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Conductometric Apparatus for Determining Photosynthesic Rate

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Abstract. A conductometric apparatus for determining the photosynthetic rate suitable predominantly for field measurements is described. In contrast with the hitherto described and applied instruments 3 samples of air can be analyzed here simultaneously, the data are temperature-independent and the entire electronic part of the apparatus is transistorized. The absorbers ($300 \times 30 \times 30$ mm.) and the leaf chambers ($140 \times 100 \times 10$ mm.) are made of plexiglass. The membrane pump is hand-operated by means of a crank. The conductivity of the absorption solution (0·02N-KOH + 0·5% isoamylalcohol + saponin) is measured in a special measuring cell into which the solution is transferred from the individual absorbers. The error of the photosynthetic rate determination is about 10—20% of the value obtained for intensities of 10—20 mg. CO_2 dm.$^{-2}$h.$^{-1}$.

The conductometric method of determining CO_2 in the air (which is one of the most suitable ones along with the use of infrared gas analysis and colorimetry) has been known for more than 40 years. It served as the basis for the construction of numerous instruments for estimating the intensity of photosynthesis which are characterized by several shortcomings: 1. they are either heavy and cumbersome or 2. possess a relatively complicated and unreliable electronic equipment to be used under field conditions, and finally 3. the absorbers of these instruments do not permit of air passage velocities that ensure normal photosynthetic processes. The measurement is also complicated by the fact that the conductivity of alkaline solutions greatly depends on temperature. Apparently for the above reasons none of the instruments is commonly used.

The present most successful apparatus of this type suitable for field work was described by HOLDHEIDE, HUBER and STOCKER (1936). On the basis of previous data STOCKER and VIEWEG (1960) constructed a fairly convenient apparatus for ecological studies of photosynthesis which can be used for short-period (1 min.) determinations of the photosynthetic rate. Its

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principal drawback lies in the pronounced temperature-dependence of the estimations, in the possibility of analyzing only one air stream at a time and in the relatively great weight of the whole equipment including batteries.

Construction of the apparatus and its operation

Work has been undertaken in this laboratory to construct a portable instrument for field determinations of the photosynthetic rate (VOZNESENSKY 1959, 1960a, b, ZALENSKY 1959). It is a characteristic feature of the latest model of the apparatus (Fig. 1) that its recordings are fully temperature-independent, that three air samples can be analyzed for CO_2 simultaneously and that the entire electronic section is transistorized. These properties made it possible to construct a completely modern low-weight apparatus.

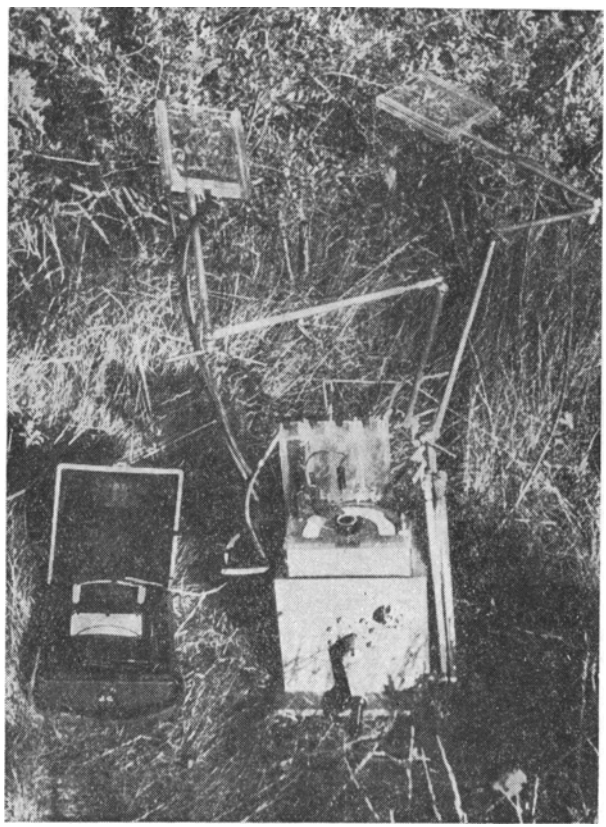


Fig. 1. General view of the conductometric apparatus for measuring photosynthetic rate

The apparatus consists of the following principal parts: three leaf chambers, four membrane pumps operated by a hand-crank, a crank-revolution gauge, a block of absorbers with an absorbing alkaline solution, the measuring cell, the electronic section and a galvanometer.

The leaf chambers [measuring $140 \times 100 \times 10$ mm.] are made of cemented organic glass, the narrow side being open and another side having a removable wall so that the leaf can be conveniently inserted inside. The air sample is pumped out of the chamber by the membrane pumps through openings in one of the narrow sides opposite the open one. During operation the chambers are held on collapsible stands fixed to the base of the apparatus. A uniform, pulse-free air passage amounting to 20—40 l./hr. is ensured by four membrane pumps with a low working volume and with a high frequency of membrane vibration (30—50 cycles/sec.). The valve mechanism of the pumps

is shown in Fig. 2. The openings of the flat block of organic glass hold two thick-wall pieces of rubber tubing 1 (closed at one end) with oblong openings 2; the general arrangement can be seen from the figure. To secure dependable operation of the valves they must be constantly lubricated with glycerol 3. as required for the apparatus of STOCKER and VIEWEG (1960). The volume of the air pumped during the experiment is determined from the number of revolutions of the hand crank on the basis of previous empirical calibration.

Four plexiglass absorbers form a single block. Each of them is formed by a rectangular vessel $30 \times 30 \times 300$ mm. in size with a glass filter No. 1 attached to its bottom with epoxy resin. The upper wall has an opening (covered with a stopper when no air is pumped through) through which the absorber is

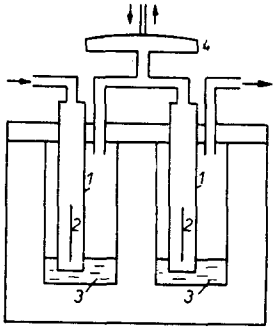
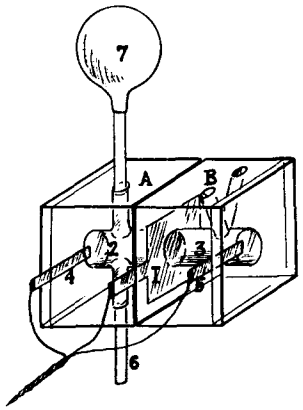


Fig. 2. Schematic representation of the valve mechanism of a single pump. 1 — a thick-walled rubber tube, 2 — longitudinal section, 3 — glycerol, 4 — membrane pump. Incoming air from the leaf chamber passes from the left into the absorber at the right

filled and through which a sample of the absorption solution is removed to be used for conductivity measurement. Each absorber is filled with 50 ml. 0·02 N-KOH containing 0·5% isoamylalcohol and saponin. This amount of the absorbing solution is fully sufficient for 3 to 4 determinations of photosynthetic rate with guaranteed complete absorption of carbon dioxide from the analyzed air. It is possible to use other concentrations of the alkaline absorbing solution.



A special measuring cell is used for conductivity measurements (Fig. 3). This cell consists of two firmly attached plexiglass halves (A and B) between which a common metal electrode is fixed (1). Each of the halves contains cylindrical openings 2 and 3 (12 mm. in diameter and 10 mm. in depth). The ends of these openings contain two further electrodes (4 and 5) 3×3 mm. in area. The electrodes are of nickel sheet 0·2 mm. thick.

Fig. 3. A cell for conductivity measurement of potassium hydroxide absorption solutions. Explanation in the text.

The right-hand cell (B) is filled with the original alkaline solution and serves as a standard resistance in the measuring bridge; in reference to it the conductivity of the solution placed in the left-hand half (A) is measured. For filling this left-hand part of the cell a polyvinylchloride tube (6) and a rubber ball (7) is used to withdraw the solution from the individual absorbers. After measurement the solution is returned into the absorber from which it has been removed. It is an advantage of this measuring cell that no air bubbles are form-

ed at the electrodes or else are readily removed from them and that temperature equilibrium of both halves of the cell is rapidly attained due to the common metal electrode. In instruments where the conductivity of the absorbing solution was measured directly in the absorbers it was rather difficult to remove the air bubbles from the electrode surface. As to the temperature of the solutions measured it can vary but it is important that it be the same in both solutions at the time of recording (VOZNESENSKY 1959, 1960a). Then the ratio of conductivities of the two solutions remains the same and it is not necessary to keep the instrument under thermostatic control or to measure the temperature of the solutions.

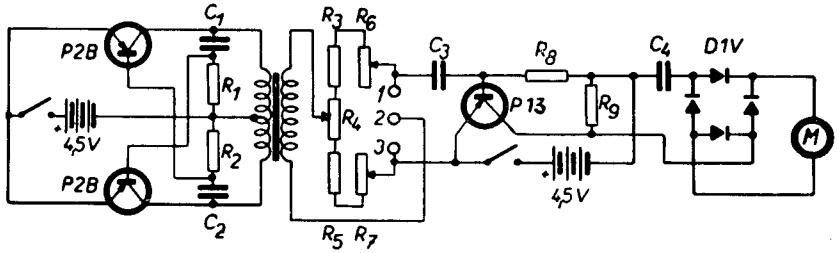


Fig. 4. Electronic equipment of the apparatus. Terminals marked 1, 2 and 3 are connected with the wiring of the measuring cell. R_1: 560 Ω, R_2: 560 Ω, R_3: 900 Ω, R_4: 200 Ω, R_5: 900 Ω, R_6: 200 Ω, R_7: 200 Ω, R_8: 27 kΩ, R_9: 900 Ω, C_1: 0·015 μF, C_2: 0·015 μF, C_3: 2000 pF, C_4: 0·1 μF. Transformer: 2 X 300 coils in the primary, 1000 coils in the secondary winding.

The ratio of conductivities of the two KOH solutions is measured with the aid of a measuring bridge working on alternating current (Fig. 4). The whole system consists of a generator, a bridge, an amplifier and a galvanometer. A two transistor generator is fed from a torch battery and provides current with a frequency of about 20 kc/s. The current is carried to the bridge consisting of a variable wire resistance with a scale, additional resistances for controlling the initial value and two branches into which the electrodes of the measured and standard solutions are connected. The current leaving the bridge is amplified, rectified and measured on the galvanometer.

According to the amount of air passing through the chamber the conductivity of the absorbing solution is changed and thus the bridge equilibrium disturbed. The deviation thus caused is compensated by a variable wire resistance with a scale, the divisions of which then correspond directly to a certain amount of carbon dioxide absorbed in the potassium hydroxide solution.

For calibration of the instrument it is of advantage to bubble a certain amount of air with a known concentration of CO_2 through the absorbers and thus to obtain a relationship between the amount of CO_2 and the scale divisions.

The possible relative error of estimation amounts to 10—20% for photosynthetic intensities of 10—20 mg. CO_2 . dm.$^{-2}$h^{-1} which meets the requirements placed on field instruments used for photosynthetic measurements.

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V. L. VOZNĚSENSKÝ, Botanický ústav V. L. Komarova, A. N. SSSR, Leningrad: **Konduktometrický přístroj pro stanovení intensity fotosynthesy.** — Biol. Plant. 6 : 79—83, 1964.

Je popisován konduktometrický přístroj pro stanovení intenzity fotosyntézy, vhodný především k terénnímu měření. Na rozdíl od dosud popsaných a používaných přístrojů analyzuje současně 3 vzorky vzduchu, jeho údaje nejsou závislé na teplotě a celá elektronická část je tranzistorována. Absorbéry ($300 \times 30 \times 30$ mm) a listové komory ($140 \times 100 \times 10$ mm) jsou plexitové. Pohon membránových čerpadel je ruční klikou. Vodivost absorpčního roztoku (0,02 N-KOH + 0,5% isoamylalkohol + saponin) se měří ve speciální měrné cele, kam se roztok nasává postupně z jednotlivých absorbérů. Chyba stanovení intenzity fotosyntézy je zhruba 10 až 20 % stanovené hodnoty při intenzitě fotosyntézy řádově 10 až 20 mg CO_2 . $dm^{-2}.h^{-1}$.

В. Л. Вознесенский, Ботанический институт им. В. Л. Комарова АН СССР, Ленинград: **Кондуктометрический прибор для определения интенсивности фотосинтеза.** — Biol. Plant. 6 : 79—83, 1964.

Дается описание кондуктометрического прибора для определения интенсивности фотосинтеза, подходящего прежде всего для полевых измерений. В отличие от описанных и используемых до сих пор приборов анализирует одновременно 3 пробы воздуха, его данные не зависят от температуры и вся электроническая часть собрана на транзисторах. Поглотители ($300 \times 30 \times 30$ мм) и листовые камеры ($140 \times 100 \times 10$ мм) склеены из плексигласа. Мембрановые насосики приводятся в движение ручным рычагом. Проводимость абсорбирующего раствора (0,02 н. KOH + 0,5% изоамиловый спирт + сапонин) измеряется в специальной измерительной ячейке, куда раствор всасывается из отдельных поглотителей. Потрешность определения интенсивности фотосинтеза порядка 10—20 мг CO_2 × $дм^{-3}$ × $ч^{-1}$ представляет около 10—20%.