and electric power supplies and the scavenger system should be made, and the appropriate preuse checkout procedures should be done for all equipment. The following is a reasonable operational approach for the Model 2800 ventilator with a circle breathing system:

1. Place the master switch in the standby mode and dial the desired settings for respiratory rate and inspiratory time, according to the patient's needs.
2. Set the inspiratory flow control to the desired rate of flow—low, medium, or high—depending on the patient's needs (typically in the high range for large animals).
3. Connect the corrugated tubing from the ventilator's bellows to the circle system's reservoir-bag mount and the ventilator exhalation port to the scavenger system.
4. Close the circle system's pop-off (APL) valve and release the ventilator's bellows. Ensure that the bellows is fully inflated and positioned at zero.
5. Turn the master switch on, and inspiration should begin.
6. If the bellows does not return to zero during the expiratory phase, the bellows can be filled with flow from the oxygen flowmeter. Alternately, the bellows can be filled with the flush valve, but the anesthetic concentration in the breathing circuit will be reduced any time this is done.
7. The inspiratory time can be adjusted to produce the appropriate tidal volume for the patient.
8. Finally, the PEEP control is adjusted to set the desired end-expiratory pressure.

Vet-Tec Model 3000 Large Animal Anesthesia Ventilator

This is a large animal anesthesia ventilator designed for use in equine and bovine practices.[67] A similar ventilator in combination with a large animal anesthesia machine (Model 2000 Large Animal Anesthesia Machine and Ventilator) is also available.[67] The ventilator system has been described as a "bag-in-a-barrel" powered by a Bird ventilator.[35] The LAVC-2000 and the LAVC-3000 systems can be converted to a 5-L system for use in foals by adding a 5000-mL bellows and a canister (bellows housing) insert. Numerous variations of these ventilator-anesthesia machine combinations were possible, because the manufacturer would customize the unit upon request. The bellows in this ventilator system is driven by a modified Bird Mark 7 ventilator. Used without a bellows, the Bird Mark 7 is classed as a single-circuit ventilator, but the LAVC ventilator system is double circuit and has been classified as a pressure-preset ventilator.[35] The ventilator has been produced with a descending bellows, but literature from the manufacturer indicates the availability of an inverted bellows. The Bird ventilator is pneumatically powered. This ventilator system can be used for ventilation in assist, control, or assist-control modes. When the system is operating, the Bird ventilator supplies gas to pressurize the space between the bellows and the bellows housing (canister) to force the bellows in an upward motion delivering gases from the bellows, through the interface hose, to the breathing system.

The controls on a Bird Mark 7 (Fig. 18.52) include inspiratory pressure, inspiratory flow rate, expiratory time (apnea control), and inspiratory sensitivity. In addition, a manometer, a hand timer (push-pull mechanism), and a DISS connector for the source of pneumatic power are prominent features of the ventilator. With the modified Bird Mark 7, inspiratory pressure can be varied from 5 to 65 cm H_2O, inspiratory sensitivity from −0.5 to −5 cm H_2O, expiratory time from 5 to 15 s, and inspiratory flow from 0 to over 450 L/min. The pneumatic power source should be delivered to the inlet of the ventilator at 50 psi. The bellows can deliver a tidal volume of up to 20 L. Inspiration can be started or stopped by use of a hand timer. The Bird Mark 7 is a time-cycled ventilator unless the push-pull manual cycling rod is pulled out, which causes the ventilator to be pressure cycled.[55]

Before using the Model LAV-3000 ventilator for controlling ventilation during anesthesia, the power-supply and scavenger system should be connected, and the appropriate preuse checkout procedures should be done for all equipment. The following is a reasonable operational approach for the ventilator with a circle breathing system in the control mode:

1. Set the inspiratory sensitivity control to a high setting to eliminate the possibility of patient-initiated ventilation.
2. Set the inspiratory pressure control to the range of 20 to 30 cm H_2O and readjust the setting to achieve the desired tidal volume after steps 5 and 6 have been completed.
3. Connect the corrugated hose (interface hose) from the bellows to the reservoir-bag port of the circle system.
4. Close the pop-off (APL) valve of the circle system. Then, the bellows may need to be filled by increasing the flow of oxygen to the patient circuit (oxygen flowmeter on the anesthesia machine).
5. Turn the inspiratory flow control on to start the ventilator and set the flow control to deliver a tidal volume in approximately 1.5 to 3.0 s.
6. Set the expiratory time control to establish a respiratory rate appropriate for the patient, often 7 to 10 breaths/min.
7. For final settings, the operator should understand that there are interactions between the controls on a Bird ventilator (e.g., changing inspiratory flow may affect respiratory rate and vice versa).

Hazards Associated with the Use of Ventilators

During anesthesia, the use of a ventilator allows the anesthetist to concentrate on monitoring and supportive procedures. If an anesthetist is preoccupied with manually controlling or assisting ventilation, monitoring and support may be neglected. A good example is the use of a mechanical ventilator in anesthesia for equine colic surgery. There is some loss of contact between the anesthetist and the patient when a ventilator is used, especially in regard to respiratory function. Without a "hand on the reservoir bag," an anesthetist may miss such developments as disconnections in the patient circuit, variations in respiratory resistance and compliance, and changes in the rate of spontaneous ventilation. In addition, a ventilator, because of its sounds and regularity, may lull an anesthetist into believing that ventilation is adequate when, in fact, it is not.[61] Ventilators are mechanical and may malfunction, and many veterinary ventilators are not equipped with the alarm systems that are now required for human ventilators. Finally, ventilators add a source of possible contamination to the breathing system.[61]

The hazards of mechanical ventilation are usually associated with malfunctions and failure of the equipment or inappropriate or inadvertently altered control settings. The operator should select a ventilator capable of meeting the respiratory requirements for the patient. Ventilators designed specifically for small animals or human patients are not necessarily appropriate for larger animals. A ventilator must be able to generate an adequate inspiratory flow rate and tidal volume if it is to be safe for use in larger animals. General hazards associated with ventilators include hypoventilation, hyperventilation, excessive airway pressure, negative pressure during expiration, and failure of alarms, if the ventilator is so equipped. Hypoventilation can be associated with power failure, dysfunction of the ventilator, cycling failure, inadequate design for the patient, leak of driving gas, loss of breathing-system gas, incorrect settings, and obstruction of flow.[61]

Respiratory Assist Devices

Several types and brands of respiratory assist devices are available. Some are completely manual in operation (resuscitation bags with one-way valves), and some use compressed gas (oxygen) to assist ventilation (demand valves). The mechanics of these devices have been reviewed.[61]

Manual Resuscitators

A manual resuscitator is appropriate for application of IPPV to small veterinary patients. Several brands of resuscitators are available. The basic components of a manual resuscitator are a compressible self-reexpanding bag, a bag-refill valve, and a nonrebreathing valve.[68] Some resuscitators can be attached to a source of oxygen to enrich the oxygen content of inspired gases (Fig. 18.59). Manual resuscitators can be fitted with a reservoir to serve as a source of oxygen when the oxygen flow to the resuscitator does not meet the filling demands of the resuscitator. The addition of such a reservoir makes the resuscitator more cumbersome to use.[68]

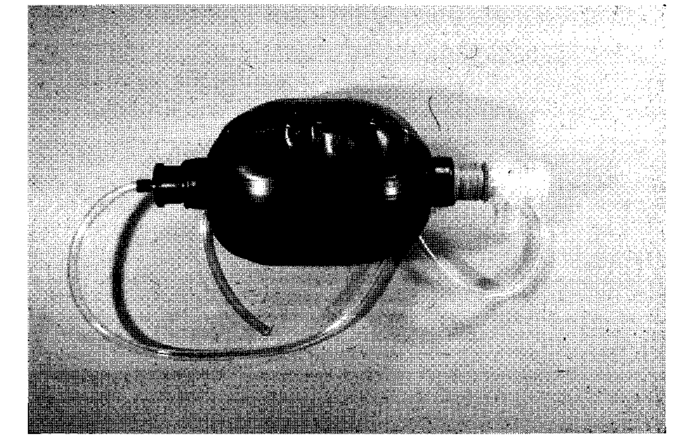

Fig. 18.59. A manual resuscitation bag. Plastic tubing, which may be connected to an oxygen flowmeter, is attached to the bag refill valve to facilitate the addition of oxygen to inspired gases. The components of the resuscitation bag include the clear elbow (*right*), which is a non-rebreathing valve, the black self-inflating bag, and a refill valve (the black apparatus on the *left* end of the bag). The non-rebreathing valve may be connected to a mask or to an endotracheal tube.

Demand Valves

A demand valve can be used to deliver intermittent positive pressure ventilation. The demand valve is set to deliver oxygen when the patient begins to inspire (creating a negative inspiratory pressure) until exhalation starts or until a certain preset pressure is reached.[68] Expiration is passive through the valve outlet. The outlet may be restrictive to expiration in large patients. The device can be disconnected from the endotracheal tube after inspiration to decrease the resistance to exhalation if the demand valve must be used for an extended time.[26] A demand valve can be triggered manually to deliver oxygen to the patient as long as the activation button is held down or until the preset pressure limit is reached. Alternately compressing and releasing the control button allows application of IPPV. A demand valve with the capacity for a high inspiratory flow rate is most desirable for use in large animals; demand valves generating low inspiratory flows will cause an excessively long inspiratory time in patients requiring a large tidal volume.

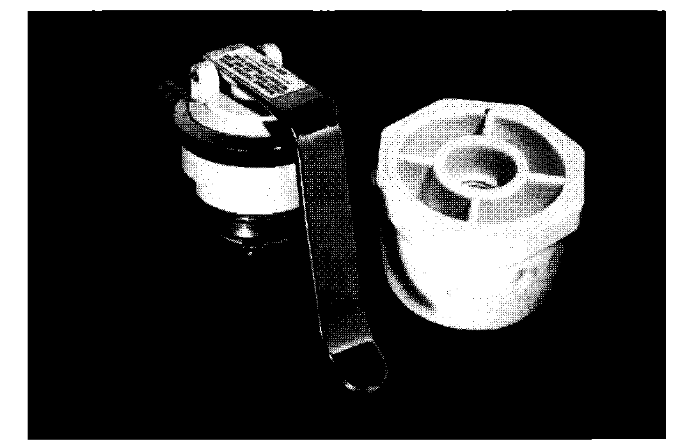

Fig. 18.60. The Hudson Demand Valve (*left*) with an adapter for attachment to a large animal endotracheal tube connector.

Demand valves are available from various manufacturers. The Hudson Demand Valve (Fig. 18.60) has been described for use in horses.[69] It delivers approximately 200 L/min if the oxygen-supply pressure is 50 psi and greater than 275 L/min if the supply pressure is 80 psi. This valve will accept a standard connector for an endotracheal tube (15 mm), and an adapter will allow attachment of the demand valve to a large animal endotracheal tube connector. The equine demand valve sold by J.D. Medical (Phoenix, AZ) functions at an inlet pressure of 50 to 75 psi. This

Fig. 18.61. The Elder CPR/Demand Valve. The oxygen inlet is shown with high-pressure oxygen hose connected. The clear plastic connector at the *bottom* of the photograph will fit endotracheal tube connectors, and the button in the *top center* of the demand valve activates and controls the flow of oxygen.

demand valve is available with various lengths of supply-gas hose and several sizes of adapters for endotracheal tubes. The Elder CPR/Demand Valve (Fig. 18.61) is intended to provide 100% oxygen to breathing or apneic patients.[70] The unit operates on a regulated inlet supply of oxygen at pressures between 40 and 80 psi. There is a variable pressure limit of 60 cm H_2O. Variable pressure (0 to 60 cm $H_2O \pm 5$ cm H_2O) can be delivered to the patient, depending on the amount of pressure that is placed on the manual control button. Two models of this demand valve allow the choice of two set flow rates: 40 L/min at 40 psi and 160 L/min at 40 psi. The inlet for the valve is a DISS male oxygen fitting, and the outlet is 15 mm ID for attachment to an endotracheal tube connector and 22 mm OD for accepting a standard adult mask. This demand valve is easily adapted to fit both large and small animal endotracheal tubes with an adapter similar to the one shown in Fig. 18.60.

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