

An Apparatus for Recording the Valve Movements and the Extrusion of Dejecta of Oysters.

By

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Introductory.

During the course of experiments in oyster purification carried out at the Fisheries Experiment Station, Conway, it was considered that it might be of interest to undertake, in addition to the bacteriological work, which constituted the predominant part of the investigation, observations on the behaviour of oysters under the various conditions set up as a result of the experimental procedure adopted.

Direct observations of the only two outward manifestations of the activity of the oyster, namely the opening of the valves and the extrusion of dejecta is, at all events in the experience of the writer, a matter of considerable difficulty. In any case, and particularly when dealing with oysters with markedly imbricated shells, it is well-nigh impossible to ascertain by inspection whether the valves are closed or very slightly open. Furthermore, when a number of oysters are under observation in the same vessel, the scattering of the dejecta, on expulsion, by the flapping of the valves, precludes any decision being arrived at as to whether particular oysters have or have not passed faeces and/or pseudo-faeces¹).

To overcome the first mentioned difficulty, that of ascertaining whether the oysters were closed or slightly open, the obvious expedient suggested itself of magnifying and recording the valve excursions on a revolving drum by means of a pen lever. An instrument was extemporized,

¹) A term introduced by Dr. DODGSON to denote the solid material evacuated by mussels, oysters and other lamellibranchs, which has not passed through the alimentary canal, but which is ejected, in the case of the mussel, in the form of threads, by the ciliary recurrent marginal streams, and in the case of the oyster, in the form of pellets, also by ciliary action, aided however, by the flapping of the valves. For a full description of the pseudo-faeces of mussels, *vide* „Report on Mussel Purification” (Ministry of Agriculture and Fisheries. Fishery Investigations. Series II. Vol. X, No. 1, 1928) by R. W. DODGSON.

allowing of tracings of four oysters being obtained simultaneously on the same drum, and with it a number of records were obtained. This instrument, though of rough construction, was quite satisfactory as regarded performance, but in spite of the advantage attaching to it by virtue of its furnishing a continuous record, it suffered, as must all such-like auto-recording devices, unless of unwieldy proportions and unmanageable complexity, from the serious defect of providing the means for observing the valve excursions of only a relatively few oysters at a time.

The expedient which was adopted to obviate the scattering of the dejecta of oysters so that it might be determined whether particular oysters had or had not passed faeces and/or pseudo-faeces was of such simplicity that it was the easiest of operations to ascertain at the end of an experiment what proportion, and which, of (say) one hundred oysters under observation had passed faeces and pseudo-faeces respectively. The procedure consisted of setting out the desired number of oysters, selected as suitable as regarded shape (somewhat convexo-concave), convex side upwards, each in a Petri dish (without cover), filling the dishes with water to prevent their floating on the filling of the tank in which the experiment was conducted, and allowing them to remain undisturbed at the bottom of the tank for the duration of the experiment, at the termination of which, the tank was emptied, any dejecta which the oysters might have passed remaining, in water, in the dishes, faeces and pseudo-faeces being readily distinguishable by inspection. This procedure, of course furnished no information as to the onset, duration or termination of the period during which the oysters were passing dejecta; no other information, in fact, than a categorical answer to the question as to whether each oyster had passed faeces and/or pseudo-faeces at some time during the experiment.

The apparatus about to be described, to which the name of "Ostrea-graph" has been given, was designed with the idea of embodying in one instrument means for recording autographically the valve movements of four oysters simultaneously, together with provision for obtaining a rough registration of the times of the extrusion of the dejecta of each oyster. It may be remarked in passing that the application of the method of autographic record — a commonplace of the physiological laboratory — to oysters is no new thing. NELSON¹⁾ and GALTISOFF²⁾ both employed

¹⁾ THURLOW C. NELSON. Report of the Department of Biology of the New Jersey Agricultural College Experiment Station, New Brunswick, N.J. for the year ending June 30th 1920.

²⁾ PAUL S. GALTISOFF. Experimental study of the function of the oyster gills and its bearing on the problems of oyster culture and sanitary control of the oyster industry. Bulletin of the Bureau of Fisheries. Vol. XLIV. 1928.

it for their respective purposes. The only interest, if any, attaching to the apparatus about to be described, *qua* apparatus, arises out of its dual function and out of the fact that it was constructed at no great cost, largely out of ready-made components.

For the construction of the instrument only the usual metal-working loose tools, including drills, stock and dies and taps up to $\frac{3}{8}$ inch are necessary. The machined components are purchasable at small cost and readily adapted. In view of the possible interest of the information to those who may wish to make instruments similar to that about to be described, the last section gives the names and addresses of the firms from which such components as are not easily obtainable locally may be purchased. Each of these components on its first mention in the section devoted to the details of construction is allotted a reference number by which the firm from which it is obtainable may be identified in the list set out in the last section. The writer need hardly add that he disclaims any connection with any of the firms mentioned in the list, which is merely appended as explained above, for the information of those who from time to time make incursions into the domain of instrument construction. If their experience tallies with that of the writer, they will not infrequently have been at a loss to know where to buy this component or that material, particularly in such small quantities as are usually required.

It cannot be said that the part played in the research on oyster purification by the apparatus which forms the subject of this article, or by its precursor, referred to above (the apparatus by which the valve movements of four oysters were recorded together on a common drum) has been a large one. In the first place such work, requires the expenditure upon it of no small amount of time, and during the seasons during which the large scale purification experiments were carried out (the winter months of the year), personal manipulation and/or supervision in connection with the preparations for and the carrying out of the large-scale experiments, together with the concomitant bacteriological analyses of samples of oysters collected at the various stages of treatment, has left little time available for subsidiary undertakings, whilst during the remainders of the years during which the investigation was in progress other pre-occupations have supervened. Secondly, the first sets of tracings obtained (with the original apparatus), of the valve movements of different oysters under identical conditions showed such lack of uniformity that the opinion was formed, rightly or wrongly, that there was little expectation that tracings typical of different sets of conditions would be forthcoming, and this particular branch of the research was made to

give way to what were conceived to be more important aspects of the investigations. Thirdly, the apparatus, a general description of which is given below, was not completed until the experiments in oyster

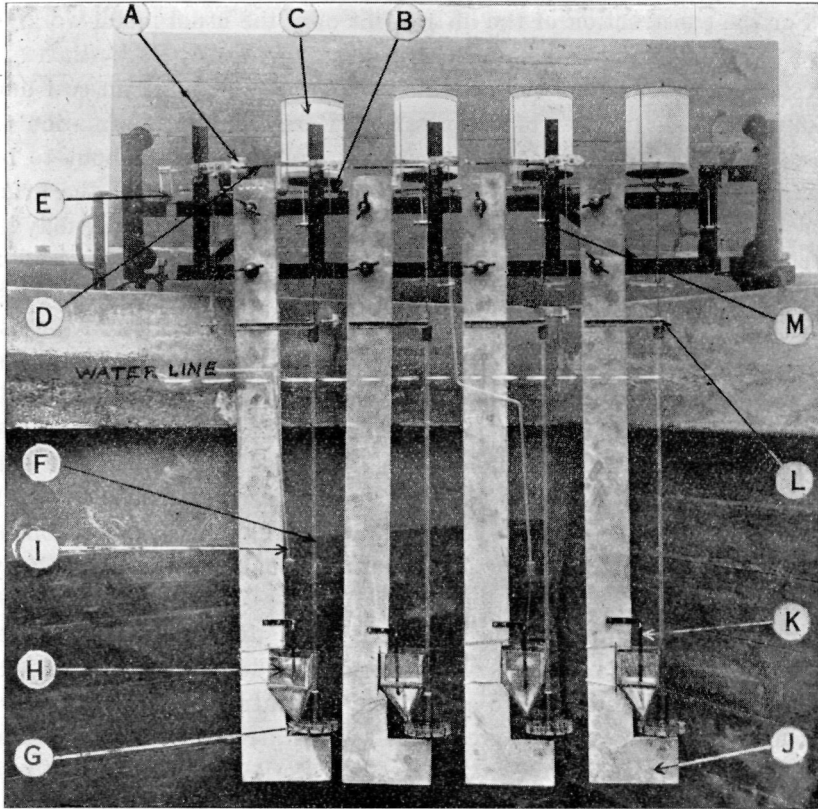


Fig. 1.

purification were nearing their conclusion. It is hoped, however, that an opportunity will offer itself for further work with the Ostreagraph in the future.

General Description of Apparatus.

A general idea of the design and working of the ostreagraph will now be given, reference being made to Fig. 1, in which attention may first be drawn to the "water-line", below which part of the instrument is submerged when in use. Allowance is made for some 18 inches of water over the four oysters under experiment, which are situated within the four celluloid hoppers *H*. Within each hopper an oyster is rigidly sup-

ported by means of a suitably bent iron rod *K*, one end of which is fixed to the lower valve of the oyster by means of Portland cement, the other end of the rod, flattened out, being bolted to the slate L-shaped member *J*. Thus each oyster is fixed under about 18 inches of water, partially enclosed by the celluloid hopper *H*, through the constricted opening at the bottom of which the dejecta fall, to be collected as will be explained later. To the upper valve of the oyster, which is free to make its normal movements, one end of a connecting rod *I* is attached by means of a simple ball-and-socket joint, the other end of the connecting rod actuating a counterpoised pen *D* which records on a rotating drum *C* the movements of the upper valve of the oyster, with a vertical magnification of 7.7 times. All four drums are driven by a common clock-work movement *A* through a horizontal shaft *B* and suitable gearing, the drums making one revolution in 65 hours. Each drum-shaft is prolonged vertically downwards by the rigid attachment of a glass rod *F* reaching to below the orifice at the bottom of the celluloid hopper *H*, the rod terminating in a radially divided dish *G*, dish, rod and drum revolving solidly together. The orifice at the bottom of the celluloid hopper *H*, is so placed that dejecta passed by the oyster within the hopper are directed into that sectorial division of the slowly rotating dish *G* which happens to be beneath the hopper orifice at the time of extrusion.

The speed of rotation of the drum and consequently of the divided dish (since the two revolve together) being known, a rough means of registration is afforded of the times of passage of faeces and pseudo-faeces.

Details of Construction.

Before entering into a detailed description of the ostreagraph, it must be pointed out that the design of the frame-work of the instrument shown in Fig. 1 was influenced by certain local considerations not likely to obtain elsewhere. Those features in the design of the framework which were incorporated on account of these local considerations are valueless in an instrument for general use, and may therefore be eliminated, with a material simplification of construction. Thus on the extreme left-hand side of the instrument, as shown in Fig. 1, the handle can be dispensed with altogether, the left-hand vertical member of the frame-work need not extend above the upper horizontal member, and the two pulleys, shown at the top and bottom respectively of the left-hand vertical member are not required for an instrument of general use, neither are the two nicks in the upper and lower horizontal members of the frame-work, immediately below the pen counterpoise, lettered *E* in Fig. 1. Similar simplification is possible as regards the right hand side (Fig. 1)

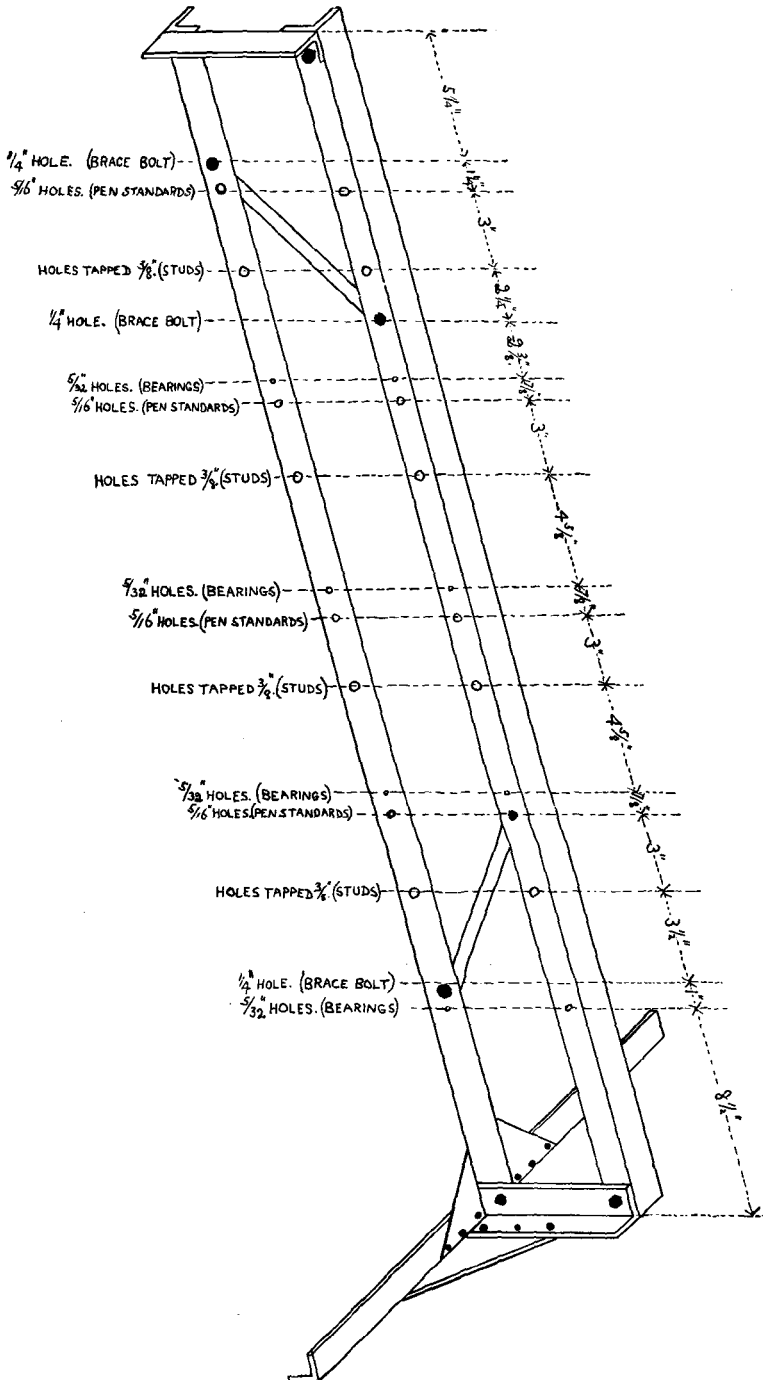


Fig. 2. Frame-work.

of the frame-work. The upper horizontal member may be carried straight along to the vertical member on the extreme right of the photograph, this vertical member and that between it and the nearest drum being cut off level with the upper surface of the upper horizontal member of the frame-work. For general use the nicks near the right-hand extremities of the horizontal members are not required, neither are the pulleys on the extreme right-hand vertical member.

Shorn of these non-essentials, the frame-work of the ostreagraph consists of two horizontal members of $1\frac{1}{4}$ inch \times $\frac{3}{16}$ inch angle-iron, each 4 feet long; three vertical members of the same material, each $6\frac{1}{8}$ inches long; a similar piece of angle-iron 19 inches long to form a *T* with the lower horizontal member; and two 45° 6 inch angle plates (1), all bolted together with $\frac{3}{8} \times \frac{3}{4}$ inch steel nuts and bolts (1), as shown in parallel perspective in Fig. 2. This frame-work is strengthened by the addition of two diagonal braces of $\frac{3}{4}$ inch \times $\frac{3}{16}$ inch iron and secured by $\frac{1}{4}$ inch nuts and bolts. The positions of attachment of these diagonal braces are shown in Fig. 2, and are of importance, being chosen so as not to interfere with other parts of the instrument. In each horizontal member there are drilled four $\frac{5}{16}$ inch holes, four $\frac{5}{32}$ inch holes, and four holes drilled and tapped $\frac{3}{8}$ inch Whitworth. The whole instrument stands for steadiness on three points, brass bolts $1\frac{3}{4}$ inches \times $\frac{3}{8}$ (Whitworth) (1) being tapped into the angle-iron at the extremities of the *T*-shaped part of the frame-work. The assembled frame-work so far as it has been described up to this juncture is shown in Fig. 2.

The drums are made from block-lid or lever-lid tins, $4\frac{1}{2}$ inches in diameter and 6 inches high (2). The block-lid is hammered in symmetrically and a small hole pierced in the lid to allow for expansion of air within the tin. Holes $\frac{3}{16}$ inch are then made in the exact centres of the lid and bottom of the tin. A piece of $\frac{3}{16}$ inch steel shafting (1) is threaded for about $\frac{1}{8}$ inch and a $\frac{3}{16}$ inch brass nut (3) screwed hard on to it. The shafting is then passed downwards through the holes in the bottom and top of the tin, which is held in the inverted position, the nut soldered to the bottom of the tin (now the top of the "drum") the shaft soldered into the lid of the tin, now the bottom of the "drum" from which $7\frac{3}{4}$ inches of shaft protrudes. Each drum-shaft is provided with a "Meccano" collar with set-screw (Meccano Part No. 59) (4) and a $\frac{1}{2}$ inch pinion wheel (Meccano Part No. 26A) (4), both reamed out to $\frac{3}{16}$ inch to slide on the drum-shaft. The correct positions of these two parts on the drum-shaft can be ascertained in the course of assembly and fixed then by means of the set screws, with which both are provided. In use it is

convenient to cover the drums with squared paper, kept in position with rubber bands.

Each drum-shaft runs in a pair of brass bearings fixed vertically one above the other on the front faces of the upper and lower horizontal members of the frame-work. Each bearing is a "Meccano" Hand-rail Support (Meccano part No. 136) (4) reamed out to $\frac{3}{16}$ inch, the threaded portions of the parts being passed through the eight $\frac{5}{32}$ inch holes in the horizontal members of the frame-work and secured with the nuts supplied with the parts. The set collars on the drum-shafts take the downward thrust due to the weight of the drums.

All four drums are driven by a horizontal shaft *B* (Fig. 1) running along the top surface of the upper horizontal member of the frame-work, by means of worm-gears on the horizontal shaft in mesh with the pinion wheels on the vertical drum-shafts. The horizontal shaft itself is a piece of $\frac{3}{16}$ inch steel shafting (1) $35\frac{1}{4}$ inches long, and runs in five approximately equally spaced bearings (Meccano parts No. 136) (4) reamed out to $\frac{3}{16}$ inch, and supported on $\frac{3}{4}$ inch lengths of $\frac{3}{4}$ inch \times $\frac{1}{8}$ inch brass angle (3) bolted to the upper surface of the upper horizontal frame member. The horizontal shaft carries at its left-hand extremity (see Fig. 1) a "Meccano" $\frac{1}{2}$ inch pinion wheel, 19 teeth (Meccano part No. 26 A) (4), four worm-gears (Meccano parts No. 32) (4) in suitable positions for their enmeshment with the $\frac{1}{2}$ inch pinion wheels on the drum-shafts, and a pair of collars with set screws (Meccano part No. 59) (4) hard up against the two sides of any one of the bearings, to prevent end play of the shaft.

The horizontal shaft is driven by a robust 16-day clock-work movement of the kind designed for lighting and extinguishing street gas lamps at predetermined times. The clock-work movement only is obtainable at the cost of £1.0.0. from firm (5) (see list in last section). To the main arbor of this clock, which rotates once in 24 hours, a $3\frac{1}{2}$ inch, 133 teeth pinion wheel ("Meccano" part No. 27 B) (4) is fixed. The clock body, being cylindrical in shape, with the main arbor axially placed, a clock-bracket is conveniently made from two $3\frac{3}{4}$ inch lengths of $1\frac{3}{4}$ inch \times $\frac{3}{32}$ inch angle iron (bedstead sides) united parallel to each other by two strips of 1 inch \times $\frac{1}{4}$ inch iron. Recesses to take about one-third of the circumference of the cylindrical clock are cut out of the upstanding parts of the angle irons, the distance between which is about $1\frac{1}{4}$ inches. The clock is firmly clamped into these recesses by means of a brass strap terminating in a screw and wing-nut (6) engaging in a slot on the outer side of the clock-bracket, for sketch of which see Fig. 3. The clock bracket, the position of which on the instrument will be seen from Fig. 1, is clamped

to the upper surface of the upper horizontal member of the frame-work by means of two $\frac{1}{4}$ inch studs let into that member, the studs passing through slots in the clock-bracket so cut as to allow for a backward and forward adjustment of the pinion wheel on the main arbor of the clock in relation to the pinion on the horizontal shaft.

At this point, having described the clock-work movement and the gearing which it actuates, it may be convenient to set down the gear ratios which determine the rate of rotation of the drums. The main

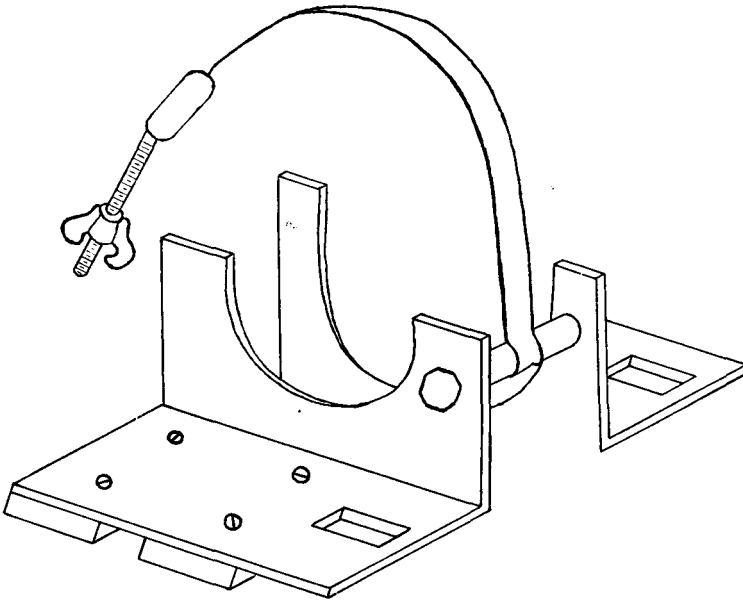


Fig. 3. Clock bracket.

arbor of the clock rotates once in 24 hours. The 133 teeth wheel on the main arbor of the clock drives a 19 teeth pinion on the horizontal shaft. Therefore the horizontal shaft rotates 7 times in 24 hours. The worm-gears on the horizontal shaft engage with 19 teeth pinion wheels on the vertical drum-shafts. The drums, and the revolving dishes rigidly connected with them, consequently make one revolution in 65 hours. The circumference of the drum being 14.3 inches, the hourly travel of the chart attached to the drum is approximately 0.2 inch, that is 2 small squares, if squared paper, divided into inches and tenths, is used for the charts.

The oysters, the celluloid hoppers by which they are partially enclosed, the bearings for the revolving dishes beneath the hoppers and the dish

shafts are all supported on *L*-shaped pieces of slate marked *J* in Fig. 1. These slates are clamped to the upper and lower horizontal members of the frame-work, into which eight $\frac{3}{8}$ inch brass studs (made from $\frac{3}{8}$ inch screwed rod (3)) are fixed, by means of back-nuts, into the $\frac{3}{8}$ inch tapped holes already referred to and shown in Fig. 2, the studs being provided with brass washers (6) and wing-nuts (6). Each slate *L*-piece is about $\frac{5}{8}$ inch thick and $45\frac{1}{4}$ inches long overall. The long limb is $3\frac{1}{4}$ inches broad, the toe being $6\frac{1}{2}$ inches broad and 3 inches high. About one and a quarter inches from the outer extremity of the toe, on its upper surface, a glass bearing, made from a piece of capillary tube sealed off at one end, of dimensions such that a gramophone needle runs smoothly in it, is fixed into a hole in the slate by means of "Murrayite" (7). Thirty-one and a half inches vertically above this glass bearing a brass bearing *L* (Fig. 1), a $\frac{3}{16}$ inch hole in a piece of $\frac{1}{16}$ inch brass strip (3), is supported on a piece of $\frac{1}{2}$ inch \times $\frac{1}{16}$ inch angle-brass (3), 6 inches long, which is fixed to the slate *L*-piece with brass bolts (3). In these two bearings runs the shaft carrying the radially-divided dish.

These radially-divided dishes are made from Petri dishes, $3\frac{3}{4}$ inches in diameter and $\frac{5}{8}$ inch deep. A $\frac{1}{4}$ inch hole is drilled in the centre of the bottom of the dish by means of a brass tube worked in a brace through wooden guides, the cutting edge of the tube being fed with a mixture of carborundum powder and turpentine. For each dish an ebonite hub is made, consisting of a two inch length of ebonite tube (6), $\frac{3}{4}$ inch external diameter and walls $\frac{1}{8}$ inch thick. One end of this tube is plugged, by cementing into it with "Murrayite", a $\frac{1}{2}$ inch length of ebonite rod (6) which is filed off flush and square with the end of the ebonite tube. Into this plug an axially placed hole is bored and tapped $\frac{1}{4}$ inch, into which a piece of threaded $\frac{1}{4}$ inch ebonite rod (6) is cemented with "Murrayite", $1\frac{1}{4}$ inches of threaded rod being left protruding from the bottom of the plugged $\frac{3}{4}$ inch ebonite tube. The protruding threaded ebonite rod is screwed through a central tapped hole of an ebonite disc, $\frac{5}{8}$ inches thick (6) 1 inch in diameter, having twelve equally spaced fine saw-cuts, radially arranged, and extending for $\frac{1}{8}$ inch inwards from the circumference of the disc. That part of the threaded ebonite rod which protrudes through the disc is passed through the central hole in the bottom of the Petri dish referred to above, which is secured on to the ebonite hub by means of an ebonite nut, between which and the bottom of the Petri dish a rubber washer is interposed. In the screwed $\frac{1}{4}$ inch ebonite rod which protrudes beyond the terminal ebonite nut, an axial hole is drilled, of sufficient depth and diameter to admit a gramophone

needle for about half its length. Into this hole the needle is cemented with "Murrayite", point outwards. Radial sub-division of the Petri dish is carried out by cementing with "Murrayite" strips of celluloid, the inner ends of which are secured in the radially-disposed saw-cuts in the hub, the outer ends and lower edges being attached to the periphery and bottom respectively of the Petri dish. The radial celluloid strips are strengthened by cross-halving ("Egg-boxing") a circular celluloid wall concentric with the periphery of the Petri dish, at a radius mid-way between it and that of the ebonite hub. The dish making (with its drum) one revolution in 65 hours, one radial division of the Petri dish will pass a given point in five hours and twenty-four minutes. Into the open end of the $\frac{3}{4}$ inch ebonite tube forming the upper part of the hub, a rubber cork is fitted, through which passes a glass rod, which, extending upwards for about 24 inches, terminates in a second rubber cork which fits into a 2-inch length of $\frac{3}{4}$ inch (external) ebonite tube, into the upper end of which is cemented an ebonite plug. Into this plug an approximately 2-inch length of $\frac{3}{16}$ inch brass rod is axially fixed. The gramophone needle in the bottom of the hub of the revolving dish runs in the glass bearing let into the toe of the slate *L*-piece, and the $\frac{3}{16}$ inch brass rod with which the revolving dish shaft is surmounted, runs in the brass bearing, already referred to (*L*, Fig. 1), and as will be seen by reference to the photograph of the ostreograph, Fig. 1 (most clearly in the case of the drum, dish etc. on the right of the instrument), that the lower end of the drum-shaft is vertically above the upper end of the corresponding dish shaft. Connection between these two shafts is made by a flexible helical spring, at each end of which is attached a brass electrical screw connector (6). The flexible connection between the two shafts provides compensation in case of slight errors of alignment, which are difficult to avoid. As an alternative to spring connections, "Meccano" Universal Couplings (Meccano part No. 140) (4) could be used.

The next items for description are the celluloid hoppers each of which directs the dejecta extruded by the oyster within it into that division of the revolving dish which happens to be beneath the hopper orifice at the time of extrusion. The hoppers, the shape and dimensions of which are shown in Fig. 4, are secured by rubber bands, as shown in Fig. 1, to the slate *L*-pieces, which are cut away sufficiently to bring the orifices of the hoppers into proper relation to the revolving dishes. As an alternative material for the construction of the hoppers, "Stay-brite" Steel (8) Sheet, (with soldered joints might be used).

The oysters under experiment are rigidly fixed by their lower valves to suitably bent iron rods, which are bolted to the *L*-shaped slates, each

rod being so shaped as to support an oyster in its normal position within its hopper *H* (Fig. 1), without interfering with the connecting rod *I* (Fig. 1) which is attached to the upper valve of the oyster. Prior to an experiment, a $\frac{3}{16}$ inch flat-head bolt is attached to the lower valve of an oyster by means of Portland cement, which is allowed to set for about a day out of water, followed for a few days in sea-water. By using Roman cement the time of the oyster out of water can be reduced to an hour or two, and it is possible that by the incorporation into Portland cement of a proprietary setting-accelerator sold under the name of "Sika" (9) of which, however, the writer has no practical experience, that the cement would be finally set and the oyster ready for experiment in the course of a few minutes. When the cement has set, the

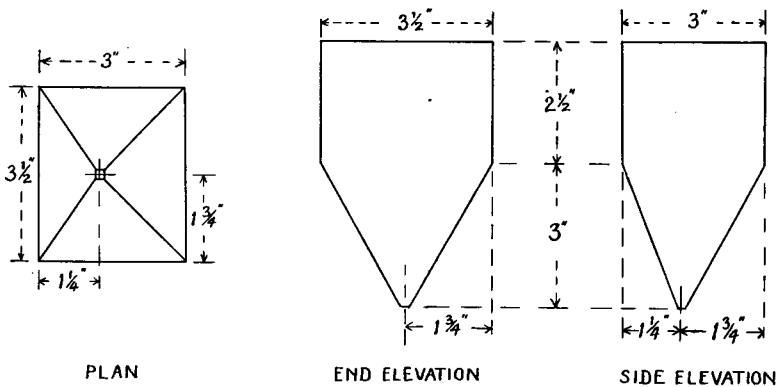


Fig. 4. Celluloid hoppers.

$\frac{3}{16}$ inch iron screw on the lower valve of the oyster is passed downwards through a hole at the end of the iron rod and fixed by means of an iron nut.

At the time of the cementing of the screws to the lower valves of the oysters, as just described, the socket parts of simple ball and socket joints are cemented to the upper valves. These ball and socket joints each consist of two "Gillette" safety razor blades, broken off about $\frac{1}{8}$ inch above the central circular hole, and united parallel to each other, with the interposition of a distance piece of iron $\frac{1}{8}$ inch thick, by a bolt and nut through their remaining straight-sided holes. An oyster having been fixed by the screw on its lower valve to the iron support, a $\frac{5}{16}$ inch steel ball (rustless balls (10) are now obtainable) to which is soldered a few inches of $\frac{1}{16}$ inch steel rod, (3) is sprung into the socket formed by the circular holes in the two parallel razor blades, with of course a liberal coating of vaseline. A sketch of this ball and socket

joint is given (Fig. 5). The steel rod soldered to the ball forms the lower extremity of the connecting rod *I* (Fig. 1), by which the movements of the upper valve of the oyster are communicated to the pen *D* (Fig. 1) and is extended upwards by the attachment to it, by means of Plaster of Paris, of a glass tube, reaching to above the water line. At this point it is joined to a $\frac{1}{16}$ inch brass rod connected with the ball of the ball and socket joint of the pen (to be described later) by means of a clamp

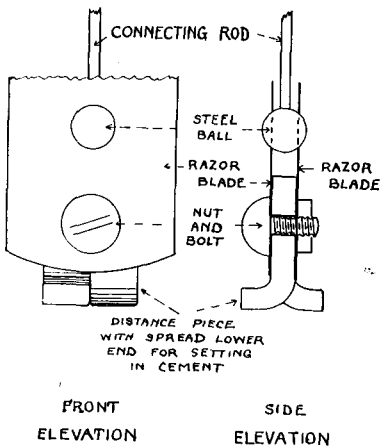


Fig. 5. Ball-and-socket joint for cementing to oyster.

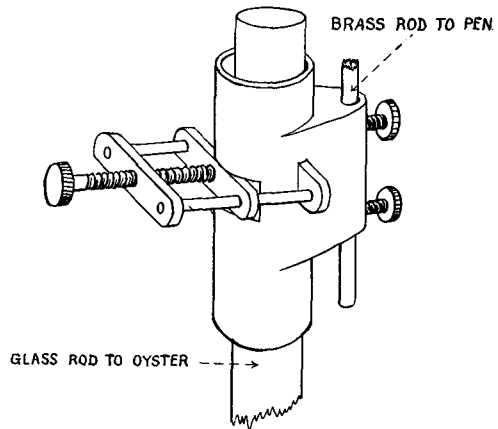


Fig. 6. Screw clamp for connecting rod.

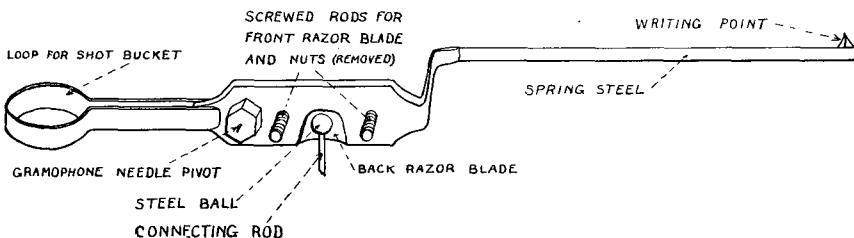


Fig. 7. Pen (front razor blade and nuts which hold it removed).

made from an electrical screw connector, a piece of brass tube and a small screw clip, which fitting, shown in Fig. 6, allows of the easy adjustment of the length of the composite connecting rod.

The last parts of the instrument to be described are the pens and their supports. The body of each pen is made from a 3 inch length of $\frac{3}{4}$ inch \times $\frac{1}{8}$ inch brass flat (3), through which is soldered, $\frac{5}{8}$ inch from one end, a piece of $\frac{3}{8}$ inch hexagon brass rod (3) of such a length that it projects $\frac{1}{4}$ inch on each side of the brass flat (see Fig. 7). A small

central hole is drilled in each end of the brass hexagon, of sufficient diameter and depth to admit a gramophone needle, which is soldered in, point outwards, the needle points working in depressions, to be described later, forming the pivots upon which the pen turns. At $\frac{1}{2}$ inch and $1\frac{1}{2}$ inch centres respectively from the vertical plane of the gramophone needles, lengths of $\frac{3}{16}$ inch brass screwed rod (3) are soldered into tapped holes in the $\frac{3}{4}$ inch \times $\frac{1}{8}$ inch brass flat, and cut off to leave $\frac{3}{8}$ inch of screwed rod projecting from each side of the brass flat, which is cut away between the screwed rods as shown in Fig. 7. A Gillette Safety razor blade, with one cutting edge ground off flat and the other hollowed out as shown in Fig. 7, is passed over the two projecting screwed rods on one side of brass flat and kept in place by means of $\frac{3}{16}$ inch nuts, which should, however, be smaller than standard $\frac{3}{16}$ inch nuts, and which are obtainable from (3). A similarly ground razor blade is slipped over the pair of projecting screw rods on the other side of the brass flat. The two circular holes of the now parallel blades form the socket of the ball-and-socket joint through which the movements of the upper valve the oyster are communicated to the pen by the connecting rod (*I* Fig. 1) already described, the ball being a $\frac{5}{16}$ inch steel bearing ball, to which is soldered a 12 inch length of $\frac{1}{16}$ inch brass rod (3); which is connected to the glass portion of the connecting rod by means of the clamp referred to above and shown in Fig. 6. To the end of the pen body further from the gramophone needles, the flexible spring arm, which keeps the writing point up to the drum, is attached. The plane of the spring arm is off-set 1 inch behind (in regard to aspect of the instrument as shown in Fig. 1) the plane of the main body of the pen, by soldering it to a suitably bent piece of $\frac{1}{4}$ inch \times $\frac{1}{16}$ inch (3) brass strip, which is soldered to the main pen body (see Fig. 7). The pen arm is made from an approximately 5 inch length of thin spring steel, $\frac{3}{16}$ inch broad (3), at the distal end of which is a V-shaped gutter pen, made from the thin brass foil used by motor engineers for making "Shims" for packing up worn bearings. The ink used in this pen is that supplied for use in thermographs; the lever ratios are such that the valve movements of the oysters are recorded on the drums with a vertical magnification of 7.7 times. To the end of the pen body nearer to the gramophone needles a loop, made from $\frac{1}{4}$ inch \times $\frac{1}{32}$ inch brass flat (3) is soldered, to take a $2\frac{1}{2}$ inch \times $\frac{7}{8}$ inch test-tube (*E* in Fig. 1), the axis of the test-tube being $2\frac{5}{8}$ inches from the vertical plane passing through the two gramophone needles. This test-tube contains sufficient shot to counterpoise the pen, the whole of the connecting-rod and the ball-and-socket joint cemented to the oyster, the adjustment being made, of

course, with the connecting rod etc., immersed to the extent to which they are to be submerged in actual experiment.

The adjustable bearings, together with their supports in which the gramophone needle pivots of the pens turn, are made by the adaption of brass battery clamps No. 211 (11). Such a battery clamp, after the necessary modification, is shown in Fig. 8. Each battery clamp is bolted in the position there shown to an 11 inch length of 1 inch \times $\frac{1}{8}$ inch

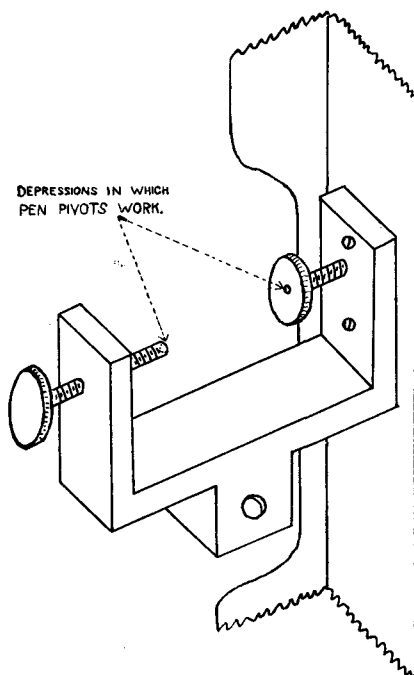


Fig. 8. Pen bearings.

angle iron (3), cut away to admit of the free working of the pen. The back surfaces (in regard to the aspect of the instrument shown in Fig. 1) of these angle iron pen standards are off-set 3 inches in front of the front surfaces of upper and lower horizontal members of the frame-work, each standard being rigidly attached thereto by two $\frac{5}{16}$ inch iron rods threaded at both ends and provided with two pairs of nuts. The screwed rods pass through the four pairs of $\frac{5}{16}$ inch holes shown in the horizontal frame-work members in Fig. 2, and through corresponding holes in the pen standards. The adapted battery clamps are so positioned on the pen standards that the axis of rotation of the pens (produced) is $1\frac{3}{4}$ inches above the upper surface of the upper horizontal frame members. The

pen standards also serve to support brass screw terminals (*M* Fig. 1) in which suitably bent lengths of $\frac{1}{16}$ inch steel rod (3) may be clamped

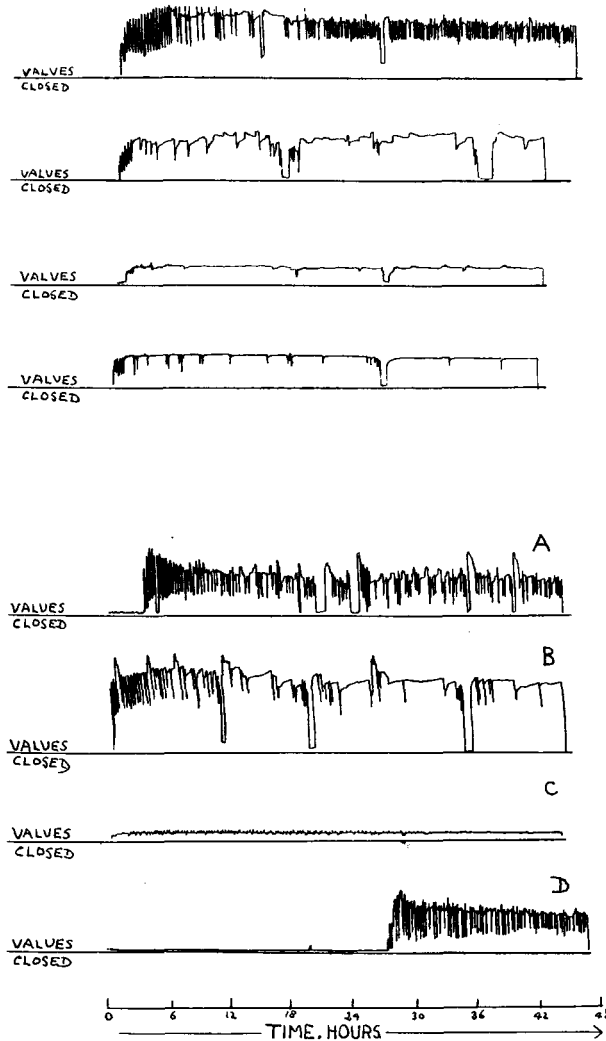


Fig. 9. Tracings of the valve movements of two batches of four oysters each. All the oysters of each batch had the same history, and were under identical conditions whilst the tracings were being taken. Valve excursions magnified 6.6 times.

to subserve the purpose of keeping the pens away from the drums whilst the charts are being changed.

The writer would here wish to acknowledge the valuable assistance which he has received at the hands of his colleagues, Mr. H. P. SHER-

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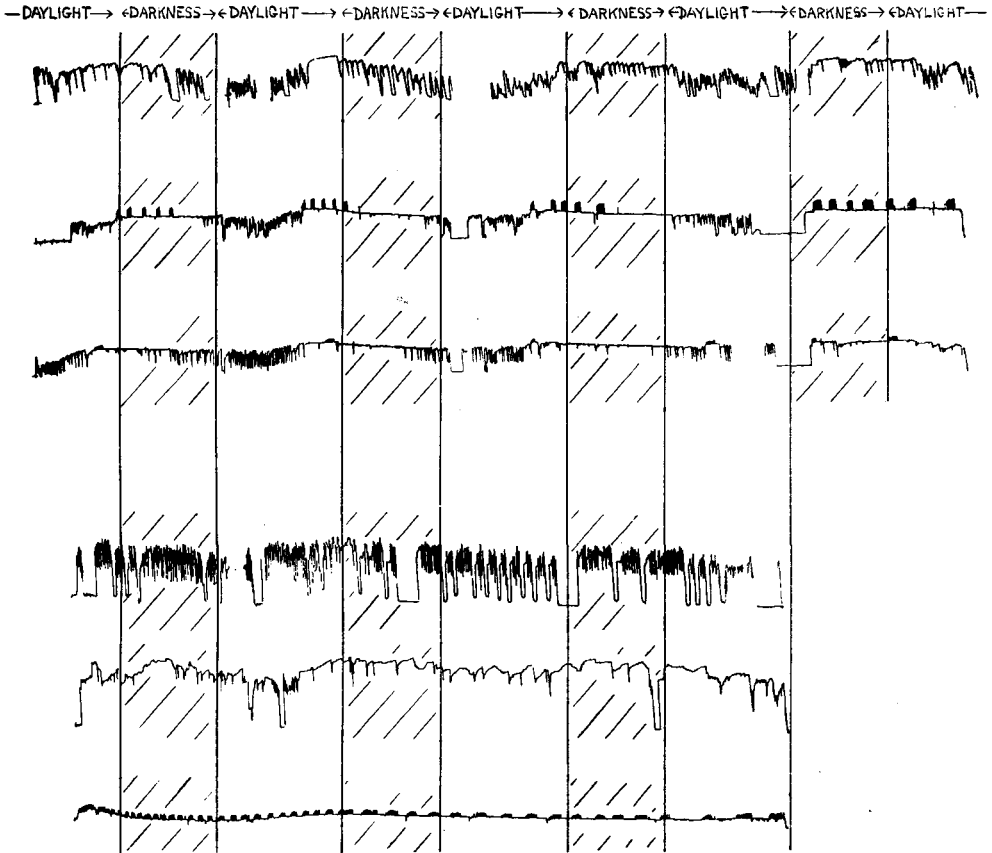


Fig. 10. Influence of daylight and darkness on the behaviour of oysters. Valve excursions magnified 6.6 times.

Results obtained.

For the reasons which have already been set forth, the volume of information obtained by the application of the method of autographic record to the observation of the valve movements of oysters is not large, and inasmuch as on the completion of the construction of the dual purpose apparatus, as stated above, at a late stage of the investigation, the

necessity for certain modifications of that part of the instrument designed for the registration of the times of the extrusion of dejecta was indicated, it has been possible up to the present to do no more in the direction of experiments on the times of extrusion of dejecta than to try out the part of the apparatus designed for that purpose. The performance, however, of that part designed for recording the valve movements was satisfactory from the beginning, as was that of the original apparatus, and, it may be of interest to give a few examples of the experiments carried out, and the results obtained with the autographic recorders.

The first two sets of tracings to be mentioned, shown in Fig. 9, have already been referred to. The oysters in question were all part of the same delivery, stored together in an open tank of 2700 gallons capacity, with frequent changes of water, for about two months, at the end of which time they were transferred, in successive batches of four, to a similar but covered tank, connected with the recording apparatus, and allowed to function undisturbed, in the dark, for about 48 hours at a depth of 12 inches of water, S.G. 1025, of maximum and minimum temperatures respectively of 52° — 47° F. in the case of the first four oysters, and 54° — 47° F. in the case of the second four. It will be seen from the tracings shown in Fig. 9, in the cases of both batches of oysters, that although, as regarded the four oysters comprising each batch, their past history for the previous two months and the conditions obtaining whilst the tracings were being taken, were identical, their behaviour as judged by their valve movements, was by no means so.

The tracings shown in Fig. 10 indicate that the onset and termination of daylight have little influence on the behaviour of oysters, as judged by their valve movements. The tracings were obtained by connecting to the recording apparatus, in batches of three, six oysters which were allowed to function at the bottom of an open tank 3 feet deep and 12 feet \times 12 feet superficially, filled with sea-water of S.G. 1025. In the case of the first three oysters the tracings of which are shown in Fig. 10, the duration of the experiment and the temperature range of the water were respectively about 96 hours and 50° — 46° F. and in the case of the second three oysters about 72 hours and 54° — 47° F. The periods of darkness are indicated by the shaded portions of the charts.

It was a matter of some interest in connection with the general question of oyster purification to ascertain the influence of immersion in fresh water on the subsequent behaviour of oysters. In Fig. 11 are shown tracings which were obtained in two experiments in that direction. In the first of these, in which the upper four tracings shown in Fig. 11 were obtained, two oysters, to serve as controls, were immersed in sea

water, of S.G. 1025, for 46 hours, the temperature range over the period of immersion being 46° — 41° F. Two other oysters were immersed for the same period in a bowl of fresh water partially submerged in the water of the above-mentioned sea-water tank, so that the temperature con-

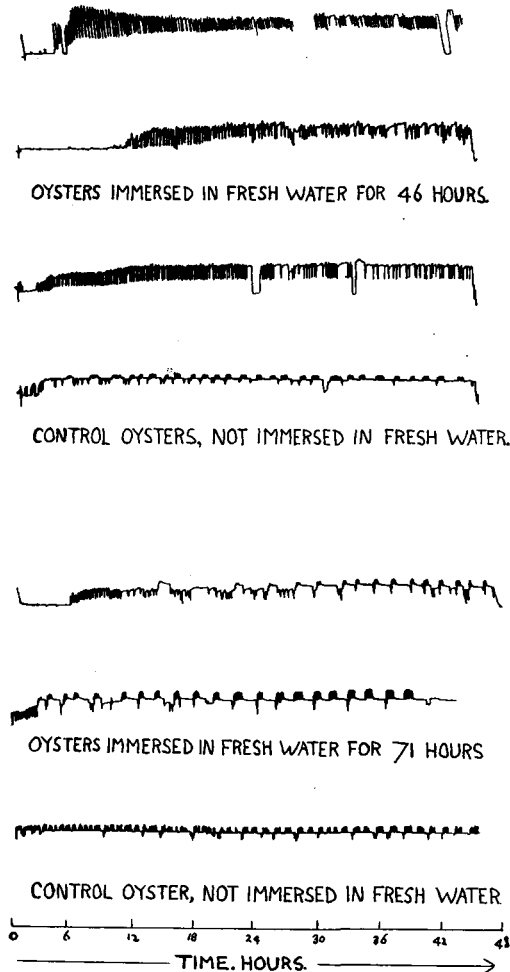


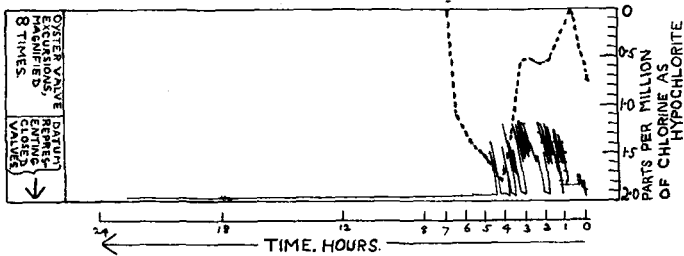
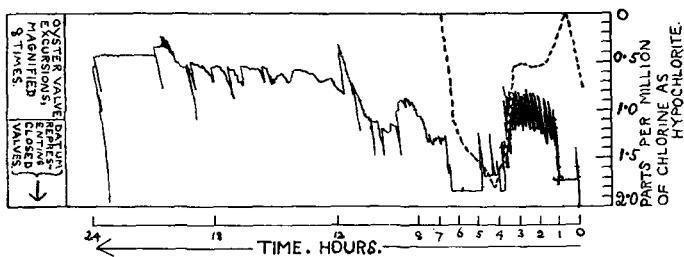
Fig. 11. Influence on the behaviour of oysters of immersion in fresh water. Valve excursions magnified 6.6 times.

ditions of the fresh water in the bowl and of the sea-water in the tank in which it stood were the same. Immersion was carried out in darkness. At the end of the immersion period, all four oysters were connected to the recording apparatus, set up over two 20 litre bowls, in one of which the oysters which had been immersed in fresh water were placed, in the

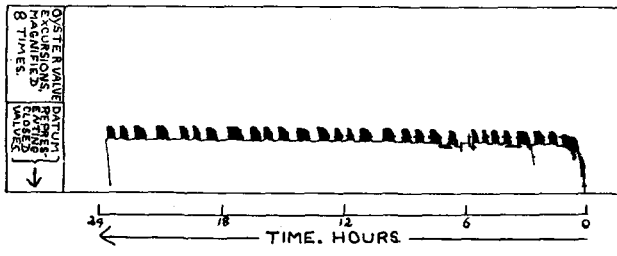
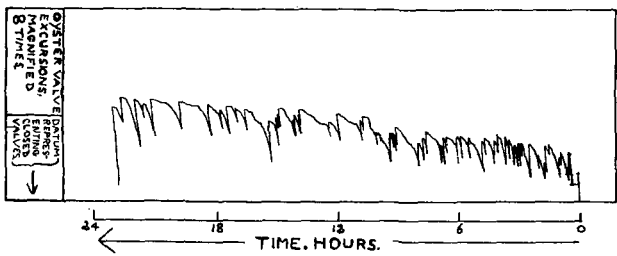
other the controls; both bowls being filled with sea water of S.G. 1025. The oysters were allowed to function in darkness for about 46 hours, over which period the temperature range of the water in both bowls was 53°—47° F.

In the second experiment of the same kind, in which the lower three tracings shown in Fig. 11 were obtained, a similar procedure was followed. The period of immersion of the oysters was, however, 71 hours, the temperature range over the immersion period 45°—41° F., and that over the period 48 hours, during which they were subsequently allowed to function undisturbed, in connection with the recording apparatus 50°—48° F. (The tracing given by one of the control oysters used in this experiment was rendered worthless by a defect in the pen which developed during the course of the experiment). From a comparison of the behaviour of the oysters which had previously been immersed in fresh water with that of the controls, as demonstrated by the tracings shown in Fig. 11, it might perhaps be said that there appears to be a tendency towards delay in opening on the part of oysters previously immersed in fresh water. Against this suggestion, however, must be set the findings of the experiment in which the lower four tracings shown in Fig. 9 were obtained. In that experiment not only were all four oysters under identical conditions whilst connected to the recording apparatus, but had identical histories extending back for the previous two months. Yet, as will be seen from the tracings in question, which have been lettered for convenience of reference *A*, *B*, *C* and *D* (Fig. 9), that the oyster furnishing tracing *B* opened widely as soon as connected to the apparatus and remained open until the time of disconnection, the oyster furnishing tracing *C* opened very slightly over the whole period of the experiment, whilst the oysters furnishing tracings *A* and *D* for no apparent reason delayed their opening until approximately 4 hours and 29 hours respectively had elapsed after their connection to the recorder.

The lack of uniformity of behaviour amongst oysters was also observed in an experiment on the action on them of "chlorine", that is, hypochlorite. In the experiment in question two oysters were placed in a 20 litre bowl through which a slow current of sea water of S.G. 1025 at a temperature of 51° F. was caused to flow. Through a similar bowl, in which were placed two other oysters, a similar current of sea-water of the same specific gravity and temperature, but containing a small concentration of hypochlorite, was likewise caused to flow. All four oysters were connected to the recording apparatus, by which the tracings shown in Fig. 12 were obtained. Arrangements were made for varying at will the hypochlorite concentration, which was estimated at frequent



OYSTERS IN WATER CONTAINING HYPOCHLORITE.



CONTROL OYSTERS. NO HYPOCHLORITE.

Fig. 12. The influence of small concentrations of hypochlorite on the behaviour of oysters.

regular intervals by the usual method. On the appropriate tracings shown in Fig. 12 the hypochlorite concentrations have been plotted. It will be seen that whatever relation may have obtained between the behaviour of the oysters and the concentration of hypochlorite whilst the latter was operative, when the hypochlorite feed was shut off, the oyster furnishing the uppermost tracing (Fig. 12) opened widely and remained open for the duration of the experiment, whilst the other oyster which had been subjected to the action of hypochlorite under exactly parallel conditions, shut during the peak period of hypochlorite concentration never to re-open during the remainder of the period of the experiment.

**Names and Addresses of Firms from which
Components not easily obtained locally may be purchased.**

The number against each firm corresponds to the number (in brackets) following the component supplied by it on its first mention in the Section devoted to details of construction.

- (1) Metal Agencies Co., Ltd., Queen Square, Bristol.
 - (2) Messrs. JOHN FEAVER, Ltd., Tower Bridge Road, London, S.E. 1.
 - (3) Mr. J. HEATH, 459, Romford Road, Forest Gate, London, E. 7.
 - (4) Messrs. Meccano, Ltd., Binns Road, Liverpool. (Also agencies in most towns.)
 - (5) The British, Foreign and Colonial Automatic Light Controlling Co., Ltd., 100, Holdenhurst Road, Bournemouth.
 - (6) The Economic Electric Co., Ltd., 10, Fitzroy Square, London, W.
 - (7) Messrs. FLATTERS & GARNETT, 309, Oxford Road, Manchester.
 - (8) Messrs. THOMAS FIRTH & SONS (Birmingham) Ltd., Blackheath, Birmingham.
 - (9) Sika Ltd., 82, Victoria St., London, S.W.
 - (10) Messrs. STUART TURNER, Ltd., Henley-on-Thames.
 - (11) Messrs. A. GALLenkAMP & Co., Ltd., 19, Sun Street, Finsbury Square, London, E.C. 2.
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