PORTABLE INTERFERENCE REFRACTOMETERS IN ANAESTHESIA

BY

G. H. HULANDS AND J. F. NUNN

(with the technical assistance of Mr A. J. JONES AND MISS J. WALLIS)

SUMMARY

The principles of interference refractometry have been described with special reference to determination of the concentration of anaesthetic agents in gas mixtures. Two commercially available portable direct-reading instruments have been adapted for use in anaesthetic practice: zero and calibration remained stable for long periods. Determination of the composition of a wide range of anaesthetic gas mixtures was found to be simple, rapid and sufficiently accurate for clinical and many laboratory purposes.

Although refractometry for gas analysis has long been known to anaesthetists, its use has been largely confined to the calibration and testing of vaporizers. Due to the bulk of these instruments and the fact that they are generally indirect reading, they have not been used extensively in clinical or research work. Furthermore, because of the lack of specificity of refractometry, the technique has not enjoyed the popularity of such methods as infra-red spectroscopy, polarography and the measurement of paramagnetism, these being both convenient and reasonably specific for particular gases. They have clear advantages for the analysis of the multiple gas mixtures which may be encountered in anaesthesia.

Nevertheless, available techniques of gas analysis are not entirely satisfactory for the measurement of the wide range of anaesthetic gases and vapours encountered in clinical practice. It is true that infra-red analyzers are suitable for this purpose, but it would be cumbersome to have specific analyzers for each agent. Gas chromatography is not convenient for rapidly changing vapour concentrations and the mass spectrometer is currently expensive and difficult to operate.

The advent of small portable direct-reading interference refractometers intended for analysis of methane (fire-damp) has led us to re-examine the use of refractometry for the analysis of anaesthetic gas mixtures, a subject which was investigated by Pask but remained unpublished during his lifetime. The technique seems to provide a valuable extension of the analytical methods available to the anaesthetist, both for research and for clinical practice. In particular, equipment designed for the range 0–100 per cent methane in air may be used to determine the vapour concentration of a wide range of agents and the problems posed by using mixtures as carrier gas are not insuperable.

BASIS OF INTERFERENCE REFRACTOMETRY

Refractive power of pure gases and vapours.

The refractive index of a gas is the reciprocal of the velocity of light through the gas relative to its velocity through a vacuum:

\[
\text{Refractive index} = \frac{\text{velocity of light through a vacuum}}{\text{velocity of light through the gas}}
\]

However, it is more convenient to work in refractive powers (\(\beta\) values) which are related to refractive index thus:

\[
\text{Refractive power} = (\text{refractive index} - 1) \times 10^4
\]

For example, oxygen has a refractive index of 1.0002715 and a refractive power of 271.5.

The refractive power of a gas although specific for that gas (at STP) is not necessarily peculiar to that gas. Nitrogen and nitric oxide, for example, have almost identical refractive powers and could not be distinguished by this property.

Values of refractive power used in this paper are listed in table I, but there is a surprisingly G. H. HULANDS, M.B., CH.B., F.F.A.R.C.S.; J. F. NUNN, M.D., PH.D., F.F.A.R.C.S.; M.R.C. Division of Anaesthesia, Clinical Research Centre, Watford Road, Harrow, Middlesex, England.
TABLE I

Refractive power of gases.

<table>
<thead>
<tr>
<th>Gas</th>
<th>Refractive power</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air</td>
<td>293.2</td>
</tr>
<tr>
<td>Carbon dioxide</td>
<td>450.6</td>
</tr>
<tr>
<td>Chloroform</td>
<td>1,453.0*</td>
</tr>
<tr>
<td>Cyclopropane</td>
<td>977.0†</td>
</tr>
<tr>
<td>Ether</td>
<td>1,550.0</td>
</tr>
<tr>
<td>Halothane</td>
<td>1,582.0</td>
</tr>
<tr>
<td>Methoxyflurane</td>
<td>1,471.0 (calculated value)</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>299.1</td>
</tr>
<tr>
<td>Nitrous oxide</td>
<td>510.0</td>
</tr>
<tr>
<td>Oxygen</td>
<td>271.5</td>
</tr>
<tr>
<td>Methane</td>
<td>441.5</td>
</tr>
<tr>
<td>Trichloroethylene</td>
<td>1,780.0†</td>
</tr>
</tbody>
</table>

* Edmondson, 1957.
† Epstein, 1970 (personal communication).

All other values taken from Kinder, 1956.

Wide range of values reported by various authors. In some cases differences are attributable to the use of white as opposed to monochromatic light. The portable instruments described in this paper use white light, but formal determinations of refractive power are most commonly made with monochromatic light (Sodium D line).

Additional difficulties arise from the presentation of the refractive power of vapours. These are normally presented for the pure vapour at 760 mm Hg pressure and 0°C, conditions under which no liquid with a boiling point above 0°C can exist. In fact, the measurement is made at a lower partial pressure of the vapour and corrected to the value corresponding to 760 mm Hg. This assumes that the vapour obeys Boyle's law, which is not strictly true, particularly for vapours of liquids with higher boiling points.

It is probable that additional error has arisen from the presence of impurities and additives in liquid anaesthetic agents and also from uncertainty about vapour pressure. Concentrations are often derived from the saturated vapour pressure which may not be accurately known when a new anaesthetic agent is first introduced. Alternatively, the concentration may be derived from the vaporization of a known mass of liquid in a known volume of air and this calculation requires a knowledge of the mole volume of the vapour, which usually differs appreciably from the value of 22.4 litres which applies to permanent gases.

Even allowing for all these sources of uncertainty, there remain differences in the published values of refractive power which are quite appreciable, even with the limited discrimination of the portable instruments described in this paper. Table I lists values which are consistently reported (Kinder, 1956) and which have been found to be mutually compatible using the instruments described.

Refractive powers of gas mixtures.

The refractive power of a binary gas mixture is linearly related to the concentration of each component in the mixture. Refractive power of mixture \((A + B) = \text{refractive power of } A + (\text{fractional concentration of } B \times \text{difference in refractive power of } B \text{ and } A)\).

For example, consider oxygen (ref. power 271.5) and nitrogen (ref. power 299.1). A mixture of 20 per cent oxygen in 80 per cent nitrogen has a refractive power of

\[
271.5 + (\frac{20}{100} \times 299.1 - 271.5) = 293.6
\]

Clearly the sensitivity of the method depends upon the difference in the refractive power of the two components of the mixture. If the difference is small, as in the example above, the sensitivity will be poor.

Special difficulties arise when refractometry is used to analyze a mixture containing three or more gases. For example, there are an infinite number of combinations of halothane, oxygen and nitrous oxide with a refractive power of 600. However, if the relative proportions of two gases are known then it is possible to determine the concentration of the third gas in the mixture.

For example, air, having an approximate refractive power of 293 (Table I), may be treated as a single gas in computing the refractive power of mixtures with halothane.

Refractive power of “100 per cent halothane” (Table I)

| Refractive power of air | 293 |

| Difference | 1289 |

Therefore 1 per cent halothane in air would have a refractive power of:

\[
293 + (\frac{1}{100} \times 1289) = 306
\]

and each increment of 1 per cent halothane increases the refractive power of the mixture by 12.89.

The same principle applies to various concentrations of halothane in nitrous oxide/oxygen...
mixtures. Provided the relative proportions of nitrous oxide and oxygen are known, the refractive powers of the carrier gas mixture can be calculated and compared with the refractive power of halothane itself.

Effect of temperature and pressure.

The refractive power of a gas is directly proportional to its density or molecular concentration, the values normally being stated under standard conditions of temperature and pressure. For other conditions a correction factor is obtained from the relationship between temperature and pressure as expressed in Charles' and Boyle's Laws.

In this paper we have related all scale readings (made under conditions close to a barometric pressure of 760 mm Hg and room temperature of 20°C) to values of refractive power reported for 760 mm Hg and 0°C. The working calibration factor which we have used therefore includes the effect of the temperature change from 0°C to 20°C. When the barometric pressure and room temperature were substantially different from 760 mm Hg and 20°C respectively, we have applied the correction factors listed in table II.

MEASUREMENT OF REFRACTIVE POWER

The absolute determination of refractive power is difficult and outside the scope of this paper, but the comparison of the refractive power of two gas samples is relatively simple. The basic principles of refractometry as applied to anaesthesia have been described by Edmondson (1957) and Kinder and Torge (1968).

The portable instruments to be described (fig. 1) differ from conventional refractometers in the following respects:

(1) The light path is folded by means of prisms to give compact, robust and self-contained instruments. Neither instrument exceeds 21 cm in length.

(2) There is no need for a set of reference bands as only one or two interference bands are

<table>
<thead>
<tr>
<th>Lab. temp. (°C)</th>
<th>740</th>
<th>745</th>
<th>750</th>
<th>755</th>
<th>760</th>
<th>765</th>
<th>770</th>
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</thead>
<tbody>
<tr>
<td>16</td>
<td>1.013</td>
<td>1.006</td>
<td>0.999</td>
<td>0.993</td>
<td>0.986</td>
<td>0.980</td>
<td>0.974</td>
</tr>
<tr>
<td>18</td>
<td>1.020</td>
<td>1.013</td>
<td>1.006</td>
<td>1.000</td>
<td>0.993</td>
<td>0.987</td>
<td>0.980</td>
</tr>
<tr>
<td>20</td>
<td>1.027</td>
<td>1.020</td>
<td>1.013</td>
<td>1.007</td>
<td>1.000</td>
<td>0.993</td>
<td>0.987</td>
</tr>
<tr>
<td>22</td>
<td>1.034</td>
<td>1.027</td>
<td>1.020</td>
<td>1.013</td>
<td>1.007</td>
<td>1.000</td>
<td>0.994</td>
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<tr>
<td>24</td>
<td>1.041</td>
<td>1.034</td>
<td>1.027</td>
<td>1.020</td>
<td>1.014</td>
<td>1.007</td>
<td>1.000</td>
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<tr>
<td>26</td>
<td>1.048</td>
<td>1.041</td>
<td>1.034</td>
<td>1.027</td>
<td>1.020</td>
<td>1.014</td>
<td>1.007</td>
</tr>
<tr>
<td>28</td>
<td>1.055</td>
<td>1.048</td>
<td>1.041</td>
<td>1.034</td>
<td>1.027</td>
<td>1.021</td>
<td>1.014</td>
</tr>
</tbody>
</table>
without spectral fringes and their recognition presents no difficulty.

(3) The bands move across a graduated scale enabling direct readings to be taken.

**Optics.**

The instruments are entirely self-contained with a battery-operated lamp. Figure 2 shows diagrammatically the general arrangement of the optical pathway of these instruments. A beam of light is collimated and passes through an assembly of glass prisms. This beam is indicated in the diagram with double arrows. It is first reflected from the fully silvered back of the beam splitter and then divided into two parts at point A, a half-silvered surface cemented to the prism. Half the light is transmitted and half reflected. The two beams pass across the instrument and are reflected back along parallel paths by the reflecting prism. The optical pathway may be modified from the configuration shown in figure 2. Thus the length of the cells is reduced to about 2 cm when supplied for the measurement of 100 per cent methane. Furthermore one of the two parts of the reference cell may be left unconnected.

**Sampling.**

Approximately 16 ml of gas are required to flush out the sampling cell and attain a stable reading. The absence of moving parts means that there is little danger of damage when high flow rates are used. An increase in pressure within the cell raises the refractive index of the contents and therefore measurements should be made with gas flow interrupted and the contents in free communication with atmosphere through tubing sufficiently long and narrow to prevent appreciable loss of sample by diffusion.

It will be clear that serious errors can arise if gas escapes from the sampling cell into the reference cell or into the body of the instrument. Unfortunately this danger exists as the cells are closed at their ends simply by optically flat glass held against the open ends of the cells which are machined out of a single block of brass. It is important to avoid excessive pressure being developed in the cells and if in doubt that a leak has occurred, the reference cell should be flushed with reference gas immediately before reading. Nevertheless, for laboratory use, it probably remains more satisfactory to pass the sampled gas into the sample cell under positive pressure rather than by aspiration as recommended by the manufacturers during use in mines.

Instruments are commonly supplied with the inlet tube interrupted by filters, silica gel dryers or soda-lime traps. These should generally be removed for laboratory use in the field of anaesthesia, since they may act as a gas chromatographic column and retard one or other components of a mixture.

An additional sampling error arises from non-uniform mixing of the effluent from vaporizers. This may be avoided by the insertion of a metal mixing chamber before the sampling point.
Loss of sample by diffusion.

Air, nitrogen or oxygen can be left in the reference cell for long periods of time, but nitrous oxide and the more lipid soluble agents may diffuse out through rubber or p.v.c. tubing in the circuit. This error may be eliminated by the use of only metal or glass connections between the vaporizer and sampling inlet. The internal connections of the portable interferometers are normally of p.v.c. or rubber and these should be replaced with copper tubing.

Zero setting.

Zero is set by moving the scale graticule sideways until the black interference band coincides with the scale zero. Zero can be set with any gas or gas mixture, provided the same gas or mixture fills both the reference and sample cells. It is convenient to pass the gas through both cells connected in series until the reading is steady, readings being taken immediately after gas flow is interrupted. Apart from correcting for any drift of the zero, this adjustment allows a deliberate offset of the zero which may be useful for measurements which would otherwise be off-scale. For example, if the black band is set to zero with nitrogen in the sample cell and oxygen in the reference cell, the upper limit of refractive power difference which can be measured is increased by 27.6.

Sensitivity and calibration.

Fire-damp refractometers are used primarily in the mining industry and are available for measuring various ranges of concentration of methane in air. All our results relate to the 0–100 per cent version of the instruments as this is a convenient sensitivity for general use in anaesthesia. Since the instruments are intended for use in mines they may be calibrated to read full scale for 100 per cent methane at 790 mm Hg and 20°C. Compared with 760 mm Hg and 20°C, this will decrease the sensitivity by 0.963. In practice, departments of anaesthesia will probably find it convenient to check the calibration with carbon dioxide in the sample cell and nitrogen in the reference cell, these gases being easily available in an anaesthetic laboratory. The refractive power difference for carbon dioxide/nitrogen is 151.5 compared with 148.2 for methane/air, and the former combination therefore gives a deflection close to full scale for an apparatus calibrated by the manufacturers on the latter combination. However, allowance must be made for the effects of the various conditions of temperature and pressure used for calibration (table III).

From the values listed it will be seen that, for an instrument calibrated to give full scale (100 divisions) with methane/air at 790 mm Hg and 20°C (Zeiss), carbon dioxide/nitrogen should give approximately 98 divisions at 760 mm Hg and 20°C. For an instrument calibrated to give full scale (100 divisions) with methane/air at 760 mm Hg and 20°C (Riken), carbon dioxide/nitrogen under the same conditions should give approximately 102 divisions. Since there is no gain control provided in the portable instruments, it is necessary to apply appropriate calibration factors having first checked the calibration as outlined above.

Reversal of cells.

For most applications in anaesthesia, it is convenient to have the known gas in the reference cell and the unknown mixture in the test cell. Usually the unknown mixture has a higher refractive power than the reference gas and the band then moves across the scale to the right. How-

<table>
<thead>
<tr>
<th>Standard temperature and pressure</th>
<th>Working conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methane/air 760 mm Hg, 0°C</td>
<td>In mines 790 mm Hg, 20°C</td>
</tr>
<tr>
<td>Carbon dioxide/nitrogen 151.5*</td>
<td>143.5†</td>
</tr>
<tr>
<td></td>
<td>146.7</td>
</tr>
</tbody>
</table>

* Values from table I
† Calibration conditions employed by Zeiss.
‡ Calibration conditions employed by Riken.
§ Convenient conditions for checking calibration in the anaesthetic laboratory.
ever, a special problem arises when measuring nitrous oxide in oxygen. In the clinical range (70 per cent nitrous oxide/30 per cent oxygen, for example) if oxygen were in the reference cell, the reading would be off scale to the right. The solution to this problem is to compare the mixture with 100 per cent nitrous oxide instead of oxygen. However, this mixture has a lower refractive power than 100 per cent nitrous oxide and the reading would be off scale on the left with nitrous oxide in the reference cell. This problem was overcome by filling the test cell with 100 per cent nitrous oxide and the reference cells with the mixture for analysis, when the bands move across the scale to the right.

**Sources of known concentrations of anaesthetic gases and vapours.**

Gas mixtures can be accurately obtained from a Wösthoff gas-mixing pump, or prepared mixtures may be analyzed by suitably accurate apparatus such as a paramagnetic analyzer. With anaesthetic agents, preparation of known concentrations of vapour is less easy. A vaporizer calibrated accurately by the manufacturer or vaporization of known weights of the liquid anaesthetic agent into known volumes of gas are two possibilities. We have preferred to saturate a carrier gas stream with vapour by passing the gas through the liquid at known temperature and calculating the concentration as the ratio of the saturated vapour pressure to the ambient pressure. It is convenient to work at 0°C and we have used two fritted glass bubblers in series. These bubblers were fitted with spray traps and the whole apparatus, made of glass, was immersed in melting ice (Nunn, Gill and Hulands, 1970).

**Stability and Calibration**

**Stability.**

The scale deflection for carbon dioxide in the sampling cell and nitrogen in the reference cell was measured repeatedly after setting the zero with nitrogen in both cells, results being corrected to 760 mm Hg and 20°C. With the Zeiss instrument the direct-reading scale did not permit discrimination better than 1 per cent of full scale and the reading did not change outside this limit from a mean value of 98 over a period of four months. The vernier attachment on the Riken instrument allowed a reading to 0.1 per cent of full scale and four observers, making 29 readings over two weeks, obtained a mean value of 101.05 (SD 0.44) for readings corrected to 760 mm Hg and 20°C.

**Linearity.**

Mixtures of carbon dioxide and nitrogen delivered by a Wösthoff pump gave readings which were linear within the discrimination of the scale on the Zeiss instrument (fig. 3). At no point did the readings differ by more than 1 from the value calculated as the appropriate fraction of 98 (the reading with 100 per cent carbon dioxide compared with 100 per cent nitrogen). Other indications of the linearity will be apparent in subsequent figures. With its greater scale discrimination, the Riken instrument showed discrepancies between the observed and anticipated readings, the maximum being 0.8 per cent of full scale.

**Calibration.**

Readings with carbon dioxide in the sample cell and nitrogen in the reference cell (given above) for the Zeiss instrument correspond to a refractive power difference of 154.6 (760 mm Hg, 0°C) for full scale (reading at 760 mm Hg and 20°C). The manufacturer's calibration corresponds to 154.1 refractive power difference (760 mm Hg, 0°C) for full scale (reading corrected to 760 mm Hg and 20°C). These values are derived from the information in table III. One year elapsed between the manufacturer's calibration and our own observations.
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With the Riken instrument, we obtained a mean refractive power difference of 139.7 (760 mm Hg, 0°C) for full scale (reading at 760 mm Hg and 20°C). This corresponds with the manufacturer's setting of 138.1 made in Japan three weeks previously.

OBSERVATIONS WITH VARIOUS GAS MIXTURES

Oxygen in nitrous oxide.

Over the usual clinical range of concentrations this analysis is most conveniently made with nitrous oxide in the test cell and the unknown mixture in the reference cell. The line in figure 4 is the theoretical relationship while the points indicate readings made at 765 mm Hg and 22°C with the Zeiss instrument. The theoretical scale reading for 30 per cent oxygen in nitrous oxide compared with 100 per cent nitrous oxide is 46.5 while that obtained was 44. The upper limit of oxygen concentration covered by the instrument is 60 per cent.

Carbon dioxide in oxygen.

Figure 4 also shows observations on carbon dioxide/oxygen mixtures compared with the theoretical relationship. The reference cell contained 100 per cent oxygen. The clinical range of carbon dioxide concentrations would be confined to the lower end of the scale with 10 per cent corresponding to only 11 divisions.

Cyclopropane in oxygen (fig. 5).

With the Zeiss instrument a good linear response was obtained with full scale deflection corresponding to approximately 23 per cent cyclopropane in oxygen. Our readings (corrected for 760 mm Hg and 20°C) suggest a value of 950 for the refractive power of cyclopropane at 760 mm Hg and 20°C compared with the value of 977 (Epstein, 1970, personal communication).

Halothane.

Saturated halothane vapour at 760 mm Hg pressure and 0°C has a concentration of 12.7 per cent. Vaporized in nitrous oxide and then compared with nitrous oxide in the reference cell, the observed scale reading for the Zeiss instrument was 87 compared with a theoretical value of 88 (fig. 6). Vaporized in oxygen, the reading for saturated halothane vapour at 0°C is off scale if oxygen is also used in the reference cell. However, if nitrogen is used as the reference gas the scale reading is 90 (calculated from values in table I). The difference in refractive power between nitrogen and oxygen is 27.6 equivalent to 18 scale divisions. Therefore the corrected scale reading for 12.7 per cent halothane in oxygen compared with 100 per cent oxygen is 108 which is close to our observed value of 109 (fig. 6). The calculated line for halothane in nitrogen (compared with nitrogen in the reference cell) lies very close to the oxygen line and the difference could hardly
They are extremely stable and from the limits set by their discrimination frequent calibration is unnecessary. If calibration is required, this can be carried out by noting the scale deflection with carbon dioxide in the measurement cell and nitrogen in the reference cell. Adjustments of calibration are possible although they are not normally required.

The Zeiss apparatus may be read to a discrimination of one scale division corresponding to a difference in refractive power of 1.5.4. This is sufficient accuracy for checking function of a vaporizer to within about 0.1 per cent vapour concentration. This is generally adequate for clinical purposes since performance of vaporizers is seldom constant or linear within such a limit. The accuracy is also sufficient for monitoring concentrations during studies where inspired concentrations must be known. The refractometer is particularly useful when a wide range of vapours is being employed. Under these conditions it is clearly impracticable to have specific analyzers for each agent.

It is questionable whether the vernier attachment greatly increases the accuracy, which is limited primarily by the definition of the black interference band. The section on calibration above suggests that the fourth significant figure read from the vernier has little practical importance. Nevertheless the vernier increases the scale length to 110 and also very effectively removes observer bias, since the reading is not known until after the vernier is set: the reading cannot be seen while observing the interference bands. On the other hand, the direct-reading instruments are simpler and more convenient.

It is fortunate that the scale length is almost optimal for the analysis of clinical concentrations of cyclopropane in oxygen and oxygen in nitrous oxide. For the former the range which can be measured is 0–21 per cent and for the latter 0–60

Table IV

<table>
<thead>
<tr>
<th>Table IV</th>
<th>Sat. vap. conc.</th>
<th>Calibrating factors</th>
<th>Conc. range with oxygen</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0°C, 760 mm Hg</td>
<td>With O₂</td>
<td>With 70% N₂O/30% O₂</td>
</tr>
<tr>
<td>Chloroform</td>
<td>8.1</td>
<td>0.130</td>
<td>0.152</td>
</tr>
<tr>
<td>Ether</td>
<td>24.3</td>
<td>0.120</td>
<td>0.139</td>
</tr>
<tr>
<td>Halothane</td>
<td>12.7</td>
<td>0.118</td>
<td>0.135</td>
</tr>
<tr>
<td>Trichloroethylene</td>
<td>2.7</td>
<td>0.102</td>
<td>0.115</td>
</tr>
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</table>
per cent. Analysis of oxygen in nitrous oxide provides a convenient alternative to the use of a paramagnetic analyzer for checking premixed cylinders of oxygen and nitrous oxide (Entonox) or the performance of demand apparatus used in dental anaesthesia.

The literature shows a surprisingly wide range of reported values for refractive power. In some instances our own results do not appear to accord with the values we have selected in table I. There are many causes for the lack of agreement on values for refractive power which include uncertainty over vapour pressures leading to doubt over the concentrations used in calibration mixtures. Obedience to Boyle's Law is also inherent in the method of calculation and this is clearly untrue for the vapours.

The method of analysis carries certain limitations which cannot easily be overcome. Thus it is difficult to see how the instrument could be adapted to record the observed concentrations. It is also unlikely that response could be made fast enough to follow changes during a single respiratory cycle. Perhaps the main disadvantage is in the use of mixtures of three or more gases. However, figure 6 shows that only a small error results from substitution of nitrogen or air for oxygen. This would apply for all the vapours tested but not for carbon dioxide or nitrous oxide. Unfortunately, the sensitivity of the instrument is unsuitable for analysis of carbon dioxide/oxygen mixtures in the concentrations which are clinically interesting. The addition of 5 per cent carbon dioxide to oxygen produces a scale reading of about 6 scale divisions (fig. 4). It would seem that the version of the instrument designed for 0–10 per cent methane might be suitable for this purpose giving full scale deflection for about 8 per cent carbon dioxide.

There is now a wide range of gas and vapour analyzers on the market and it is useful to consider what might be the place of a portable fire-damp analyzer in the field of anaesthesia. Its immediate advantage is that it can perform a wide range of analyses without preliminary calibration. Thus one instrument would permit useful estimations of oxygen in nitrous oxide, cyclopropane in oxygen, and any vapour carried in any known carrier gas. The analysis is extremely simple and takes less than a minute. It would appear suitable for departments which are unable to provide a wide range of measuring instruments specific for different gases and vapours. Its portability also commends it for inspection and servicing of equipment in outlying hospitals. Research departments will find it particularly valuable for covering the wide range of vapours which may be used in comparative studies. It was interesting that during the course of the evaluation we came to rely increasingly on the instrument for our own research work.

ACKNOWLEDGEMENTS

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REFERENCES


