A FLUIDICALLY CONTROLLED VENTILATOR FOR BRONCHOSCOPY

D. G. ROSS AND H. J. MANSON

SUMMARY

A simple time-cycled device uses an oscillating, fluidic, bistable element to control the high-pressure oxygen supply to the ejector of a ventilating bronchoscope. Both manual and automatic modes of function are available, and inflation pressure and respiratory rate are controlled. Its construction is simple, the cost is low and the number of components is small.

Using an automatic flow interrupter in conjunction with a venturi ventilating bronchoscope, the anaesthetist is free to perform tasks other than depressing an on-off switch. Although their use is uncommon (Jardine, Harrison and Healy, 1975), a few such automatic devices have been described. Spoerel (1969) used a Bird Mark II ventilator driven by oxygen at 100 lb/in² (7.0 kg/cm², 690 kPa) to obtain inflation pressures up to 30 cm H₂O. Bradley, Moyes and Parke (1971) described a device which interrupted the high-pressure oxygen supply to the venturi ejector by means of an electronically timed solenoid valve. Jardine, Harrison and Healy (1975) evaluated the performance of a time-cycled automatic flow interruption device and concluded that the method enabled bronchoscopy to be performed with more satisfactory pulmonary ventilation than had been obtained hitherto using other techniques, although they did not describe the nature of the device used.

We have designed and made a simple ventilator which utilizes a fluidic bistable element to control interruption of the high-pressure oxygen supply to a bronchoscope ejector, thus providing automatic intermittent positive-pressure ventilation. In designing the ventilator, we intended that it should be reliable, simple in construction and cheap to produce, with provision for control of inflation pressure and with rapid regain of manual control when required.

EQUIPMENT

Three Negus bronchoscopes, (1) small adult size i.d. 9.0 x 7.1 mm, (2) adolescent size i.d. 8.0 x 6.7 mm and (3) child size i.d. 7.0 x 6.0 mm, were modified by the addition of an ejector needle as described by D. G. Ross, M.B., CH.B., F.F.A.R.C.S.; H. J. MANSON, M.B., CH.B.; Department of Anaesthesia, Aberdeen Royal Infirmary, Foresterhill, Aberdeen AB9 2ZB.

Based on a paper presented to the North-east of Scotland Society of Anaesthetists, April 1975.
the “automatic” position. Pressure on the push-button moves the spindle into the “manual on” position and gas flows to the needle valve which controls inflation pressure and thence to the ejector on the bronchoscope. In this way, intermittent depression of the push-button produces ventilation.

To select “automatic”, the push-button is released and the spindle returns to the “off” position. The selector-ring is turned until its projection encounters a slot in the spindle cap, and the spring then moves the spindle to “automatic”. High-pressure gas is then directed to the step-up valve and also to the fluidic device. The step-up valve remains closed until actuated by a signal from the fluidic oscillator. The fluidic bistable amplifier (Conway, 1971) is connected via restrictors to two capacitors (vessels of 500-ml volume) which are in turn connected via restrictors to the respective signal ports of the bistable. When a signal appears at either output port the feedback through the network causes the bistable to oscillate; the mark–space ratio is determined by the lengths of restrictor tubing used. One output is connected additionally to the step-up valve, which controls the flow of high-pressure oxygen to the primary jet of the bronchoscope. Thus the mark–space ratio determines the inspiratory–expiratory ratio. The inspiratory to expiratory ratio varies linearly between 2.5 : 1 at 15 respirations/min and 1 : 1 at 30 respirations/min. In addition to its feedback network, the other output of the bistable has a leak restrictor, which lowers the mark–space ratio and diminishes noisy venting of gas from the bistable. The restrictors used in the feedback network consist of plastic tubing of 1.14 mm i.d. of the following lengths: on the inspiratory side, \( I_1 = 190 \text{ mm} \) and \( I_2 = 265 \text{ mm} \); on the expiratory side, \( E_1 = 220 \text{ mm} \) and \( E_2 = 295 \text{ mm} \). The leak restrictor is a 25-mm length of tubing i.d. 0.48 mm. The rate of cycling is controlled by a needle valve which restricts the supply pressure to the bistable element between 5 and 10 lbf/in\(^2\) (0.35–0.7 kg/cm\(^2\), 34.5–69 kPa) to give ventilating rates of 15 and 30 per min respectively.

**METHOD OF USE**

The spool-valve is set in the “off” position and the inflation pressure valve is turned to zero. When the bronchoscope is in the trachea the push-button is depressed intermittently while inflation pressure is gradually increased until chest and abdominal excursion indicates that tidal volume is adequate. The spool-valve can then be set at “automatic” and the rate control adjusted.

**DISCUSSION**

Fluidic control has the advantage that only one energy source is required for both the control system and the ejector primary flow. Since the gas supply is filtered to less than 5 µm, the fluidic and pneumatic components are highly reliable. Control of inflation pressure and ventilatory rate is accomplished easily in clinical use and manual control can be regained rapidly. We decided to control only inflation pressure and respiratory rate in the interest of simplicity in use; however, inspiratory and expiratory times could be controlled independently by using variable restrictors in the feedback network and supplying the bistable element with a constant flow of gas. The ejector needles used with the ventilator have been restricted to provide maximum inflation pressures much greater than those used normally for pulmonary ventilation and certainly in excess of those recommended by Bethune and others (1972) for bronchoscope injectors, but we wished to have a reserve of pressure available for use when the lumen of the bronchoscope is partly obstructed by a fibre-optic instrument or biopsy forceps, which disturbs the primary flow and decreases the inflation pressure. If pressure has been increased for this reason, care is necessary when the obstruction is removed subsequently, since a sharp increase in inflation pressure will occur unless the needle valve is readjusted before the next inspiratory phase.

**ACKNOWLEDGEMENTS**

We wish to thank Mr G. Bowie for his technical assistance, Dr C. R. Dundas and Dr I. Smith for advice and encouragement and Mr F. J. Sambrook Gowar, Mr P. L. Brunnen and Mr A. V. Foote for permission to use this ventilator during their theatre lists. The fluidic bistable amplifier and pneumatic step-up valve were from British Fluidics and Controls Ltd, Forest Road, Hainault, Ilford, Essex, and the gas filter from Pall Biomedical Ltd, Walton Road, Portsmouth PO6 1TD.

**REFERENCES**


A FLUIDICALLY CONTROLLED VENTILATOR


VENTILATEUR POUR BRONCHOSCOPIE
COMMANDE PAR FLUIDE

RESUME
Un dispositif cyclique simple fonctionnant à l'aide d'un élément fluidique oscillant bistable règle l'arrivée d'oxygène à haute pression à l'éjecteur d'un bronchoscope à ventilation. Il peut être fourni avec deux modes de fonctionnement: manuel ou automatique, avec régulation de la pression d'inflation et du rythme respiratoire. Ce dispositif est de construction simple, son prix est peu élevé et le nombre des pièces composantes est relativement petit.

EIN ZYKLISCH KONTROLLIERBARES
BEATMUNGSGERÄT ZUM GEBRAUCH BEI
BRONCHOSKOPIE

ZUSAMMENFASSUNG

UN VENTILADOR CONTROLADO
FLUIDICAMENTE PARA LA BRONCOSCOPIA

SUMARIO
Un dispositivo sencillo con control del ciclo de tiempos utiliza un elemento oscilatorio, fluido, bistable para controlar el suministro de oxígeno de alta presión al eyector de un broncoscopio de ventilación. Están disponibles las dos formas de funcionamiento manual y automático, y se controlan la presión de inflación y el ritmo respiratorio. Su construcción es sencilla, su costo es bajo y el número de sus componentes pequeño.