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A Respirator Alarm for General Use

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Respirator alarms to indicate ventilatory failure have been incorporated in commercially available respirators such as the Bennett MA-1, the Bourns Model LS 104.150, and the Bird respirator, which is equipped with a Minute-tidal-volume meter. The respirator alarms described by Lamont¹ and Wilger² do not respond to respiratory obstruction, because the inspiratory pressure of a pressure-preset respira-

tor does not change even when respiratory obstruction occurs. Unfortunately, the commercially available respirator alarms can be used for particular types of respirators only, and the costs of some alarms are higher than the costs of the respirators.

The inexpensive respirator alarm we have designed (fig. 1) can be used accurately for both volume-preset and pressure-preset respirators simply by turning a selector switch. The alarm has been used during the past two years in the Tokyo Medical and Dental University and has proved to be reliable and useful for both types of respirators.

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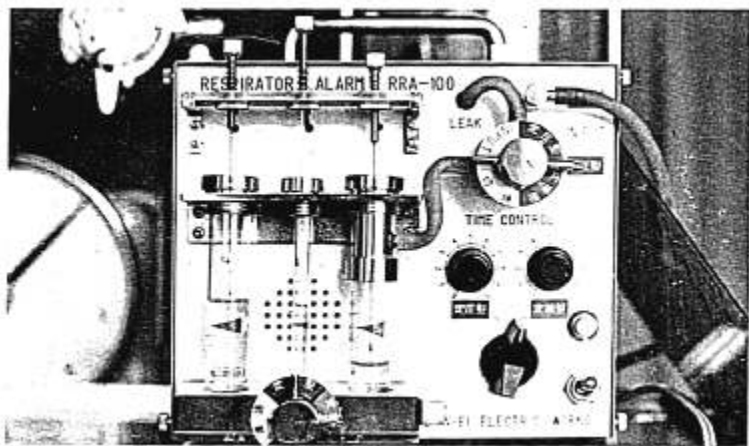
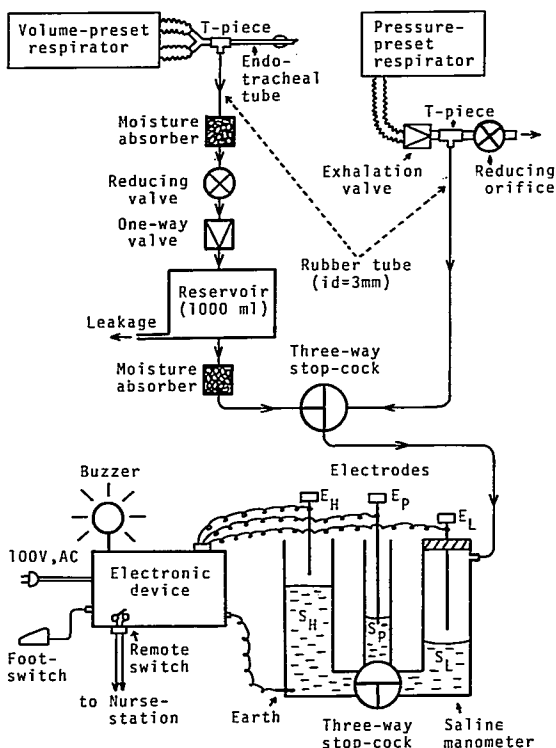


FIG. 1. Front view of the respirator alarm.

FIG. 2. Flow diagram of the components of the respirator alarm and their functional arrangement for use with volume-preset and pressure-preset respirators.



DESIGN AND CONSTRUCTION

The alarm unit is approximately $19 \times 17 \times 15$ cm in size. It contains two systems of saline manometers with silver electrodes (fig. 2).

Volume-preset respirator alarm. The T-piece is inserted between the endotracheal tube and the Y-connector of the volume-preset respirator and the intratracheal pressure is led to a reservoir box, sized to accommodate approximately 1,000 ml, through a reducing valve and a unidirectional valve (fig. 2). The pressure in the reservoir is transmitted to a U-tube containing saline solution which has two adjustable silver electrodes above the

level of the solution. The reservoir has a small leak, and the reservoir pressure is reduced by this leak. When intratracheal pressure is reduced by leakage of the cuff of the endotracheal tube or disconnection of the respirator from the patient's airway, the reservoir pressure decreases, the saline solution rises to the low-pressure electrode, and the buzzer is activated. When the intratracheal pressure is elevated by an increase in airway resistance or a reduction of pulmonary compliance, the reservoir pressure continues to be elevated, the saline solution reaches the high-pressure electrode, and a different buzzer rings.

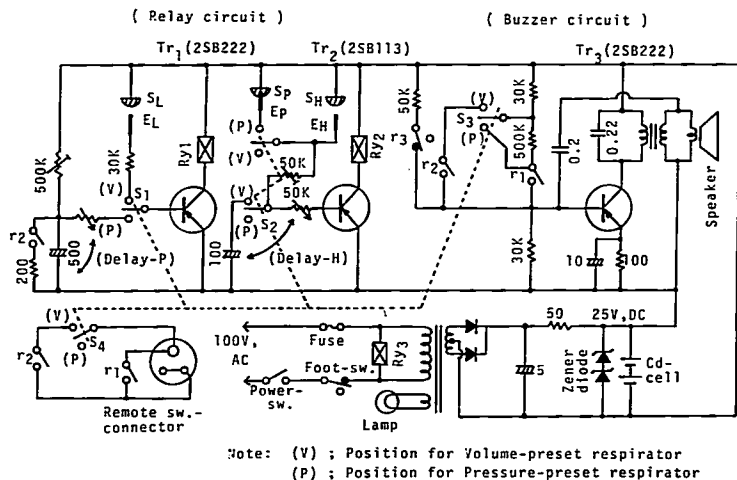


FIG. 3. Diagram of electrical connections for volume-preset and pressure-preset respirator alarms.

The time required to set off the buzzer depends on the height of the silver electrodes above the saline solution. When the electrode is separated by only 1–2 mm from the solution, the alarm rings with slight changes in airway resistance or pulmonary compliance. Usually the electrodes are separated from the solution by 3–4 mm and the alarm is activated by changes of 20 per cent in intratracheal pressure within ten seconds.

Pressure-preset respirator alarm. The T-piece, with a reduced orifice, is connected to the expiratory port of the pressure-preset respirator. The pressure proximal to the orifice is 0.5–1 cm H₂O higher than the ambient pressure, and this pressure is conducted to a saline-sensing manometer. The level of the silver electrode is adjusted to touch the saline solution with each expiration. When the respirator leaks or airway resistance increases, the volume of the expired gas decreases. Reduction in the volume of gas expired is reflected by a reduction in the expiratory peak flow. With each expiration the saline solution rises to touch the silver electrode, but when peak flow decreases,

fluctuation of the level of the saline solution causes it not to make contact with the electrode. If the electrode does not conduct the electric current for ten seconds, the alarm sounds. The alarm is sensitive to a change of the magnitude of 20 per cent of the expiratory gas volume.

Circuit. Figure 3 is a diagram of the electrical connections for both volume-preset and pressure-preset respirator alarms.

To set the volume-preset respirator alarm: 1) The selector knob is turned to "v" position, which simultaneously positions switches S_1 , S_2 , S_3 , and S_4 in "v" positions. 2) The distances between saline solution levels (S_L and S_H) and silver electrodes (E_L and E_H) are adjusted. 3) The power switch is turned on.

When the intratracheal pressure is reduced, S_L and E_L contact. Transistor Tr_1 and relay Ry_1 are energized, and all r_1 switches close. Then lower-pitched alarm rings through the speaker. When the intratracheal pressure is elevated, S_H and E_H contact. Ten seconds later transistor Tr_2 and relay Ry_2 are energized by the delay-H circuit and all r_2 switches close.

The higher-pitched alarm rings through the speaker.

To set the pressure-preset respirator alarm: 1) The selector knob is turned to "p" position, which simultaneously positions switches S_1 , S_2 , S_3 , and S_4 in "p" positions. 2) The level of Ep is adjusted to touch Sp with each expiration. 3) The power switch is turned on.

When the volume of gas expired by the patient is reduced, Ep does not make contact with Sp. Transistor Tr₂ and relay Ry₂ are not energized, and all r₂ switches remained open. Ten seconds later transistor Tr₁ and relay Ry₁ are energized by the delay-p circuit and all

r₁ switches close. The higher-pitched alarm rings through the speaker.

Electric power source alarm. When the electric power source is disconnected, relay Ry₃ does not energize and switch r₃ closes. The middle-pitched alarm rings through the speaker.

REFERENCES

1. Lamont II, Fairley HB: A pressure-sensitive ventilator alarm. *ANESTHESIOLOGY* 26:359, 1965
2. Wilger RN, Myers RA, Duffy JP, et al: Warning system for piston-type respirator. *ANESTHESIOLOGY* 27:509, 1966

Pneumotachometry—A Means to Prevent Malfunction Caused by Mucous Deposition

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Pneumotachometry, the measurement of air flow into and out of the lungs, is being increasingly employed to monitor ventilation during acute illness. The pneumotachometer is placed in the air stream close to the patient's mouth. On the patient end it may be attached to a mask or an endotracheal or tracheostomy tube. On the other end a pneumotachometer may be open to the atmosphere or it may be attached to an anesthesia apparatus or a ventilator.

The two most commonly used devices for this purpose are the Fleisch and the Silverman pneumotachometers, which function by creating a very slight resistance to air flow. The pressure differential across this resistance is proportional to, and in phase with, the speed of air movement. Through electronic means, change in pressure is converted to an electrical signal which may be displayed on an oscilloscope. Such a tracing is informative of respiratory flow patterns. This flow signal, coupled with airway and/or intratracheal pres-

sure, can be manipulated by an analog or digital computer to measure continuously many ventilatory values such as minute volume, compliance, and work of breathing. The information thus obtained is valuable for both diagnosis and treatment. Such data may also be used to evaluate and guide ventilator performance and adjustment.

In the Silverman pneumotachometer the resistance is produced by a very fine wire mesh screen, and in the Fleisch device, by a series of parallel tubes. In clinical use, the screen and the parallel tubes accumulate both water condensation and mucus or exudate coughed up by the patient. Deposits of such material on the screen or within the parallel tubes result in an immediate but unknown change in the metering characteristics of the apparatus. The pneumotachometer becomes nonfunctional. The effect of water condensation is overcome by electrical heating, but the heating device does not prevent the alterations in the efficiency of the instrument by deposition of exudate. Pneumotachometry is sufficiently im-

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