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BUILDING RESEARCH STATION, GARSTON, NR. WATFORD, HERTS.

THE MEASUREMENT OF THE RATE OF AIR CHANGE

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Introduction.

FOR some considerable time the need has been felt of a simple method of measuring the rate of ventilation. A knowledge of this quantity is valuable in the design of heating systems, but in the majority of instances only a vague estimate of it has hitherto been possible. Occasionally, the air velocity in supply ducts can be measured, but frequently a system of ducts is not employed and the task of determining the rate of air change becomes one of considerable difficulty.

In experiments conducted at the Building Research Station in 1927[1], the ventilation of a room was determined by measurement of the increase in carbon dioxide consequent upon the burning of three standard candles for three hours. A 2.5 litre sample of air was taken by means of rubber hand-bellows, the flask being moved round the room about 3 ft. 6 in. from the floor, and the carbon dioxide was estimated by absorption in barium hydroxide and titration of the excess with oxalic acid. Using this method of measurement the efficacies of an unheated flue and a wall ventilator were compared.

[1] Report of the Building Research Board for the Year 1927, p. 102.

Experiments have been made to investigate the possibility of utilising the rate of supply of steam, necessary to maintain an increased water content in the air of the room, as a measure of the rate of ventilation.[2] This method proved unsatisfactory, however, owing to the absorption of water vapour by the walls, and furniture of the room.

Hydrogen Method.

A simple accurate method has now been devised, based upon the fact that, if a small quantity of hydrogen be released into the air of the room, the rate of decay of concentration affords a measure of the rate of air change.

The thermal conductivity of hydrogen is seven times that of air and, consequently, traces of this gas in air can be readily estimated by a careful measurement of the thermal conductivity. This is conveniently performed with a katharometer, an instrument devised by Shakespear[3] and now used commercially for the determination of carbon dioxide concentration in flue gases.

The Katharometer.

Two spirals of platinum wire R_1 and R_2 (Fig. 1) having identical resistances, are enclosed in separate cells A and B, which are located in

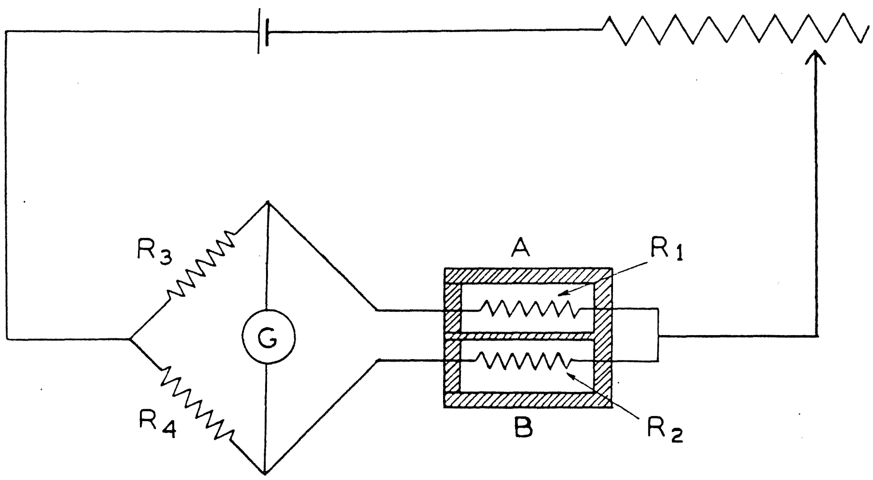

FIG. 1.

a solid copper block to ensure their being at the same temperature. Each spiral forms one arm of a Wheatstone bridge circuit, while two

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[2] Dufton, A. F., and Marley, W. G., *Journ. of Inst. of Heating and Ventilating Engineers* 1934. Volume I. pt. 12. p. 645.

[3] Shakespear and Daynes. *Proc. Roy. Soc.*, 1920. Vol. A. 97. p. 273.

other identical resistances R_3 and R_4 complete the bridge. A definite electric current flows through the bridge, heating the spirals, which in turn lose heat, through the gases surrounding them, to the walls of the cells. A standard gas—normal air—is trapped in cell A, which is sealed. The air of the room diffuses into cell B continuously and the change in its thermal conductivity due to the trace of hydrogen causes spiral R_2 to vary in temperature and, therefore, in resistance compared with spiral R_1. This unbalances the bridge producing a deflection in galvanometer G and this deflection is a measure of the change in thermal conductivity of the air, and therefore, of the concentration of the hydrogen producing that change. The actual instrument used gave a deflection of approximately one inch on the galvanometer scale for a change in concentration of 0.1 per cent.

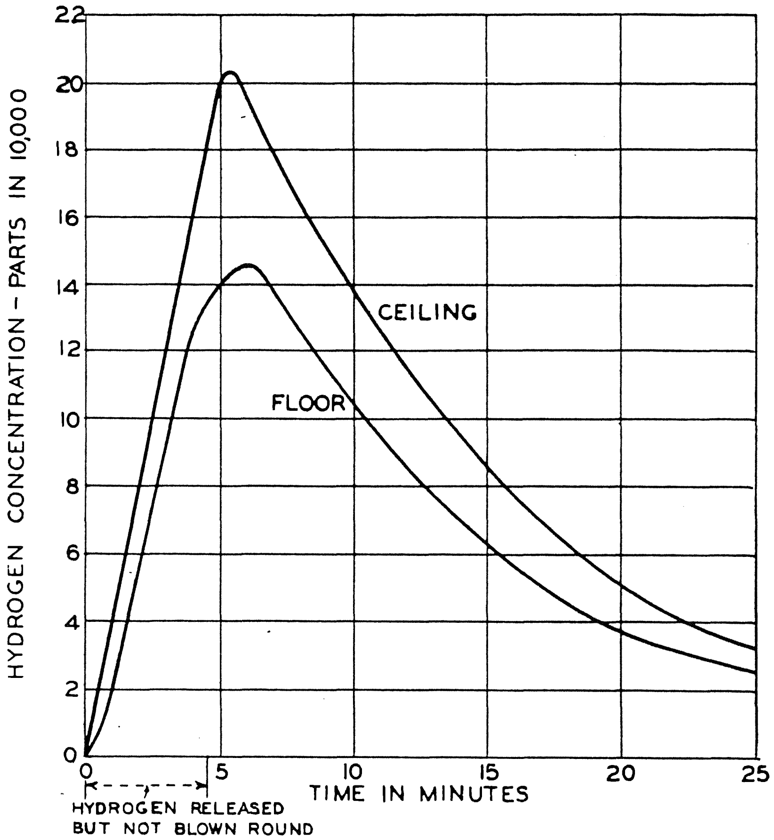

FIG. 2. HYDROGEN CONCENTRATION CURVES.

Development of the Method.

With a gas of the nature of hydrogen care must be taken to ensure that the concentration never reaches the explosive limit of 9 per cent. In these experiments the maximum concentration employed was 0.2 per cent. Other gases could be used, notably carbon dioxide, but hydrogen is fifteen times as effective and diffuses five times as fast.

The concentration of hydrogen tends to be greater near the ceiling. Experiments have shown that when the gas was simply released from a cylinder the subsequent concentration at floor level was about 70 per cent. of that at ceiling level. This proportion remained sensibly constant as the amount of hydrogen decreased (Fig. 2) and, consequently, the measured rate of ventilation is independent of the height of the katharometer above the floor. With such a gradient of concentration, however, the amount of hydrogen in the room would decrease more rapidly if the room were ventilated by extracting air near the ceiling than if the air were extracted near the floor, and a different figure would thus be obtained for the rate of air change. The hydrogen was therefore released into the horizontal air stream from an electric fan, which was run only while the gas was being admitted. A much more uniform concentration was obtained in this way and the measured rate of air change was reasonably independent of the height of the exit.

The Accuracy of the Method.

In order that the possibilities of the method could be readily explored, a fan was arranged to extract air from the room and deliver it to the outside through a duct. With such an arrangement all other apertures became inlets and the air flow could be computed from the pressure drop across an orifice plate in the duct. In the table below a comparison is shown between the rate of air change so calculated and that measured by the present method, with various sets of conditions.

In these experiments the air was removed from the room at one point, situated near the floor or near the ceiling ; the conditions were consequently more stringent than would be encountered in practice and the good agreement in the results of experiments 3 to 7 is regarded as highly satisfactory.

When a room is occupied, the concentrations of carbon dioxide and water vapour increase and both these substances affect the katharometer slightly. In order to minimise errors due to these changing concentrations the number of persons in the room was kept constant during and immediately prior to an experiment.

Experiment No.	Air changes per hour from orifice plate method.	Air changes per hour from hydrogen method.	Suction point of fan.	Remarks.
1	7.0	6.2	Floor	No circulating fan while hydrogen was admitted.
2	7.0	8.1	Ceiling	
3	7.5	7.0	Floor	Hydrogen blown round room with fan.
4	7.5	7.5	Ceiling	
5	7.7	8.0	Floor	Ditto. Air-brick ventilator open.
6	7.7	7.5	Ceiling	
7	4.0	4.1	Floor	Comparison at lower rate.

Experimental Procedure and Calculation of Results.

In the conduct of an experiment the katharometer is placed as central as possible in the room and an electric fan arranged to circulate air at floor level. Hydrogen is admitted to the air stream of the fan till the katharometer indicates a concentration of 0.2 per cent. The fan is switched off and the katharometer read every minute for some twenty minutes. The readings are plotted on semi-logarithmic graph paper and a straight line drawn through them.

If a room be ventilated at a constant rate the amount of original air decreases exponentially. When a volume of air equal to p times the volume of the room has been introduced, that is after p air changes, the volume of original air remaining is equal to e^{-p} times the original volume, thus :—

p	0	$\frac{1}{2}$	1	2	3	4
Volume of original air, per cent. ..	100	60.7	36.8	13.5	5.0	1.8

From the graph of the observations of hydrogen concentration it is possible to read the number of minutes taken for the concentration to fall to 36.8 per cent. of its value at any time ; this is the time of one air change.