HALOTHANE CONCENTRATIONS OBTAINED WITH A DRÄGER "VAPOR" VAPORIZER

BY

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SUMMARY

The design and testing of a Vapor vaporizer for halothane by Drägerwerk is described. The tests substantiate the makers claims that the vaporizer is accurate, stable and unaffected by pressure fluctuations produced by the action of a ventilator.

The Vapor vaporizer made by Drägerwerk of Lübeck, Germany, has been designed to deliver an accurately known halothane concentration over a wide range of gas flow rates, to maintain the desired concentration for a long time if required, and to be unaffected by the action of a ventilator. The vaporizer is not suitable for use inside a circle anaesthetic system and has been designed for use outside the circle as recommended by Mushin and Galloon (1960) when intermittent positive pressure ventilation is to be employed.

Precision vaporizers such as the Copper Kettle (Foregger Co. Inc.), the Fluotec (Cyprane Ltd.), and the Vapor (Drägerwerk) consist of a vaporizing chamber and a bypass. The fresh gas stream flowing into the vaporizer is divided into two portions. The larger portion is passed straight through the bypass. The smaller portion is ducted through the vaporizing chamber, where it becomes saturated with halothane vapour, and emerges to rejoin the bypass stream. The fact that the vaporizing chamber produces fully saturated vapour ensures that there is no burst of a high vapour concentration when the vaporizer is first switched on, and the output of the vaporizer is unaffected by shaking.

The vaporization of the liquid halothane results in the removal of latent heat of vaporization from the liquid, with a resultant fall in the liquid temperature. If this fall is not checked, the rate of evaporation will fall, and the output concentration of the vaporizer diminishes with time. In the Fluotec, temperature compensation is achieved by means of a thermostatically controlled valve. This valve is arranged to act as a control over the volume of gas passing through the vaporizing chamber. As the temperature of the halothane falls, a bimetallic strip opens the valve further, allowing more gas to pass through the chamber. In the Copper Kettle and the Vapor, the vaporizer is constructed from a large mass of copper. The high thermal conductivity of the copper allows heat to pass into the liquid from the room and this, together with the high thermal capacity, supplies the necessary latent heat, holding the liquid temperature constant.

In the Fluotec, temperature compensation is automatic and there is only one control to set the output concentration of halothane. In the Copper Kettle, the output concentration is computed from a knowledge of the liquid temperature indicated on a thermometer, and the values of the vaporizing chamber and bypass gas flows read on flowmeters. The Vapor combines these principles. The output control carries several concentration scales, each corresponding to a different temperature of the liquid, which is indicated on a thermometer. The thermometer is first read, and then the appropriate scale selected. The concentration dial is calibrated 0.3 per cent to 5 per cent v/v over the temperature range 16° to 28°C.

A major problem in vaporizer design lies in the design of the valve which divides the incoming gas between the bypass and vaporizing chamber. The flow division ratio of this valve, for a given output concentration setting, should remain constant over a wide range of flow rates, from 100 ml/min to 10 l/min. It is not possible to achieve such great uniformity with the thermostatic type of valve and hence the Fluotec is provided with auxiliary calibration graphs for use with gas flow.
rates of less than 4 l./min. It is now well known that the pressure fluctuations produced in a circle system by intermittent positive pressure ventilation may have a considerable effect on the vapour concentration produced by a vaporizer which is situated outside the circle (Hill and Lowe, 1962). This "pumping effect" can amount to a doubling of the output concentration when the fresh gas flow rate is 1 l./min. For use with closed circle systems it is desirable that the vaporizer should be designed to counteract this effect which can be produced by the action of a ventilator or by bag squeezing.

![Diagram of the Vapor halothane vaporizer.](https://example.com/diagram)

A schematic diagram of the Vapor vaporizer is shown in figure 1. The vaporizing chamber contains wicks designed so that the gas passing through the chamber comes in contact with the maximum area of wick. Two valves of special design are employed to control the gas flows through the bypass and vaporizing chamber. The bypass valve is preset in the factory; the chamber valve acts as the concentration control. The valves are designed to produce laminar flow over the flow range 300 ml/min to 10 l./min, whether the flow is in the forward or reverse directions. Each valve consists of a male and female cone, the ratio of the length of the cones to the gap between them being of the order 100:1. The male cone is moved axially to alter the flow. Filters are built into the vaporizer to prevent any particles of grit damaging the valves. The weight of the Vapor for halothane is 14 kg.

The fact that the flow characteristics of the valves are independent of the direction of gas flow enables the concentration of vapour delivered by the vaporizer to be independent of the action of a ventilator. When the ventilator inflates the patient, gas tends to be forced back up the fresh gas supply pipe to the vaporizer. The valves split this gas in the correct proportion between the bypass and the vaporizing chamber. It is also necessary to ensure that the pressure arising from the ventilator cannot force saturated vapour back from the vaporizing chamber into the input of the bypass. For this reason, a long tube connects the input to the bypass and the vaporizing chamber. The length of this tube is such that the action of the ventilator cannot force saturated vapour along the whole length of the tube. During the deflation phase, this vapour is pushed back into the vaporizing chamber by the inflowing fresh gas. As a result, the calibration of the vaporizer is the same, whether the gas flows are steady or intermittent.

**METHOD**

The performance of the Vapor vaporizer was tested at the Royal College of Surgeons, feeding into a circle system with a ventilator running. Halothane concentrations were measured with an infra-red analyzer. Inflation pressures of up to 30 cm H₂O were used and it was found that these did not affect the calibration of the Vapor. The method used for testing vaporizers by Dräger is shown in figure 2.

Air from a compressed air line is fed via a filter to the Vapor, a Rotameter measuring the flow rate. The pressure existing at the outlet of the vaporizer is measured by means of an aneroid manometer. After this manometer is placed a needle valve in parallel with a solenoid-operated valve, which is normally closed. The needle valve is adjusted to give the desired pressure, say 30 cm H₂O, at the exit of the vaporizer. The solenoid-operated valve is controlled by means of an electrical multivibrator timing circuit, which can be set to run at typical respiratory frequencies.
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The method used for testing vaporizers by Dräger.

Calibration curves for the Vapor halothane vaporizer.
When the valve is open the gas stream from the vaporizer vents to atmosphere and the manometer at the vaporizer outlet indicates zero pressure with respect to the atmosphere. In this way fluctuating pressures of variable magnitude and rate can be applied to the outlet of the vaporizer under test.

For binary mixtures, the most accurate method of measuring vapour concentrations lies in the use of the Rayleigh refractometer, Edmondson, 1957; Kinder, 1956). This method is used to calibrate individually both the Fluotec and Vapor vaporizers. When the vaporizer is to be tested on steady flows, the output of the vaporizer passes directly to the atmosphere. A small portion of the output is sucked through the cell of the Rayleigh refractometer by means of an entrainer worked from the compressed air line. A second aneroid manometer monitors the pressure in the cell of the refractometer which must be at atmospheric pressure. The vaporizers are tested in batches in a room the temperature of which is thermostatically controlled. The batch is tested at several temperatures, several hours being allowed for the vaporizers to attain temperature equilibration with the new room temperature. The temperature of each vaporizer block is measured with a carefully embedded mercury-in-glass thermometer.

RESULTS AND DISCUSSION

The results found with a standard Vapor selected from a production batch, and a standard Fluotec Mark 2, are shown in Table I.

It should be mentioned that the Fluotec vaporizer can now be fitted with a pressurizing valve (Edmondson and Hill, 1962) to reduce the magnitude of the "pumping" effect.

The readings of both the Rayleigh refractometer and, to a lesser extent, the infra-red analyzer are affected by the pressure swings arising from the ventilator. Hence, when tests are carried out under intermittent positive pressure conditions, the output from the vaporizer is passed into a plastic bag.

TABLE I

<table>
<thead>
<tr>
<th>Dial setting (per cent v/v)</th>
<th>Refractometer reading (per cent v/v)</th>
<th>Gas flow conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) 0.5</td>
<td>0.3</td>
<td>Steady 0.5 l/min.</td>
</tr>
<tr>
<td>(b) 0.5</td>
<td>3.7</td>
<td>0.5 l/min fresh gas flow into circle.</td>
</tr>
<tr>
<td>(c) 1.5</td>
<td>1.1</td>
<td>17 b.p.m.</td>
</tr>
<tr>
<td>(d) 1.5</td>
<td>2.1</td>
<td>25 cm H2O peak inflation.</td>
</tr>
<tr>
<td>(e) 0.5</td>
<td>0.5</td>
<td>Steady 0.5 l/min.</td>
</tr>
<tr>
<td>(f) 0.5</td>
<td>0.51</td>
<td>0.5 l/min fresh gas flow into circle.</td>
</tr>
<tr>
<td>(g) 1.5</td>
<td>1.55</td>
<td>17 b.p.m.</td>
</tr>
<tr>
<td>(h) 1.5</td>
<td>1.55</td>
<td>25 cm H2O peak inflation.</td>
</tr>
</tbody>
</table>

Fig. 4
Showing the Vapor apparatus mounted on the table of a Dräger Tiberius anaesthetic machine.
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which has previously been flattened to expel the contained air. The interior surfaces of the bag have been sprayed with a polytetrafluoroethylene dispersion to minimize the uptake of halothane. After some ten pressure cycles, the contents of the bag are fed into the refractometer for analysis.

Figure 3 shows the calibration curves obtained for a Vapor halothane vaporizer, and figure 4 shows the vaporizer mounted on the table of a Dräger Tiberius anaesthetic machine.

The independent tests carried out by the author bear out the makers' claims that the vaporizer is accurate, stable and unaffected by the use of a ventilator. It is interesting to trace out the logical steps in the design of the vaporizer to ensure a reliable performance. This extreme care in the design has to be reflected in the price (approximately £100) in Germany. However, it is claimed by the makers that the cost can soon be recovered by the consequent saving in the cost of the halothane, since the vaporizer facilitates the use of lower fresh gas flow rates with circle systems. Some pertinent comments on the cost of halothane have been made by Wolfson (1962). Stable, accurate vaporizers are also of great use in the laboratory for the evaluation of monitoring devices such as gas chromatographs. A similar Vapor vaporizer is also available to deliver 2 to 20 per cent v/v ether. The standard model covers the temperature range 16° to 28°C, and the tropical model 20° to 36°C.

ACKNOWLEDGMENT

It is a pleasure to acknowledge the co-operation of the Dräger Company in the comparison of testing methods for vaporizers.

REFERENCES


MIT DEM DRÄGER "VAPOR"-VERDÄMPFER ERZIELTE HALOTHANE-KONZENTRATIONEN

ZUSAMMENFASSUNG

Es wird die Konstruktion und die Erprobung des "Vapor"-Verdampfers für Halothane der Drägerwerke beschrieben. Die Untersuchungen bestätigten die Angaben des Herstellers, daß der Verdampfer genau dosiert, stabil ist und durch die von einem Beatmungsinstrument herbeigeführten Druckschwankungen nicht beeinflußt wird.

THE IX ARGENTINE CONGRESS OF ANAESTHESIOLOGY

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