THE PRESENT STATUS OF ETHYLENE.*

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March 12, 1933, marked the tenth anniversary of the introduction of ethylene in the anaesthetic field, and it seems a fitting time to discuss its merits, demerits, and general application in surgery.

In order to determine the present status of this agent, a questionnaire was sent to the leading anaesthetists of the United States, Canada and foreign countries. One thousand questionnaires were sent out. Five hundred and thirty-four replies were received. Two hundred and twenty were using ethylene and 314 were not using it. Ethylene was administered alone 737,815 times and combined with ether for varying periods 267,560 times, making the total of recorded ethylene anaesthesia 1,005,375. There were no explosions or deaths recorded.

The various odours of ethylene are due to impurities and the administration of such ethylene may be accompanied by nausea, gagging, vomiting, and more or less cyanosis. Impure ethylene usually produces an accumulation of yellow oily material in the machine connections. Since these objectionable features have been nearly eliminated by the reliable expert manufacturers, it is a rare occasion to have a patient refer to or object to the odour.

Ethylene is not unpleasant to inhale if it is administered slowly, with a liberal amount of oxygen during induction of the anaesthesia.

The administration of nitrous oxide before ethylene is not practised in the Presbyterian Hospital of Chicago because, as stated before, pure ethylene is not unpleasant if properly given and because of the feeling that a combination of the two gases on the same machine and in a patient's lungs may not be safe. So strong is this belief that we have separate gas machines for ethylene and for nitrous oxide; in other

words, tanks of the two gases are never on the same carriage. The decision is made before operating as to which gas is to be used, and then its administration is continued throughout the operation unless a change to ether becomes desirable.

After an extensive experience with local analgesia, chloroform ether and nitrous oxide-oxygen, I feel that ethylene possesses distinct advantages over all other anaesthetics, especially when combined with local infiltration in pelvic and upper abdominal operations.

One of the many advantages of any gas anaesthesia is the early awakening with little or no vomiting and the ability to clear the throat of mucus, and the trachea and bronchi of aspirated stomach contents, pus from lung abscess or material following jaw, mouth and throat operations. Gas is not irritating to lung epithelium and consequently can be given when anaesthesia becomes necessary following pneumonia or any acute respiratory infection. At present the two gases, nitrous oxide and ethylene, are available and quite naturally a decision must be arrived at as to their relative safety and efficiency if the advantages of each are to be taken into account. When ether is combined with nitrous oxide-oxygen, the explosive hazard is fully as great as it is with ethylene-oxygen. Further, ethylene has the advantage over nitrous oxide in that it produces greater relaxation, and better oxygenation can be maintained throughout long and difficult operations.

Cyanosis is distressing to both surgeon and anaesthetist, especially when they are accustomed to the appearance of normal oxygenated blood.

The immediate safety of a gas anaesthesia is due to the percentage of oxygen that can be administered with it. It is now quite generally agreed that blood changes depend on the amount of oxygen in the circulating blood; and as cyanosis does not develop in a properly administered ethylene anaesthesia, it is quite clear that blood changes are practically absent. The results of the early studies of Luckhardt and his co-workers, relative to blood changes under ethylene anaesthesia, have been repeatedly confirmed by other investigators. Brumbaugh found "no changes in haemoglobin, no appreciable change in the icterus index;
blood-sugar is increased but quickly returns to the pre-anæsthetic level. There was no increase in blood urea immediately following ethylene anaesthesia and but a slight increase in twenty-four hours, a moderate temporary decrease of the carbon dioxide combining power of the blood, no change in coagulation time, or in character of the clot.

An exhaustive study of ethylene concentration in the air of operating rooms showed (1) no evidence of building up of ethylene percentages in any portion of the room after the longest period of anaesthesia; (2) electric switches were shown to be harmless, the maximum ethylene concentration at these points being 0.1 per cent, and the minimum percentage which is inflammable is 3.02 per cent; (3) the tests show the rapid rate of diffusion of ethylene in air which obviously is the basic reason for the low concentration found; (4) the tests showed that the only points where explosive mixtures of ethylene and air occurred were in the immediate vicinity of the face mask. The dangerous area may be described as one foot above the mask and two feet to the side of the exhalation valve. All the tests were made in hospitals of modern construction with no unusual ventilating systems.

The direction in which the patient's inhalations are pointed is an important matter if the mask is fitted with an adjustable vent.

Tests were made by the Bureau of Mines to determine the limits of inflammability of ethylene oxygen mixtures. It was found that the ethylene content must be 80 per cent or higher. Nine volumes or more of carbon dioxide per volume of ethylene were found necessary to render ethylene non-inflammable. This method would therefore be impracticable as it would prevent a sufficient percentage of oxygen from being used with the ethylene.

METHODS OF INSURING SAFETY.

Safety in the use of ethylene oxygen and nitrous oxide-oxygen machines must be reached by removing sources of ignition, open flames, gas-burn cauteries near the point of administration forfulgurating machines with an open spark, X-ray machines. It is open to question whether there is any
advantage in passing ethylene over or through water. Experience shows that it is the static from without, not from within, the machine that is to be feared. Several of the reported explosions occurred after the end of operation when the machine had been idle for from a few minutes to two or more hours. The explanation of these accidents is simple. The machine had accumulated static on its external surface in sufficient amount to cause a spark when contact was made.

If the charge on the machine is discharged through grounding such accidents will not occur. During dry, cold weather the air is full of static electricity, and any moving body accumulates a sufficient amount to produce a spark as is evidenced by a shock when one touches an electric button or lights a gas jet after scuffling along on a rug. It is a mistake to believe that the flow of gas creates static although the explosion may occur at the point of exit of the gas because of a spark at that point. Two of the explosions, one ethylene and the other nitrous oxide-oxygen, in our hospital were caused by friction, one on the outside of the breathing tube, and the other on the outside of the bag, some distance from where the gas was being delivered to the patient. A relative humidity of 60 per cent will render surfaces conductive and prevent an accumulation of static. If the humidity in operating rooms could be kept high enough charges brought in from outside would leak off. There are great drawbacks to this high humidity plan, which would need constant watching. Our plan for preventing electro-static explosions is to have all objects on which a charge might exist connected together by a metallic connection, and held at a standard potential such as ground. This floor plan was devised and installed. The floors and base are cloissonné terrazo, similar to the kind of floor used in some modern hotels. It consists of small squares of terrazo separated by narrow brass strips. These strips are place five inches on centres each way, and slotted together at the intersections. The entire surface is ground down to a smooth finish, which brings the edges of the strips flush with the floor. The general appearance is that of a tile floor with the joints brass instead of cement. This grille of brass strips is electrically connected together and then grounded to the water pipes. Every piece of mov-
able equipment has on the underside several small-link brass chains, long enough to drag on the floor. At least one of these chains is in contact with a brass strip. Thus all are grounded and a difference in potential is impossible. Operators and assistants, too, are grounded, owing to the smallness of the terrazo squares. Thus no one can bring a charge of different potential after going to another room or to ungrounded equipment.

The netting covering the breathing tube and bags is made of tinsel cord which is connected to the metal frame of the machine. Pendent brass chains are fastened to the axles of the operating table and the gas machine to ground them to the floor. A chain is used with a small metal plate on one end which is placed under the patient to ground him to the table. The other end is thrown over the shield at the patient’s head and down to the grounded table. Experiments and the administration of more than 20,000 anaesthesias without the slightest indication of an explosion confirm the belief that this system of grounding and of electrical inter-connection prevents electro-static sparks. Electric fans of the alternating current type have no brushes, and may be used with safety in the operating room. If the room is small and the point of administration near the electric light switch, it is good protection to have mercury switches which do not produce a spark when turned on and off, or have the switches outside the operating room. The deaths from explosions during oxygen-ether anaesthesia lead to the belief that the mixture of pure oxygen and ether forms a more highly combustible agent than do ether and atmospheric air. A gallon of ether under proper air conditions has the explosive power of 75 pounds of dynamite. No one thinks of discarding ether because of the possible accidents for which it might be responsible. Then why abandon such a valuable agent as ethylene when its hazards can be as surely controlled?

A summary of the reported explosion gives: Ethylene, 20 explosions with one injury and five deaths; nitrous oxide and ethylene, two deaths; nitrous-oxide-oxygen-ether, 39 explosions with seven injuries and five deaths. Nine explosions occurred when the machine had been idle from a few minutes
to two hours or more. In two of these instances the machine had been used for ethylene, in the rest for nitrous-oxide-oxygen-ether. Two deaths were recorded as due to impure ethylene.