mine the exact details, but in general it is necessary to standardize the diaphragm openings of both microscope condenser and light source, rheostat setting of the lamp,

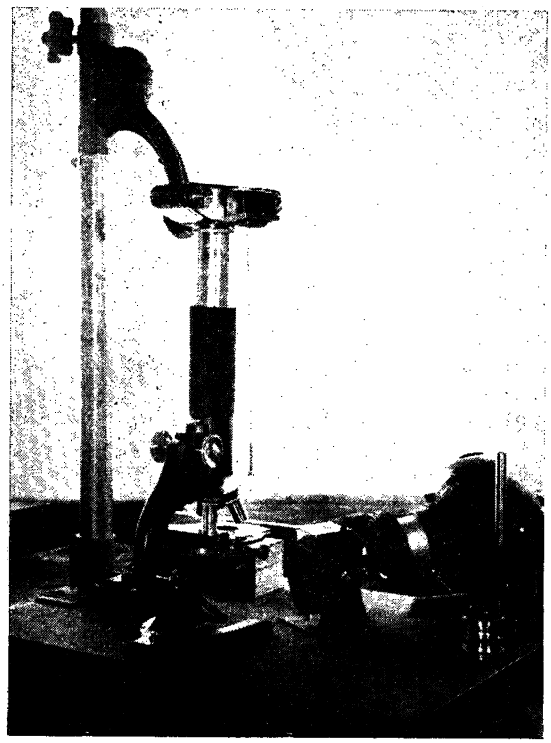

FIG. 1. The camera in position for taking a photomicrograph.

distance from lamp to microscope mirror, and height of camera above the eyepiece. Once this is done, it is no problem to establish proper exposure times for the several desired magnifications. Choice of film, filters, etc. are matters best left to the whims of the individual researcher.

Perhaps the only disadvantage of this apparatus is the high initial cost of the camera itself. We feel that this is more than offset by the following:

(1) Photomicrographs can be so quickly and effectively taken that the newly popular smear techniques in cytology are fully applicable. One can work at the microscope unimpeded, photographing with expenditure of but a few minutes whatever seems of interest.

(2) Cost of film is sufficiently low that large numbers of photomicrographs can be taken and records kept in this form, rather than as drawings or as stage vernier readings. There is decidedly less need for maintaining large stocks of old preparations.

(3) Kodachrome slides can be directly produced, and $2'' \times 2''$ black-and-white transparencies can be made simply by contact printing on a high contrast ortho film. For that matter, negatives of larger sizes can be photographed by transmitted light and reproduced as $2'' \times 2''$ transparencies.

(4) The same camera can be used for photomicrographs, for close-up photographs through dissecting microscope or extension tubes, for copying illustrations or microfilming books, and for ordinary work in the field. Frequently not even a change of film is necessary.

Use of the Dropping-Mercury Electrode for the Continuous Measurement of Dissolved Oxygen in Flowing Water[1]

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In connection with measurements of the basal metabolic rates of fishes, it was found desirable to obtain continuous records of the oxygen content of a stream of water issuing from the metabolism chamber. Giguère and Lauzier (*1*) have described a polarographic method for measuring the dissolved oxygen in flowing water, but the conditions necessary for its performance make it unsuitable for the present application. The polarized dropping-mercury electrode seemed to be more promising, particularly as employed by Manning (*3*), who obtained a continuous 24-hr record of the oxygen content of unmodified lake water. However, because of progressive changes in the surface of the quiet pool of mercury (the anode), this method could not be made to yield satisfactory results when applied to flowing tap water.[2] Although the oxygen content of the water did not change, the limiting current at constant voltage (1 v) decreased steadily throughout all trials. A calomel electrode with saturated KCl solution and an agar bridge (*2*) performed somewhat better, but the results were still not satisfactory, the limiting current continuing to diminish. A sealed calomel electrode with a fiber bridge gave the same result. Apparently the concentration of the salt across the bridge, or the pressure within it, undergoes a progressive change while the electrical current is flowing which alters the potential across the bridge.

The difficulty can be overcome by opening the bridge to an open reservoir containing a saturated solution of KCl and calomel, the reservoir being set at such a level that the pressure of the solution on the bridge is slightly greater than that driving water into the electrolysis cell. A pressure of a few centimeters of water is sufficient. Under these conditions there is an extremely slow flow of saturated solution through the bridge into the electrolysis cell (less than 0.4 ml in 24 hrs), so that there is no change in potential across the bridge. With this modification of the calomel electrode, the limiting current remains constant for extended periods, sometimes for as long as a week. Experimental changes in the oxygen content of the water flowing through the cell are accompanied

[1] Aided by a grant from the Committee for Research in Problems of Sex, National Research Council.

[2] Charcoal-filtered, aerated city water.

by corresponding changes in the limiting current over the range of concentrations tested so far (2.3–7.4 mg/liter). By use of recording equipment[3] $i_{\frac{1}{4}}^{*}$ is possible to obtain continuous records of the oxygen content of running tap water for long periods. Unless records are desired, the combination of a Weston cell and galvanometer, described by Petering and Daniels (*5*), is very satisfactory for continuous operation.

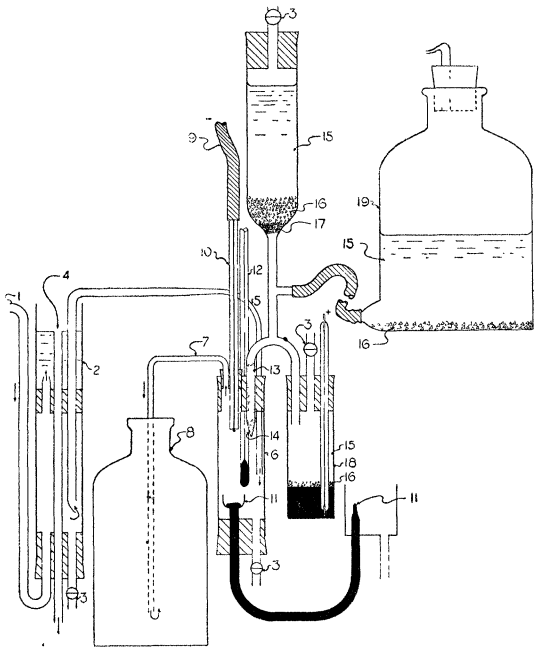

FIG. 1. Assembly of apparatus: 1, water inlet from metabolism chamber; 2, constant-level reservoir (glass tubing 20 × 115 mm); 3, stopcocks (closed during operation); 4, overflow; 5, inlet to electrolysis cell; 6, electrolysis cell (glass tubing 20 × 65 mm); 7, outlet from electrolysis cell; 8, constant-level overflow bottle; 9, Neoprene tubing from mercury reservoir; 10, capillary; 11, mercury overflow; 12, thermometer; 13, 3% agar gel in saturated solution of KCl and calomel; 14, opening from agar bridge; 15, saturated KCl and calomel; 16, KCl crystals; 17, glass-wool retainer; 18, calomel electrode; 19, reservoir for bridge.

It is necessary to control the flow rate of the water, the pressure of the mercury in the capillary, the pressure of the saturated solution on the bridge, and the temperature, as variations in these cause the limiting current to vary in the same direction. The changes in the limiting current are relatively small, however, so that when it is desired merely to indicate the approximate concentration of oxygen in the water (to within a few tenths of a milligram/liter), the assembly requires very little attention. For precise measurements it is necessary to maintain nearly constant conditions throughout the run. The assembly shown in Fig. 1 has been found to be quite satisfactory for this purpose. Although the diagram is self-explanatory for the most part, several features require further description. In general, the techniques described by Kolthoff and Lingane (*2*) are employed; only those more or less peculiar to the present assembly are described here.

The flow of water is held constant by use of a constant-level reservoir (arranged to protect the water from exposure to the atmosphere before entering the electrolysis cell), an inlet and an outlet of glass tubing of approximately 1.5-mm inner diameter, and a constant-level bottle through which water overflows from the cell. The bottle also serves for the collection of samples for Winkler determinations of dissolved oxygen, against which the dropping mercury electrode is calibrated. With an electrolysis cell of the dimensions given, it is necessary to keep the flow rate of the water below 40 ml/min, as the stronger water currents associated with higher flow rates seem to interfere with the formation of the mercury drops.

Marine barometer tubing of about 0.05-mm bore serves as the capillary, being connected with the mercury reservoir by Neoprene tubing. A constant head of pressure (about 60 cm of mercury) is maintained by the method described by Mueller (*4*). The drop rate is set at about 15 drops/min, at which rate approximately 12.5 ml of mercury pass through the capillary in 24 hrs. It is necessary to clean the tip of the capillary from time to time in order to prevent irregularities in the drop rate, but as a rule it can be operated continuously for from four days to a week before these irregularities appear. Under ordinary conditions of operation, this is the only part of the assembly that requires attention.

The electrolysis cell is enclosed in a water jacket, not shown in the diagram, through which water is kept circulating to prevent changes in the temperature.

Although it should be held reasonably constant, the pressure of the saturated solution on the bridge may be permitted to vary by a few millimeters of water in the course of a run without affecting the results appreciably. As the flow of solution through the bridge is very slow, the pressure change in the course of a week can be made negligible by use of a large reservoir.

The glass tube containing the agar plug is drawn to a narrow tip, with an opening about 1 mm in diameter on one side, about 1 mm back from the blind tip. In this manner the occasional air bubbles and debris that find their way into the system are prevented from accumulating under the agar connection, being swept by it in the water current.

[3] Recording was accomplished by means of a Leeds and Northrup "Electrochemograph," with the polarizing unit set at −1 v and the chart speed reduced.

References

1. GIGUERE, P. A., and LAUZIER, L. *Canad. J. Res.*, 1945. **B23**, 223–233.
2. KOLTHOFF, I. M., and LINGANE, J. J. *Polarography*. New York: Interscience, 1941.
3. MANNING, W. M. *Ecology*, 1940, **21**, 509–512.
4. MUELLER, E. F. *Ind. eng. Chem.* (Anal. ed.), 1940, **12**, 171.
5. PETERING, H. G., and DANIELS, F. *J. Amer. chem. Soc.*, 1938, **60**, 2796–2802.