TABLE I

RESPIRATION OF MILDEWED AND HEALTHY WHEAT LEAVES WITH AND WITHOUT SULFUR TREATMENT. TEMPERATURE 20.5° C.

Days after inoc.	C. mm. O_2/cm.²/hr.					
	Mildewed plants			Mildew free plants		
	0 hrs.	Sulfur for 12 hrs.	28 hrs.	0 hrs.	Sulfur for 12 hrs.	28 hrs.
6–7 ..	8.6	8.4	8.3	4.2	3.8	4.1
12–13 ..	8.5	8.0	8.0	3.2	3.2	3.3

insufficient to account for the increased oxygen consumption of mildewed leaves, since dusting with finely pulverized sulfur, which quickly destroys the mildew, caused little decrease in respiration. Thus, infection of wheat leaves by mildew markedly increased the rate of oxygen consumption by the host tissues. Clover leaflets infected with powdery mildew also respire more rapidly than controls, even when the fungus has been killed by sulfur dust.[1] Although the mildew penetrates only the epidermal cells, Allen and Goddard,[2] in this issue of SCIENCE, show that the increase in respiration occurs principally in the mesophyll tissues of the host.

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SCIENTIFIC APPARATUS AND LABORATORY METHODS

A MICRO-METHOD FOR MEASURING SPECIFIC CONDUCTANCE

RECENT trends in biological research have emphasized the importance of a knowledge of the physical properties of various biological fluids. Unfortunately, although excellent methods for the measurement of specific conductance, surface tension, etc., are known, these generally involve the use of such large quantities of the fluid to be tested that they are impractical for the biologist.

In connection with some as yet unpublished investigations dealing with the specific conductance of the extra-embryonic fluids of the developing chick, the following method was employed. The essential elements of the apparatus are an approved type of alternating current bridge and a special type of conductance cell designed for the measurement of small volumes of fluid. The importance of the type of apparatus used is emphasized and discussed in detail by Jones and Josephs[1] The bridge consists of arms of two matched Ayrton cards (General Radio Co., Cambridge, Mass.) giving an equal-arm, direct-reading bridge. A non-inductively wound resistance box was used (Leeds-Northrup Co. No. 202886). This was equipped with six dials, permitting of measurements to hundredths of an ohm. Connected in parallel with this resistance box was a 45-plate variable air condenser for balancing out the capacitative effects of the conductance cell located in the opposite arm of the bridge. The cell itself will be described below.

The oscillator used was the one specified by Jones and Josephs, and it, together with a three-stage amplifier in the input leads, was encased in a grounded metal filing cabinet drawer, an effective electrostatic shield. Although measurements were possible at frequencies of from 400 to 4,500 cycles, for the sake of convenience a frequency of 1,000 cycles per second was employed.

Inserted between the bridge proper and the telephones was a three-stage amplifier (manufactured by Magnavox). Grounded metal shields separated this piece of apparatus, the resistance box and the variable condenser from the ratio arm of the bridge and from each other. The telephones were grounded in the manner recommended by Jones and Josephs. All the equipment (except the water bath, conductance cell and its leads to the bridge) was placed within a large grounded wire cage, in which the observer stood upon an insulating fiber platform while making readings.

In the designing of the conductance cell, the recommendations of Jones and Bollinger[2] were followed in so far as possible. On account of the small volumes of fluid to be tested, a considerable number of modifications had to be made. It was found necessary to reduce the area of the electrodes and also to shorten the distance between them to permit the measurement of volumes as small as 0.1 cc. The design finally adopted is shown in Fig. 1. A piece of Jena glass tubing, 2 centimeters long and 0.3 centimeter in diameter, was selected for the central portion. The ends were sealed and the filling tubes and tubes for mercury added. The electrodes consist of tight coils of platinum wire, about a square millimeter in area, set a distance of one centimeter apart. The working volume of this cell is approximately 0.07 cubic centimeter. These modifications would theoretically result in an increase in the error due to capacitative shunt, but inasmuch as the liquid under test is run in from one side only, and since it barely fills the central portion of the cell, there will be, at the most, only a thin film of liquid in one filling tube. Whatever small increase this film may produce is easily balanced out by tuning the variable condenser in the opposite arm of the bridge. To control the experimental tem-

[1] C. E. Yarwood, *Jour. Agr. Res.*, 49: 549, 1934.

[2] P. J. Allen and D. R. Goddard, SCIENCE, in press.

[1] G. Jones and R. C. Josephs, *Jour. Am. Chem. Soc.*, 50: 1049–1092, 1928.

[2] G. Jones and G. M. Bollinger, *Jour. Am. Chem. Soc.*, 53: 411–451, 1931.

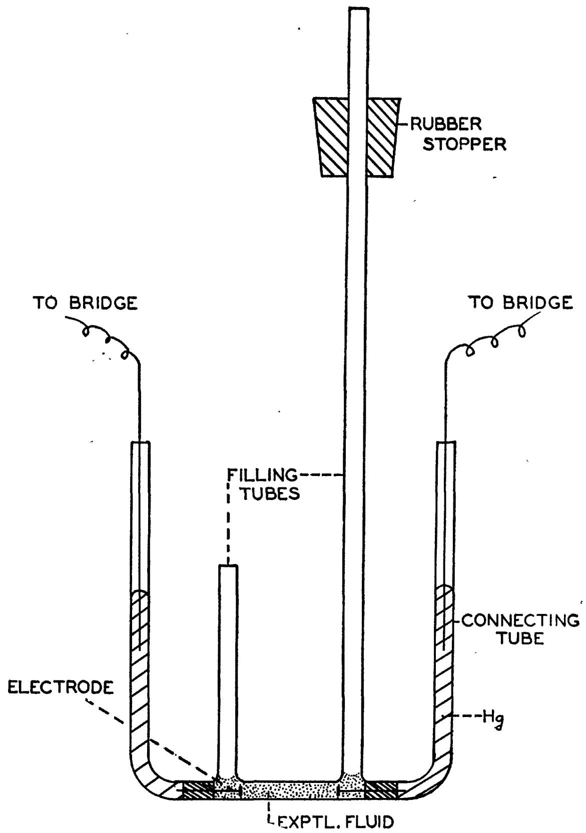

FIG. 1

perature, the cell was suspended in a water thermostat capable of regulation to ± 0.1° C.

The subject of polarization resistance and its significance in experiments on electrical conductance has been discussed by Jones and Christian,[3] and they show how one may determine the exact magnitude of this error at any given frequency for any given cell. Accordingly, the cell was filled with 0.1M KCl and its resistance measured at various frequencies. The measured resistance at a frequency of 1,000 cycles was found to be 1187.0 ohms; correcting for the polarization error according to their method, the true resistance was found to be 1182.9 ohms, indicating a percentage error of 0.346 per cent.

Jones and Bollinger[4] have made a quantitative study of platinization of electrodes and recommend a degree of platinization represented by from 5.94 to 12.73 coulombs per square centimeter of electrode surface. Following their paper, the cell was filled with platinizing solution and a current of 0.004 ampere passed through it, with a reversal of polarity every ten seconds, for a total time of one minute. Thus, each electrode acted as a cathode while 0.12 coulomb, or 12 coulombs per square centimeter, were passing. Such a degree of platinization imparts a distinct dusky hue to the electrodes. Moreover, electrodes platinized to this extent gave consistent readings on various test solutions over considerable periods of time.

The conductance cell may be standardized by measuring its resistance when filled with a solution of known specific conductance, for example, 0.1M KCl, which has a specific conductance of 0.01167 mhos per cm at 20° C. (the experimental temperature). In making up this solution, Merck's chemical was used, with stated total impurities of 0.0458 per cent. It was therefore deemed unnecessary to attempt further purification. The measured resistance of this solution was found to be 1187.0 ohms, or to correct for poralization, 1182.9 ohms. Measurements made at approximately weekly intervals throughout the course of the experiments showed no deviations from this value. Measured resistance and specific conductance are related according to the following equation:

$$R = \frac{L}{A} \times \frac{1}{k}$$

where R is the measured resistance
L is the distance between the electrodes
A is the cross-sectional area of the cell
k is the specific conductance

The term L/A is also known as the Cell Constant, C, or

$$C = R \times k$$

In the case of the cell described above, $C = 1182.9 \times 0.01167$ or 13.804 cm^{-1}. Once having determined the Cell Constant, it is possible to obtain the specific conductance of any desired solution merely by measuring its resistance (and correcting for polarization errors) and dividing the Cell Constant by this figure, *viz.:*

$$k = C/R$$

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[3] G. Jones and S. M. Christian, *Jour. Am. Chem. Soc.*, 57: 272–280, 1935.

[4] G. Jones and D. M. Bollinger, *Jour. Am. Chem. Soc.*, 51: 280–284, 1935.

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