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A NEW GAS-OXYGEN-ETHER APPARATUS; DESCRIPTION AND USE OF THE INSTRUMENT.

By H. CLIFTON LUKE, M.D.,

NEW YORK.

ANESTHETIST TO ST. LUKE'S HOSPITAL.

FOR the safe, intelligent, and satisfactory administration of nitrous oxide in general surgery an efficient and practical apparatus of comparative simple design is of first importance, and the writer believes that the following requirements should be met in such an instrument:

1. Provision for the even and continuous delivery of nitrous oxide and oxygen by the use of reducing valves.
2. An unchangeable and sufficiently accurate device from a clinical standpoint for separately measuring these gases.
3. Independent valve controls for each gas.
4. A system of rebreathing and ventilation which without waste or excessive accumulation of carbon dioxide will insure a fairly even mixture of the gases in the rebreathing bag at all times.
5. A reliable ether device which has independent valve control.
6. Four yokes to accommodate two gas and two

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oxygen cylinders, the extra one of each serving as a reserve supply.

7. The instrument should be obtainable in portable form; substantially built with as little glass and other fragile parts as possible. With these ideas as a guide, the writer has planned and completed the apparatus here described.

Description of Apparatus (See Fig. 1).—A graduated ether reservoir of about one ounce capacity is seen above and in the center. This is controlled by a pin valve (1) which allows the ether to pass drop by drop through the sight feed (2), whence it falls into the vaporizing chamber (3), through which a stream of all the used gases are made to pass. A small opening closed with a screw cap (4) is used for filling the ether cup, while a pet-cock (5) in the dependent part is used to empty it. At the lower part of the instrument are four yokes; two on the right (6) to accommodate two 100-gal. nitrous oxide cylinders, and two on the left (6A) for two 40-gal. oxygen cylinders. These yokes are strongly connected to a solid brass segment (7), which is tunneled on each side so that the gas from both cylinders may pass through it and upward through the high-pressure pipe (8), the oxygen taking a similar course on the left, thence entering the reducing valve (9), the oxygen passing through the opposite valve (9A). From these valves the gases pass through the low-pressure tubing (10, 10A) to the final control cocks. A low-pressure gauge of 30 pounds capacity is attached on each side (11, 11A), distal to the regulators, to indicate the pressure against these control cocks. The circular plates (12, 12A) are immovably attached to the stem of these cocks. A calibration appears on the upper part, which is read from a fixed indicator point (13) in the center at the top of each, in terms of liters per minute of the gas delivered to the rebreathing bag. On the lower side of this cir-

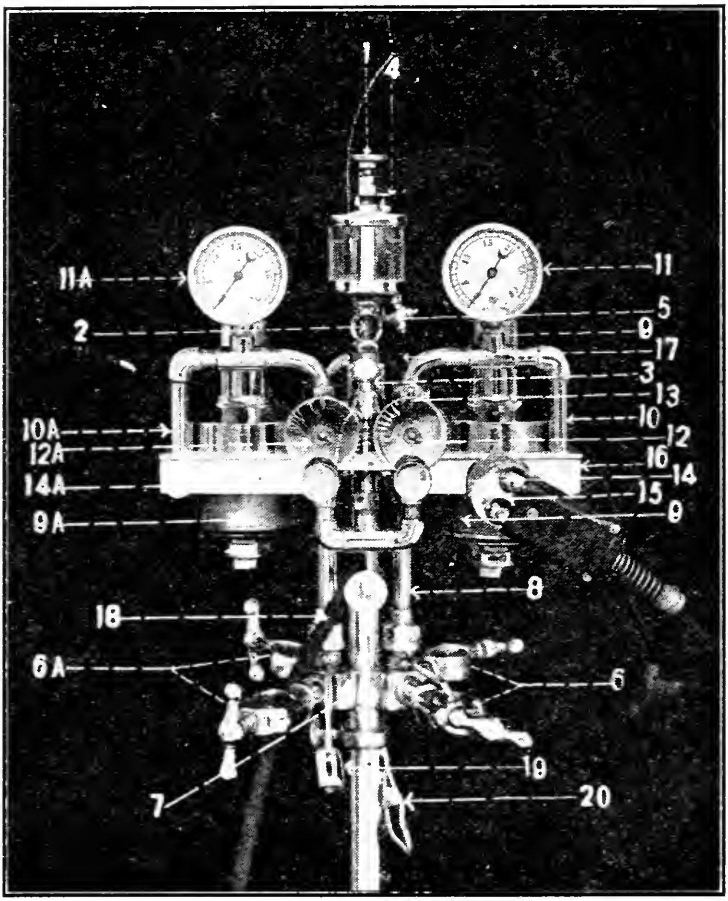

Fig. 1.

cular plate is a gearing which engages a pinion whose shaft is continuous with the two thumb-screw controls (14 and 14A). An electrical heating attachment (15) is built into the nitrous oxide controller. This line is also tapped to provide a connection (17) for the ether heating device. The main portion of the apparatus, consisting of the center segment (7) supporting the yokes and all above this, is one connected unit, and may be raised or lowered by use of the spring catch (20) placed at the upper part of the supporting stand. If it is desired to use only one tank of oxygen and one of nitrous oxide on the machine, the two unused yokes are closed off by inserting into the same the two adjustable dummies or blanks (19). The one on the right, not numbered, is seen in position. The portable stand (Fig. 2) is light, strong, and can be easily taken apart and packed into a small compartment in the carrying case. The rubber outlet tubing (18) conducts the gases to the face mask.

A cut of the apparatus as recently made up for hospital use is shown in Fig. 4. A number of minor improvements have been made on this new model, but it chiefly differs from the original portable one by having a strongly constructed, non-collapsible stand which can be raised or lowered if desired. A larger ether reservoir has also been used here, and control cocks have been placed on each yoke, thus obviating the little inconvenience of momentarily turning off the supply of gas or oxygen to the rebreathing bag while a full tank is being inserted on either side in place of an empty one.

Calibration of the Instrument.—The volume of a gas delivered at a fixed and standard pressure (ten pounds in this case) through a graduated metal cock is very constant, and should remain so under such conditions for an indefinite period. In this apparatus a large cock has been constructed of hard composition-metal with an extra long tapered stem, accurately ground and fitted, having an offset to prevent leakage in the arrangement of the inlet and outlet channels. A pair of small, tapering V-shaped grooves in the stem in connection with the channels regulates the escape of the gases. For purposes of calibration a circular metal plate was attached immovably to the stem of the cock and a fixed indicator point arranged at the top of this plate. A reliable and proved dry gas meter of the three-light type was attached distally to the valve which was furnished with a gas supply at an even pressure of ten pounds. The cock was then opened to a point, for instance, where the gas meter indicated that the delivery rate was 2 liters per minute, then to a point where 4 liters per minute was delivered, and so on until on the nitrous oxide side a calibration was made for 2, 4, 6, 8, 10 and 12 liters per minute, while on the oxygen side the reading in liters was ½, 1, 1½, 2, 2½ and 3 per minute. Finer changes could be had by opening the valve to points between those placed on the scale. A manometer was attached distally to the meter and a resistance from 3 to 5 mm. of mercury was carried during the calibration, which would compensate for the slight positive pressure usually present in the breathing bag and mask. However, the effect on the amount of gases delivered is so slight that this is unnecessary.

Necessity of a Heating Device.—In a portable apparatus of this kind the small cylinders containing 40 gallons of oxygen and 100 gallons of nitrous oxide are mostly used. In the case of oxygen, where the tank pressure is about 1,200 to 1,500 pounds, it can be reduced and maintained at an even pressure of 10 pounds without difficulty, since it is used so slowly that a relatively small amount of cold is generated (average 1 liter or less per minute); but with nitrous oxide the rate is 4 to 6 liters per

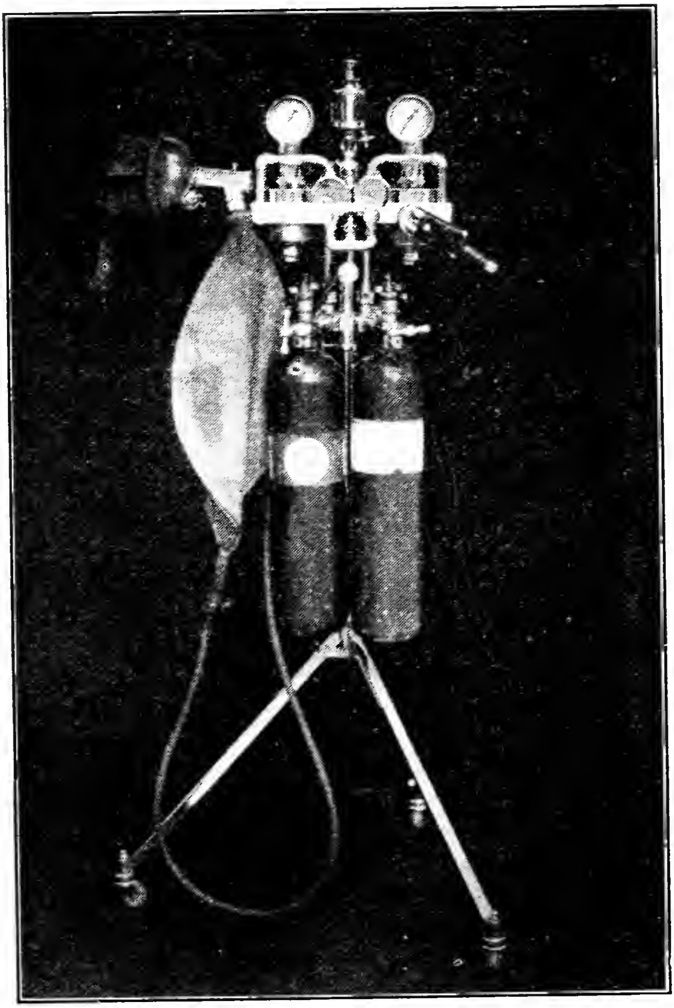

FIG. 2.—Portable apparatus; weight 22 lbs. without cylinders.

minute, and the ordinary controllers tend to alternately freeze and thaw after the first fifteen and twenty minutes, causing a continuous fluctuation of the low pressure. This must be overcome, since the accuracy of any measuring device for gases is dependent quite as much on the constancy of the pressure as on the amount of it. By the use here of a regulator having incorporated in its body a good electric heater it has been found possible to secure and maintain a 10-pound pressure continuously for long periods.

The Ether Device.—When ether is needed, it is, by the use of a direct thumb control at the top of the ether chamber, caused to be sent through the sight feed drop by drop into the electrically heated tunnel, through which all the gases are made to pass in a sweeping uphill direction, the ether tending to run downward against the oncoming stream of gases. This mechanical arrangement assists substantially in the vaporizing of the ether. The tunnel has, in general, the course which the letter U would indicate when the latter is placed on its side, thus ⊐ ; the space between the two limbs of the letter representing a receptacle for a tubular electric light which affords ample heat to prevent any freezing tendency of the ether even when being vaporized at the rate of 60 to 120 or more drops per minute. This heater can be disconnected independently, and need only be used when rather large amounts of ether are called for.

The Face Mask and Other Parts.—In an effort to simplify the portable apparatus and lessen its weight, turn-off valves have not been provided in connection with the yokes, but instead two light adjustable dummies or blanks, one on each side, are available to lock in the unused yokes in case only one tank is inserted on each side. The conducting tube from the instrument to the rebreathing bag should have about one-quarter inch inside diameter,

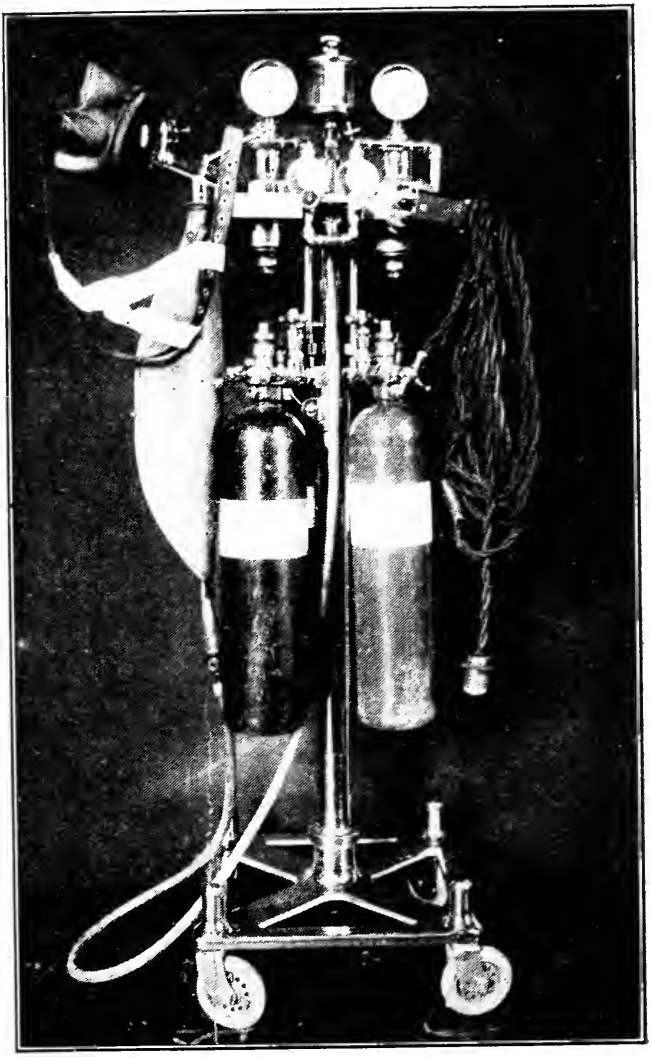

FIG. 4.—Hospital apparatus.

and be relatively short, that is, about 4 feet. The reasons for this are, first, to avoid possible accumulation of expired gases in the tube, and, secondly, to allow the quick delivery of fresh gases into the rebreathing bag. The rebreathing bag is placed next to the face piece, thus facilitating the ease of respiratory interchange which would not be obtained were a long, rigid tube to intervene between the mask and working supply.

The Boothby-Cotton rubber face piece, an improvement on the one originally devised by Gatch, has been modified here by providing extensions at the chin and nasal ends, and attaching the retaining straps at a more acute angle with a double adjustable loop to fit over the crown of the head, thus leaving the back of the neck, so often the site of abscesses and carbuncles, free as a field for operation. A celluloid hood is used, and the metal parts of the mask are of light weight so that the rubber face piece, with its adjustable strap, makes the mask practically self-retaining. The exhalation valve has been specially designed, and regulates the ventilation very evenly. It consists of a valve seat, above which is a flat, circular aluminum float, which rides freely up and down on a small triangular-shaped vertical standard running through its center. The float is kept seated by a very delicate adjustable coil spring. The valve is all metal, and can be easily taken apart and boiled. The rubber face piece can be briefly boiled many times without serious damage; but the celluloid hood* should be sterilized in bichloride or oxycyanide of mercury solutions.

General Technique and Use of the Instrument.—In advance of the actual administration it is very

*An aluminum hood will be tried in the near future.

important to give some alkaloidal adjuvant, since gas-oxygen as compared with ether or chloroform is just a veneer form of anesthesia. In the average case we have found that morphine sulphate, 1/6 grain with hyoscine hydrobromate, 1/200 grain, given together, hypodermically, one hour before operation is very safe and satisfactory. Where a definite contraindication to the use of hyoscine exists, atropine sulphate, 1/100 grain may be substituted. In the old and the young we usually omit the preliminary medication. The morphine, aside from its general sedative effect, is an efficient aid in blocking shock, while hyoscine gives substantial help through its powerful cerebral sedative action. It should also be remembered that at the start a word of explanation and encouragement to the patient but seldom fails to do real good, and frequently helps materially to accomplish a quiet, smooth induction.

The ether reservoir should always be filled, and the cock on the pipe running downward at the rear opened. This pipe serves to equalize the air pressure in the reservoir and vaporizing chamber, thus allowing the ether to escape freely from the former. One should also be certain beforehand that an ample supply of gas and oxygen is on hand. Our experience with this particular instrument indicates that in the average case a 40-gallon tank of oxygen will suffice for about two hours (average rate of 1 liter per minute), and a 100-gallon tank of nitrous oxide is usually sufficient for about 1 hour and 10 minutes (equal to 4.84 liters or 1.28 gallons per minute). Amounts of oxygen in excess of the average, up to 2 liters per minute, are occasionally required, because, as Connell has mentioned, a diminished tidal volume, a decreased oxygen carrying capacity of the blood or rate of blood flow must be compensated for by increased oxygen supply. Practical examples of this are seen in the case of young children, old people, individuals with marked anemia, septic cases, those with diminished pulmonary capacity, as in advanced tuberculous conditions, pneumonia, empyema, etc., uncompensating cardiac cases, and conditions of inanition, exhaustion, and shock from various causes.

Where excessive amounts of oxygen are demanded in cases not exhibiting such deficiencies it is usually

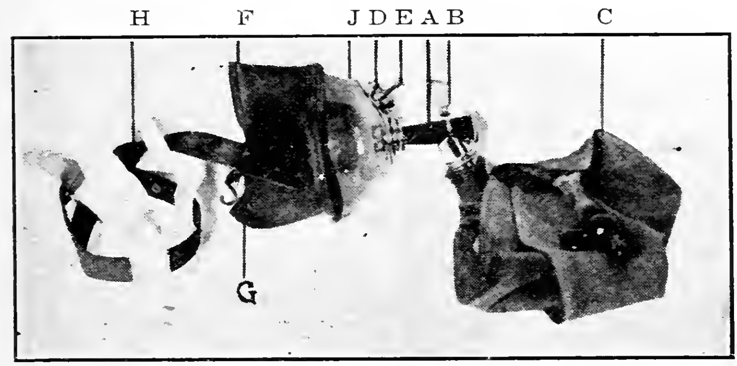

Fig. 3.—The face mask. The body (A) is of light weight and can be rotated in any desired direction. The thumb control (B) when pushed to the right to limit of slot opens an air vent on the opposite side of the body; in its present position the air vent is closed and free interchange of gas is allowed between the rebreathing bag (C) and mask. The exhalation valve (D) has a thumb screw (E) to regulate the tension of its spring. The nasal end (F) of the rubber hood shows the rubber flap beneath which cotton is packed on each side, while G indicates the chin extension. H is the head strap and J the celluloid face piece.

due to partially obstructed breathing. A free airway, indicated by a quiet, regular respiratory rhythm, is of paramount importance. To obtain this some mechanical aid is frequently necessary, and we have found that the simplest, least expensive and most practical device consists of a pair of fairly soft rubber tubes of about $3/8$ inch bore, the ends to be passed into the mouth over the base of the tongue being beveled and seared in a flame to make them smooth, while the opposite ends which protrude beyond the lips are pierced by a strong safety pin, which is locked and has attached to it a loop of tape 6 inches long, which will extend from beneath the mask to the outside. They are simple to make, can be used several times, and are readily sterilized by boiling. If sterterous breathing with cyanosis persists one should expose the mouth by raising just the lower end of the face piece, and with firm downward pressure of the chin by the left hand, if necessary to overcome the set jaw, quickly pass with the other hand the tubes, previously smeared with a little K-Y lubricant, between the teeth and over the tongue until the pinned ends extend just beyond the lips. By this device a troublesome and often dangerous anesthesia is quickly converted into one which is smooth-going and satisfactory, and it should always take the place of constant jaw pressure, which is irksome, inefficient and harmful. During the past four years this device has been used in about five thousand cases of general anesthesia at St. Luke's Hospital with the utmost satisfaction.

Before adjusting the mask the air vent on the body of same should be closed; this locks in the bag any gas turned into it. One should next fill the bag about three-fourths full of pure gas, avoiding delay by opening the gas valve to the limit. This done, the gas is turned off completely until the rubber face piece, a modification of the Boothby hood, is arranged. It has at one end an extension which hooks over the chin and lifts it somewhat, thus encouraging the forward position of the lower jaw when the retaining strap which goes over the crown of the head is pulled fairly tight and fastened. The nasal end fits snugly over the bridge of the nose, but does not bind. Beneath the rubber flap on each side of the nose should be tucked a moderate-sized wad of non-absorbent cotton. This gives a snug fit along the side of the nose. The air vent is now closed, allowing free flow of gases into the face mask while the gas valve is opened to the point indicating 6 liters per minute, and the oxygen valve set at the ½-liter mark. When the slightest bluish tinge appears in the ear (the most practical place to observe color) the oxygen is turned up to the 1-liter mark. Later, consistent with the behavior of the patient, it may be and often is possible to decrease the gas delivery to 4 liters per minute, while the oxygen indicator may usually be held at or a little behind the 1-liter mark. However, in intractable patients, such as alcoholics, large muscular men, highly nervous individuals, etc., as much as 8 liters of gas per minute may be required throughout. This is also the case where the tidal volume is much increased, due to very rapid and deep breathing. With the gases delivered at the average rate, as mentioned above, the tension of the spring in the exhalation valve should be so adjusted that the rebreathing bag at the end of expiration is completely filled without being tense. Positive pressure is unnecessary and is advised against.

It should be remembered that it requires from seven to ten minutes to establish a good gas-oxygen anesthesia, which does not mean the mere state of unconsciousness usually obtained in from fifteen to forty seconds, but a balance of gases between the alveolar air and blood which will maintain a sufficient saturation of the nerve centers to obtain the most complete anesthetic state without the presence of anything more than a very slight degree of cyanosis.

Ether as an Adjuvant to Nitrous Oxide.—It is during the induction period when a relatively light anesthetic state exists that the moving and placing of the patient in special positions, followed by the powerful reflex stimulation of the skin incision (where no local anesthetic is used), and this in turn perhaps by intraabdominal manipulations, that offers some of the greatest difficulties to overcome with this anesthetic. Ether is a powerful synergist to nitrous oxide, and it is due to this fact that a pronounced quieting effect is frequently observed during the induction period when very small amounts (2 or 3 drachms) are added at the rate of 40 to 60 drops per minute over a period of three or four minutes. After this in a majority of cases no more ether will be required, but a certain percentage of these will necessitate a small amount again at the time of closing the wound, especially when it is in the upper section of the abdomen.

In certain intractable cases it may be necessary to continuously add a little ether (20 or 40 drops per minute) throughout the operation, and at the same time it is usually best, though not absolutely necessary, to increase the oxygen percentage sufficiently to obtain a pronounced pinkish color. The use of local anesthesia in the line of incision, if surgeons could be induced to use it routinely, would conduce to a much more quiet anesthesia, far better muscular relaxation and minimize the necessity for the use of ether as an adjuvant.

At the commencement of this article certain requirements were set forth as representing the writer's idea of a clinically efficient and practical gas-oxygen apparatus. It is believed that all of these have been attained in the instrument here described, and the final test, its practical utility, has been satisfactorily established during the past three months in St. Luke's and other hospitals here.

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