EVALUATION OF A NEW HALOTHANE VAPORIZER:  
THE CYPRANE FLUOTEC MARK 3  
BY  
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SUMMARY  
The construction, working principles and evaluation of the new Cyprane Fluotec Mark 3 vaporizer for halothane are described. The high output facilities at low flows with the Fluotec Mark 2 have been omitted. With the Mark 3, the output is linear at all flows, and the "Hill-Lowe pumping effect" is negligible. The construction and overall performance are satisfactory, the vaporizer providing halothane in acceptably consistent concentrations over a wide range of conditions encountered during routine use by anaesthetists.  

Calibrated halothane vaporizers of the Fluotec series have been in widespread use for over ten years and, while proving generally very satisfactory, have been criticized on three points:  
(a) sticking of control valve spindles;  
(b) non-linearity of halothane concentration characteristics at low gas flows;  
(c) increased halothane output during intermittent positive pressure ventilation (IPPV) (Hill and Lowe, 1962).  
A new Cyprane Fluotec vaporizer, the Mark 3, has been developed in an attempt to meet these criticisms; several new features have been incorporated. We have assessed the performance of this vaporizer under conditions encountered during routine use by anaesthetists. Studies have covered the following aspects:  
(1) Gas flow resistance.  
(2) Total volume of vaporizing chamber.  
(3) Priming volume for liquid halothane.  
(4) Flow/concentration characteristics.  
(5) Temperature and time-dependent characteristics.  
(6) Effect of IPPV.  
(7) Reassessment after prolonged cycling of control valve.  

DESCRIPTION  
Principle.  
Carrier gas entering the vaporizer is split into two streams, designated vaporizing chamber and bypass flows respectively. Flow through the vaporizing chamber is controlled by a graded laminar resistance governed by the concentration-setting dial. Flow through the bypass is controlled by a resistor operated by a bimetallic strip, and so is influenced by temperature. The bypass is mounted concentrically within the vaporizing chamber so that its temperature is close to that of the halothane charge. This arrangement is novel to the Fluotec Mark 3.  

Construction.  
The Fluotec Mark 3 differs in appearance from its predecessors (fig. 1). It weighs 6.3 kg, is 18.5 cm high and 10.5 cm in diameter. It is constructed from brass coated with copper and nickel, and is chromium-plated on its outer surfaces.  
Internally, the vaporizer has two main sections, the lower vaporizing and bypass chambers, and the upper duct and valve systems for channelling gas (fig. 2). The vaporizing chamber encloses the temperature-controlled bypass chamber. The outlet of the vaporizing chamber (Y) leads from the top of the long annular space (D). This is lined by two concentric wicks which enclose a nickel-plated copper helix, so that the space is converted into a long spiral outlet channel. The wicks, dipping into liquid halothane, ensure that the...
vapour is maintained at saturation concentration in the gas leaving the vaporizing chamber; also, this concentration will not be affected when the vaporizer is shaken. Within the cover of the vaporizing chamber lies the duct system, and above this the concentration-setting dial and the rotary valve with its associated ducts and vapour control channel (A). The dial is factory-calibrated for percentage halothane (v/v) and the scale is engraved in 0.5 per cent increments from 0 (OFF) to 5.0 per cent. It is linked directly to the underlying rotary valve which replaces the horizontally lying spindle valve of previous marks. The rotary valve of the Mark 3 is of completely new design and comprises two opposed brass discs. The upper disc has ducts and the curved vapour control channel (A) machined into its under surface. This is a long, wide, but shallow channel which deepens gradually from 0.002 inch to 0.011 inch.

Fig. 1
Fluotec Mark 3 vaporizer.

Fig. 2
Schematic diagram showing construction of Fluotec Mark 3 vaporizer. Concentration-setting dial in an "ON" position, A = vapour control channel; B = annular expansion chamber; C = long annular throat; D = spiral outlet channel of vaporizing chamber; X = inlet to vaporizing chamber; Y = outlet from vaporizing chamber; Z = inlet to bypass chamber.
as the overlying dial is turned towards 5.0 per cent. The opposed lower disc is coated with a thin layer of polytetrafluoroethylene (PTFE), to provide a non-stick surface. Operation of the concentration-setting dial thereby controls the flow from the vaporizing chamber. In the OFF position, a duct in the rotary valve makes a direct link between the inlet and outlet channels, so that very little gas passes through the bypass resistor when the vaporizing chamber is not in use.

A combined filling and drainage point for liquid halothane is provided near the base of the vaporizing chamber and adjacent to this is a window which serves to indicate the level of liquid halothane in the chamber.

Inlet and outlet ports are situated to left and right respectively behind the dial and may be adapted to provide alternative pairs of anaesthetic taper connection. A low resistance filter is inserted close to the inlet port to exclude particulate matter from the rotary valve and bypass resistor. The whole vaporizer may be attached to a standard anaesthetic trolley or portable stand and it should be fixed upright when charged.

**METHODS OF ASSESSMENT**

*Gas flow resistance.*

The Fluotec Mark 3 was mounted on a Boyle anaesthetic trolley (BOC Model K) and carrier gas was metered from the Rotameter block. Gases used were 100 per cent oxygen or 35 per cent oxygen in nitrous oxide. The resistance to gas flow at various flow rates and dial settings was assessed by measuring the pressure gradient across the vaporizer. A circumferential pressure-tapping sleeve interposed with the Rotameters and vaporizer inlet was connected to a strain-gauge transducer. The outlet of the vaporizer was at atmospheric pressure. Pressure readings were made following stepwise increases of carrier gas flow at each of three dial settings: OFF, 0.5 per cent and 5.0 per cent. Flow rates ranged from 0.5 to 18 l./min.

*Total volume of vaporizing chamber.*

The volume was measured using a carbon dioxide dilution technique. With the filler stopper removed and the control dial set at 5.0 per cent, the vaporizer was flushed with 100 per cent carbon dioxide. The filler stopper was then replaced and the dial turned to OFF, so isolating the vaporizing chamber and its contained carbon dioxide. All other parts of the vaporizer were then purged of carbon dioxide by flushing with 100 per cent oxygen. An infra-red gas analyser (URAS Model IV, Hartmann & Braun) was used to monitor washout of carbon dioxide at the outlet of the vaporizer. When this instrument registered zero carbon dioxide concentration, the Fluotec dial was turned to 5.0 per cent and all gas issuing from the vaporizer collected into a Douglas bag. Completion of carbon dioxide wash-out, from the vaporizing chamber in this instance, was again monitored by the infra-red gas analyser, whereupon the bag was detached and a 50-ml sample of its contents withdrawn for determination of carbon dioxide concentration with the Lloyd-Haldane apparatus. The volume of gas collected in the Douglas bag, varying between 15 and 30 l., was measured in a Tissot spirometer. All gas volumes were corrected to ATPD. These estimations were carried out before charging the vaporizer with liquid halothane.

*Priming volume for liquid halothane.*

When filling the dry vaporizer with halothane the volume required to fill the vaporizing chamber to the FULL line on the window was measured using a graduated glass cylinder. The filling process was staged over a period of 10 minutes to allow the wicks to take up their full charge. The liquid halothane was then drained from the vaporizing chamber and the deficit calculated; this was taken to represent the volume of liquid retained by the wicks.

*Flow/concentration characteristics.*

A Rayleigh refractometer (Hilger & Watts) was used to determine the output concentrations under various conditions of carrier gas composition, flow rate and control dial setting (fig. 3). A baffle system was placed in series with the outlet port of the vaporizer to ensure complete mixing of halothane with its carrier gas. A T-piece sampling arrangement at the distal end of the mixing baffle was connected to the refractometer by brass tubing. Samples of halothane/carrier gas mixture were aspirated through the right-hand chamber of the refractometer at a rate of 200 ml/min, whilst the bulk of the mixture escaped along the wide-bore exhaust channel. The left-
Hand chamber of the instrument was kept charged with halothane-free carrier gas as a reference medium. With carrier gas flowing and the vaporizer in the off position, the instrument was set to zero, then serial readings were taken at all dial positions. The actual halothane concentrations were calculated from the refractive indices of the gases and vapours (Edmondson, 1957). Performance was studied using both 100 per cent oxygen and 35 per cent oxygen in nitrous oxide as carrier gases. Flow rates ranged from 0.5 to 16 l./min.

Dial positions between off and 0.5 per cent also were studied with 100 per cent oxygen at flows ranging from 1 to 12 l./min. Settings between 0.5 and 2.5 per cent were studied with 100 per cent oxygen at 8 l./min passed through the vaporizer in the reverse direction: from outlet to inlet port.

Temperature and time-dependent characteristics.

Flow/concentration characteristics were studied using 100 per cent oxygen at flow rates ranging from 2 to 14 l./min with dial settings of 0.5, 2.5 and 5.0 per cent under the following temperature conditions: (a) in a warm air incubator at 34°C; (b) in a cold water bath at 16°C. A minimum of 3 hours was allowed for the vaporizer to achieve temperature equilibrium.

Since the temperature within the vaporizer tends to fall during use we also studied performance under conditions conducive to such a change. A carrier gas flow of 10 l./min of oxygen and a dial setting of 5.0 per cent were chosen to challenge the effectiveness of the temperature-controlled bypass resistor. Halothane output concentrations were determined at 10-minute intervals over a period of 1 hour with the outside of the vaporizer exposed to laboratory temperature (20°C). Over a similar period of time with a dial setting of 5.0 per cent and a flow rate of 8 l./min, the temperature within the vaporizer was monitored. For this purpose the glass window was replaced by a thick rubber diaphragm through which a thermocouple probe was passed to be immersed within the liquid halothane. The temperature was displayed on a telethermometer (Yellow Springs Instrument Co., Inc.). Temperature was monitored also with the vaporizer subjected to the less challenging conditions of a gas flow rate of 5 l./min and dial setting of 1 per cent. We also noted how the output fell when the liquid halothane was allowed to fall below the lowest level visible through the window.

Effect of IPPV.

The performance of the vaporizer during IPPV was assessed with the experimental arrangement depicted in figure 4. With the Mark 3 vaporizer mounted on the Boyle machine, the pressure tapping sleeve was interposed with the vaporizer outlet and mixing baffle and connected to an aneroid airway-pressure gauge. Carrier gas/halothane mixtures were drawn from the distal end of the mixing baffle through brass tubing to an ultra-violet halothane meter (Hook & Tucker) at a rate of 250 ml/min. The meter had been calibrated using the refractometer. Pressure fluctuations during IPPV rendered direct refractometry impracticable. The bulk of the carrier gas/halo-

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The halothane mixture was fed from the distal end of the baffle to a circle absorber system (BOC Mark 3), the vaporizer being situated outside the circle. The patient's lung was simulated by a 2-litre anaesthetic reservoir bag. The non-return valve fitted between vaporizer and patient circuits of the Model K Boyle machine was excluded from the experimental arrangement. The halothane output was measured with oxygen flowing at 0.5, 1, 3 and 5 l./min and dial settings of 0.5, 1, 2, 3, 4 and 4.5 per cent, before and during IPPV carried out manually at a rate of 12 b.p.m., with inspiratory times of 1 second. With this arrangement, the pressure at the outlet of the vaporizer fluctuated between 0 and 35 cm H₂O. Readings were taken when the composition of the mixture became stable, usually after about 2½ minutes. The experiment was repeated using a Fluotec Mark 2 vaporizer and dial settings of 0.5, 1, 2, 3 and 4 per cent, the vaporizer calibration having been checked against the refractometer.

Reassessment after prolonged cycling of the rotary control valve.

The vaporizer was returned to the manufacturers who arranged for the control knob to be rotated mechanically over 11,000 times, estimated to represent more than one year's use. We then checked flow/concentration characteristics with 100 per cent oxygen over a range of flows and dial settings.

RESULTS

Gas flow resistance.

Figure 5 shows how the pressure difference across the vaporizer (ΔP) varied with the carrier gas flows (V) for both 100 per cent oxygen and 35 per cent oxygen in nitrous oxide. ΔP was the lowest in the OFF position, but even so it rose to over 30 cm H₂O at 16 l./min. On turning to the 0.5 per cent setting the resistance increased considerably, but decreased somewhat as the dial was turned towards 5.0 per cent, permitting a greater proportion of the carrier gas to flow through the vaporizing chamber and less through the bypass resistor. With the more commonly used flows of less than 10 l./min, the maximum ΔP was 70 cm H₂O at the 0.5 per cent setting. At carrier gas flows below 8 l./min, resistance to the oxygen/nitrous oxide mixture was slightly lower than with oxygen alone. At higher flows, the presence of nitrous oxide was associated with a comparatively large increase in resistance.

Total volume of vaporizing chamber.

The volume was calculated for each of seven experiments. Values ranged from 261 to 279 ml (mean 269.5 ml).

Priming volume for liquid halothane.

The volume of halothane required to charge the dry vaporizer over a 10-minute period was 150 ml. Of this, 100 ml of halothane was recovered by rapid drainage in the upright position, but then a fluid level was seen to remain at the lower border of the window. The volume recovered was increased to 115 ml by tilting the vaporizer through almost 90 degrees, a procedure not recommended under normal circumstances. The volume of liquid halothane retained by the wicks was therefore approximately 35 ml.

Flow/concentration characteristics.

Halothane concentrations delivered were within 0.4 per cent of dial settings at all carrier gas flows studied for settings up to 3.0 per cent. At the higher settings, delivered concentrations rose at low flows and fell at high flows (fig. 6). The output characteristics for 35 per cent oxygen in nitrous oxide were close to those for 100 per cent oxygen (fig. 7).

Halothane output was studied whilst moving the dial between the OFF and 0.5 per cent settings.
Halothane was first detectable in traces in the refractometer when the dial had reached a position corresponding to a "0.35 per cent" setting. Turning the dial through as little as 2 mm from the 0.5 per cent setting towards OFF (corresponding to a change from 0.5 per cent to "0.45 per cent") effected a marked reduction in output, particularly at higher flow rates (table I).

<table>
<thead>
<tr>
<th>Output with dial set at</th>
<th>Dial setting</th>
<th>% halothane</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5%</td>
<td>0.5%</td>
<td>0.34</td>
</tr>
<tr>
<td>1.0%</td>
<td>1.0%</td>
<td>0.25</td>
</tr>
<tr>
<td>1.5%</td>
<td>1.5%</td>
<td>0.20</td>
</tr>
<tr>
<td>2.0%</td>
<td>2.0%</td>
<td>0.12</td>
</tr>
<tr>
<td>2.5%</td>
<td>2.5%</td>
<td>0.14</td>
</tr>
</tbody>
</table>

Temperature and time-dependent characteristics.

Figure 8 shows flow/concentration characteristics with 100 per cent oxygen at the alternative temperatures of 16 and 34°C, compared with those for the usual laboratory temperature of 20°C. Environmental temperature change had very little influence on the accuracy of output at the 0.5 per cent dial setting, whereas the 5.0 per cent curve shows how the performance is progressively improved as the temperature is raised from 16 to 34°C.

During passage of oxygen at 10 l./min for 1 hour with the dial set at 5.0 per cent, the delivered halothane concentration fell by 0.3 per cent, while the liquid halothane fell to the lowest level visible through the window of the vaporizing chamber. During passage of 8 l./min of oxygen...
for 1 hour with the dial set at 5.0 per cent, the delivered halothane concentration fell by 0.4 per cent, while the temperature within the vaporizer fell by 6°C. When the flow rate was 5 l./min and the dial setting 1 per cent, the delivered halothane concentration did not fall, while the temperature within the vaporizer fell by 2°C within 10 minutes and did not change further over a period of 1 hour.

With the vaporizer drained of liquid halothane, oxygen was passed at 8 l./min with the dial set at 1 per cent. The output of halothane was not maintained and the concentration fell continuously to reach zero after 25 minutes.

**Effect of IPPV.**

Figure 9 compares the effect of IPPV on the flow/concentration characteristics of the Mark 2 and Mark 3 Fluoteccs at four flow rates. Marked rises in concentration result when low dial settings and flow rates are used with the Mark 2; these have been eliminated from the Mark 3 vaporizer.

**Reassessment after prolonged cycling of the rotary control valve.**

Figure 10 shows some flow/concentration characteristics of the vaporizer after prolonged cycling of the control knob. It can be inferred that no deterioration occurred in our vaporizer.

![Graphs showing halothane output (per cent v/v) in 100 per cent oxygen from Fluotec Marks 2 and 3 during IPPV with various carrier gas flow rates (V) and dial settings.](image-url)
DISCUSSION

Construction.

The vaporizer is robust but heavy, and this may demand stronger attachment facilities than are available on some types of anaesthetic trolley or ventilator.

The siting of the drainage point in a more obvious position should encourage users of the Fluotec Mark 3 to remove liquid halothane when the vaporizer is to be transported or laid up, and also at regular intervals before recharging. This is to curb the tendency to coating of the vaporizing chamber and rotary valve with the thymol stabilizing agent, which accumulates otherwise during vaporization of successive charges of halothane.

The spindle control valve of the Mark 1 and Mark 2 vaporizers is susceptible to sticking when contaminated with thymol. The rotary control valve of the Mark 3 is expected to prove more satisfactory in this respect. Its bearing surfaces are flat and the machined ducts and control channel in the upper disc reduce by about 70 per cent the surface area actually in contact with the PTFE-coated lower disc. Also, should a film of thymol accumulate between the opposed surfaces the upper disc can yield upwards to forestall seizing of the valve. This design is also more adaptable to variation in the range of increments and output concentrations that might be required for special purposes.

Tilting of the vaporizer when charged may cause liquid halothane to spill over into the bypass chamber and duct systems unless the dial is maintained in the off position, and this may be difficult to ensure in the Mark 3. Subsequent usage could then cause surges of halothane vapour in potentially dangerous concentrations. Drainage in the upright position does leave a fluid level of halothane at the lower border of the window, and although it is permissible to tilt the vaporiser to drain it completely prior to transportation a more satisfactory approach is always to dry out the chamber by flushing with gas. The vaporizer has a flat base so that it will stand upright without support.

The siting of the temperature-controlled resistor within the bypass is novel to the Fluotec Mark 3 and confers theoretical advantages. The bimetallic strip assembly is a sensitive control and is now placed where it cannot readily become contaminated with thymol, nor exposed to halothane vapour which can corrode the strip when moisture is present. Also, the placing of the resistor in the bypass stream allows it a wider tolerance as it has then to control higher gas flows. The mounting of the bypass assembly concentrically within the vaporizing chamber ensures that the thermal compensator is held at a temperature close to that of the liquid halothane.

Gas flow resistance.

The pressure required to drive gas through the Fluotec Mark 3 is of the order of one hundred times greater than that required for comparable flow rates in the Mark 2 (Nunn, 1961). Even in the off position, the pressure difference required is still very high. Clearly, the Mark 3 is totally unsuited to inclusion in the patient circuit of any draw-over anaesthetic system. Resistance to the flows encountered under such circumstances is unacceptably high at all dial settings (fig. 5). Removal of the filter from the inlet channel does not reduce the pressure difference to any great extent, although accumulation of dirt in the filter after more prolonged usage might lead to a rise in resistance.

Total volume of vaporizing chamber.

This is now comparatively low and the reduction minimizes, though by itself does not abolish, the "Hill-Lowe pumping effect".

Flow/concentration characteristics.

The concentration characteristics are more uni-
formly flat than is the case with the Fluotec Mark 2 and the calibration is in fact satisfactory for the most commonly employed dial settings and gas flow rates (figs. 6 and 7). The rising concentration characteristics at low flows and high dial settings (fig. 11) were an intentional feature introduced in the Mark 2 Fluotec to facilitate build-up of vapour concentration in circle systems during induction of halothane anaesthesia with the vaporizer outside the circle. However, this has been criticized as being of doubtful value, particularly if these vaporizers are to be made available to relatively inexperienced personnel, or if the calibration card becomes separated from the vaporizer and its user. Accordingly, this feature has been minimized in the Mark 3 Fluotec and the 5.0 per cent calibration setting substituted to help meet any demand for overpressure facilities. However, the design of the rotary valve provides for ready modification should even higher dial settings be required.

It is evident that attempts to employ this type of vaporizer for the provision of halothane in concentrations below 0.5 per cent will be defeated by the sharp cut-off in output below that dial setting (table I) and so attempts to provide accurately any lower concentrations are unlikely to be successful. This consideration also applies to the Fluotec Mark 2. Factory-calibrations of less than 0.5 per cent could be provided by modifying the vapour control channel, should the demand arise, even though the usefulness of such concentrations appears to be limited.

We have anticipated the possibility of gas being passed through the vaporizer in the reverse direction if it is added to pre-existing circuitry without attention to the manner in which the circuit is reconstituted. Under such circumstances, the vaporizer will deliver halothane in concentrations more than double those indicated by the dial setting (table II).

**Temperature and time-dependent characteristics.**

To ensure accurate function of the vaporizing chamber outlet control channel at any given dial setting and carrier gas flow rate, the amount of halothane vapour passing through it should be kept constant. The amount of halothane vapour leaving the vaporizing chamber through this control channel depends on the saturation concentration of the vapour and the rate of gas flow through the chamber. The saturation concentration of halothane vapour at any given barometric pressure depends on the temperature of the halothane. It is 31.2 per cent at 20°C and 760 Torr. The arrangement of wicks around the spiral channel leading up to the outlet of the vaporizing chamber ensures virtually complete saturation of the carrier gas leaving the chamber for the control channel.

As vaporization proceeds, the temperature of the halothane and therefore its saturation concentration will fall. Accordingly, the amount of halothane passing through the control channel will fall also unless the flow of carrier gas through the vaporizing chamber is increased. Similar principles apply if the whole vaporizer comes into equilibrium with ambient temperatures outwith the normal working range, when the temperature of the halothane charge might become either lowered or raised.

These considerations justify the incorporation of a temperature-compensating mechanism in the design of these vaporizers. At any given dial setting of the Fluotec Mark 3, the carrier gas splitting ratio for bypass and vaporizing chamber is determined by the restriction of the temperature-sensitive resistor in the bypass chamber, although the total gas flow rate itself may also become important at high and low flows.

When the temperature in the vaporizing chamber begins to fall with use, the bimetallic strip operates to increase the restriction in the bypass chamber.
so that more gas flows through the vaporizing chamber to maintain constant the amount of halothane vapour reaching the control channel.

With the vaporizer exposed to a normal temperature environment (20°C), the compensating mechanism was capable of maintaining a satisfactorily consistent output concentration even when challenging conditions were imposed that were sufficient to cause a temperature fall of 6°C within the vaporizer. Normally, the temperature fall will be such that the interior of the vaporizer is unlikely to be more than 2°C below ambient. However, there is a deterioration in flow/concentration characteristics at low and high flows when the whole vaporizer is in equilibrium with an environment at 16°C. Conversely, improvement occurs with corresponding flows at 34°C. These effects are exaggerated at high dial settings (fig. 8).

**Effect of IPPV.**

The vaporizer design has been modified to eliminate the effect reported by Hill and Lowe (1962) whereby pressure fluctuations transmitted from patient and ventilator circuits during IPPV invalidate the calibration of the Fluotec Marks 1 and 2 so that output concentrations of halothane are raised, particularly at low gas flows (0.5 and 1.0 l./min) and low dial settings (0.5 and 1.0 per cent) (fig. 9).

The mechanism of this effect is as follows: the pressure in the vaporizer rises during the positive phase of IPPV. Compression of the gas in the vaporizing chamber occurs in accordance with Boyle's Law and so additional gas is then driven into the vaporizing chamber. The volume of this surge is given by the following expression:

\[
\text{gas volume of vaporizing chamber} \left( \frac{\text{airway pressure}}{\text{barometric pressure} + \text{airway pressure}} \right)
\]

where “airway pressure” refers to the pressure (above atmospheric) transmitted to the vaporizer during the positive phase of IPPV. The “gas volume of vaporizing chamber” equals the volume when empty minus the volume of the liquid halothane charge. It will increase progressively as the charge is consumed.

**Example for this vaporizer (when fully charged).**

Assume: (1) barometric pressure

\[=1000 \text{ cm } H_2O\]

(2) airway pressure

\[=35 \text{ cm } H_2O\]

\((3)\) gas volume of vaporizing chamber

\[=270-115 \text{ ml} \]

\[=155 \text{ ml approx.}\]

then: volume of gas entering vaporizing chamber during compression

\[=155(35/1035) \]

\[=5 \text{ ml approx.}\]

When the positive phase ends, decompression occurs and the gas surge will then leave the vaporizing chamber. Without precautionary modifications to the vaporizer, the gas will have been saturated with halothane vapour at a concentration of approximately 33 per cent. It will leave the chamber not only through its normal outlet (Y) but also through its inlet (X) (fig. 2), so contaminating the carrier gas stream destined to pass through the bypass chamber. This initiates a rise in halothane concentration delivered at the outlet of the vaporizer and, as pumping proceeds, a progressive rise will occur as the bypass chamber becomes increasingly contaminated with halothane vapour issuing from the vaporizing chamber inlet (X). After some 20 to 30 compressions, the delivered concentration reaches a fairly steady raised level.

With each decompression, the 5 ml of carrier gas issuing from the vaporizing chamber will carry approximately 2.5 ml of halothane to give 7.5 ml of 33 per cent halothane vapour. Thus, if the respiratory frequency is 20/min, an additional 50 ml of halothane vapour per minute will leave the vaporizing chamber. If all of this is added to the carrier gas stream, the percentage enrichment will be as follows:

<table>
<thead>
<tr>
<th>Carrier gas flow rate (ml/min)</th>
<th>Additional halothane (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>500</td>
<td>10</td>
</tr>
<tr>
<td>1000</td>
<td>5</td>
</tr>
<tr>
<td>2000</td>
<td>2.5</td>
</tr>
<tr>
<td>3000</td>
<td>1.7</td>
</tr>
<tr>
<td>5000</td>
<td>1, etc.</td>
</tr>
</tbody>
</table>

Enrichment is greatest at low flow rates and although independent of the dial setting, its effect upon the concentration delivered at the outlet will be more conspicuous at low settings. The enrichment is also influenced by the level of the liquid halothane: as this falls, the gas volume of the vaporizing chamber approaches 270 ml, when 9-nil surges of gas will issue from the vaporizing chamber carrying about 90 ml of halothane vapour per minute. The percentage enrichment figures will then be almost doubled.
In the Fluotec Mark 3, various modifications have been employed to minimize the pumping effect:

1. Reduction of the volume of the vaporizing chamber will minimize the effect of compression. This principle has been applied in the Mark 3 vaporizer and the volume of 270 ml represents a considerable reduction upon that of the Mark 2, which has a chamber volume of approximately 750 ml.

2. The foregoing considerations have shown that reduction of compressible volume cannot by itself entirely eliminate the pumping effect, and so in addition it is necessary to control the direction of entry of the pressure surge into the vaporizing chamber. This is achieved by arranging for the resistance of the chamber outlet to be higher than that of the inlet. In the Mark 3, the siting of the vapor control channel on the outlet side of the vaporizing chamber contributes to this, especially at low dial settings and so, during compression, the surge tends to pass back through the bypass to enter the vaporizing chamber through its inlet. Also, the bypass acts as an expansion chamber for damping the pressure surge during its transmission. However, the most important measure is to arrange for this gas to be protected from impregnation with halothane vapour. This has been achieved by:
   
   a) providing a small annular expansion chamber (B) adjacent to the vaporizing chamber inlet channel (X) (fig. 2);
   
   b) providing a long, narrow, annular throat (C) leading down from B to the liquid halothane;
   
   c) excluding wicks from sites B and C.

These measures serve to confine halothane vapour to regions of the chamber remote from its inlet and to restrict the entry of gas during compression to the region close to its inlet. When decompression follows, this gas, returning to the bypass stream mainly via the inlet, will not have picked up any appreciable amount of halothane.

These modifications underlie the elimination of the pumping effect from the Fluotec Mark 3 vaporizer.

Reassessment after prolonged cycling of the rotary control valve.

Whilst it was to be hoped that prolonged cycling would not affect the function of the rotary valve adversely, we were surprised to note that, on the contrary, the flow/concentration characteristics were somewhat improved by such usage! (fig. 10).

These studies suggest to us that the Cyprane Fluotec Mark 3 is a satisfactory vaporizer under conditions encountered during routine use by anaesthetists. It appears that the adverse features attributed to its predecessors have been minimized.

ACKNOWLEDGEMENTS

The Fluotec Mark 3 vaporizer and the Rayleigh refractometer were provided by Messrs. Cyprane Ltd., Keighley, Yorkshire.

REFERENCES


EVALUATION D'UN NOUVEAU VAPORISATEUR D'HALOTHANE: LE CYPRANE FLUOTEC MARK 3

SOMMAIRE

La construction, le principe d'action et l'évaluation du nouveau vaporisateur d'halothane, le Cyprane Fluotec Mark 3, sont décrits. Les possibilités de grand débit à flux bas, que possédait le Fluotec Mark 2, ont été abandonnées. Avec le Mark 3, le débit est linéaire à tous les niveaux de flux, et "l'effet de pompage Hill-Lowe" est négligeable. La construction et les performances générales sont satisfaisantes et le vaporisateur produit l'halothane dans des concentrations acceptablement constantes, dans les diverses conditions qu'on rencontre habituellement lors de son emploi par les anesthésistes.

BEURTEILUNG EINES NEUEN HALOTHAN-VERDUNSTERS: CYPRANE FLUOTEC MARK 3

ZUSAMMENFASSUNG