OXYGEN FAIL-SAFE DEVICE FOR AN ANAESTHETIC APPARATUS

BY

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SUMMARY

The criteria for an oxygen fail-safe device are designed to prevent the patient breathing an asphyxiating mixture if the oxygen supply should fail, be disconnected, or be turned off. Such a device should operate when the patient is breathing spontaneously or being artificially ventilated whatever the circuit arrangement may be. A fail-safe device which fulfils these criteria is described.

There are circumstances when the oxygen supply to an anaesthetic apparatus can fail. If this is not noticed immediately, the patient becomes anoxic. Many of the oxygen failure warning devices available at the present time only give a visual or audible signal of the failure and they rely on a second gas supply (usually nitrous oxide) and/or batteries for their operation (Falkner Hill, 1956; Hospital Equipment Information, 1965; Grogono. 1965; Wilson, 1965; Adler and Burn, 1967; Cooke and Waine, 1967; Ward, 1968b). Recently others (Epstein et al., 1962; Lucas and Fisher, 1967; Ward, 1968a; Matteo, Gissen and Lee, 1969) have been described which not only signal the failure of the oxygen supply but also switch or cut off the supply of all other anaesthetic gases. These latter mechanisms go a long way to providing improved safety, but some hazards still remain.

A complete fail-safe system incorporates the following features.

(1) It is operated by the oxygen supply alone.
(2) When it comes into operation:
   (a) all gas and vapours from the anaesthetic apparatus to the patient are stopped;
   (b) the breathing circuit is opened to the atmosphere;
   (c) the inspired concentration of oxygen is not less than the concentration in air nor should any build-up of carbon dioxide occur either during spontaneous breathing or artificial ventilation no matter what breathing circuit is in use.
(3) It is not possible to start administering an anaesthetic unless the oxygen supply is connected or restored after a failure.
(4) There should be a warning of impending oxygen supply failure.
(5) There should be a further warning that failure has occurred.

No anaesthetic apparatus, as yet, is fitted with a fail-safe system which conforms to all these criteria. However, a device which fulfils these requirements has now been developed in association with the British Oxygen Company and can be fitted to the Boyle model M. It consists of two valves 1 and 2 (fig. 1) permanently fitted and connected to the reduced pressure (60 Lb./sq.in.) oxygen supply.

The pressure behind the diaphragm (6) of valve 1 (fig. 2) holds the valve (9) open, and the air inlet valve (3) closed, against the force of the spring (5). Gases from the flowmeters and vaporizers flow freely through the valve (9) to the breathing circuit. When the oxygen pressure falls to 40 Lb./sq.in. the valve (9) begins to close, oxygen leaks through a restrictor (2) and the valve (8) to a whistle (7) which continues to sound until the pressure has fallen to about 10 Lb./sq.in. When the oxygen pressure falls to about 20 Lb./sq.in. the valve is snapped over by its spring and magnet (4), the valve (9) closes, cutting off the supply of gases to the breathing circuit and the one-way air-inlet valve (3) is released. If another gas in addition to oxygen is in use, the pressure in the flowmeter circuit increases to 5 Lb./sq.in. when a relief valve (1) opens and that gas is vented to atmosphere.

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A warning whistle sounds during the time taken for pressure to fall from 40 to about 10 Lb./sq.in. although the supply of oxygen and other anaesthetic gases cut off after the pressure falls to about 20 Lb./sq.in. The time that the warning sounds depends on the amount of oxygen stored in the circuit of the anaesthetic apparatus and the flow of oxygen set on the flowmeter, which falls progressively as the cylinder pressure falls. If the flow is set initially at 2 l./min, and the oxygen is supplied from a 24 cu.ft cylinder the warning of impending failure lasts for about 4 minutes. If the flow of oxygen set is 5 l./min the warning time is about 1.5 minutes. If the oxygen is supplied to the apparatus from a pipeline these periods of warning are reduced considerably.

In the air inlet (10) for the one-way valve (3) there is another whistle, with a different pitch, which sounds as air is drawn into the circuit. This signifies that the oxygen has already failed or, when starting to anaesthetize, that the oxygen supply has not been connected to the apparatus.

The second valve (fig. 3) is incorporated in a bag mount which replaces the conventional bag mount on the outlet of the anaesthetic apparatus. Its action is to prevent rebreathing after the safety valve (1) has been operated by a failure of the oxygen supply. Oxygen at the reduced pressure (60 Lb./sq.in.) is supplied at the port (4) forcing up the piston (2). The rod (3), attached to the piston, lifts the valve (6) which closes the port (5). The gases then pass through the modified bag mount in the same way as they pass through...
When a T-piece circuit is used the warning of impending oxygen failure and the anaesthetic gases shut-off operates as before. However, once the oxygen has failed, the patient rebreathes through the open pathway of the T-piece and the whistle in the air-inlet of valve 1 does not sound.

An automatic ventilator can be connected in place of the reservoir bag (8) on the bag mount. If the oxygen supply fails, then, during inspiration, the now-freely-moving valve (6) is forced up on to its top seating, closing the connection with atmosphere, and gas is delivered to the patient. During expiration, the valve (6) moves down and expired gas flows to atmosphere through the one-way valve (5). The ventilator draws air in through the air-entry port in valve 1, sounding the whistle. Naturally, any automatic ventilator

![Diagram](https://academic.oup.com/bja/article-abstract/43/1/103/251106/fig1)

**Fig. 2**
Valve 1 with oxygen supply on.

1. Pressure relief valve set at 5 Lb./sq.in.
2. Restriction.
3. Air-inlet valve.
5. Spring.
6. Diaphragm.
7. Whistle.
8. Valve.
10. Air inlet.

a conventional bag mount. If the oxygen supply fails, the piston (2) is returned to its resting position by the spring (1). This lowers the rod (3) and the valve (6) is free to move. When a Magill circuit is in use and the patient is breathing spontaneously, inspired gas is drawn from the reservoir bag (8) and expired gas flows to atmosphere through the normal expiratory valve near the patient. When the reservoir bag (8) becomes empty inspired gas is drawn in through the air entry port in valve 1 and the whistle sounds. Valves 1 and 2 are connected by a wide-bore tube.

When a circle absorber is in use the reservoir bag on the absorber is removed and the port from which it is removed is connected to the outlet (7) of the modified bag mount by a wide-bore breathing tube. The reservoir bag (8) on this bag mount is then the reservoir bag for the circle system and fresh gases are supplied into it instead of directly into the circle absorber. If the oxygen fails when the patient is breathing spontaneously the valve (6) is free to operate, inspired gas is drawn from the reservoir bag and expired gas escapes to atmosphere through the one-way valve (5) in the bag mount. When the reservoir bag (8) becomes empty, air is drawn in through the air entry port in valve 1 and the whistle sounds.

![Diagram](https://academic.oup.com/bja/article-abstract/43/1/103/251106/fig2)

**Fig. 3**
Valve 2 with oxygen supply off.

1. Spring.
2. Piston.
3. Rod.
4. Oxygen supply.
5. One-way valve.
6. Valve.
7. Outlet to patient.
8. Reservoir bag.
functioning from the same oxygen supply would fail also.

The valves require no servicing other than that they be included in the usual 3-6 months maintenance. Their action can be tested at any time by shutting off the oxygen, listening for the whistles, and watching the movement of the reservoir bag.

REFERENCES

Hospital Equipment Information No. 15, December 1965. Warning devices and contents gauges for anaesthetic machines.

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