VAPORIZATION OF HALOTHANE AND ETHER IN THE *COPPER KETTLE*

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In 1952, a vaporizer with a circuit design which provides vernier control over small increments of concentration was described and introduced (1). The value and usefulness of the concepts embodied in its design have since been established. Although this vaporizer was originally constructed for administration of chloroform, its greatest application has been with diethyl ether. Data have been accumulated which show that it can be used effectively with all anesthetic agents which are liquid at room temperature.

Safe and effective administration of the extremely potent halothane * (2, 3) requires the control of vapor concentration within narrow limits by the provision of small increments or decrements in concentration (4). Clinical observations during use of the new type of vaporizer with halothane have indicated that these exacting requirements are met. Data presented in this paper show the characteristics and performance of this vaporizer with ether and with halothane. Studies are reported from observations made on a Foregger Copper Kettle, large table model with a copper table top, which satisfactorily embodies all the principles of design as originally described (1). This vaporizer utilizes a copper container, a sintered bronze vaporizing surface (Porex), and a separate flow of metered gas which is bubbled through the liquid anesthetic agent.

Determination has been made of the vapor pressure of halothane and ether at the delivery outlet of the apparatus, and these findings compared with the known vapor pressure data for these agents. The partial pressure of oxygen was determined using a model C Beckman oxygen analyzer. The partial pressure of a particular vapor can be determined by subtracting the partial pressure of oxygen from the total ambient pressure in any system containing oxygen and one other gas, or vapor, provided the other gas or vapor does not of itself exert an appreciable effect upon paramagnetic waves in the oxygen analyzer. The results determined by the method of oxygen difference, as described above, were checked by measuring the volume of liquid evaporated per unit time at a given flow and known temperature. Temperature changes were under constant observation and were recorded from a thermistor unit. The values obtained from these observations are

* 1,1,1, Trifluoro-2,2 bromochlorethane (Fluothane).

TABLE 1

THE TENSION OF ETHER AND HALOTHANE AT VARIOUS TEMPERATURES, DETERMINED BY THE
BECKMAN ANALYZER, AND VOLUME EVAPORATED METHODS, COMPARED WITH THE STANDARD
VAPOR PRESSURE OF ETHER AND HALOTHANE

Temperature 0 C.	Di-ethyl Ether Pressure (mm. Hg)			1,1,1, Trifluoro-2,2 bromochlorethane (mm. Hg partial pressure)		
	Standard Vapor Pressure	Beckman Analyzer Data	Calculated from Volume Evaporated	Standard Vapor Pressure	Beckman Analyzer Data	Calculated from Volume Evaporated
+10	291.7			157		
+15	360.7	368	362		210	186
+20	442.2	455	455	243	262	256
+25	537.0					
+30	647.3			364		

compared with the standard vapor pressure curves for these agents
in table 1.

Ether vapor has been measured repeatedly from the outflow of the
vaporizer itself at a partial pressure of 455 mm. of mercury by the
Beckman analyzer method, while the measured temperature of the
liquid was 20 C. as compared with an accepted saturated pressure of
442 mm. of mercury at 20 C. (5). Similarly, halothane was measured
in the outflow from the vaporizer alone at a partial pressure of 262 mm.
of mercury at 20 C. as compared with a stated saturated pressure of
243 mm. of mercury at 20 C. These apparent discrepancies may be
due to inherent error in the method of measurement, temperature dif-
ference between the point of measurement and the gas-liquid interface,
or to the production of a fine mist which is carried over to a more distal
part of the machine allowing saturation at a warmer temperature than
exists in the vaporizer.

Heat must be supplied for the vaporization of any liquid. If not
supplied from an external source heat will be taken from the liquid
itself, the temperature of the liquid will fall, and the pressure of the
saturated vapor above the liquid will be correspondingly lower. The
concentration of vapor in the gas vapor mixture emerging from the
vaporizer is determined by the temperature of the liquid at the gas-
liquid interface. In the Copper Kettle heat is conducted from the
ambient atmosphere through the apparatus and the copper table top
to the copper vaporizer itself, and through the vaporizing surface
directly to the gas-liquid interface, so that the fall in liquid tempera-
ture incident upon evaporation is minimized by this continual supply of
heat. Various flows through ether in the vaporizer produce an effect
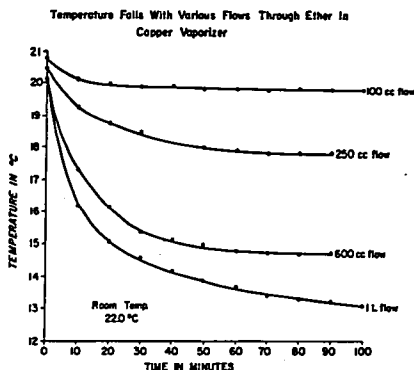on temperature of the liquid as shown in figure 1.

FIG. 1. Temperature falls with various flows through ether in the Copper Kettle.

The original paper (1) described a small insert for the vaporizer which was designed for economical use of smaller quantities of more potent agents such as chloroform, trichloroethylene and halothane. A
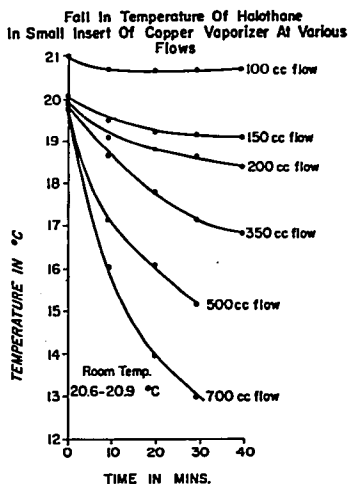

FIG. 2. Temperature falls with various flows through halothane in small insert of Copper Kettle.

comparison of curves in figures 2 and 3 shows that the small insert has less thermostable properties than the large container and therefore is not as suitable for use when it is important to deliver a constant and precise percentage of vapor. It seems evident that by its original design the small insert is effectively insulated from the ambient atmosphere, by the air surrounding it and separating it from the wall of the large container. An alternative metal insert has, therefore, been suggested that has an adjustable central copper insert, which can be lowered to displace the liquid anesthetic towards the wall of the container so that smaller quantities of the more potent agents can be satisfactorily used without detracting from the thermostable properties of the Copper Kettle.
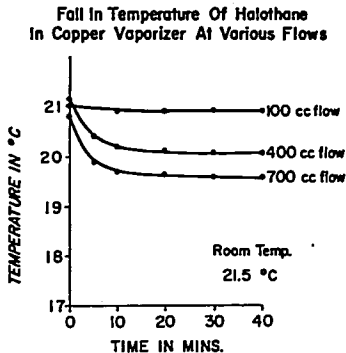

Fig. 3. Temperature falls with various flows through halothane in Copper Kettle.

The sintered bronze vaporizing surface is important because the small size of bubbles produced maximally increases the gas-liquid interface, which in turn reduces the importance of time of contact between liquid and gas, since saturation is accomplished almost instantaneously. Therefore, vaporization is always maximal and uninfluenced by alteration in the fluid level, provided the vaporizing surface is covered with liquid anesthetic. When the temperature of the liquid anesthetic in the vaporizer is known, the concentration of vapor being delivered by the apparatus can be predicted simply by reference to the vapor pressure curve of the particular liquid.

The precise control of concentration delivered to the patient is accomplished by altering independently the total amount of vapor produced and the degree of dilution. Concentration is directly proportional to the flow through the vaporizer and inversely proportional to the diluent flow. The amount of liquid vaporized depends on the
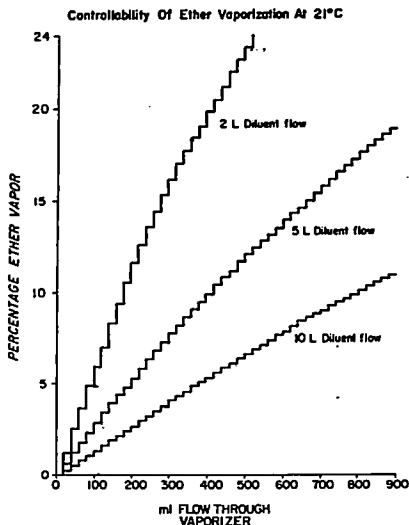
Fig. 4. Changes in ether concentration produced by 20 ml. increments in flow through the Copper Kettle at 21 C., with diluent flows of two, five, and ten liters.

volume of oxygen passed as a carrier gas through the vaporizer. It is easily possible to adjust this in increments of from 10 to 20 mL per minute. The volume of diluting gas can be varied independently from 0 to as much as 20 liters. The ease with which vernier control of concentration can be obtained with ether and halothane is illustrated in figures 4 and 5. These show the change in calculated concentration produced by 20 mL increments in flow of gas through the vaporizer. An increase in the flow through halothane from 240 to 260 cc. per minute in a system with a 10 liter diluent flow increased the percentage of halothane from 1.12 per cent to 1.2 per cent. Conversely were the total flow to be increased by addition of 100 ml. diluent gas as from 10,000 to 10,100 ml., the percentage of halothane would be decreased to 1.19 per cent. Similarly increasing the flow through ether by 20 ml. results in approximately 0.3 per cent additional concentration when used with a 10 liter diluent flow. During clinical use the adjustment of the diluting gases to change concentration is not ordinarily required. It is obvious, however, that the smoothness of vernier control is enhanced and the increment in concentration of vapor delivered is actually made smaller when a truly high flow system is being used, in contrast to low flow or closed system techniques. Caution is mandatory when adding
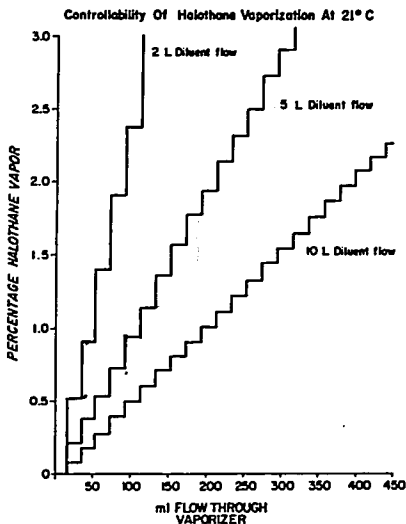
Fig. 5. Changes in halothane concentration produced by 20 ml. increments in flow through the Copper Kettle at 21 C., with diluent flows of two, five and ten liters.

potent vapors to a closed system, since lethal concentrations equalling ten to twenty times the concentration required for maintenance of anesthesia are provided by this type of vaporizer.

SUMMARY

Studies have been presented to show the characteristics of performance of the Copper Kettle vaporizer. The sintered bronze vaporizing surface has been shown to be highly efficient. The use of copper in the container and table top provides considerable thermostability even with ether which has a high latent heat of vaporization. Precise control of the percentage of vapor is obtained with all agents, and allows potent anesthetics such as halothane to be administered safely.

REFERENCES

1. Morris, L. E.: New Vaporizer for Liquid Anesthetic Agents, ANESTHESIOLOGY 13: 587 (Nov.) 1952.
2. Raventós, T.: Action of Fluothane—New Volatile Anaesthetic, Brit. J. Pharmacol. 11: 394 (Dec.) 1956.
3. Johnstone, M.: Human Cardiovascular Response to Fluothane Anaesthesia, Brit. J. Anaesth. 28: 392 (Sept.) 1956.
4. Editorial, Anaesthesia 12: 371 (Oct.) 1957.
5. Handbook of Chemistry. Handbook Pub. Inc., 1952, p. 1471.