come into contact with the polished pulley face, and wear at this point is practically a negligible factor, but the lever is adjustable so any material wear is easily compensated.

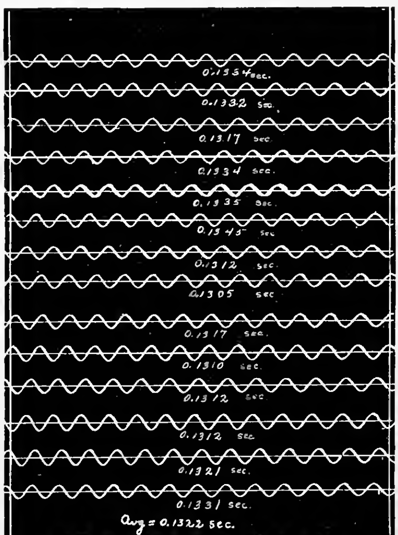

Fig. 66. Tests of drum for uniformity of rate at fast speeds. The test was made with one winding of the weight cord. Especial care was not exercised in the experiment. The results would indicate a variation of only a few per cent. When such possible error is considered as in measuring a tracing for latent period, it becomes practically negligible. (Cf. Figs. 33 and 34.)

The viscosity chamber is filled with glucose and covered with a metal diaphragm to insure uniform action of the glucose on the pulley. The diaphragm, Fig. 62, is of cast brass and provided with a grease cup seal surrounding the spindle. It is fastened to the upper surface of the viscosity chamber cover, and separates the viscosity chamber below from the air chamber of the cap above, except for a small hole in the diaphragm, which serves as an expansion outlet for the glucose. Viscosity changes due to temperature variations introduce no practical difficulties, as such changes are so slight during the course of an ordinary experiment as to be negligible. For special use, a temperature compensating attachment may be introduced. The results shown in Figs. 65, 66, 68, 72, 33, 34, 51, 52, etc., give a good idea of the efficiency of the drum under various conditions.

Combined Primary and Secondary Circuit Controller

The controller, Fig. 67, automatically performs the following operations:

1. Closes and opens the primary circuit at any rate from one per minute to 100 per second.

2. Makes uniform closing contacts and opening interruptions.

3. Eliminates closing or opening secondary currents or permits both to flow through the electrode circuit.

The controller is actuated by an electro-magnet. The rate of interruption is regulated by an oil brake and is readily adjustable. Uniform electrical contact is made by a coil spring acting eccentrically on a rocking arm bearing a contact surface. All parts are adjustable. The contact period is short, being under 0.03 second at slow speeds and less at rapid speeds. The contact is opened by the movement of the magnet bar in response to the pull of the magnet. No special retarding force is opposed to the movement. The oil brake retards closure of the contact. It requires one to two amperes of current. One or two dry batteries are adequate. When used with an induction coil they are wired in series.

The secondary controller is operated from the same magnet. It automatically short-circuits the secondary before closure of the primary contacts, and breaks the short-circuit while the primary circuit is closed. It is connected in parallel with the secondary circuit. It is easy to extend the short-circuit attachment so that it may be adjusted for eliminating either opening or closing shocks.

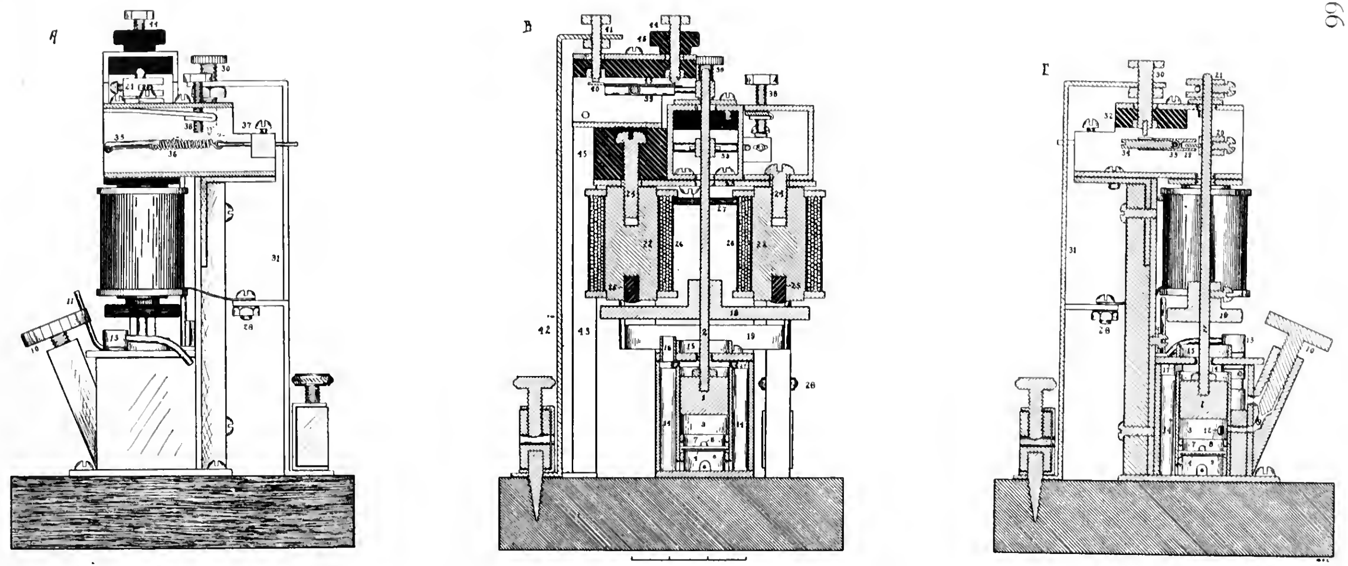

Fig 67. Combined primary and secondary circuit controller.

A. External view. B. Lateral cross-section. C. Anterior-posterior cross-section.

I. REGULATOR. 1, Piston. 2, Piston shaft. 3, Cylinder. 4, Inlet valve. 5, Inlet valve seat. 6, Inlet from oil outside to valve chamber. 7, Inlet valve check. 8, By-pass for oil past valve check into cylinder. 9, Cylinder outlet. 10, Cylinder outlet control screw. 11, Cylinder outlet control screw ratchet spring. 12, Cylinder outlet to cock. 13, Cylinder outlet cock (for fast speed and rapid acceleration). 14, Oil space in regulator outside cylinder. All space in regulator is filled with oil. 15, Oil collar on top of regulator. 16, Air vent on top of regulator. 17, Regulator top screws and gasket. 18, Magnet bar. 19, Magnet bar guide. 20, Arm to primary key bar. 21. Slot for secondary key bar.

II. PRIMARY CIRCUIT. 22, Magnet cores. 23, Iron connector between magnet cores. 24, Magnet screws. 25, Buffers for magnet bar. 26, Magnet coils. 27, Connection between coils. 28, Direct coil connection to binding post. The end of the wire from the other coil is grounded to the frame and thus the current may reach 29. 29, Primary contact bar. 30, Primary contact screw. 31. Primary contact lead to binding post. 32, Insulation. 33, Axle of primary contact bar. 34, Set screw. 35, Trip arm of axle. 36, Trip arm spring. 37, Tension adjusting screw. 38, Spring side pressure screw (for very fast speed).

III. SECONDARY CIRCUIT. 39, Secondary contact bar. 40, Secondary contact spring. 41, Secondary contact screw. 42, Lead from secondary contact screw to binding post. 43, Lead from other secondary contact screw to frame and thus to 39. 44, Contact bar spring pressure screw. 45, Insulation.

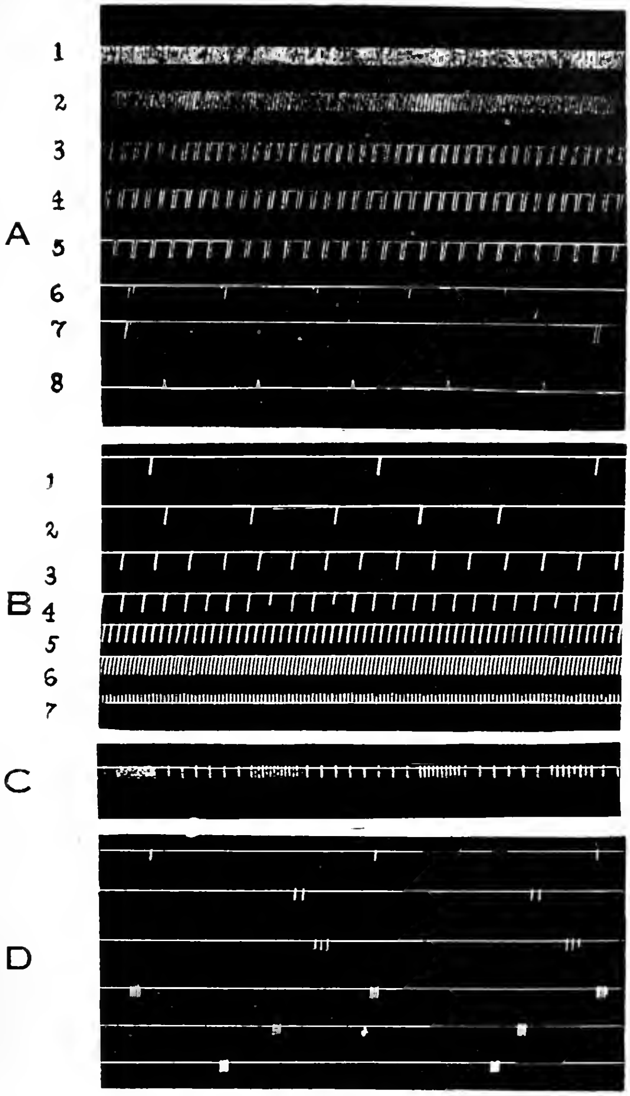

Fig. 68. Primary interrupter test.

A. Tracings 1 to 7, inclusive, taken with electro-magnetic signal; tracing 8, Jacquet time-marker set for seconds. Drum speed was the same for all tracings.

B. Same as A, only tracing 7 is by Jacquet time-marker set for seconds.

C. Primary interrupter set for seconds with periodic groups of rapid interruptions controlled at will. Thus used it serves as a base line, time, and signal recorder. The induced current during periods of rapid interruption may be led to stimulating electrodes by means of the secondary hand key.

D. Automatic periodic grouping of interruptions with control of time between periods and number and rate of interruptions in each period obtained by connecting two interrupters.

The mechanism is substantially constructed and is very durable. It is easy to adjust and requires very little attention. It closes and opens the circuit in a uniform manner and is easily adjusted while in operation for any rate from one per minute or slower to 100 contacts and interruptions per second. With a battery and signal it may be used as a time marker; or connected in the primary circuit of an induction coil, to open the circuit uniformly to closure with a hand key, or to both close and open the circuit automatically at any rate desired within the limits mentioned, Fig. 68.

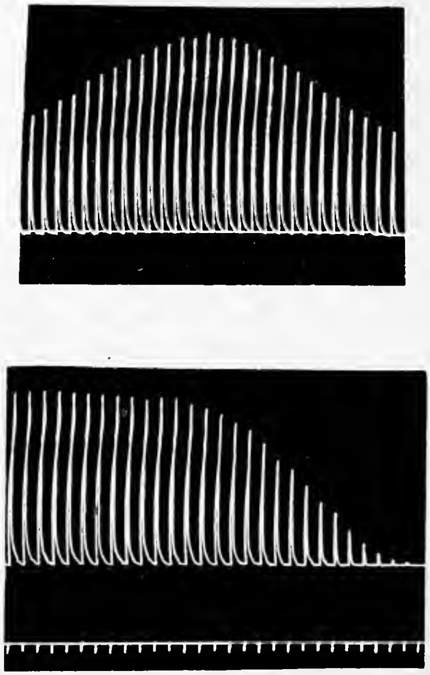

Fig. 69. Myograms illustrating current control with the interrupter and rheocord.

COMBINED COIL, CURRENT CONTROLLER, RHEOCORD, PRIMARY AND SECONDARY KEYS, SWITCH AND COMMUTATOR (Combined Coil and Current Controllers)

The various parts of this apparatus, Fig. 70, are mounted on a three-ply wooden base measuring 223 x 190 x 16 mm. At the back the base projects upward 75 mm. Upon the upper edge of the back are mounted the primary and secondary binding posts. The primary division of the circuit controller is connected in parallel through the primary hand key with the rheocord and coil. The rheocord may be removed from the circuit by means of a contact screw. It may be so mounted that it can be used independently of the other parts of the apparatus. The coil is of the Porter form. The core of the primary

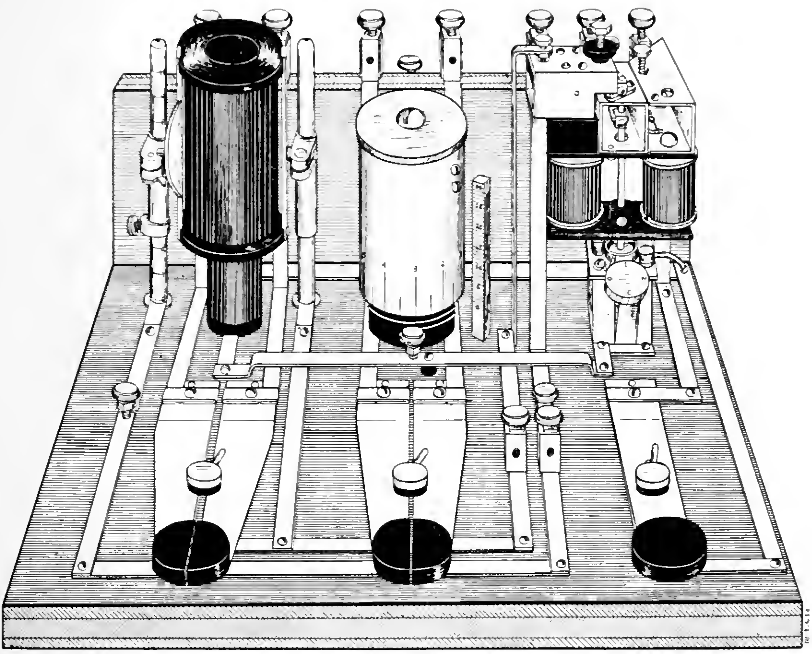

Fig. 70. Combined coil and current controllers.

may be removed. The secondary may be raised perpendicularly. The finer degrees of the stimulating current are obtained with the rheocord. The secondary leads are connected with the secondary key leads and with the secondary division of the current controller. The circuit may be broken to the controller by means of a contact screw. Also, the circuit to the keys may be broken by another contact screw. By opening both these screws the secondary keys are isolated, so they may be used for a battery current. A pair of binding posts on the key leads serves for such connection. Commutator connectors (see Fig. 38) are provided. When not in use, they are attached to the back side of the base.

In Fig. 71 the apparatus is shown in use with the drum. The tracing shown in Fig. 72 was taken in this manner.

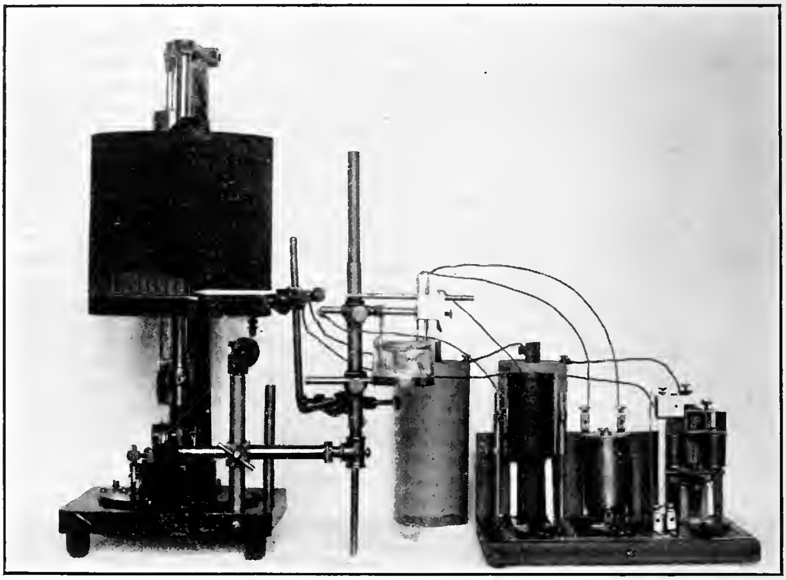

Fig. 71. Drum, myograph, signal, and combined coil and current controllers.

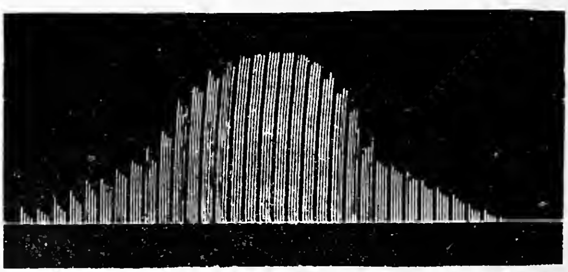

Fig. 72. Myogram taken with apparatus as shown in Fig. 71.

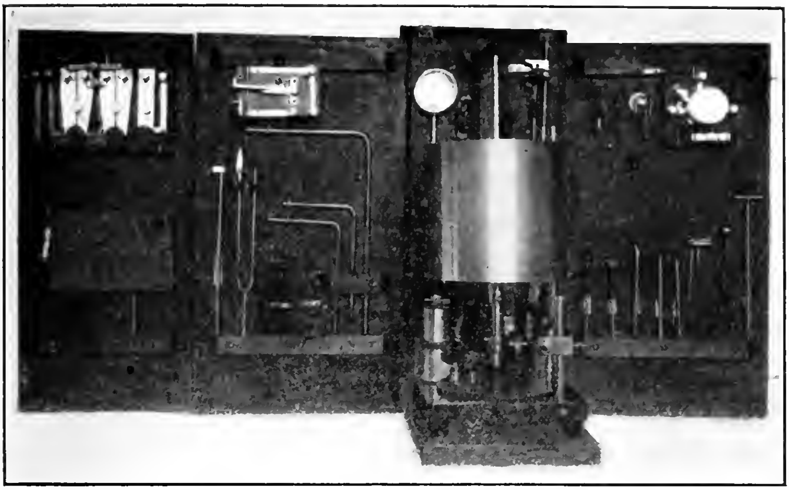

Fig. 73. Drum and attachments and accessories in case.

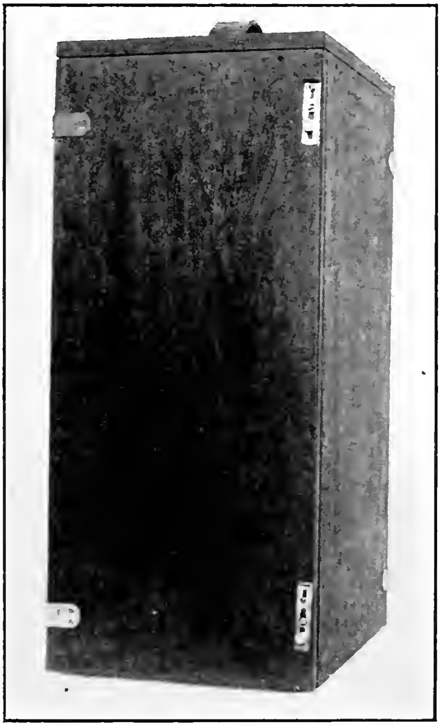

Fig. 74. Drum case closed. It measures 8½ x 11 x 20 inches.

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