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A THIRD REPORT ON LIMNOLOGICAL APPARATUS

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Notes from the Biological Laboratory of the Wisconsin Geological and Natural History Survey. XXV.

The present paper is a continuation of the two reports that have already been published regarding limnological apparatus, one by Juday in 1916 and the other by Birge in 1922.

THE FOERST ELECTRIC CENTRIFUGE

Quantitative and chemical studies of the net plankton of lakes in the vicinity of Madison, Wisconsin, were begun in 1911 and were continued until 1917. In the early stages of this investigation it was found that a very large portion of the plankton material was lost through the meshes of the net. Various methods of obtaining the lost organisms were tried and a centrifuge proved to be the most efficient instrument for their recovery. A large size De Laval centrifuge was installed in 1915 and was used until 1917 for the investigations relating to the organisms that are lost by the net. A report on this work was published in 1922.

The importance of the results obtained with this large centrifuge made it desirable to extend these studies to lakes in other parts of Wisconsin. The large size and the equipment required to operate it made this De Laval centrifuge impractical for field work in other lake districts. Mr. J. P. Foerst, mechanician of the Physics Department, University of Wisconsin, then undertook the task of constructing a portable centrifuge which could be readily taken into the field and operated wherever electric current is available. The result of his work is the Foerst Electric Centrifuge which is shown in figure 1. This instrument has been used for a period of five years and very interesting and valuable results have been obtained with it during this time.

The motor (M, figure 1) consists of a standard grinding motor manufactured by the Wisconsin Electric Company of Racine, Wisconsin. It has a speed of 20,000 revolutions per minute and operates on either direct or alternating current of 110 volts. Instead of the usual wheels that are attached to the spindle for grinding purposes, a small centrifuge bowl is used.

The motor is mounted on a cast iron base (B) which holds it in a vertical position. Inside the base is a rheostat which gives a range in speed from a few hundred up to 20,000 revolutions per minute. The amount of resistance introduced into the circuit, which determines the speed of the motor, is regulated by turning the wheel marked R in figure 1.

A centrifuge with a still higher speed has been used for the past four years. The motor has a speed of 4,000 revolutions per minute and the spindle is driven by a belt. Seven interchangeable pulleys give a range in speed from 3,600 to 50,000 revolutions per minute; except for a few experiments at the maximum speed this centrifuge has been operated at 32,000. It is a larger and heavier machine than the one shown in figure 1, but it can be readily handled in the field; in fact it has been used for this purpose almost as much as the small machine.

The same bowls are used on both machines. Several hundred duplicate determinations have shown that the small machine removes substantially the same amount of plankton at 20,000 as the large one does at 32,000 revolutions per minute. Likewise several experiments have shown that a speed of 32,000 yields as much material as 50,000. The weight of the small centrifuge is 8 kilograms and of the large one 22 kilograms.

Eight different kinds of bowls have been used in the experimental tests to ascertain which one is most efficient for general use. The two that have given most satisfactory results are shown in cross section in figures 2 and 3. Figure 2 represents the original type. In this bowl the side is vertical; that is, it forms a right angle with the bottom. The corner is rounded off somewhat so that the material can be more readily removed from the angle. At the top of this bowl there is a rim 1.5 millimeters long which projects inward 1 millimeter. The outside diameter of the bowl is 57 millimeters and the height is 29 millimeters. The inside diameter is 50 millimeters at the rim and 52 millimeters below the rim; the depth is 25 millimeters.

The bowl shown in figure 3 has the same outside diameter at the base and the same height as that in figure 2, but the sides slope inward at an angle of 5 degrees; that is, the angle between the side and the bottom of the bowl is 85 instead of 90 degrees.

There is no rim at the top. The inside diameter at the top is 50 millimeters and the depth is 25 millimeters. Experiments have shown that this bowl is just as efficient in removing plankton organisms as the one with the rim; since the catch can be washed out of the bowl with sloping sides a little more conveniently than out of the one with a rim, the former type has been adopted for general use. These bowls are made of brass or steel; the latter has a tendency to rust, which may be prevented by plating it with nickel.

A hub projects upward from the bottom of the bowl for a distance of about 15 millimeters. The upper part of a hole in the middle of this hub is provided with threads by means of which the bowl is screwed onto the spindle of the motor. The point of attachment to the spindle is raised in this manner in order to lower the center of gravity of the bowl and thus prevent undue vibration. In the sloping bowl, the upper part is made thinner in order to keep the center of gravity as low as possible.

A bronze guard (G in figure 1) is fastened to the framework of the motor at the upper end of the spindle; this guard surrounds the greater part of the bowl and is provided with an outlet tube (O) through which the water escapes from the centrifuge. The side wall of this guard is 3 millimeters thick; the inside diameter of the guard is 70 millimeters and the depth is 22 millimeters inside and 27 millimeters outside.

A cover (C in figure 1) made of sheet brass one-half millimeter thick fits snugly inside the guard and completes the housing for the bowl. The cover is 40 millimeters high and possesses a tube (T) in the the center 17 millimeters in diameter, through which the water is fed into the bowl. The feeding tube extends down to within one millimeter of the bottom of the bowl and a diaphragm at the lower end prevents the water from being thrown over the top of the bowl before it is centrifuged. This diaphragm is 49 millimeters in diameter. When the water strikes the bottom of the revolving bowl it is quickly set into rotation and thrown against the side where its speed of rotation is increased as it passes up toward the top of the bowl; it is finally discharged over the top in a fine spray. Most of the organisms are deposited on the side of the bowl within five millimeters of the bottom, thus showing that the water promptly acquires sufficient speed of rotation to cause their deposition. At a speed of 20,000 revolutions per minute, the inner surface of the side of the bowl travels at a rate of 3,200 meters per minute; at a speed of 32,000 the rate is 5,120 meters per minute.

The only water that remains in the bowl at the end of a run is that below the rim in the first type of bowl or that in the angle of the second type; in the bowls described above it amounts to about 4 cubic centimeters.

Bowls with inside depths of 17, 20, 25, and 29 millimeters have been used in the experiments to determine the effectiveness of the different types. It was found that efficiency increases somewhat with increasing depth up to 25 millimeters, but there was no difference between the 25 and 29 millimeter bowls. Two v-shaped grooves 1.5 millimeters wide and 0.5 millimeter deep were cut into the side on the upper half of one of the 29 millimeter bowls, but these grooves did not give this bowl any advantage over the others. In another experimental bowl the top rim projected inward a distance of 3.5 millimeters instead of the usual 1 millimeter, but this made no difference in the size of the centrifuge catch. Two small holes were drilled in the rim so that the quantity of water left in the bowl could be reduced to the usual amount at the end of the run.

Two modifications were made for the purpose of giving the water the same speed of rotation as the bowl. One bowl was provided with four thin brass wings which project inward from the side for a distance of 5 millimeters. The water passes up the side of the bowl between these wings so that it attains substantially the same speed as the bowl before it reaches the top. The amount of material obtained from this bowl, however, did not prove to be any larger than that of a bowl with smooth sides and the same height.

Another bowl was fitted with a special feeding cone which has a rim 6.5 millimeters wide at its lower end; this device is attached to the bottom of the bowl by means of three screws passing through the rim. The water is fed into the top of the cone, passes down to the bottom of the bowl and then out to the side through a series of small grooves on the lower side of the rim. This rim extends out to within 2 millimeters of the side of the bowl, so that the water acquires the same speed of rotation as the bowl before it leaves these grooves. This special bowl did not yield any larger catches of plankton than the duplicates taken with the regular bowls of the same height.

With one exception the first centrifuging removes approximately 98 per cent of the organisms that are usually considered in a plankton catch. Aphanizomenon is the only form noted thus far which is troublesome in this respect; only about half of it is removed in the first centrifuging, but substantially all that remains is taken out by a second centrifuging. With very few exceptions this form is present in such small numbers that a second centrifuging is not necessary.

Plate counts have shown that 40 to 70 per cent of the bacteria are removed from the water by the first centrifuging. This high efficiency is maintained for plankton catches that will weigh as much as 8 milligrams when dry. The water is centrifuged at a rate of one liter in 5 to 8 minutes, 6 to 7 minutes being the usual time. The water is fed into the centrifuge from a one liter aspirator bottle which is placed on a box beside the centrifuge; the rate of flow is regulated by a glass stop-cock in the outlet tube of the aspirator bottle.

With this type of centrifuge, plankton material may be obtained for numerical, gravimetric, and micro-chemical studies. For purposes of enumeration one-half liter samples are used; if some of the organisms are abundant, they are enumerated without concentration and the less abundant forms are then enumerated in the centrifuge catch. Duplicate samples of one liter each are usually used for the gravimetric determinations; when the plankton is scarce a two or three liter sample may be used. The catch is rubbed off the side of the bowl with a glass rod which is tipped with a piece of gum rubber tubing and transferred to a platinum dish with a capacity of 8 cubic centimeters; the bowl is then washed twice with distilled water, about one cubic centimeter being used each time, and this is added to the material in the dish. The catch is placed in an electric oven where the water is evaporated and the material is dried for a period of 24 hours at a temperature of 60° C. After weighing, the catch is ignited in an electric furnace at a temperature of about 600° C. for a period of 30 minutes. A second weighing shows the gross loss on ignition. In order to correct for the loss on ignition sustained by the 4 cubic centimeters of lake water included with the catch, a blank consisting of 10 cubic centimeters of centrifuged water is run along with the plankton sample. The net loss after making this correction is regarded as the organic matter of the plankton. The quantity of organic matter in the plankton of the Wisconsin lakes that have been studied, varies from a minimum of about 700 milligrams to a maximum of 6,000 milligrams per cubic meter of water.

Both numerical and gravimetric results are obtained for the net plankton as well as for the total plankton secured with the centrifuge; the closing net described in the first report is used for these catches. For the gravimetric determinations, the net is hauled through the desired stratum and the catch is transferred from the plankton bucket to a piece of bolting cloth placed in a funnel. After the water has drained off, the net plankton is carefully removed from the bolting cloth with a sharp knife or scalpel and placed in a small platinum dish. The catch is then dried, weighed and ashed as indicated for the centrifuge material.

In addition to the plankton organisms, the centrifuge also removes a certain amount of silt from the lake waters; this is shown by the fact that the ash of the centrifuge catch usually amounts to 50 per cent or more of the dry weight. The percentage of ash in all of the plankton forms, except the diatoms, is much smaller; it is less than 10 per cent in many of these forms.

A certain amount of organic matter is removed by the centrifuge even after all of the plankton organisms, except the bacteria, are gone. With the exception of a small percentage of the bacteria, the plantkon material is all removed from the water by the end of the third centrifuging, yet this water continues to yield small amounts of organic matter up to the eleventh centrifuging; no attempt has been made to carry the experiment further than this. This result suggests that the lake water contains organic matter in a collodial state which is gradually thrown out as the centrifugal process continues.

During the summer of 1925 the centrifuges and the electric furnace were successfully operated in the field by a Kohler Light–Power plant made by the Kohler Company of Kohler, Wisconsin. The plant is especially designed for use on a farm; it furnishes a direct current of 110 volts and has a capacity of 1,500 watts. The plankton material was dried in a copper drying oven which was heated to 60° C. by a kerosene incubator lamp.

Keller Portable Balance

A good portable balance is required for gravimetric studies of the plankton during the summer field work. A Keller portable assay balance, made by the G. P. Keller Manufacturing Company of Salt Lake City, Utah, has given excellent service in such investigations during the past four years. A sketch of it is shown in figure 4. This balance has given good results and has not shown any appreciable effects of ordinary vibrations when used upon tables or temporary benches; it has a capacity of 100 grams and is sensitive to 1/200 milligram.

The balance case is trapezoid in form, 30 centimeters long, 15 centimeters high and 14 centimeters wide at the base. The carrying case is 37 centimeters long, 19 centimeters high and 17 centimeters wide. It requires only a very few minutes to dismantle the balance and place it in the carrying case, or to set it up again upon removal from the case.

Bottom Dredge

The bottom dredge shown in figure 5 is a modification cf the one described by Ekman in 1911. It is especially designed for the capture of organisms that live *on* the bottom, such as Mysis and Pontoporeia, and not those that burrow into the mud.

The dredge consists of two parts, namely, a canvas part in front and back of this a straining part made of silk gauze. The dredge has a rectangular opening 16 by 38 centimeters; the canvas part is 40 centimeters long and the gauze part is 55 centimeters long. The dimensions at the point where the canvas and gauze parts join are 19 by 42 centimeters. A canvas apron extends back over about half of the gauze part in order to protect it.

The canvas and gauze are attached to quadrangular frames made of brass. The frame at the mouth of the dredge is made of brass 2 centimeters wide and 3 millimeters thick; the one in the middle of the dredge is 2.5 centimeters wide and 3 millimeters thick. The front part of the middle frame is provided with small holes, about a centimeter apart, through which the canvas is sewed to the frame. In addition to the canvas, the two brass frames are connected at each end by small ropes which pass through holes made to receive them.

The silk gauze is attached to a separate quadrangular frame made of a strip of brass 2.5 centimeters wide and 1 millimeter thick as shown in figure 6. This frame fits snugly over the one in the middle of the dredge to which the canvas is attached and is fastened to the latter by six small screws, two on each side and one at each end. Gauze of different meshes is attached to three or four of these frames, so that one can readily change from one size of mesh to another whenever it is desirable to do so. Small holes in the outer part of these frames provide for the attachment of the canvas band to which the gauze is sewed. A band of light canvas is sewed around the opening in the lower end of the gauze net; a line tied around this canvas closes the bottom of the dredge. During dredging operations a weight is attached to the line about a meter or a meter and a half in front of the mouth of the dredge.

Trap for Plant Dwelling Animals

Many animals dwell upon the larger aquatic plants, such as Potamogeton and Myriophyllum, and the trap shown in figure 7 was designed for the capture of such forms. The sides of the trap are made of light canvas or drilling and the bottom is made of No. 72 extra heavy grit gauze. At the top the canvas bag is sewed to a brass frame which possesses small holes for this purpose. The frame is made of brass 2.5 centimeters wide and 3 millimeters thick; there are two double hinges in the center so that the mouth of the trap can be completely closed. The opening of the trap is 36 by 37 centimeters and the depth is 85 centimeters.

In making a catch the open trap is lowered over the plants to be examined; the plants are then loosened from the bottom and the mouth of the trap is closed. The trap is raised to the surface with the mouth upward and hauled into the boat, the water being allowed to drain out through the gauze before it is taken on board. The plants are transferred to a pail containing some water and taken to the laboratory where the animals are washed off and enumerated. Two individuals are required for the most convenient operation of the trap, one in the water to make the catches and the other in the boat to haul the apparatus on board and remove the material. By using a diving hood the trap has been operated at depths of 5 and 6 meters.

Apparatus for Determining the Coefficient of Nets

The plankton trap described in the first paper on limnological apparatus (Juday 1916) may be used for the determination of the coefficient of nets. Trap catches are made at meter or half meter intervals in the stratum through which the net is hauled and the average result yielded by these catches is a fair index of the efficiency of the net. The trap has been operated successfully at a depth of 60 meters so that the coefficient of a net can be determined in the lower as well as in the upper strata of a lake.

Another instrument was briefly described by Birge in 1898. It consists of a galvanized iron tube 3 meters long and 10 centimeters in diameter which is provided with a closing device at its lower end. A side view of the closing part is shown in figure 8; it consists of a slide and a carrier that bears a small plankton net. The carrier and net can be slipped to one side so that the opening is entirely free when the tube is lowered into the water. The slide is made of a brass plate 26 centimeters long, 15.3 centimeters wide and 3 millimeters thick; two pieces of brass 26 centimeters long and 3 millimeters thick are attached to each side of the brass plate, flush with the edge, by means of four screws. The upper piece of brass is 7 millimeters wide and the lower one is 15 millimeters wide, so that the latter projects inward 8 millimeters beyond the former and forms a track or groove in which the carrier can be moved back and forth.

At one end the brass plate possesses a hole 10 centimeters in diameter around which is soldered a tube 10 centimeters long; this tube is just a little larger than the iron tube so that the latter slips inside and attaches to the brass part by means of two bayonet joints. The other end of the brass plate has a tube 1 centimeter in diameter and 1.5 centimeters long through which the air escapes from the net when the apparatus is submerged; a piece of gauze is tied over the small tube in order to keep plankton organisms out of the net.

The carrier is made of a brass plate 13.8 centimeters square and 3 millimeters thick; it has a hole 10 centimeters in diameter in the middle around which is soldered a tube 5 centimeters long. The net is attached to the lower end of this tube by means of a clamp activated by a screw. The bolting cloth net is 15 centimeters long and the lower end of it is attached to a brass ring that fits one of the standard plankton buckets described in the first report. The weight of the bucket is supported by three pieces of line which are attached to the clamp at the top of the net and to the clamp at the bottom.

A small pulley is soldered to each end of the slide; the lines with which the carrier is moved from one side to the other pass over these pulleys and are tied to a loop soldered to the carrier. These pulleys project below the lower edge of the brass plate and serve as stops to prevent the carrier from being pulled out too far. In actual practice only the closing line is used because the net is moved away from the tube opening before the apparatus is lowered into the water. The slide and carrier are closely fitted together, so that plankton organisms can not escape between the bottom of the tube and the top of the net.

The galvanized iron tube is provided with a heavy wire handle at the upper end to which a rope is attached when the apparatus is being used. The top of the tube also possesses a close fitting, hinged cover. A wire soldered to the cover projects outward 10 centimeters at the point where the hinge is attached; a lead weight at the outer end of this wire keeps the cover open when the tube is being lowered into the water. The cover is closed by means of a line which is attached to a wire loop on the edge of the cover opposite the hinge and which passes through a loop on the side of the iron tube.

In making a catch, the tube is lowered into the water with the net carrier moved to one side of the opening; it is lowered slowly so that no appreciable currents are set up in the water. When the top of the tube is half a meter or a meter below the surface, the cover is closed and the net carrier is drawn across the bottom of the tube, thus imprisoning a column of water 3 meters long and 10 centimeters in diameter. The tube is then slowly raised to the surface and lifted out of the water so that the imprisoned water is filtered through the net. Several catches with the tube as well as with the net, the coefficient of which is to be determined, are taken at the same time through the same stratum of water. A comparison of the number of plankton organisms in the tube catches with that in an equal number of net catches, gives an index of the efficiency of the net.

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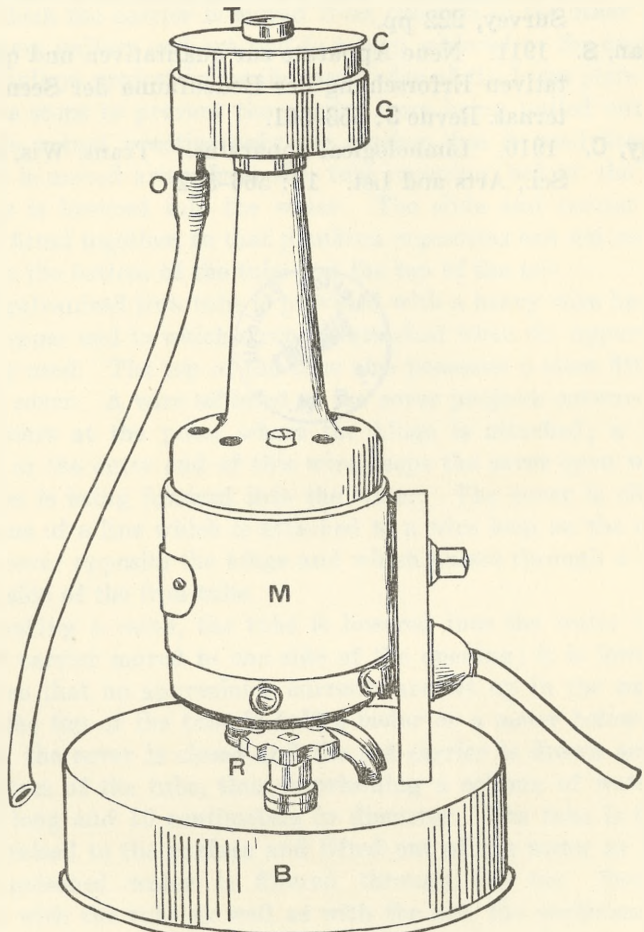

FIG. 1. Sketch of Foerst electric centrifuge. B, base, M, motor, R, rheostat wheel, O, outlet tube, G, guard, C, cover, T, inlet tube.

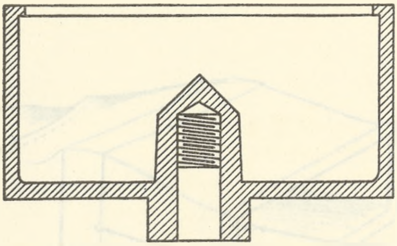

FIG. 2. Cross section of bowl with a rim. Natural size.

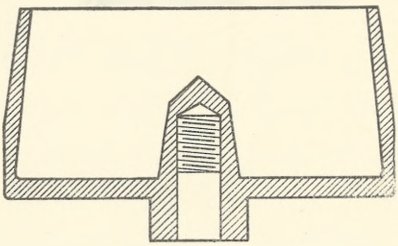

FIG. 3. Cross section of bowl with sloping sides. Natural size.

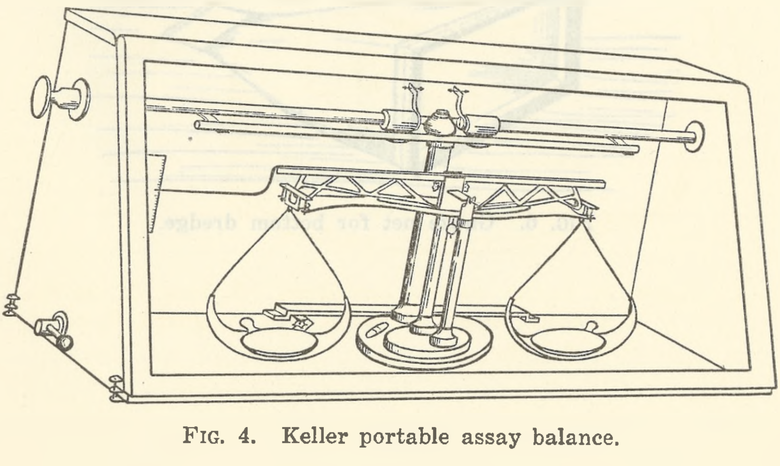

FIG. 4. Keller portable assay balance.

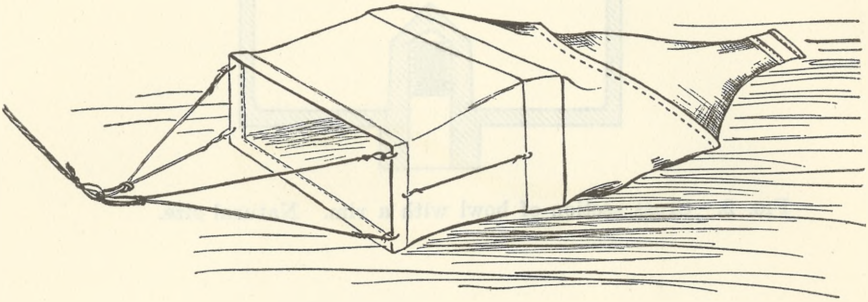

FIG. 5. Bottom dredge.

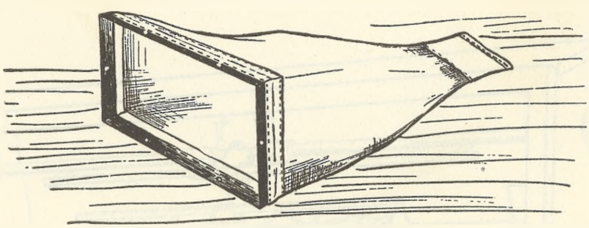

FIG. 6. Gauze net for bottom dredge.

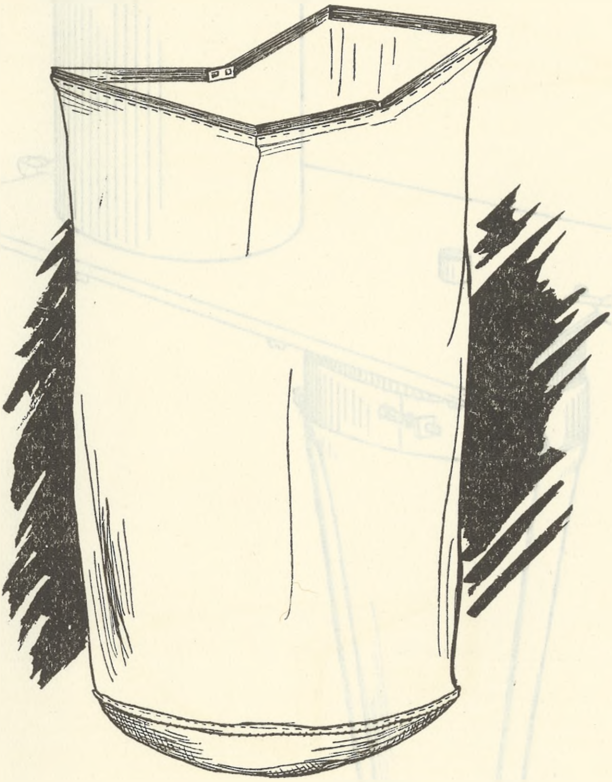

FIG. 7. Trap for capturing plant dwelling animals.

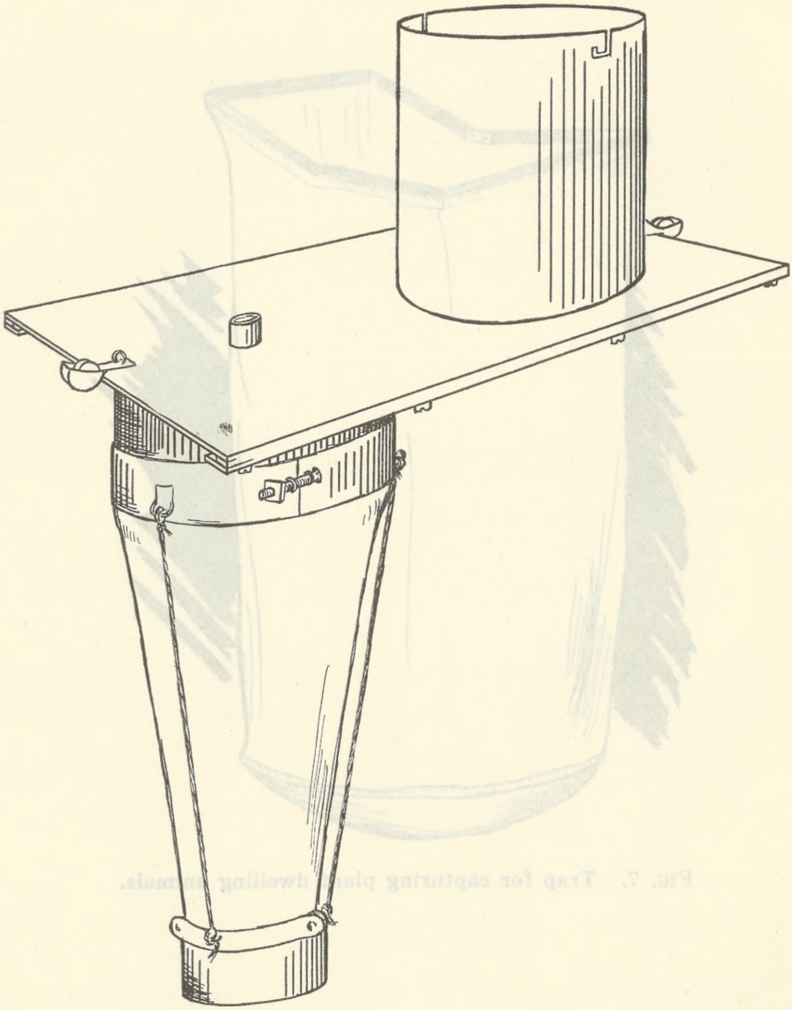

FIG. 8. Closing device attached to lower end of tube used in determining the coefficient of nets.