W^s Anes. Dept.

THE OXFORD VAPORISER

Issued by

The Nuffield Department of Anaesthetics

University of Oxford

Drawings by Miss M. McLarty

Morris Motors Limited

COWLEY, OXFORD

THE OXFORD VAPORISER

Certificate of Acceptance

This is to certify that the Oxford Vaporiser No. 14

has been finally tested and approved.

Signed [illegible]

13 AUG 1942

ORIGINAL TO BE PACKED WITH VAPORISER

THE QUANTITATIVE ADMINISTRATION OF ETHER VAPOUR

R. R. MACINTOSH K. MENDELSSOHN

THE OXFORD VAPORISER

H. G. EPSTEIN
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THE OXFORD VAPORISER No. 2

S. L. COWAN
R. D. SCOTT S. F. SUFFOLK

PERFORMANCES OF OXFORD VAPORISERS WITH ETHER

H. G. EPSTEIN E. A. PASK

Reprinted from THE LANCET, *July* 19, 1941, *pp.* 61–67.

Before using this apparatus the anaesthetist should read the following four articles in "The Lancet" of 19th July, 1941 :—

1. The Quantitative Administration of Ether Vapour
   By R. R. Macintosh and K. Mendelssohn.

2. The Oxford Vaporiser
   By H. G. Epstein, R. R. Macintosh and K. Mendelssohn.

3. The Oxford Vaporiser No. 2
   By S. L. Cowan, R. D. Scott and S. F. Suffolk.

4. The Performances of the Oxford Vaporisers with Ether
   By H. G. Epstein and E. A. Pask.

These four articles are included at the back of this booklet.

Paper No. 3 is included in the above series because the vaporiser which it describes is of general interest, and because the two vaporisers work on the same principle.

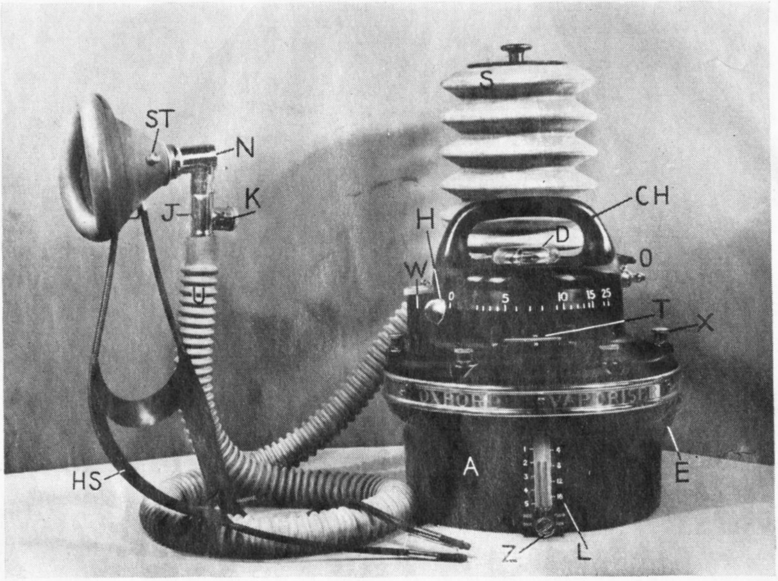


Fig. 1.

A. Ether chamber.
D. Glass dome for observing inspiratory valve.
E. Ether filler.
H. Control handle.
J. Valve unit.
K. Expiratory valve.
L. Ether level indicator.
N. Angle piece.
O. Tap for oxygen (if used).
S. Hand-bellows.
T. Thermometer.
U. Tube to mask.
W. Filler for hot water.
X. Cover thumb nut.
Z. Plug for draining ether.
CH. Handle and cover.
HS. Harness.
ST. Stud.

Each vaporiser has been tested in the laboratory at a respiratory rate of 23 and a minute volume of 7.5 litres. When the vaporiser is used as described in this booklet, the figures on the scale correspond closely to volumes per cent. of ether vapour in the ether/air mixture delivered.

INSTRUCTIONS WHEN USING THE OXFORD VAPORISER WITH ETHER

To bring the vaporiser into use the following instructions should be carried out **in the order given :**

1. Study the illustration Fig. 1, on page iv.
2. If the vaporiser is still in the cabinet, lift out angle piece (N), valve unit (J) and corrugated rubber breathing tube (U).
3. Lift out vaporiser by handle (CH).
4. Withdraw face-mask from socket in lid of cabinet and attach to angle-piece.
5. Remove harness (HS) from beaker in bottom of cabinet.
6. Remove ether filler cap (E) and fill to about the 4 oz. mark. Replace filler cap.

   The capacity of the vaporiser is about 30 oz. The ether level gauge (L) does not begin to register until about 15 oz. have been poured in.
7. Remove water filler cap (W) and bung in water outflow spout (Q, Fig. 2, page vi).
8. Remove beaker from cabinet and place under water outflow spout (Q).
9. Pour in water as hot as available through water filler (W) until the stream flowing out through (Q) seems to the finger as hot as that being poured in. About a pint is necessary, and a jug of about this size should be used. **Care must be taken not to knock the water filler (W) with the spout of the water jug, nor must the water filler be allowed to take the weight of the spout.**
10. Five minutes later refill with hot water until the outflowing water again seems to be as hot as the water being poured in. The refilling with hot water should be repeated at five-minute intervals until the mercury in the thermometer has risen to the right of the thick vertical white line which crosses the thermometer.

    N.B. The temperature of the water from the average hot water tap seldom exceeds 60° C. ; the hotter the water used the less frequently will it be necessary to refill.

HOT WATER MUST NOT BE ADDED AFTER THE MERCURY HAS RISEN ABOVE (i.e. TO THE RIGHT OF) THE THICK VERTICAL WHITE LINE WHICH CROSSES THE THERMOMETER.

The apparatus is now ready for use.

If at any time the level of the mercury in the thermometer falls below (i.e. to the left of) the white line, water as hot as is available should again be poured through the water filler (W) until the outflowing water seems as hot as the inflowing water.

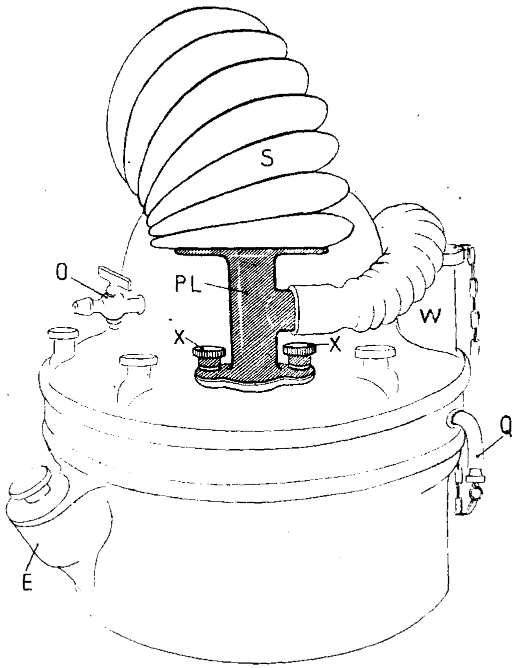


Fig. 2.

If the thermometer registers to the right of the vertical white line DO NOT POUR ANY MORE HOT WATER through the water filler (W).

If, after carrying out instructions 9 and 10 the mercury column in the thermometer does not rise, the thermometer is probably broken and should be replaced according to Servicing Instruction 2, page xiii. Another indication of a broken thermometer is that the mercury remains permanently visible even if the vaporiser is cold.

If at any time the ether level falls below the 16 oz. mark, more ether should be poured in through the ether filler (E). The concentration of ether vapour coming from the apparatus is not substantially affected by a fall of the ether level to the 16 oz. mark on the gauge.

The ether level should be kept between the 4 and 16 oz. marks on the gauge (L).

If the vaporiser is to be transported, the ether chamber should be drained through plug (Z) to prevent the escape of an explosive mixture of ether vapour.

The two cover thumb nuts (X, Fig. 2, page vi) holding the pedestal (PL) of the hand-bellows (or " spring reservoir bag " S) should be tight. Check this by attempting to rock the pedestal.

Any leak at this point results in a diminution in the concentration of ether vapour reaching the patient.

The valve unit (J, in Figs. 1, 3 and 4) consists of a non-return valve (NV) and an adjustable spring-loaded expiratory valve (K).

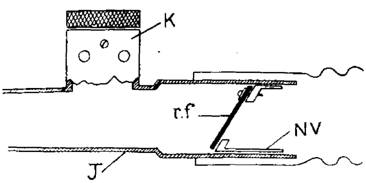


Fig. 3.

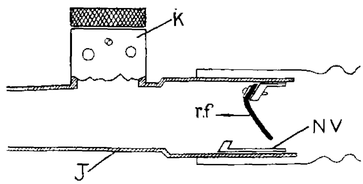


Fig. 4.

The non-return valve should be inspected frequently by taking off the corrugated rubber tube and making sure that the rubber flap (r.f.) has not become everted as in Fig. 4. Should this have happened, the flap must be pushed back again with a pencil. Re-breathing into the bellows is now impossible.

If the vaporiser is to be used in exceptional climatic conditions, see page xvi.

THE OXFORD VAPORISER IN USE

The control handle (H, Fig. 1) should be set at zero and the hand-bellows pumped gently two or three times to remove any ether vapour which may be in the corrugated tube.

Methods of induction are discussed on pages 20 and 21, but since these were written the **induction bag** has been added and in some cases is of considerable assistance.

Induction is generally facilitated by introducing the induction bag (i.b., Fig. 5) between the angle piece (N) and the valve unit (J). The face-piece is in circuit with the ether vaporiser throughout,

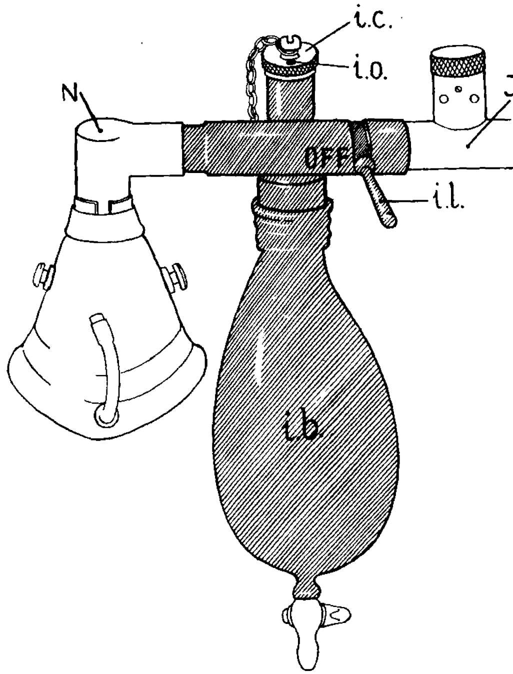


Fig. 5.

but the induction bag can be cut off from the circuit by moving the lever (i.l.) to the " OFF " position. When the lever is in the " ON " position the induction bag is fully in circuit with the face-piece, so that rebreathing takes place freely into the bag. The amount of breathing which takes place in and out of the induction bag is determined by the position of the lever.

Ethyl chloride can be sprayed through the opening (i.o., Fig. 6) in the cap (i.c.), or the cap can be unscrewed and vinesthene or other liquid anaesthetic poured in (Fig. 7).

The lever (i.l.) of the induction bag is gradually moved into the " ON " position and in this way anaesthesia is induced with whatever anaesthetic is in the induction bag. As soon as anaesthesia deepens, the control handle (H, Fig. 1) of the vaporiser is set at the appropriate

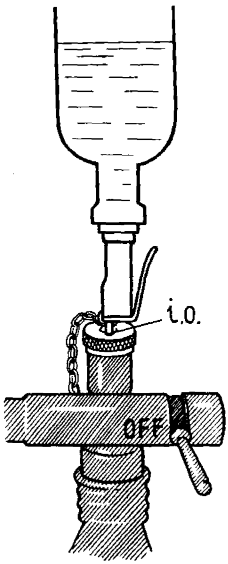


Fig. 6.

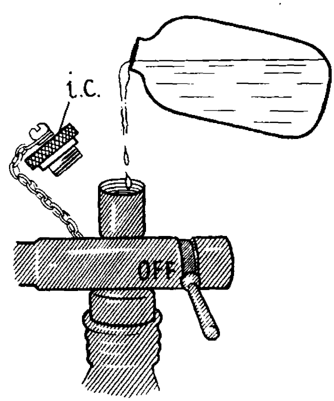


Fig. 7.

position and the lever of the induction bag gradually moved to the " OFF " position. If the concentration of ether vapour is too high to be tolerated comfortably, the induction bag can again be brought into circuit.

If no other means of induction is available, ether must be used from the beginning. In this event the mask is placed lightly on the face, the control handle (H) set at 2, and the resulting mixture of ether vapour in air is delivered to the patient by the anaesthetist compressing the hand-bellows (S). When the bellows is released the spring causes it to expand, drawing in a fresh supply of ether/air mixture. **This is the correct way to use the hand-bellows.** If it is rapidly and forcibly expanded, the ether vapour concentration delivered may become much higher than when it is used in the correct way. The control handle is moved so that the concentration of ether vapour in the mixture is increased steadily and as rapidly as the patient will tolerate. As soon as the patient is unconscious the head harness (HS, Figs. 1 and 8) is adjusted so that it holds the mask closely to the face (Fig. 8). It is now no longer necessary for the anaesthetist to deliver the anaesthetic mixture to the patient by compressing the hand-bellows, since the patient will draw in the mixture himself.

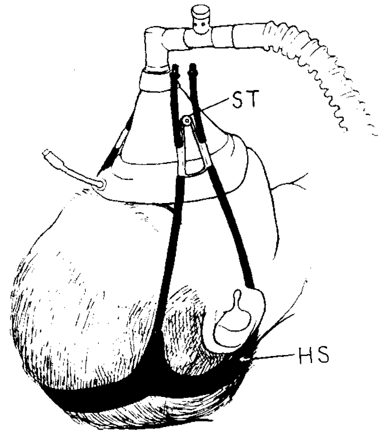


Fig. 8.

Use of the Hand-bellows (S, Fig. 9)

This bag is in no way a rebreathing bag, since a one-way valve situated near the mask ensures that expirations are directed entirely through the expiratory valve (see page vii, para. 5).

(i) In case of necessity the bellows can be used to perform artificial respiration. The control handle is set at zero and the mask lifted from the patient's face. The expiratory valve (K) is screwed down, and the bellows and tubing freed from

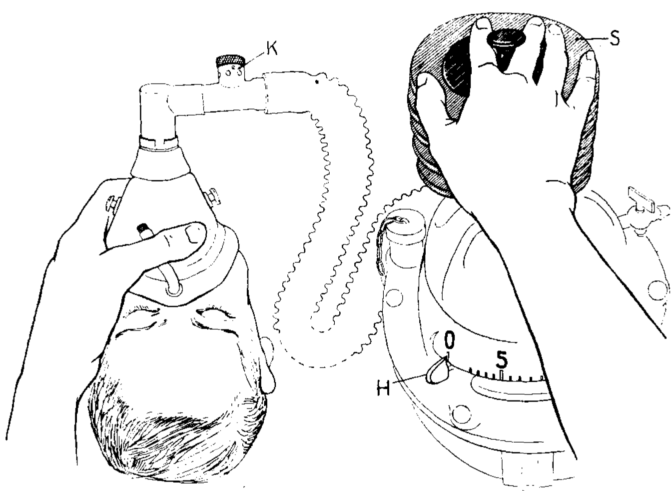


Fig 9.

ether vapour by a few pumps. The mask is then held firmly to the face with the jaw drawn forward, so that the airway is clear. On pressing down the bellows, air will be forced into the patient's lungs. The mask should now be lifted momentarily to allow expiration, due to the elastic recoil of the lungs, to take place. This manoeuvre is repeated as often as is necessary.

(ii) Where induction has been carried out by a moderately large dose of a short-acting intravenous barbiturate it will be found that respiration is depressed. The larynx of the patient can be accustomed to ether vapour, or the lungs may be inflated with the anaesthetic mixture, by setting the control handle to the appropriate position and working the hand-bellows in the way described on page ix, para. 2. By the time normal respiration is resumed, a high percentage of ether vapour will be tolerated by the larynx.

Use of the Rubber Nasal Airway

In some robust individuals, especially the thick-necked, there may be difficulty in maintaining a clear airway during induction. Spasm of the masseter muscle may prevent breathing through the mouth, and approximation of the soft palate to the posterior pharyngeal

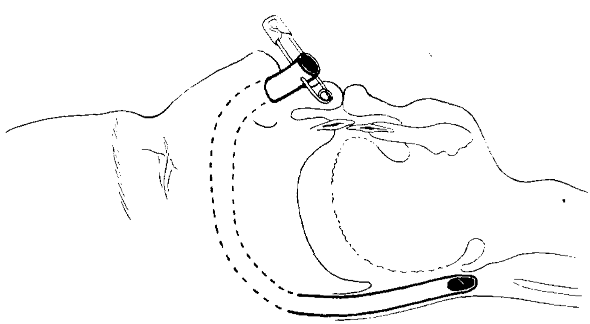
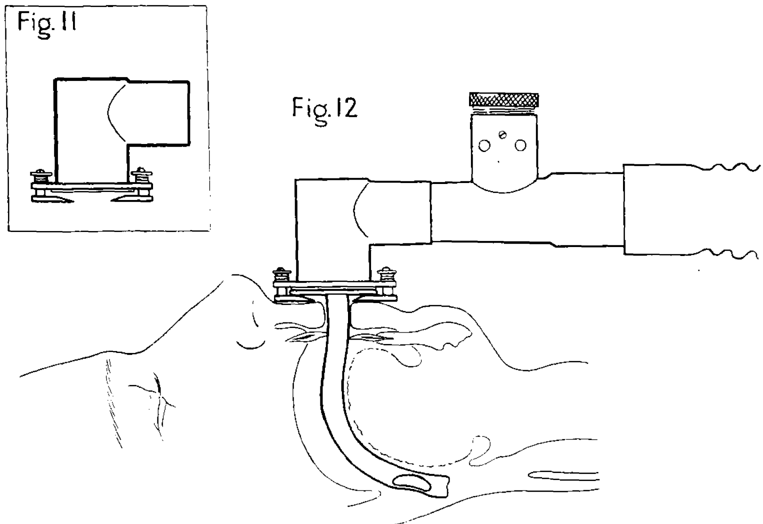


Fig. 10.

wall may prevent nasal respiration. In these cases a clear airway can be attained by inserting a short rubber tube of large bore straight back through one nostril, so that its end lies over the larynx (Fig. 10). A safety-pin may be inserted through the proximal end.

A metal airway may be inserted once an adequate depth of anaesthesia is established.

In some operations, such as those on the antrum, or on the eye, or in performing the toilet of burns of the face and neck, the use of a face piece is not practicable. Here the metal airway can be connected (Fig. 12) to the valve unit by the connector (Fig. 11).



Figs. 11 and 12.

It will be obvious that the system is no longer air-tight and that the composition of the final ether/air mixture inspired by the patient is no longer represented by the position of the control handle, since additional air is drawn in by the patient around the airway.

The bellows can be used as a *vis a tergo* to drive over the ether/air mixture when a Davis gag is used during tonsillectomy.

If an endotracheal tube is passed, this can be connected to the valve unit in the usual way.

SERVICING INSTRUCTIONS

1. If any leak is observed at the ether drain plug (Z, Fig. 1, page iv) replace washer. Spare washers will be found in the spare parts drawer in the cabinet.

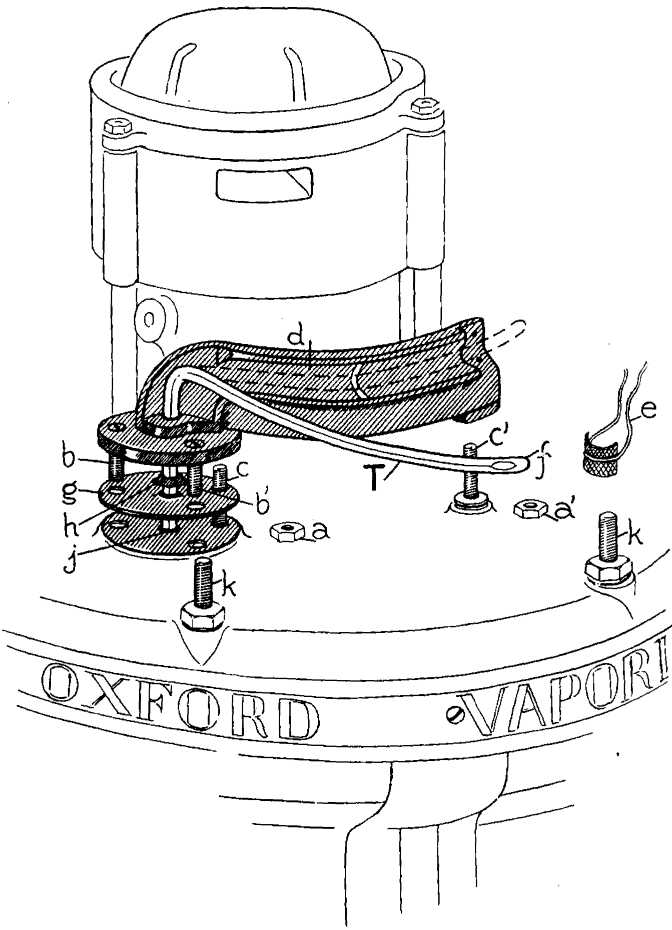


Fig. 13.

2. To replace broken thermometer.
   This replacement involves exposure of the crystals and their efficiency is spoilt by addition of water or by more than brief exposure to air.
   The replacement should not be attempted unless it is impossible to have the vaporiser serviced by experts.

A. **To remove broken thermometer.**

1. Drain off ether through drain plug (Z).
2. Unscrew the eight cover thumb nuts (X) and remove washers.
3. Remove hand-bellows (S) with pedestal (PL, Fig. 2, page vi) and gasket.
4. Unscrew control handle and oxygen tap (H and O, Fig. 1) together with their washers.
5. Lift out water filler stopper (W).
6. Lift off top cover (CH).
7. Fill in ten fillings of hot water at five-minute intervals.
8. Refer to Fig. 13 and then remove nuts a and a' from fixing studs c and c', and screws b and b', thus loosening thermometer housing d.
9. Remove wire and packing material (e) from round the tip (f) of the thermometer (T).
10. Rotate thermometer round its vertical stem by pulling the tip forward.
11. By gentle rocking movements lift thermometer housing (d) sufficiently to expose rubber washer (g) underneath.
12. Prise up rubber washer (g) with knife to position shown in drawing.
13. Carefully lift up thermometer with washer and housing and remove from vaporiser.
14. Slip thermometer housing off thermometer and slide the two rubber washers—one large (g), the other very small (h)—over the tip of the thermometer.
15. Remove all broken pieces of glass which can be found in the thermometer hole (j), as these would scratch and break the new thermometer when this is inserted. It is essential to push down a metal rod into the hole to make quite sure that there is free passage for the mercury bulb of the new thermometer. If this rod comes into contact with solid crystals, pour in more hot water through (W) until all the crystals are molten, taking care that no water is spilt near the thermometer hole (j). When the passage is free, proceed **at once** to insertion of new thermometer.

B. **To insert new thermometer.** This is to be found in spare parts drawer in the cabinet.

16. Slip large rubber washer (g) over tip (f) of thermometer and slide until it is about half inch below angle of thermometer.

17. Slip small rubber washer (h) into position above washer (g); the conical end should be uppermost.

18. Thread tip of thermometer through hole in thermometer housing (d).

19. Make sure that instruction 15 above has been carried out, i.e. that no solid crystal will obstruct the descent of the thermometer bulb.

20. Carefully insert bulb of thermometer into hole (j) of vaporiser and lower gently until housing (d) is in position on the two fixing studs (c and c').

21. Screw down nuts (a and a') and screws (b and b') finger tight.

22. The horizontal part of the thermometer is fitted into its housing by simultaneous rotation and adjustment of height of the thermometer.

23. Replace packing material (e) round tip of thermometer and fix with retaining wire.

24. Screw up tightly nuts (a and a') and screws (b and b').

25. Replace top cover (CH, Fig. 1).

26. Replace water filler stopper (W).

27. Screw in oxygen tap (O) and control handle (H) with their washers in place. See that the tip of the control handle is square with the lines of the calibration scale.

28. Replace gasket and hand-bellows (S, Fig. 2). Replace the small red washers and screw up the two cover thumb nuts (X). Make particularly sure that these nuts are tight and that the pedestal (PL) cannot be rocked backwards and forwards.

29. Replace washers on studs (k, Fig. 13) round cover (CH, Fig. 1) and screw up the six remaining thumb nuts (X).

30. Do not refill with ether until mercury meniscus falls sufficiently to become visible. It is not advisable to cool the apparatus by pouring in cold water through (W).

SPECIAL CLIMATIC CONDITIONS

Cold

1. If the apparatus is to be exposed to temperatures below freezing point, the water compartment (C, Fig. 2, page 9) should be drained by blowing through the water filler (W).

2. After having been exposed to such cold, the apparatus will need considerably more than the usual number of fillings with hot water to bring it into use.

3. If the apparatus is likely to be exposed to cold again, do not forget to empty the water compartment.

Heat

4. If the apparatus has been exposed to temperatures above 30° C. (85° F.) the mercury meniscus will already be to the right of the white line without addition of any hot water.

   If it is more than 1 in. to the right of the white line, pour in a pint of cold water through (W). Repeat this filling at ten-minute intervals until the mercury meniscus is 1 in. or less to the right of the white line. Now only should ether be filled in through (E).

Dust

5. The entry of dust or sand-laden air into the apparatus must be prevented. For this purpose special filters which present low resistance to air flow have been designed. They are available, together with instructions for their use, from Medical & Industrial Equipment Ltd., of 12 New Cavendish Street, London, W.1.

Dry Climates

In very dry climates there is a possibility of an explosion occurring if oxygen is mixed with dry ether vapour. It is therefore recommended if oxygen is to be used in very dry climates that it should **not** be introduced through the tap O, but that it should be led through a tube inserted under the face mask, where there is always a considerable amount of water vapour present.

If it is necessary *to use ether in confined spaces, near open fires, or near electrical equipment,* it is advisable to take precautions against the escape of the ether vapour in the patient's expired air. One method of doing this is by connecting an adsorbent cartridge to the expiratory valve. Such cartridges and instructions for using them can be obtained from Medical & Industrial Equipment Ltd.

THE QUANTITATIVE ADMINISTRATION OF ETHER VAPOUR

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AN anæsthetic which is in the gaseous state at N.T.P. can be administered in any desired quantity or concentration, by regulating the measured rate of its flow. The object of the work to be described in this and the following papers was to devise means by which the anæsthetist shall be able to control, in a similarly simple and accurate manner, the composition of a mixture containing the vapour of a liquid anæsthetic. The fact that a liquid anæsthetic is stored in the liquid state and administered in the gaseous state confers great advantages of portability and compactness. At the same time, this fact makes the problem of its quantitative administration more difficult because an intermediate process of vaporisation is necessary.

A method of historic interest of administering the vapour of a liquid anæsthetic quantitatively is that of Snow, who in 1849 introduced a measured quantity of liquid chloroform into a large bag, sufficient when the bag was filled with air to form a mixture containing 4% of chloroform vapour. The method proved cumbersome and was abandoned, because, said Snow (1858), " it seemed necessary to sacrifice a little of absolute perfection to convenience." The method was revived for a short time by Clover (1862). More practical methods of administering chloroform dosimetrically were introduced by Vernon Harcourt (1903), Levy (1905), and more recently by Rowling (1932), but for reasons which will be apparent later none of these methods is suitable for ether, of which a much larger volume must be evaporated in order to obtain a corresponding degree of anæsthesia.

In order to explain the present method by which this problem has been dealt with, it is necessary to refer briefly to the physical laws governing the vaporisation of liquids. The concentration of vapour in the atmosphere above the surface of a liquid depends solely on the temperature of the liquid. If the temperature changes the concentration of vapour in the air above the liquid changes accordingly. The vapour-pressure curve for ether (fig. 1) shows the strength of the saturated ether-air mixture corresponding to temperatures ranging between $-20°$ C. and $40°$ C., expressed both as partial pressure in mm. Hg and in volume per cent. of ether vapour in the mixture. This strength is about 10% at $-17°$ C., 25% at $0°$ C., 50% at $17°$ C. (room temperature) and 100% at $34°$ C., the boiling-point of ether.

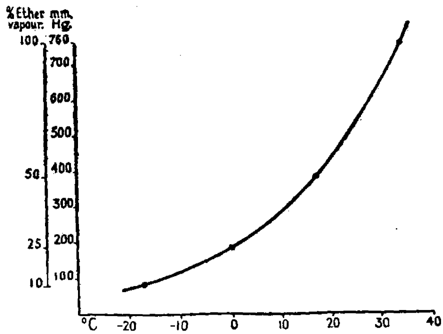

FIG. 1—Vapour-pressure curve for ether.

This gradual variation of the vapour concentration with temperature might seem to offer a means of administering a mixture containing any desired strength of ether vapour simply by changing the temperature of a vessel containing liquid ether, but unfortunately, for practical reasons, the construction of a device which allows such rapid well-controlled changes of temperature is not feasible. We have therefore directed our attention to maintaining in an ether container a constant high concentration of ether vapour, diluting this with air or other gases in such a way that the percentage of ether vapour in the mixture delivered to the patient is known and can be altered at will.

In order to ensure this constant and high concentration of ether vapour it is necessary to keep constant the temperature of the liquid ether within the container. It is here that we meet with our first difficulty. The vaporisation of a liquid is a process which involves consumption of heat—for example, the transformation of 1 gramme of liquid ether into ether vapour of the same temperature requires 90 calories. Unless this " heat of vaporisation " is furnished from outside the liquid will cool, and there will be a continual decrease in the strength of the vapour above the liquid.

The jacket of warm water commonly used round the familiar Boyle's bottle does not provide this heat in a satisfactory manner. If the heat content of such a jacket is to be adequate the size of the jacket will be unwieldy, since the initial temperature of the water must not exceed the boiling-point of ether, $34°$ C. Further, the temperature of such an assembly will not remain constant, because the temperature of the water will fall as heat is taken from the system.

CRYSTALS AS A HEAT RESERVOIR

The use of an electrical thermostat while theoretically satisfactory is not so in practice, because electricity is not always available, and because of risks of ignition.

Instead we have made use of the latent heat of a subsidiary substance to act as a *heat reservoir* at constant temperature. It is well known that if heat is added to or lost from a vessel containing melting ice the temperature of the ice - water mixture does not change. There is an increase in the amount of water present when heat is added, or in the amount of ice when heat is taken away, in each case at the expense of the other phase. Thus any changes in heat content of the system either melt ice or crystallise water, but do not result in changes of temperature. Such a thermostat is well suited to our purpose, but instead of ice we must choose another crystalline substance with a melting-point lying at a more convenient temperature. The maximal concentration of the vapour desired determines the temperature to be maintained within the ether container, and the melting-point of the heat-reservoir substance must correspond with this temperature.

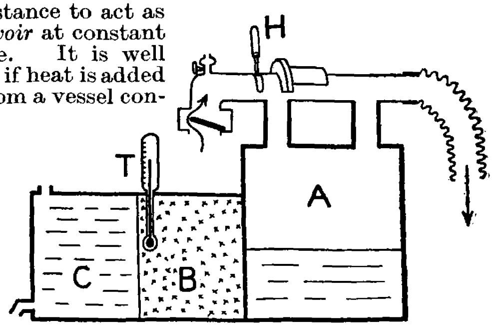

FIG. 2—Scheme of ether vaporiser. A ether container, B heat reservoir containing crystals, C hot-water chamber, H tap for controlling ether concentration, T thermometer.

The general scheme of the new type of ether vaporiser is shown in fig. 2. A is the container in which ether is evaporated, B the heat reservoir containing the crystals, and C is a chamber into which hot water is poured to provide heat to melt the crystals. Let it be assumed that just sufficient hot water has been put into the chamber C to melt all the crystals in the reservoir B. When ether vapour is taken out of the container A, more ether will evaporate in order to restore the original concentration of vapour above the surface of the fluid ether. The temperature of the fluid ether does not fall, because the heat used for the evaporation is furnished from the reservoir B, in which an equivalent amount of molten "reservoir" substance crystallises. This process goes on at constant temperature until all of the liquid in the reservoir B is solidified, which will be shown by a sudden fall in the reading of the thermometer registering the temperature of B. In order to re-melt the crystals hot water is again poured into C. There is no need for the temperature of the water to be below the boiling-point of ether, for the crystals in B will act as a thermal buffer, taking up heat at any higher temperature but releasing it only at the temperature of their melting-point.

Both the vaporisers to be described in the following papers work according to the principle outlined. In the Oxford Vaporiser No. 1 the temperature of the ether is kept *below* its boiling-point by choice of a suitable reservoir substance, and the machine is in fact an ether-vapour inhaler from which a constant supply of highly concentrated ether vapour is available and may be diluted with air to any desired strength by means of a calibrated mixing tap. In the Oxford Vaporiser No. 2, by the use of a reservoir substance whose melting-point is *above* the boiling-point of ether the concentration of ether vapour in the container is maintained at 100% ; pure ether vapour is thus available and can be measured and then administered by methods similar to those used with other anæsthetic gases.

The questions with which we have dealt so far are all related to the heat balance which must obtain within the system, and we have so far made the assumption that equilibrium is reached instantaneously. Unfortunately this is not the case in practice. It is well known that it is very difficult to saturate with ether vapour a stream of air passing over an ether surface, and also that it may take a long time before thermal equilibrium is reached between adjacent containers the contents of which are initially at different temperatures. In the construction of vaporisers, therefore, we have not only to ensure that sufficient energy is furnished for the evaporation and that this evaporation takes place at a constant temperature but we must also see that attention is given to the problems of heat transfer, heat insulation, and the mixing of the anæsthetic vapour with air or other gases. It is not possible to give a simple general solution of these problems, so that the way in which they have been dealt with is outlined in the descriptions of the two vaporisers.

SUMMARY

The physical principles involved in the vaporisation of any liquid anæsthetic are discussed. In order to maintain a constant supply of vapour it is necessary to keep constant the temperature of the liquid. Two requirements must be satisfied. First, an amount of heat equal to the latent heat of evaporation of the liquid must be supplied ; this is done conveniently by utilising the latent heat of crystallisation of a " reservoir " substance which has previously been melted. Secondly, the heat transfer from the molten reservoir substance to the liquid anæsthetic must be sufficiently rapid. If these are satisfied, a measured amount of the vapour of a liquid anæsthetic can be delivered to a patient just as easily as a measured amount of any anæsthetic which is a gas at room temperature.

The principle of utilising the latent heat of crystallisation has been used for the purpose of maintaining bacteriological specimens at constant temperature by Mislowitzer (1937) and Harrison (1937). We have to thank Colonel L. W. Harrison for his helpful interest in the initial stage of this work.

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THE OXFORD VAPORISER

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The operation of this ether inhaler depends on the principles outlined in the previous paper. A diagrammatical sketch of the apparatus is given in fig. 1. A, B and C contain ether, the reservoir substance and hot water respectively (cf. fig. 2 of the preceding paper).[1] The mask G is placed on the patient's face so that on inspiration air is drawn through the valve V. The air goes straight to the patient (full arrows), or by means of the mixing tap H it can be directed over the surface of the ether (broken arrows). Any concentration of ether-air required for anæsthesia can be attained by setting the tap suitably.

The dimensions of the various chambers are determined by : (1) the amount of ether vapour which is to be furnished in a given time ; and (2) the frequency with which it is convenient to supply heat by refilling the apparatus with hot water. In order to fulfil comfortably the maximum demands which may be made upon the machine during induction and maintenance, the vaporisation of 15 fl. oz. of ether per hour has been provided for. The vaporisation of this amount of ether requires 28,000 calories. If we decide that the hot-water chamber is to be refilled once every 60 minutes, then we must be able to add 28,000 calories each time we refill, and this amount of heat will be furnished by 400 c.cm. of boiling water as it cools from 100° C. to 30° C., the melting-point of the reservoir substance. The capacity of the hot-water container is thus determined at 400 c.cm.

Hydrated calcium chloride ($CaCl_2$ 6 H_2O) was chosen as a suitable reservoir substance. Various other inorganic and organic compounds with melting-points in the neighbourhood of 30° C. were tried but rejected because they were too active chemically or were subject to considerable supercooling. The minimum amount of calcium chloride which can be used is that amount which will just be melted completely by the addition of 28,000 calories, since, if less calcium chloride is used, the heat added in filling the hot-water chamber might completely melt the substance and then raise its temperature above the boiling-point of ether. By calculation, this minimum amount of calcium chloride is 700 grammes. In practice, however, it is desirable to use considerably more than this minimum amount. This is a safeguard in case the water container is inadvertently refilled with

1. *Lancet*, July 19, 1941, p. 61.

boiling water twice in rapid succession—although such a mistake can occur only if the reading of the thermometer is ignored. In order to provide a considerable margin of safety we have therefore incorporated a calcium-chloride container with a capacity of 1300 g.

Good heat transfer must be provided between the hot water and the calcium chloride, and between the calcium

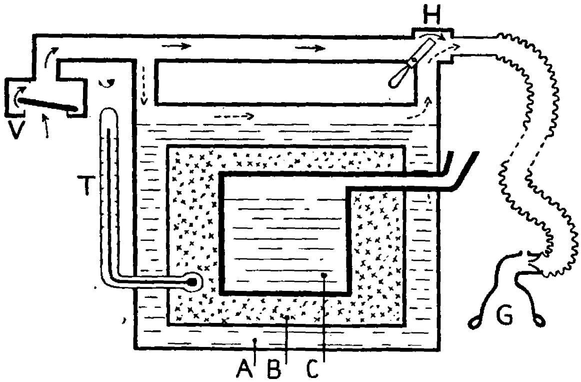

FIG. 1—Diagram of Oxford Vaporiser No. 1 to show general principles. A contains ether, B crystals and C hot water. G mask, H mixing tap, V inlet valve, T thermometer.

chloride and the ether; on the other hand, direct transfer of heat between the hot water and the ether must be prevented. These conditions are achieved by arranging the containers concentrically. The hot-water container C is cylindrical and placed centrally; surrounding this is the calcium-chloride container B, and outside this again the ether container A. Since the ether container is maintained at about 30° C., heat loss from the apparatus is small because the temperature difference between its outside wall and the surrounding air is slight. Heat exchange between the containers is increased by making them of an alloy of good heat conductivity, and by equipping the walls with radial fins.

DETAILS OF CONSTRUCTION

A modified cross-section through the actual model is given in fig. 2. In order to represent as much as possible in one plane, the layout has been somewhat distorted, and various parts have been simplified—for example, by the omission of fins from the walls of the containers. Fig. 3 is a sketch of the apparatus.

The hot-water chamber (*C*).—Hot water is poured in through the filler W and impinges on the baffle plate P. In this way the freshly added hot water occupies the upper part of the chamber and displaces the cooled water through the outlet tube Q. When the chamber has been completely filled with hot water, the stream flowing from the outlet changes quite suddenly from cold to hot.

The calcium-chloride chamber (*B*) is a cylindrical chamber the bottom of which is rounded so that bubbles cannot be trapped underneath it. It contains the bulb of the thermometer T which registers the temperature of the calcium chloride. After it has been filled this chamber is sealed off by the manufacturers and it should not be opened. The hydrated calcium chloride does not deteriorate with time, but if exposed to air the crystals lose water and become inefficient for our purpose.

The ether container (*A*) is filled through the funnel E, whose upper rim is so arranged that the chamber cannot be overfilled. If by mischance hot water is poured into this filler it would not enter the chamber because of the constriction at the apex of the funnel. The hot ether-water mixture would instead be blown back from the filler with considerable violence. The ether level in A is shown by the level indicator L, and Z is a drain plug through which ether may be drained away.

The inspiratory valve (*V*) *and mixing-tap assembly* (*M*).—When the patient breathes, air is drawn into the vaporiser through the slot in the outer container from which the ether concentration control lever H projects. The air then passes

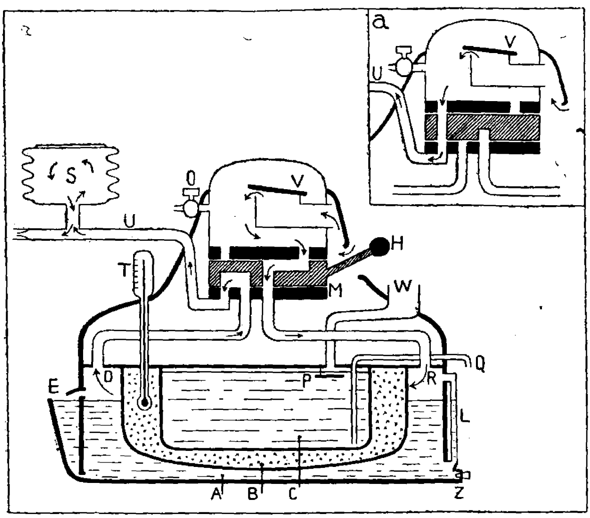

FIG. 2—Modified vertical section through Oxford Vaporiser No. 1. A ether chamber, B heat reservoir containing calcium-chloride crystals, C hot-water chamber, D exit for air plus ether vapour, E ether filler, H lever for controlling ether concentration, L ether level indicator, M mixing-tap assembly, O tap for oxygen, P baffle plate, Q water outlet, R inlet for air, S bag, T thermometer, U tube to mask, V inlet valve, W filler for hot water, Z plug for draining ether. In inset (*a*) the mixing tap is turned so that air passes direct to the patient.

through the inspiratory valve V, whose action can be observed through the transparent dome (D in fig. 3). If required oxygen may be added through the tap O.

The mixing tap consists of three discs in which ports are cut. The upper and lower discs are fixed and the intermediate one can be rotated about a central axis by moving the lever H. By means of the mixing tap the air can now be : (1) diverted wholly or in part over the surface of the ether ; or (2) by-passed directly to the patient, who thus receives air only. In fig. 2 the tap is shown in the position in which all of the air reaching the patient passes through the ether chamber, the pathway being marked by small arrows. Inset (a) shows the course taken by the air when it is passed direct to the patient without any part of it passing through the ether chamber. The control handle H can be adjusted to any intermediate position ; the figures above it (see fig. 3) indicate the percentage of ether vapour (v/v) reaching the patient.

The spirometer-type bag (*S*) is lightly spring-loaded so that it tends always to remain expanded. In normal use its action is to draw air gently through the vaporiser during the intervals between the patient's inspirations. When the patient inspires, part of the contents is drawn from the bag, but the spring loading cannot produce any resistance to inspiration since air can at all times be drawn freely through the inspiratory valve V. Rebreathing into the bag does not occur because of a one-way valve placed between the mask and the bag. When required the bag can be used as a pump to draw air over the surface of the ether and to deliver the resultant mixture to the patient. This will be found of value during induction, and when an air-tight junction cannot be made between the face and mask, as for example during tonsillectomy. The bag can be used too for artificial respiration ; the ether indicator is set at zero, the mask held firmly to the face, and the lungs inflated with air by pressure of the anæsthetist's hand on the bag.

In fig. 3 a portion of the outer wall of the apparatus has been cut away, so that the outer wall of the calcium-chloride container and the radial fins come into view. These fins project almost to the outer wall of the ether chamber, dividing it into twelve separate compartments. Wicks are placed in each compartment. These considerably increase the effective ether surface and since they are applied closely to the wall of the calcium-chloride chamber their temperature does not fall appreciably as evaporation takes place. Slots are cut in the fins to allow the air to pass from the inlet tube (R, fig. 2) to the exit tube (D, fig. 2). The arrangement of the slots is such that the current of air is made turbulent and passes close to the surface of the ether no matter what the ether level may be. In this way, provided the position of the control tap remains unaltered, a constant concentration of ether vapour is delivered to the patient irrespective of the amount of ether in the apparatus.

OPERATION OF THE VAPORISER

The ether chamber is filled. Water, as hot as available, is poured into the water filler W to displace the cold water which escapes from the outlet tube Q. The stream of water emerging from Q is cool at first, but quite suddenly changes to hot. When this occurs no more hot water should be poured in. After a few minutes it will be seen that the mercury in the thermometer T, which for convenience has a horizontal stem (fig. 3),

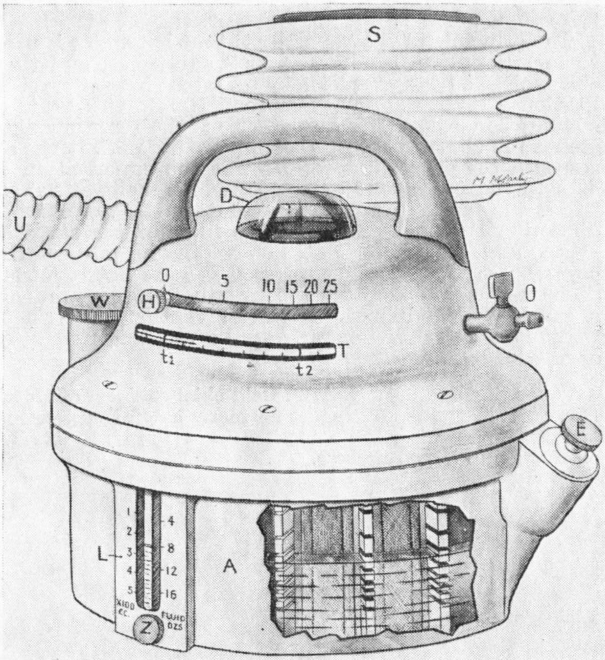

FIG. 3—Sketch of Oxford Vaporiser No. 1 with part of outer wall cut away. For normal working the thermometer reading should be between the marks t_1 and t_2. D glass dome for observing inspiratory valve ; other key letters as in fig. 2.

stands above the mark t_1. The apparatus is now ready for use, the concentration of ether vapour delivered from it being determined by the position of the control handle H.

The apparatus requires no further attention until the temperature falls below t_1. This indicates that all the calcium chloride has been solidified and a further filling of hot water is now required. The hotter the water added the less often is it necessary to refill. If by any mistake hot water is added too frequently the mercury in the thermometer may rise above the danger mark t_2. If this happens *cold* water must be poured into W to prevent the ether from boiling.

SUMMARY

In the Oxford Vaporiser No. 1, a liquid anæsthetic, such as ether, is maintained at a constant temperature below its boiling-point, thus making available a constant supply of vapour. The concentration of anæsthetic vapour in the inspired air is controlled by a calibrated mixing tap which determines how much of the inspired air passes through the vaporiser, and how much by-passes it.

The principle of the vaporiser is that hot water is used to melt a crystalline " reservoir " substance, and then this molten substance yields up its latent heat of crystallisation to provide, as required, the latent heat of evaporation of a liquid anæsthetic ; the reservoir substance remains at a constant temperature until it has all resumed the crystalline form. For the vaporisation of ether, hydrated calcium chloride, which melts at 29° C., has been found suitable. To maintain the vaporiser in operation it is necessary only to fill at intervals with ether, and with sufficient hot water to re-melt the crystals ; cylinders of compressed gas are not required. Since the machine delivers vapour only during inspiration it is economical in use. Artificial ventilation, with or without anæsthetic vapour, can be administered by a spring-loaded bag.

We are indebted to Mr. A. V. Oak, chief engineer of Morris Motors Ltd., and his colleagues for many helpful suggestions, and for redesigning the vaporiser in a form suitable for production in large numbers.

THE OXFORD VAPORISER NO. 2

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IN the Oxford Vaporiser No. 1 a liquid anæsthetic, such as ether, is maintained at a temperature below its boiling-point and the concentration of anæsthetic vapour in the patient's inspired air is controlled by means of a calibrated mixing tap, which determines the fraction of the inspired air passing over the liquid surface. The Oxford Vaporiser No. 2 has been developed to maintain a quantity of liquid anæsthetic at a temperature at which its vapour pressure exceeds atmospheric pressure—i.e., above its boiling-point.* The undiluted vapour can be obtained from a vessel containing an anæsthetic liquid in this condition, just as at room temperature gaseous nitrous oxide can be obtained from a cylinder of liquid nitrous oxide. The rate of flow of the undiluted vapour is measured, and the vapour is then mixed with any other gas or gases desired. Condensation must not be allowed to take place either during these operations or during the subsequent passage of the gas mixture to the patient.

The latent heat of evaporation of the anæsthetic liquid is provided by the latent heat of crystallisation of a "reservoir" substance previously melted by hot water. The reservoir substance is chosen so that the anæsthetic liquid is maintained at such a temperature as to produce a vapour pressure of less than one atmosphere above normal. Thus the necessity of constructing a vessel to withstand high pressures is obviated. We have endeavoured to make the heat transfer from the reservoir substance to the anæsthetic liquid sufficiently rapid to ensure an adequate supply of vapour (*a*) by constructing the dividing wall of metal of high thermal conductivity, and (*b*) by providing fins of similar metal which pass from one vessel to the other.

DETAILS OF CONSTRUCTION

The most convenient arrangement of the compartments was found to be in the form of three vessels, one inside the other (fig. 1). The anæsthetic liquid is contained in the inner vessel A, the reservoir substance in the intermediate B, and water in the outer vessel C. The inner vessel is a strong metal cylinder closed at each end, and will hold 12 fl. oz. of anæsthetic liquid. Fins of

* S. R. Wilson and K. B. Pinson (*Lancet*, 1921, **1**, 336) produced an apparatus similar to the one described here in that it consisted of a strong metal vessel which was filled with ether and then immersed in very hot water.

the same metal are inserted radially (fig. 2). A fine-adjustment needle valve H, situated on the top of the cylinder, controls the rate of outflow of the vapour. To prevent condensation the valve is immersed in the reservoir substance so as to leave only the spindle and

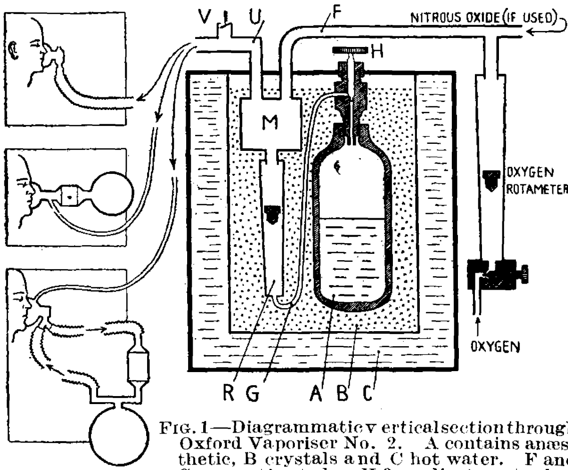

FIG. 1—Diagrammatic vertical section through Oxford Vaporiser No. 2. A contains anæsthetic, B crystals and C hot water. F and G connecting tubes, H fine adjustment valve, M mixing chamber, R flowmeter (" Rotameter "), U connecting tube, V inspiratory valve.

packing gland uncovered. Although the pressure in the vessel and valve should never reach one atmosphere above normal they are tested to not less than ten atmospheres.

The rate of flow of the vapour is measured by a flowmeter of the rotating bobbin type R (" Rotameter "). To prevent condensation of the vapour, the flowmeter has to be warmed to at least the same temperature as the anæsthetic liquid. Moreover, the temperature of the meter must be maintained constant in order to prevent inaccuracies due to the changes in density and viscosity of the vapour, which would result from fluctuations in temperature. In order to achieve this constant temperature, the flowmeter is surrounded by a metal sleeve of high thermal conductivity and several fins attached to the sleeve pass deep into the reservoir substance. The sleeve is fixed in the outer wall of the reservoir compartment. At this point the water compartment is interrupted, and a window Y cut in the metal sleeve to expose the graduations on the meter and enable the position of the bobbin to be read (figs. 2 and 3). The connecting metal tube G between the needle valve and the bottom of the flowmeter is also kept warm by immersion in the reservoir substance.

After leaving the flowmeter the anæsthetic vapour passes through a short tube to a mixing chamber M, where it mixes with oxygen, or any mixture of gases desired—e.g., oxygen and nitrous oxide. The rate of flow of each gas used is measured by passing it through a rotameter (see fig. 3) before it enters the mixing chamber. This chamber is made of metal of high thermal conductivity and is immersed in the reservoir substance so that mixing takes place at a temperature which prevents condensation of the anæsthetic vapour. Condensation can, however, take place in the tubes connecting the apparatus to the patient unless the precautions discussed below are observed. Both in the tube F leading the oxygen or gas mixture to the mixing chamber and in the tube U leading to the patient a short length of tubing of low thermal conductivity, such as a length of bakelite tubing, is interposed. This greatly reduces the loss of heat by conduction from the reservoir substance to the outer parts of the apparatus.

The vessel for the reservoir substance, like the inner vessel, is made of metal of high thermal conductivity and fins are inserted radially. These pass into the reservoir substance and through into the water contained in the outer vessel (fig. 2). This construction ensures that heat from hot water poured into the outer compartment reaches the reservoir substance as rapidly as possible. A funnel (W in fig. 3) is provided above the water compartment whereby the water is poured in. By an

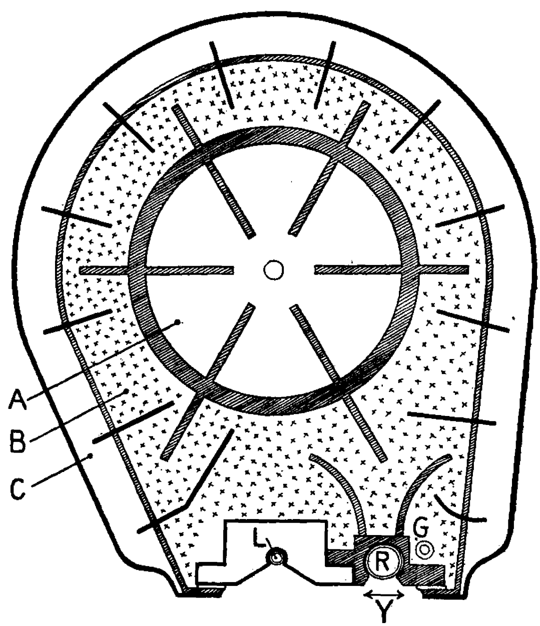

Fig. 2—Horizontal section through Oxford Vaporiser No. 2. A, B, C, G and R as in fig. 1. L gauge showing level of liquid anæsthetic, Y window in metal sleeve.

arrangement of tubes this hot water is directed first to the region of the flowmeter, which is thus warmed prior to the remainder of the apparatus, so that risk of condensation of the anæsthetic vapour in the flowmeter is obviated. An outflow for displaced cool water is provided, Q.

At the bottom of the vessel containing the reservoir substance there is a safety device in the form of a fusible metal plug. The metal is chosen to melt at about 10° C. above the melting-point of the reservoir substance. If by accident the water container is refilled too many times so that all the reservoir substance is melted, before the temperature, and therefore the pressure, in the inner vessel can rise appreciably, the metal plug will melt and allow the molten substance to run out.

When the reservoir substance is heated to its melting-point the pressure in the inner vessel rises above atmospheric, and therefore it would be impossible to fill this vessel with anæsthetic liquid without the aid of a pump. A pump P and safety device have been constructed which will deliver anæsthetic liquid to the inner vessel, but no air. This obviates the danger that the pressure in this vessel might be increased unduly by pumping in air ; also, it prevents the production, under pressure, of a possibly explosive mixture of anæsthetic vapour and air. The pump is of the hand-operated piston type, the piston being fitted with rings to minimise leakage. It is contained in a small tank filled with the anæsthetic liquid so that any leakage which may occur merely results in the liquid returning to the main bulk. Suitably arranged non-return valves allow the passage of liquid to the inner vessel. In the small tank there is a float which closes the orifice leading to the pump when the level of liquid in the tank falls to within a short distance of this orifice, thus preventing entry of air into the pump. Loss of heat from the warmed part of the apparatus to the pump via the connecting pipe is minimised by interposing a short length of bakelite tubing.

In order that the amount of anæsthetic liquid present in the inner vessel may be ascertained, a liquid-level gauge L is provided. This is recessed into a bakelite block which is mounted in the wall of the middle vessel alongside the metal sheath of the flowmeter.

OPERATION OF THE VAPORISER

The method of putting the apparatus into operation can be described conveniently with special reference to ether. When this liquid is used, para-dichlorobenzene has been found a suitable reservoir substance. The melting-point of a moderately pure sample is usually about 52° C. From the data given in International Critical Tables (vol. I, p. 196, 1926 ; vol. V, p. 130, 1929) it can be calculated that the latent heat of fusion is approximately 43 calories per c.cm. A rotameter graduated in c.cm. of ether vapour per minute, at room temperature, should be fitted into the sheath ; also, a fusible metal plug melting at about 62° C. should have been fitted before putting in the reservoir substance.

Ether is poured into the tank through aperture E and pumped into the inner vessel until this is full. Three lots of two pints each of hot water (approx. 85° C.) are poured into the water compartment at five-minute intervals. The amounts of reservoir substance and of hot water are chosen so that when enough heat has been stored to vaporise all the ether in the inner vessel there remains enough unmelted reservoir substance to absorb the heat from a further filling with hot water. This provides a reasonable safety margin against filling too frequently with hot water. If, however, this safety margin is

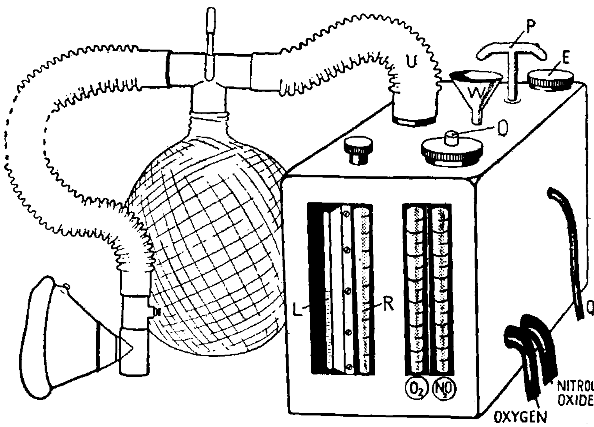

FIG. 3—Sketch of Oxford Vaporiser No. 2. E filler for ether, L fluid anæsthetic gauge, O press-button-actuated emergency oxygen supply, P pump for use when refilling ether chamber, Q outflow for cool water, R flowmeter for anæsthetic vapour, U connecting tube, W unnel for hot water, O_2 and N_2O flowmeters for oxygen and nitrous oxide.

exceeded the temperature of the reservoir substance will rise and the fusible plug previously described will operate. While the three amounts of hot water will provide sufficient heat to vaporise all the ether contained in the inner vessel, it is preferable, if more ether is likely to be required, to refill before the supply has become exhausted. To do this the inner vessel is refilled from the tank by operating the pump, and two more fillings of hot water are poured in allowing a five-minute interval.

Provided that the flow of gases (essentially the flow of oxygen) is maintained, mixtures of any desired concentration can be produced by adjusting the control valves to give suitable rates of flow as measured by the respective flowmeters.

To prevent total failure of the supply of any gas the usual precaution in anæsthetic practice of using a pair of cylinders, one always full, is observed. A lightly loaded inspiratory valve V opening to the air is also provided and comes into play only if an insufficient total volume of gas mixture is available to the patient. Should it be desirable at any time to inflate the patient's lungs with oxygen this can be done readily by means of a valve O actuated by a press-button which permits oxygen to pass under pressure to the patient, without passing through the flowmeter.

As the work of Epstein* shows, the temperature of the inspired mixture during its passage from the apparatus to the patient falls to slightly above room temperature. Condensation of ether will not occur in the tube leading to the patient provided that the partial pressure of ether in the mixture does not exceed the vapour pressure of ether at room temperature. As this vapour pressure is about half an atmosphere, the ether concentration in the mixture leaving the apparatus must not exceed 50%—that is to say, the reading of the warmed flowmeter must not exceed the sum of the readings of the other meters in use. If the machine is used to vaporise some other anæsthetic liquid instead of ether, the saturation concentration of that vapour at room temperature must be ascertained and a similar "safety ratio" between the readings of the flowmeters must be decided upon and never exceeded.

SUMMARY

In the Oxford Vaporiser No. 2 a quantity of liquid anæsthetic, in a closed vessel, is maintained at a temperature above its boiling-point, so that its vapour pressure exceeds atmospheric pressure. The outflow of undiluted vapour from the vessel is controlled by a valve, and is measured by a flowmeter which is maintained at a constant temperature approximately the same as that of the liquid. The vapour is afterwards mixed in a mixing chamber, also at approximately the same temperature as the liquid, with a measured flow of oxygen, together with any other gas if desired. In this way condensation of vapour is avoided and mixtures containing any desired concentration can be prepared; moreover, condensation will not occur during passage of the mixture from the apparatus to the patient so long as the saturation concentration at the temperature of the coolest part of the connecting tubing is not exceeded. When ether is used at usual room temperatures, condensation will not take place unless the concentration of vapour exceeds 50%; in clinical anæsthesia percentages above 20 are rarely necessary.

The principle of the apparatus is that the anæsthetic liquid, the flowmeter and the mixing chamber are maintained at constant temperature by drawing upon the latent heat of crystallisation of a thermal reservoir substance previously melted by hot water.

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* See *The Lancet*, July 19, p. 66.

THE PERFORMANCES OF THE OXFORD VAPORISERS WITH ETHER

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THE ability of the Oxford Vaporiser No. 1 to maintain constant any selected concentration of ether vapour has been estimated by analysis of samples of the ether/air mixture taken from its outlet. In fig. 1 the concentration of ether vapour in percentage by volume when the tap of the machine is set to 15, is shown graphically over a period of thirty minutes. (A concentration of 15% v/v of ether vapour in a stream of 6·5 litres per min. corresponds to the evaporation of 1 fl. oz. in 7 min.) During this period air was drawn through the vaporiser by a respiration pump at the rate of 6·5 litres per min. in 25 pulsations of 260 c.cm. each, so that respiration under anæsthesia was simulated. For comparison the output of a Boyle's bottle, with a continuous stream of 6·5 litres of air per min. passing through it, is shown. It will be seen that the output of ether vapour by the vaporiser remains substantially constant, but that that of the Boyle's bottle falls off very sharply. The figure of 15% was chosen for comparative purposes because it is impossible to deliver a concentration greater than this from an un-jacketed Boyle's bottle for more than one or two minutes.

With the Oxford Vaporiser No. 2 it is, of course, possible to maintain a completely constant output of ether vapour; with a given setting of the outflow tap, however, the amount delivered does fall off a little over a period. The change in the flowmeter reading which occurs if the outflow tap is not readjusted is shown graphically in fig. 2. It is clear that a substantially constant output can be maintained by a small adjustment of the flowmeter every few minutes.

In fig. 3 the temperature of the ether mixture as it leaves a Boyle's bottle and the Oxford Vaporisers No. 1 and 2 (the "etherometer") is represented over a period of time by the unbroken lines T 1. The rate of gas-flow through the machines was 6·5 litres per min. in all cases. In the case of the Boyle's bottle the temperature of the mixture is considerably below room-temperature and

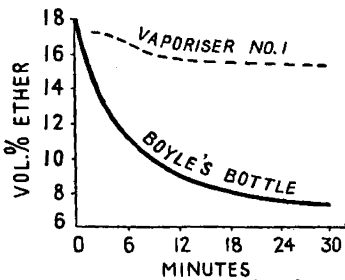

FIG. 1—Concentration of ether in output of Oxford Vaporiser No. 1 set at 15%, compared with that of Boyle's bottle, with 6·5 litres of air per min. passing through each.

in the case of Vaporiser No. 2 considerably above it. The dotted lines T 2 indicate the temperatures of the mixtures by the time they reach the distal end of a corrugated rubber tube 2·5 cm. in diameter and 90 cm. long, such as is used in anæsthesia for connexion to the face-mask. It will be seen that with all three machines the mixtures as they are delivered to the patient are at approximately room temperature.

CLINICAL PERFORMANCE OF VAPORISER NO. 1

1. *Using ether as the sole anæsthetic.*—Though not recommended if the more usual methods are available, induction with ether vapour is perfectly practicable. The spring reservoir bag is put into circuit, and with the mask held a short distance from the patient's face a gentle current of air containing gradually increasing concentrations of ether vapour is blown over by rhythmic pressure on the bag. The mask is gradually lowered on the face and as soon as the patient becomes unconscious it is applied firmly ; the ether concentration is thereafter increased as rapidly as the patient will tolerate it. Surgical anæsthesia is produced usually in about 10 min. In a short series of experimental inductions using ether alone on an open mask, and comparable in comfort and smoothness with those obtained with this vaporiser, it was found that about 30 min. was needed to reach surgical anæsthesia. The extra speed and smoothness of induction with this vaporiser may in part be due to the steady gradual increase in ether concentration which is possible, and it is also probable that the ether vapour at room temperature delivered by the vaporiser is less irritant than the cold vapour from an open mask.

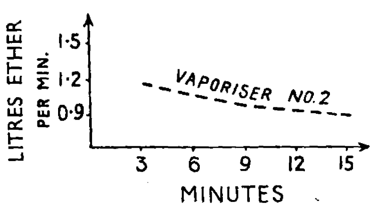

FIG. 2—Output of Oxford Vaporiser No. 2 if outflow tap is not adjusted during administration.

2. *Following induction with ethyl chloride or di-vinyl ether.*—Induction with either of these agents is carried out as usual until automatic respiration denotes the onset of surgical anæsthesia. The mask of the vaporiser is then applied and the mixture control set to 15%. A concentration of this order is now readily accepted and after some minutes the mixture can be enriched or weakened as the requirements of the patient indicate.

3. *Following induction with Pentothal, Evipan, &c.*—The "induction dose" varies between 0·2 and 1 g. according to the robustness of the patient. This dose is given rather quickly, and during the transient respiratory depression which follows the mask of the vaporiser is applied to the face, the spring reservoir bag put into circuit, and an attempt made rhythmically to inflate the lungs with air containing 15% of ether vapour. At first the inspiration of this mixture may be resisted, but if the attempt is continued the patient will shortly accept the vapour and breathe normally. In this way he is rapidly brought under the influence of ether as the effect of the barbiturate wears off. There is, of course, considerable individual variation between patients, but it is found in the majority of cases that percentages of ether vapour greater than 15, used in this way, excite troublesome laryngeal spasm, while percentages below 15 allow the patient to recover from the barbiturate narcosis more rapidly than he is depressed by the ether.

Maintenance of anæsthesia.—When the required plane of anæsthesia is reached the mixture control is brought back to a low percentage, usually between 4 and 6, and the selected plane is then readily maintained with great constancy. Provided the mask is firmly applied, and the airway is maintained clear, the patient inspires the percentage of ether vapour indicated by the control lever. If desired, a stream of oxygen can be supplied through the tap provided.

The definite, smooth control which this vaporiser affords allows one anæsthetist, in an emergency, to supervise with confidence the administration of anæsthesia to several patients by less experienced helpers; it also seems to make the administration of *light* ether narcosis easier than with any other method known to us. The vaporiser has also proved satisfactory for the production of analgesia. The low concentrations of ether vapour needed are not unpleasant to breathe

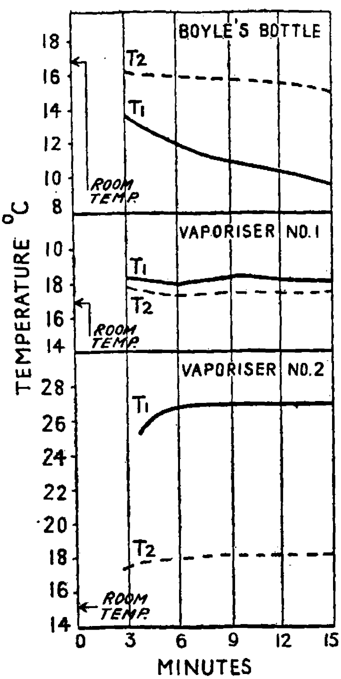

FIG. 3—Temperature of ether mixture on leaving Boyle's bottle and Oxford Vaporisers No. 1 and 2 (T_1), and after passing through 90 cm. of corrugated rubber tubing (T_1).

and the apparatus has proved of value in obstetrical cases.

Experiments are being carried out to see whether it is worth while incorporating a humidifier in the vaporiser. A saving of the patient's body heat will be effected as the inspired mixture will be saturated with water vapour at almost body temperature. The warm moist vapour will approximate that which obtains during closed-circuit anæsthesia.

CLINICAL PERFORMANCE OF VAPORISER NO. 2

The administration of ether with this machine differs in no significant way from the administration of a gaseous anæsthetic. The ether vapour delivered can be used for induction, or can follow induction by any other agent, and can be combined with any desired gas mixture. The one essential is that a sufficient volume of other gases shall flow into the mixing chamber of the Etherometer to take up all of the ether vapour being delivered, so that the concentration of ether vapour in the final mixture shall not exceed the saturation concentration at room temperature.

* * *

One of the more important advantages of these machines is that they enable clinical observations to be correlated with exact data concerning the amount of ether vapour being administered. Anæsthetists will almost certainly form an entirely new conception of the "strength" of ether as an anæsthetic, and will realise that our present views of the potency of ether are largely conditioned by the methods of administration hitherto available.

SUMMARY

In the Oxford Vaporiser No. 1 the concentration of ether vapour in the inspired mixture is indicated by the position of the tap. The various forms of induction and maintenance of anæsthesia with this vaporiser are discussed. The simplicity of action and control allow an anæsthetist in an emergency to supervise the administration of anæsthesia to several patients by less experienced helpers. The maintenance of ether narcosis of any depth or of analgesia is easy.

In the Oxford Vaporiser No. 2 the vapour of a liquid anæsthetic is measured, mixed with other gases, and delivered to the patient in known concentrations. This vaporiser is essentially one for the experienced anæsthetist.

Both machines make available higher concentrations of ether vapour than are commonly used, and anæsthetists may have to revise their conception of the "strength" of ether as an anæsthetic.

The Lancet Office,
7, Adam Street, Adelphi, London, W.C.2

THE OXFORD VAPORISER

SPECIAL SERVICING FACILITIES AND SPARE PARTS LIST

SPECIAL SERVICE

To reduce to a minimum the inconvenience caused by the occasional need for repairs or overhauls to Oxford Vaporisers, a special servicing scheme is in operation whereby a replacement Vaporiser can be obtained.

A stock of replacement instruments is held ready for dispatch immediately application is received. These replacements have been completely rebuilt at the Factory so that they are in every way equal to new.

As far as possible, all improvements in design which have been introduced since manufacture commenced are incorporated in the replacements. The charge for a replacement Vaporiser will vary according to the age and condition of the instrument returned for reconditioning. Vaporisers bearing Serial Numbers prior to 2177/4 will be converted to incorporate all improvements.

It will be understood that use of this scheme not only reduces the time during which a Vaporiser is out of commission, but enables a Factory-built replacement to be obtained at a very reasonable exchange price.

If damage or a breakdown takes place (needing components not indicated amongst the spare parts listed in this folder) the Vaporiser should be returned to the Factory for attention.

When making use of this replacement service please address your enquiries—and return any Vaporisers—to Morris Motors Ltd., Cowley, Oxford.

NOTE

When ordering spare parts always quote the Vaporiser Serial Number, which is to be found on the band in front of the water filler spout or on the name plate inside the case.

PRODUCED AND SERVICED BY

MORRIS MOTORS LIMITED

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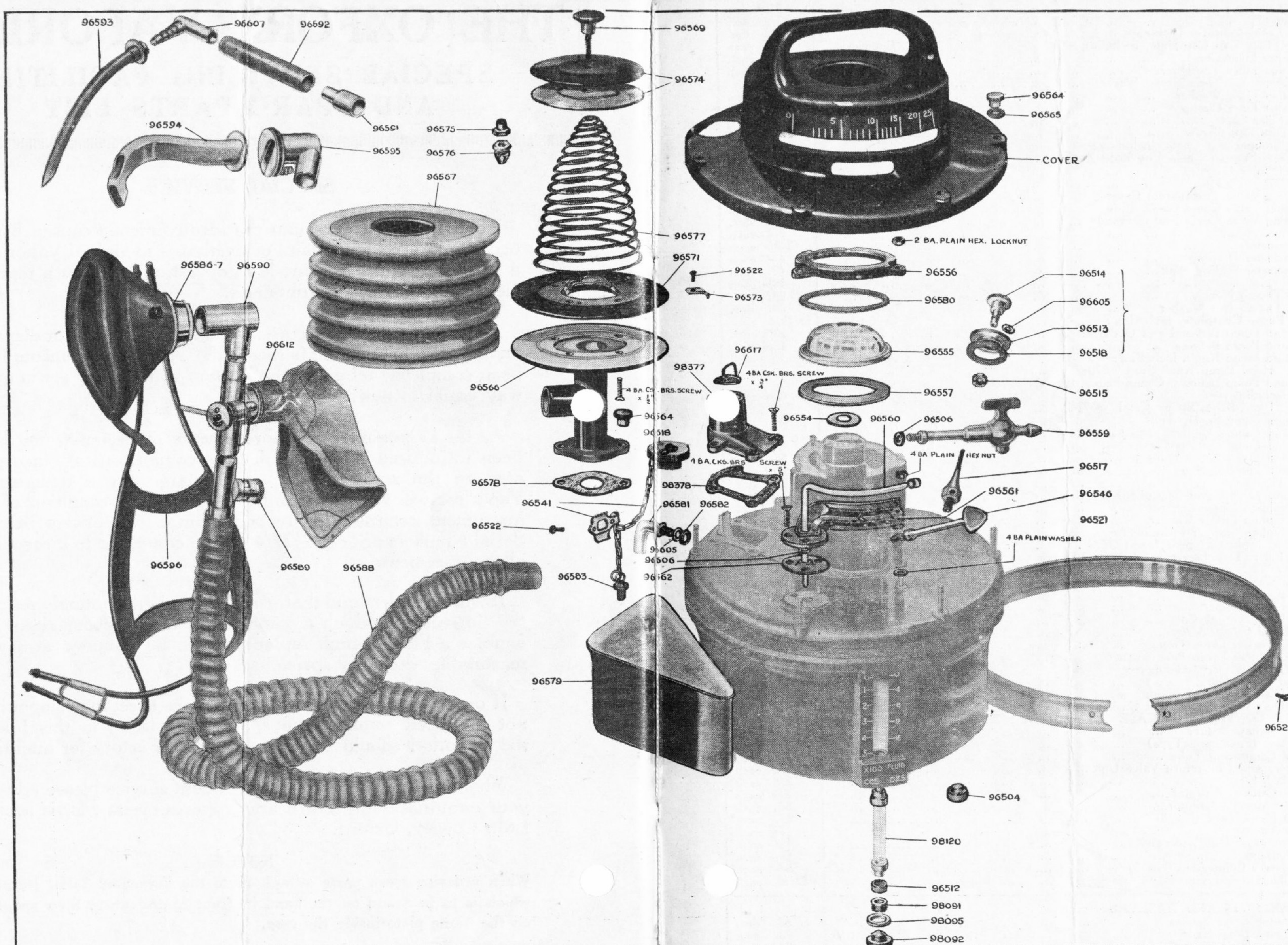
January, 1946



96504 Ether Container Foot.
96506 Washer.
96512 Ether Level Indicator Packing.
96513 Ether Filler Cap.
96514 Ether Filler Thumbscrew.
96515 Ether Filler Circlip.
96517 Ether Filler Stud.
96518 Ether Filler Washer.
96522 Duct Disc Ring Screw.
96541 Water Stopper Chain.
96546 Control Valve Handle.
96554 Breathing Valve Disc.
96555 Breathing Valve Transparent Cover.
96556 Breathing Valve Cover Clamp Ring.
96557 Breathing Valve Cover Seal (Bottom).
96559 Oxygen Cock.
96560 Thermometer.
96561 Thermometer Housing.
96562 Thermometer Sealing Ring.
Cover.
96564 Cover Thumb Nut.
96565 Cover Thumb Nut Washer.
96566 Hand Pump Pedestal and Outlet Elbow.
96567 Hand Pump Bellows.
96569 Hand Pump Knob.
96571 Hand Pump Bellows Clamp Plate.
96573 Hand Pump Spring Tab.
96574 Hand Pump Bellows Clamp Plate.
96575 Hand Pump Bellows Clamp Nut.
96576 Hand Pump Catch Plunger.
96577 Hand Pump Spring.
96578 Outlet Pipe Joint.
96579 Water Overflow Beaker.
96580 Breathing Valve Cover Seal.
96581 Water Siphon Elbow.
96582 Water Siphon Elbow Washer.
96583 Water Siphon Stopper.
96586 Face Mask (Pneumatic Type).
96588 Flexible Connecting Tube.
96589 Expiratory and Non-return Valve Unit.
96590 Face Mask Elbow.
96591 Magill's Catheter Adaptor.
96592 Tube for Magill's Adaptor.
96593 Magill's Nasal Tube (No. 8).
96594 Water Airway.
96595 Connection for Water Airway.
96596 Head Harness.
96605 Thumbscrew and Siphon Elbow Washer
96606 Rubber Washer for Thermometer.
96607 Rowbotham's Connection (No. 3).
96612 Ethyl Chloride-Vinesthene Attachm't.
96617 Water Filler Strainer.
96618 Water Filler Stopper.
96540 Water Filler Stopper Cap.
98091 Ether Level Gauge Screw.
98092 Ether Container Drain Plug.
98095 Ether Container Drain Plug Washer.
98120 Ether Gauge Glass.
98377 Upper Duct Disc Filler Spout.
98378 Upper Duct Disc Filler Spout Gasket.

PRICE LIST

Part No.	Description	Retail Price
96504-Z	Ether Container Foot	3/10 doz.
96506-Z	Washer	1/- doz.
96512-Z	Ether Level Indicator Packing	2/2 doz.
	Ether Filler Cap Complete, including :— Complete	5/2 each
96513-Z	Ether Filler Cap	2/8 each
96514-Z	Ether Filler Thumbscrew	2/- each
96605	Ether Filler Thumbscrew Washer	8d. doz.
96518-Z	Ether Filler Washer	8d. doz.
96515-Z	Ether Filler Circlip	1/4 doz.
96517-Z	Ether Filler Stud	10d. each
96522	Duct Disc Ring Screw	6d. doz.
96541-Z	Water Stopper and Chain, including :— Water Stopper Chain Lug 96558-Z	5/10 each
96546-Z	Control Valve Handle	2/10 each
96554-Z	Breathing Valve Disc	3d. each
96555-Z	Breathing Valve Transparent Cover	3/4 each
96556-Z	Breathing Valve Cover Clamp Ring	3/2 each
96557-Z	Breathing Valve Cover Seal (Bottom)	3/4 doz.
96559-Z	Oxygen Cock	5/4 each
96560-Z	Thermometer	£1/8/- each
96561-Z	Thermometer Housing	4/- each
96562-Z	Thermometer Sealing Ring	4d. each
	Cover	19/- each
96564-Z	Cover Thumb Nut	8d. each
96565-Z	Cover Thumb Nut Washer	6d. doz.
	Hand Pump Complete, including :— Complete	£1/15/3 each
96566-Z	Hand Pump Pedestal and Outlet Elbow	12/6 each
96567-Z	Hand Pump Bellows	12/6 each
96569-Z	Hand Pump Knob, including :— Hand Pump Knob Stud 96570-Z	1/7 each
96571-Z	Hand Pump Bellows, Clamp Plate (Bottom) including :— Hand Pump Spring Catch 96572-Z	4/- each
96573-Z	Hand Pump Spring Tab	6d. doz.
96574-Z	Hand Pump Bellows Clamp Plate (Top)	3/2 each
96575-Z	Hand Pump Bellows Clamp Nut	3d. each
96576-Z	Hand Pump Catch Plunger	4d. each
96577-Z	Hand Pump Spring	1/10 each
96578-Z	Outlet Pipe Joint	8d. doz.
96580-Z	Breathing Valve Cover Seal (Top)	3/4 doz.
96581-Z	Water Siphon Elbow	1/4 each
96582-Z	Water Siphon Elbow Washer	6d. doz.
96583-Z	Water Siphon Stopper including :— Water Siphon Stopper Insert 96584-Z	1/6 each
96605-Z	Ether Filler Thumbscrew and Water Siphon Elbow Washer	8d. doz.
96606	Rubber Washer for Thermometer	10d. doz.
96617-Z	Water Filler Strainer	8d. each
96618-Z	Water Filler Stopper	1/2d. each
96540-Z	Water Filler Stopper Cap	2/8 each
98091-Z	Ether Level Gauge Screw	4d. each
98092-Z	Ether Container Drain Plug	6d. each
98095-Z	Ether Container Drain Plug Washer	8d. doz.
98120-Z	Ether Gauge Glass, including :— End Cap 98119-Z	10/3 each
98377-Z	Upper Duct Disc Filler Spout	6/3 each
98378-Z	Upper Duct Disc Filler Spout Gasket	1/8 doz.
	CONTENTS OF CASE	
96579-Z	Water Overflow Beaker	4/8 each
96586-Z	Face Mask (Pneumatic Type)	19/6 each*
96588-Z	Flexible Connecting Tube	12/6 each*
96589-Z	Expiratory and Non-return Valve Unit	£1/5/- each*
96590-Z	Face Mask Elbow	8/6 each*
96591-Z	Magill's Catheter Adaptor	3/6 each*
96592-Z	Tube for Magill's Adaptor	8d. each
96593-Z	Magill's Nasal Tube (No. 8)	3/- each*
96594-Z	Water's Airway	13/9 each*
96595-Z	Connection for Water's Airway	15/- each*
96596-Z	Head Harness	15/- each*
96607-Z	Rowbotham's Connection (No. 3)	5/- each*
96612-Y	Ethyl Chloride and Vinesthene Attachment	£2/10/- each

SCREWS, NUTS AND WASHERS	
4 B.A.× $\frac{1}{2}$ in. Countersunk Brass Screws	6d. doz.
4 B.A.× $\frac{5}{8}$ in. Countersunk Brass Screws	7d. doz.
4 B.A.× $\frac{3}{4}$ in. Countersunk Brass Screws	8d. doz.
4 B.A.× $\frac{11}{16}$ in. Countersunk Brass Screws	8d. doz.
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2 B.A. Plain Brass Nuts	7d. doz.
2 B.A. Plain Brass Lock Nut	6d. doz.
4 B.A. Plain Brass Washer	6d. doz.
2 B.A. Plain Brass Washer	6d. doz.

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