

the removal of nitrous oxide from intracardiac gas would first require loss of nitrous oxide from venous blood. This process takes longer since it is dependent on the washout of nitrous oxide from the vessel-rich tissues. Removal of intracardiac gas would occur only while adequate cardiac function is maintained, suggesting that the use of nitrous oxide requires proper patient monitoring to ensure early diagnosis of intrapulmonic gas.

Until a more complete evaluation of the incidence and severity of venous air embolism during nitrous oxide anesthesia can be made, we believe it is best avoided in patients in whom the risk of air embolism is great. However, the intermittent use of nitrous oxide as a diagnostic test for the presence of early and asymptomatic venous air embolism, in combination with continuous monitoring of FETCO_2 and pulmonary arterial pressure, is a safe and useful procedure.

The authors gratefully acknowledge the helpful assistance of Drs. P. A. Cullen and J. H. Modell in the preparation of this manuscript.

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More Failsafe Failsafes

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Failsafe devices for anesthesia machines are, as most of us know, not failsafe.¹ Despite these devices, an anesthesia machine can still deliver pure nitrous oxide. Solutions to this problem have not been generally applied, perhaps because they are too expensive or restrict the versatility of the standard types of machines.^{2,3}

The two devices presented here greatly decrease the chances for delivering hypoxic mixtures without altering the way flows are selected. They are simple, relatively inexpensive, and can be applied to most existing

machines. Both have performed without failure in extensive laboratory trials.

The fluidic device is simply an OR/NOR logic gate⁴ which controls a pressure-electric switch.¹ The nitrous oxide is connected to the power supply position of the OR/NOR gate (fig. 1); if insufficient diverting flow of oxygen is present, the nitrous oxide will exit via outlet 2, close the pressure-electric switch and sound an alarm. If an adequate flow of oxygen is present, then the nitrous oxide flow will be diverted to exit via outlet 1 and the alarm switch remains open. The components used here have a maximum operating pressure of 10 psi, so 3-psi pop-off valves⁵ were used to allow extra flow to

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Received from the Department of Anesthesiology and The Anesthesia Research Center, University of Washington School of Medicine, Seattle, Washington 98195. Accepted for publication August 28, 1974. Supported by NIH Training Grant GNO 1160-10.

⁴ Corning Glass Works, Fluidic Products Department, Corning, N.Y. 14803, Catalog number 191453.

¹ Corning Glass Works, Catalog number 191491.

⁵ Nupro Company, 15635 Saranac Road, Cleveland, Ohio 44110, Model number 4C.

bypass these components. All gases flow to the anesthetic circuit. The only external power source was a 9-v battery used to drive the alarm.[†]

The pressure-electric switch requires a minimum of 800 ml/min of nitrous oxide to close. The flow of oxygen necessary to prevent the switch from closing (and the alarm from sounding) can be varied with the bypass valve,^{**} but has a minimum of 500 ml/min. A 1-liter setting proved most practical. There

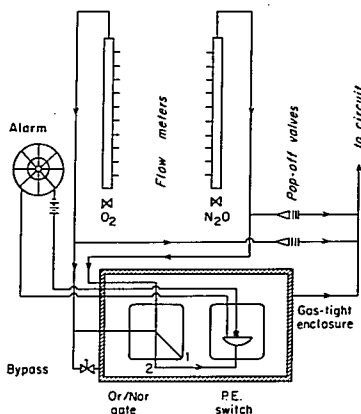


FIG. 1. Schematic of the fluidic failsafe. Numeral 1 is at the exhaust port and numeral 2 is at the port going to the pressure-electric switch.

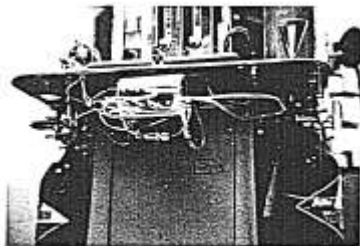


FIG. 2. Fluidic failsafe mounted on rear of machine.

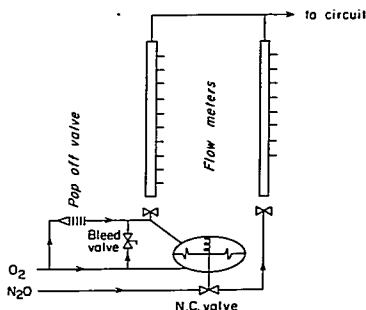


FIG. 3. Schematic of mechanical failsafe. N.C. valve is the normally closed diaphragm-controlled valve.

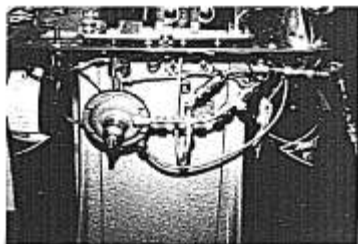


FIG. 4. Mechanical failsafe mounted on rear of machine.

is a small hysteresis around the set point and a slight (less than 10 per cent) increase in the set point at high flow rates. With a 1-liter setting, for example, the alarm will sound if more than 800 ml/min of nitrous oxide and less than 1,000 ml/min of oxygen are flowing. Thus, the device can be used with low-flow or closed systems. The parts of the fluidic system are compact and fit into a cylinder 3 inches in diameter and 4 inches long (fig. 2).

The fluidic device is an active system, *i.e.*, one must react to the alarm to avoid

[†] Mallory Company, 3029 East Washington St., Indianapolis, Indiana 46206, Sonalert Model SC-628 (369-85C).

^{**} Corning Fluidic Products, Miniature Control Valve, Catalog number not available.

an error. A passive system was also designed and built. With this device a minimum flow of oxygen is necessary before nitrous oxide will flow. The nitrous oxide flows through a normally closed diaphragm-controlled valve†† (fig. 3). This valve overrides the nitrous oxide-flow valve. The oxygen is connected to both sides of the diaphragm, and the line going to the opening side of the diaphragm is direct. The line going to the other side has a pop-off valve with an opening pressure that exceeds the opening pressure of the diaphragm-controlled valve. I use a 25-psi pop-off valve and an 18-psi diaphragm-controlled valve. Downstream from the pop-off valve the two oxygen lines are connected by a bleed valve.†† The setting of the bleed valve regulates the minimum oxygen flow required to open the nitrous oxide-override valve (the diaphragm-controlled valve). As oxygen flow increases, the differential pressure between the two sides of the diaphragm increases until the opening pressure is exceeded. If, for example, the bleed valve is set for a 1-liter/min opening flow, then the nitrous oxide cannot be turned on unless at least 1 liter/min of oxygen is flowing. At 1.1 liter/min oxygen flow, the nitrous oxide flow

can be controlled in the usual way. At oxygen flows between 1.0 and 1.1 liter/min, the override valve is opened in direct proportion to the oxygen flow. In this narrow range a change in oxygen flow can also change the nitrous oxide flow.

Each system has its advantages and drawbacks. If one builds any such system he must use only parts manufactured for use with oxygen because of the explosion hazard. Either system should not increase the maintenance requirements of the anesthesia machine. Fluidic components are sensitive to particulate matter, so filters might be necessary to assure proper long-term function. While the mechanical system appears more durable and is passive, the fluidic system allows the use of nitrous oxide in low-flow states. Both systems operate continuously without consuming power, and neither can be turned off.

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†† Hoke Valve Company, 1 Tenakill Park, Cresskill, N.J. 07626, Model 69003.

†† Hoke Valve Company, Needle valve with 0–3 liter/min oxygen flow range at 50 psi, Model number not available.