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APPARATUS

PEPP and the Bird ventilator

Application of a positive end expiratory pressure plateau to the Bird Ventilator for assisted and controlled ventilation

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Several workers[1–5] have, in the last few years, demonstrated improved gas exchange during mechanical ventilation by adding a positive expiratory pressure plateau (PEPP) to the pattern of ventilation. PEPP has been used both to improve oxygenation in patients with large alveolar–arterial oxygen gradients and to allow ventilation with lower inspired oxygen tensions than would otherwise be possible.

Attempts to apply PEPP with *controlled* ventilation to the Bird mark 7 or 8 ventilator have, in the past, proved unsuccessful,[6] since, when the expiratory pressure is applied, the ventilator either slows down or ceases to cycle. This is due to the inability of the cycling mechanism to function when there is positive pressure present in the ventilator–patient system from the expiratory valve back through the humidifier and into the patient side of the ventilator. The problem can be solved by the addition of two standard Bird expiratory valves,[7] but there is then a slow leak back through the humidifier power line from the pressurized part of the patient's system to the part of the system at atmospheric pressure. This leak is slow but it becomes significant with prolongation of the expiratory time and hence the value of the positive end-expiratory pressure applied is inversely proportional to the expiratory time. If a non-return valve is placed between the humidifier and the power line (Fig. 1) the pressurized part of the patient's circuit is isolated from the atmospheric part during expiration and the value of PEPP which is applied remains stable and is independent of the duration of expiration. This system can only be used when it is desired to use controlled ventilation because patient-triggering is rendered impossible.

The addition of PEPP to a ventilator during *assisted* ventilation is ineffective[8] because the patient must create a subatmospheric pressure sufficient to overcome the prescribed PEPP and this prevents the maintenance of continuous positive airway pressure.

The following describes a device which can be fitted easily to the Bird mark 7 or 8 ventilators. It will allow use of PEPP during assisted as well as during controlled ventilation. The cost of adapting Bird ventilators to make use of this device should be minimal and this is an important consideration in view of the high cost of the few

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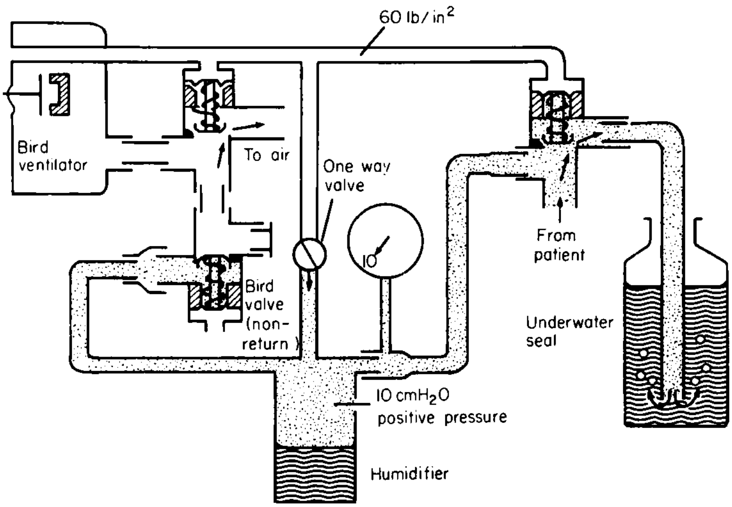

Fig. 1. Diagram illustrating application of PEPP to Bird ventilator (after Wrigley[7]) but incorporating one-way valve in humidifier power line.

ventilators which otherwise offer this facility for controlled or assisted ventilation separately.

Apparatus

The sensitivity mechanism in the Bird ventilator responds to the pressure differential between the breathing system and ambient atmospheric pressure. In order to initiate the inspiratory phase of the ventilator the patient must inspire enough to cause a negative pressure in the breathing system but when PEPP is used this pressure is added to that which the patient must overcome to initiate machine-cycling.

Compression of the spring (A, Fig. 2) during expiration by the outward travelling manual-cycling control (B) provides, at the right setting, a recoil pressure on the ambient side of the diaphragm equivalent to the patient's end-expiratory pressure. The sensitivity mechanism then operates on the same pressure baseline as the patient and allows the ventilator to cycle at the same sensitivity level as it would without PEPP. The baseline for sensitivity is no longer ambient pressure but becomes ambient plus whatever increment of PEPP has been added. Thus the patient is able to activate the

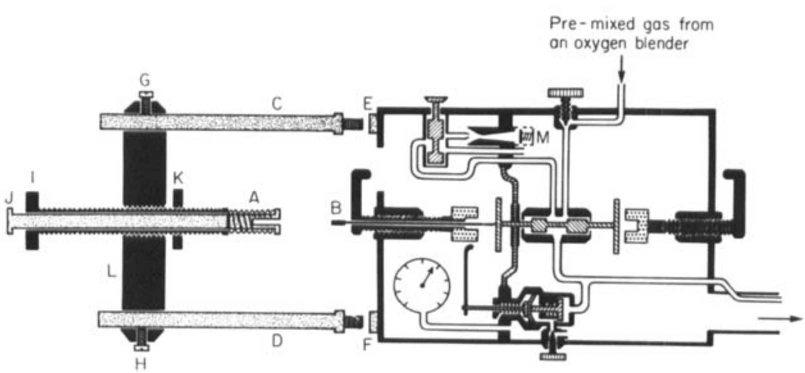

Fig. 2. Diagram illustrating Bird Mark 7 ventilator with PEPP compensator in 'off' position.

machine while still maintaining total airway pressure at the pre-set positive pressure value.

The automatic cycling mechanism no longer has to overcome the positive pressure present in the ventilator–patient circuit and can reliably control or assist ventilation. If the latter is used the safety mechanism is functional in the event of apnoea.

The PEPP compensator is made of light aluminium and consists of two supporting rods (C & D, Fig. 2), the threaded ends of which are screwed into the casing of the ventilator, in place of the two Allen bolts (E & F) present on the side of the ambient chamber. The main body of the PEPP compensator is then made to engage the free ends of the supporting rods and secured firmly by the grub screws (G & H). When the PEPP compensator control knob (I) is in the 'off' position, the free end of the manual-cycling control (B) should be free to travel outwards during expiration without causing any compression of the spring (A).

Setting the Bird ventilator for the application of PEPP

The ventilator must be driven with a pre-mixed gas of the required oxygen concentration without use of the venturi,[6] if PEPP is to be used with the Bird mark 7 or 8. This is essential since the use of the venturi with PEPP would cause an increased resistance to flow through the venturi which would alter the percentage of oxygen delivered. If PEPP were great enough to resist the opening of the spring gate of the one-way valve (M) there would be no flow through the venturi. There is a slow leak of pressure during expiration through the venturi which is open to atmosphere, which results in an expiratory resistance rather than PEPP.

The ventilator is connected to a one litre bag as a test lung and a reasonable pattern of ventilation is achieved by setting the controls of pressure, sensitivity, flowrate and expiratory time to the same figures (e.g. 15-15-15-15) and the rate at which the ventilator is cycling at these settings is noted. PEPP is then applied by connecting the exhalation port to an underwater seal. The value of PEPP in cmH_2O depends approximately on the height in centimetres of the tubing submerged under water and this should, if the circuit is leak free, equal the value of PEPP recorded on the pressure gauge of the ventilator and the ventilator immediately ceases to cycle and stops in expiration at the selected PEPP.

The inspiratory pressure control is then increased from 15 cmH_2O by an equivalent amount to the applied PEPP, i.e. if applied PEPP is 10 cmH_2O the new pressure control setting should be 25 cmH_2O and the PEPP compensator control knob (I) is screwed in gradually until the free end of the manual-cycling control (B) comes in contact with the blind end of the central tunnel in the piston (J). Further screwing in of the control knob (I) will cause compression of the spring (A) between the shoulders of the piston (J) and the controller (I).

The precise degree of spring compression required to compensate for the applied PEPP is reached when the ventilator starts cycling again at the same rate as that recorded prior to application of PEPP. The control knob (I) is then locked in this position by the locking nut (K) against the fixed main body (L). The ventilator is now ready to be connected to the patient in place of the test lung. Final adjustments of the ventilator controls can then be made to obtain the desired respiratory pattern, tidal volume and sensitivity.

It is important to note that whenever the pressure control is moved in order to achieve a change of the tidal volume, an equivalent movement of the sensitivity control in the opposite direction must be made if the initial pre-set base line for sensitivity is to be maintained, i.e. if the pressure control setting is increased the pressure magnet is moved closer to its plate and would therefore have the effect of prematurely triggering the ventilator into inspiration. In order to compensate for this it is necessary to decrease the sensitivity by an equivalent movement of the sensitivity magnet closer to its metal plate.

Discussion

The inspiratory effort required during spontaneous respiration prevents the maintenance of positive airway pressure during expiration and thus controlled ventilation is necessary in order to achieve the full therapeutic benefits of positive end expiratory pressure.[9,10] There are, however, inherent drawbacks to controlled ventilation.[9,11]

A PEPP compensator has been designed to make the application of PEPP to the Bird ventilator possible both during assisted and/or controlled ventilation. No system has hitherto been described for any ventilator which will allow both controlled and assisted ventilation with PEPP. The major advantage of the use of the device described is that a commonly available ventilator, the Bird, can be used as a triggered ventilator, with the over-riding safety provision of controlled ventilation should apnoeic spells occur. The absence of asynchrony between patient and ventilator with this system might, theoretically, lead to a lower incidence of complications such as pneumothorax, pneumomediastinum and circulatory insufficiency.

Two Bird mark 7 and mark 8 ventilators have been fitted with this device and have been reliable and efficient in routine use; the system has not yet been used for infants.

Summary

A device is described with which the PEPP may be used with the Bird ventilator (mark 7 or 8) during assisted and/or controlled ventilation. Advantages over other currently available systems providing PEPP are discussed and these include ease of use, cheapness, versatility and safety.

The device will be available from the British Oxygen Co. Ltd.

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