Preliminary Communications

A Quantitative Detector-tube Method For Breath-alcohol Estimation

Although estimation of breath alcohol was first introduced 35 years ago (Bogen, 1927), only in the last five has its value and validity begun to be fully recognized, mainly as a result of the invention of the "breathalyser" (Borkenstein, 1956), which is the only apparatus to gain general acceptance. In this instrument a 50-ml. sample of breath is collected in a heated reservoir and then bubbled through an ampoule containing a dilute solution of $K_2Cr_2O_7$ in 50% H_2SO_4 . The reduction of the bichromate by the alcohol is measured photometrically, using a null-point photo-cell system and galvanometer.

The breathalyser has been found by several workers to give quite reliable and accurate results (Monnier, 1956; Coldwell and Ward Smith, 1959; Drew *et al.*, 1959), and we ourselves can confirm this. Monnier has claimed that the agreement between the breathalyser reading and the mean of two independent analyses of the blood by different methods is closer than the agreement between the blood results.

It thus seems that not only is the breathalyser capable of measuring breath-alcohol concentration with sufficient accuracy but also that estimation of breath alcohol is at least as good a measure of the tissue-alcohol concentration as blood analysis.

Unfortunately, although capable of giving excellent results in skilled and experienced hands, the breathalyser has a number of practical defects which have hitherto prevented its general adoption in this country.

In the first place, although it is normally simple to operate, it still remains a piece of laboratory equipment not really suitable for use in a police station. The liquid reagent is particularly troublesome, as it is highly corrosive, and great care must be used in handling the ampoules and disposing of them after use. In addition, some care and vigilance on the part of the operator, and co-operation by the subject, are needed to ensure that a true alveolar sample of breath is obtained in a standard way.

An attempt has therefore been made to develop a simpler apparatus based on the use of a detector tube. These tubes, in which a granular reagent in a glass tube changes colour in the presence of alcohol, are in use in a number of countries (Kobayashi, 1953; Bina, 1960) for quick checks of breath alcohol, but they are intended only for screening purposes, anyone giving a positive result being required to submit to a blood test.

In the last 10 years, however, the use of detector tubes for the estimation of a variety of atmospheric gases and vapours has undergone much development (Kusnetz *et al.*, 1960), and a few quite simple improvements have turned them into at least a semi-quantitative and sometimes even a fully quantitative method.

AN IMPROVED TYPE OF TUBE

Professor Kitagawa has been particularly associated with this work, including the breath-alcohol detector tube, known as the "Drunkotester," in use in Japan (Kobayashi, 1953). This, however, has no pretensions to accuracy, so in November, 1960, it was decided to try to produce an improved type of tube which, if used

in an apparatus similar in principle to the breathalyser, might give equally accurate results.

After some experimentation a satisfactory tube was produced in 1961. The required sensitivity was obtained by using silica particles instead of the more usual silica gel as a base, and chromic acid instead of bichromate as the reagent. The anhydrous chromic acid when adsorbed on silica particles is yellow and changes to bluish grey on reduction by alcohol. Chemically the reaction is essentially the same as that used in the breathalyser.

The sensitivity of the tube is such that 100 ml. of breath from a subject with a blood alcohol of 100 mg./100 ml. gives a stain a little more than 20 mm. long. The relationship is practically linear from 50 to 200 mg.

These tubes must be operated at a temperature well above the dew-point of breath, and the sample of breath must also be kept above its dew-point to avoid loss of alcohol and its accumulation in the apparatus; so it was evident that some kind of heated testing-box would be required. One of us (B. M. W.) therefore started designing this at the same time as work on the tubes was begun, and fortunately a satisfactory design was evolved at about the same time as the work on the tubes was completed.

Full details of the apparatus cannot be given here, but the following brief description will give some idea of its mode of operation.

MODE OF OPERATION

The apparatus consists of a box about $24 \times 18 \times 16$ cm. weighing about 3 kg. It is designed to be operated off 240 V. 50-cycle A.C. mains, but could be designed for 12-V. D.C. if required. The box contains an insulated compartment maintained thermostatically at $60^\circ C$. In this compartment is a metal reservoir made of two flat truncated cones placed base to base. Across the base of the cones is clamped a flexible diaphragm which is moulded to the shape of the reservoir. When this diaphragm is transferred from one cone to the other it sweeps out the contained volume of 100 ml. exactly.

Below this main reservoir is an auxiliary reservoir in the form of a flat dish with a flexible diaphragm on its upper surface.

When the subject blows into the apparatus his breath initially goes straight through with no resistance except a slight restriction on the outlet. This restriction causes a rise in pressure of a few mm. Hg, which produces a small flow of air into the auxiliary reservoir, controllable by a needle valve. This raises the auxiliary diaphragm, which, when it has risen far enough, opens a valve in the main reservoir and allows breath to enter. By this means the subject is forced to blow away a certain volume of air, which can be adjusted by means of the needle valve, before his breath sample is collected. If he blows hard he will fill the auxiliary reservoir quickly, while if he blows softly it will fill slowly, so that within wide limits he will discard the same volume however he blows. The actual volume is usually about 1 litre, but experiments to determine the most suitable volume are still being conducted. The breath sample entering the main reservoir transfers the diaphragm from the bottom to the top, during which time it offers no appreciable resistance, but once it is applied to the upper cone it stops the flow completely and the pressure below the diaphragm rises sharply. This pressure operates a switch which starts a pump, and also turns on a warning light to tell the subject he can stop blowing. As soon

as he does so the diaphragm on the auxiliary reservoir relaxes and the inlet valve to the main reservoir closes. The pump then pressurizes the upper part of the main reservoir and forces the diaphragm down so that the breath sample is discharged through a detector tube which has been previously inserted in a socket in the heated compartment. When the sample is completely expelled the diaphragm is applied to the bottom cone, flow ceases, and the pressure below the diaphragm falls, switching off the pump and light.

Thus the whole process of discarding a fixed volume of air, and collecting and analysing a breath sample, is completely automatic and standardized, and out of the control of either operator or subject. All the operator has to do is to cut off the ends of the detector tube, insert it in its socket, and instruct the subject to blow into a mouthpiece, and then measure the length of the stain. The stain can be read easily in good daylight, but since this is often not available a reading device with built-in illumination is provided on the box. With this, stain lengths can be measured readily to the nearest 0.5 mm. (approx. 2.5 mg. blood alcohol). If the ends of the tube are sealed with rubber caps the stain will remain readable and substantially unchanged for several weeks. It can thus be produced as evidence in court if required.

One of the troublesome features of the breathalyser is that there is nothing to prevent breath being blown into it when it is cold. If this is done it is usually necessary to dismantle the apparatus completely so as to dry it before it is used. In our apparatus, therefore, an electromagnetic valve is fitted, controlled by the thermostat, which prevents breath being blown in until the apparatus is warmed up.

In addition, a removable filter is fitted to the breath inlet, so the apparatus does not require to be dismantled periodically and cleaned, and can be completely sealed and made tamper-proof.

PERFORMANCE

The new apparatus has so far been tested mainly in the laboratory on artificial alcoholic breath of known alcohol content, and Fig. 1 shows a comparison between calibration tests carried out simultaneously with the

FIG. 1.—Comparison between calibration tests of Kitagawa-Wright method and breathalyser. Each point is the mean of 10 observations, the range being shown by the vertical lines. Note 1: The falling away from linearity of the Kitagawa-Wright method above 150 mg./100 ml. has since been largely corrected by raising the operating temperature. Note 2: The slight over-reading by the breathalyser is probably an experimental error.

same equipment on the Kitagawa-Wright apparatus and the breathalyser. It will be seen that their performance is similar.

Only a limited amount of work has been done so far on actual alcoholic breath. In one experiment a subject who had taken alcohol with food, so that his blood alcohol remained steady for some time, filled 12 tubes in succession with the apparatus. The readings were as follows: 10, 9, 9, 10, 9, 9, 10, 9, 9, 9, 9, 9 mm.

In another series of experiments on six different subjects two successive breath samples were taken at intervals of 10 minutes or less, and Fig. 2 shows the degree of correlation between the two readings.

FIG. 2.—Correlation between two successive readings by the Kitagawa-Wright method, on breath samples from six subjects, taken at an interval of 10 minutes or less, at a time when the blood alcohol was not changing rapidly.

From these results it appears that the method is capable of estimating the concentration of breath alcohol with a precision comparable to that of the breathalyser. It is suggested that its great simplicity of operation and the fact that it produces a permanent record make it suitable for use in forensic practice.

Fields trials to test its performance under actual operational conditions and to compare it with blood-alcohol estimations are now being conducted.

TETSUZO KITAGAWA, D.Sc.,

Professor,
Yokohama National University, Ohka-machi,
Minami-ku, Yokohama, Japan.

B. M. WRIGHT, M.A., M.B.,
National Institute for Medical Research,
Mill Hill, London.

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