NORTH AMERICAN DRÄGER

DRAGER AV-E
ANESTHESIA VENTILATOR SPECIFICATIONS AND EQUIPMENT

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4106116 A (NM Standard)
4106032 A (NM2A)

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Instruction Manual

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CONTENTS

Classification

The DRAGER AV-E Anesthesia Ventilator is a volume preset, time-cycled ventilator that features solid state timing, pneumatic circuitry, independent controls, and ease of operation and cleaning. The unit acts as a controller of respiratory rate. The Inspiratory/Expiratory phase time ratio is variable, in steps from 1:1 to 1:4.5.

The DRAGER.AV-E is recommended to be used with the NAD/AV Absorber System which incorporates a special selector valve having two alternate positions. In the BAG position (valve lever toward the operator), the standard relief valve of the absorber, as well as the breathing bag, are activated and the system is ready for spontaneous breathing, or manual assisted or controlled ventilation. In the AUTO position (valve lever away from the operator), breathing bag and standard relief valve are cut out and ventilator bellows, as well as the ventilator relief valve, are activated for automatic ventilation.

The above-described arrangement offers a maximum ease of operation and places the rebreathing bag in a most convenient location for the operator. Standard anesthesia system relief valve as well as ventilator relief valve are connected to the same exhaust gas scavenger system. The ventilator relief valve is mounted on the bellows assembly.

The ventilator itself is conveniently designed as a monitoring shelf and placed above the anesthesia machine. This arrangement does not take any valuable space from the operating room.

The components of the ventilator in contact with the patient's breathing may be removed for cleaning as described under "Sterilization".

Warranty

DRAGER AV-E Anesthesia Ventilators are guaranteed as set forth in the original purchase agreement between North American Drager or its Authorized Distributor and the Buyer

Installation

Installation of the DRAGER AV-E Anesthesia Ventilator shall be by or under the direction of an authorized representative of North American Drager.

Service and Repair

All North American Drager anesthesia equipment shall be serviced and/or repaired by persons authorized by North American Drager.

North American Drager recommends that anesthesia equipment be serviced at regular intervals. Preventive maintenance service contracts are available upon request.

Specifications

1. Electrical Power Supply
1.1 Primary - 120 V.A.C.
1.2 Secondary - 5.0 V.D.C. (output is short circuit protected, current limited to 250 mA).

2. Gas Connection: oxygen 40-60 PSIG (air optional)

3. Controls
3.1 On-Off Switch: coupled to control electric power and gas input to unit.
3.2 Tidal Volume: adjustable as indicated in milliliter markings, on the bellows chamber.
3.3 Frequency Control: variable from zero (0) to ninety-nine (99) breaths per minute (BPM) in one BPM increments.
3.4 Inspiratory/Expiratory Phase Time Ratio Control: variable in indicated steps of 1:1, 1:1.5, 1:2, 1:2.5, 1:3, 1:3.5, 1:4, 1:4.5.
3.5 Flow Control: continuously variable within the minimum and maximum values indicated on the FLOW gauge.

1. ON/OFF
This switch controls the power supply to the ventilator. When the switch is in the OFF position, the unit is not operable regardless of adjustment. The ON/OFF switch features two (2) ON positions. The upper ON position shall be used under conditions of normal operation. The lower ON position is to be used when the ventilator is operated at extremely low frequency and high I:E phase time ratio which results in expiratory phase time in excess of fifteen (15) seconds. The lower ON position actuates the sixty (60) second disconnect alarm delay described in the DPM-S and Narkomed 2 Instruction Manual.

Controls

2a. Tidal Volume, Descending (Hanging) Bellows

The tidal volume on ventilators with descending bellows (Fig. 1) may be preset between 250cc and 1750cc; smaller tidal volumes can be adjusted by volume settings above minimum calibration of 250cc as well as by the easy conversion to pediatric bellows. As in any volume preset anesthesia ventilator, the actual ventilation of the lung may be different from preset volume, due to the compliance of the equipment as well as the influence of fresh gas flow into the system. Exact measurements should be obtained by using a DRAGER MINUTE-VOLUMETER inserted in the expiratory side of the system. Control of tidal volume is by means of a self-locking knob located immediately below the ventilator bellows assembly.

2.b Tidal Volume, Ascending (Standing) Bellows

The tidal volume on ventilators with ascending bellows (Fig. 2) may be preset between 200 and 1600cc; smaller tidal volume can be adjusted by volume setting below the 200cc marking on the bellows chamber. As in the ccase with the hanging bellows the actual ventilation of the lung may be different from the reset volume due to the compliance of equipment in the breathing system and to the influence of fresh gas flow into the system. Exact measurement should be obtained by use of a minute-volumeter in the expiratory side of the system. Control of tidal volume is by means of a self-locking knob located at the top of the bellows assembly.

3. Frequency Control (BPM)

The respiratory frequency may be preset between 01 and 99 cycles per minute in one BPM steps by means of thumbwheel controller-indicator switch. The thumbwheel located right of center of the control panel is labeled FREQUENCY.

4. Flow Control

Control of inspiratory flow rate is by means of a rotary control knob located at left of center of the control panel. The flow setting should be adjusted so that the bellows is fully compressed at the end of the inspiratory phase. The rate of flow is indicated on a gauge, labeled FLOW, adjacent to the flow control knob.

5. Inspiratory/Expiratory Phase Time Ratio Control (I:E)

Inspiratory/expiratory phase time ratio is variable in calibrated steps from 1:1 through 1:4.5. Calibration at each 0.5 increment is marked on the I:E controller-indicator thumb-wheel. The thumbwheel is located to the right of the frequency thumbwheel and is labeled I:E RATIO.

Principle of Operation

The DRAGER AV-E Anesthesia Ventilator operates at 5.0 V.D.C. supplied from an isolated source, see Fig.1 (1). Pneumatic power for the ventilator is supplied by oxygen or AIR via inlet connection (2). The pressure of this gas should be between 40 and 60 PSIG. The ventilator will cease to function if this pressure drops below 28 PSI.

Control of frequency (BPM) and inspiratory/expiratory (I:E) phase time is by means of a 5.0 V.D.C. solenoid (9), which controls flow of gas to control valve (10) and, therefore, to the pneumatic portion of the ventilator.

With on-off switch (3) in the ON position gas is supplied to the pneumatic portion of the ventilator and electric power is supplied to the electronic control module (5) of the ventilator. The gas switch supplies pressure to a transducer (4) which acts as an electric on-off switch. The electronically controlled solenoid valve (9) delivers a pressure signal to the pneumatic control valve (10) which opens and closes the valve (10) with a frequency of oscillation produced by the solid state timing circuit (5). The ratio of open to closed time is variable in steps of 1:1, 1:1.5, 1:2, 1:2.5, 1:3, 1:3.5, 1:4, 1:4.5, this is controlled by thumbwheel indicator-control switch (6). The ratio in use is indicated on the thumbwheel. The BPM setting is indicated on thumbwheel indicator-controller switch (7).

Pressure regulator (11), the power flow regulator, is adjustable and controls the gas pressure delivered to the control valve (10). The pressure adjusted at regulator (11) is indicated at pressure flow gauge (12). The flow gauge (12) is divided into three zones, these are:

1. LOW inspiratory flow

2. MEDIUM inspiratory flow

3. HIGH inspiratory flow

The indicator needle must be set in the low portion of the LOW zone if extremely low flows are required.

When valve (10) is activated by the timing circuit, gas is allowed to flow via venturi (13) into the bellows chamber (16). During the process of gas flow delivered to the chamber (16) the power circuit relief valve (15) parallel to the venturi (13) is actuated and closes. The increasing pressure in the bellows chamber (16) produces a pressure on the bellows (17) and compresses the bellows thus delivering the breathing gas contained in the bellows into the breathing system

The preset tidal volume of the bellows (17) may be altered by adjusting the position of the volume adjustment plate (18). Movement of the volume adjustment plate is accomplished by depressing the lock bar on volume adjustment control knob (19) and rotating the control knob. The pressure within the chamber (16) closes breathing system relief valve (21) by means of pilot line (20) as long as the pressure in the chamber (16) is greater than the pressure in the breathing system (approximate inspiratory phase time). All the gas contained in the bellows has been discharged into the anesthesia system after the bellows has been completely compressed. All further gas delivered by the venturi is now released through the venturi opening (14) to atmosphere and the pressure in the bellows chamber does not further increase.

In the event that the bellows fails to completely compress within the preset inspiratory phase time it may be necessary to increase the FLOW setting.

It is known that ventilator dials cannot be calibrated in values of inspiratory flow due to the influence of such parameters as airway resistance, total lung compliance, and equipment compliance upon the flow generated by the ventilator. Therefore, we have taken the approach of indications of low flow, medium flow, and high flow.

The expiratory phase starts when the timing circuit (5) closes valve (10) and the power circuit relief valve (15) opens simultaneously. The pressure in the chamber (16) is then released through valve (15) and bellows (17) expands until the bottom of the bellows is stopped by volume adjustment plate (18). During the expansion of the bellows the pressure in chamber (16) keeps breathing system relief valve (21) closed. The valve opens approximately when the bellows bottom has completely expanded and the excess gas is released from the breathing system.

Control of respiratory frequency (BPM) is maintained by use of thumbwheel switch (7). The control is calibrated in frequency from 01 to 99 BPM, in one BPM increments.

Control of inspiratory/expiratory phase time ratio is by means of thumbwheel switch (6). The control knob dial is calibrated in steps of 1:1, 1:1.5, 1:2, 1:2.5, 1:3, 1:3.5. 1:4, 1:4.5.

Performance

The DRAGER AV-E Anesthesia Ventilator performs as a time-cycled ventilator for the change from inspiratory to expiratory phase as well as for the change from expiratory to inspiratory phase. The independent controls of frequency, generated flow, and tidal volume facilitates the performance of an inspiratory pause time when desired. Inspiratory pause time, by definition, is a period of no flow at the end of the inspiratory phase which supports distribution of gas between anesthesia breathing system and the lungs and within the lungs themselves.

The pressure time diagram (1) shows a typical performance of the DRAGER AV-E. The solid pressure line in the diagram demonstrates the pointer movement of the system pressure gauge as a function of time. The dotted line demonstrates the imagined mean pressure within the alveoli. The volume preset in the bellows is delivered when $P_I max$ is reached. During the final period of T_{IF} an equalization of pressure between the system and alveoli takes place resulting in a decrease of system pressure and an increase of alveolar pressure until both pressures have equalized. It should be noted that system pressure and alveolar pressure are equal during the inspiratory pause time T_{IP} facilitating the possibility to determine alveolar pressure with the system pressure gauge.

The system pressure gauge itself becomes an important instrument when used in combination with a ventilator like the DRAGER AV-E. The peak pressure in the system may be effected by generated flow, airway resistance, compliance and preset tidal volume. The end inspiratory pressure, when an inspiratory pause is performed, will be effected by preset tidal volume and compliance.

The influencing parameters listed above can be separated into two different groups: parameters which are changed as a result of a re-adjustment of the ventilator and parameters which are changed as a result of a change in the patient's condition.

Diagrams II and III demonstrate changes in the reading of the system pressure gauge as a result of changes in the condition of the patient or changes within the anesthesia breathing system (II A-B) and changes resulting from alteration of the ventilator controls (III A-E). The left side diagram in each case demonstrates the same original condition, while the right side diagram indicates the effect on the pressure time pattern as a result of changes in resistance or compliance (II) or ventilator adjustment (III). It is assumed that the working pressure setting permits the bellows to reach the upper stop with all examples.

II - Changes in Patient's Condition or Patient System

II-A

Assuming that the left side of the Diagram II-A represents an original pressure pattern of ventilation, the right side indicates an increase of resistance which may be either an increase of airway resististance or a mechanical occlusion of any other gas passage. It should be noted that increase of peak pressure as a result of increase of resistance may be accompanied by no or little change of pressure during the inspiratory pause.

II-B

Diagram II-B demonstrates the effect of compliance change on the reading of the system pressure gauge; such a compliance change may be the result of a change in lung compliance or total equipment compliance. It should be noted that the increase of pressure during the inspiratory pause is accompanied by a slight increase of peak pressure only.

III - Changes in Ventilator Controls

III-A

Diagram III-A does indicate an increase of generated flow, that means: increasing the setting of flow control knob (12). It should be noted that the increase of flow increases the peak pressure during the flow period but does not effect the pressure during the inspiratory pause. A similar effect may be noticed when increasing the maximum pressure setting.

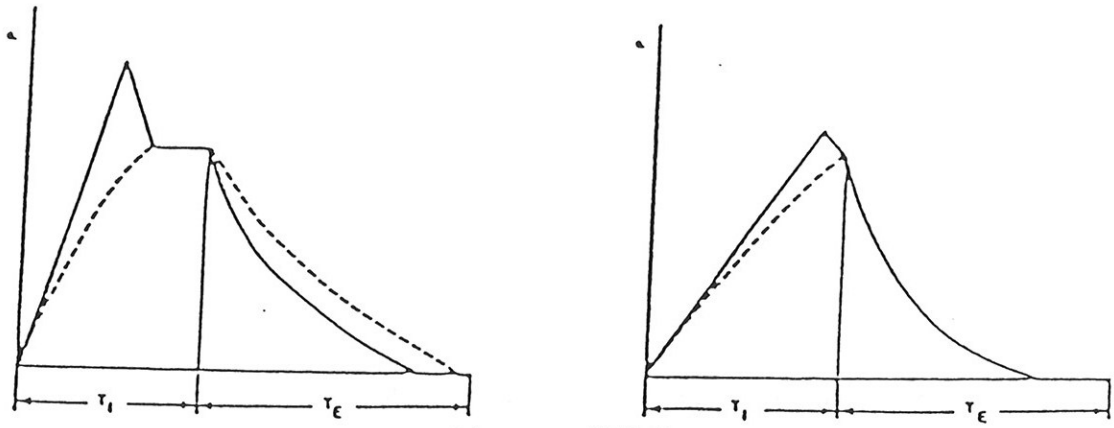

Diagram III-B

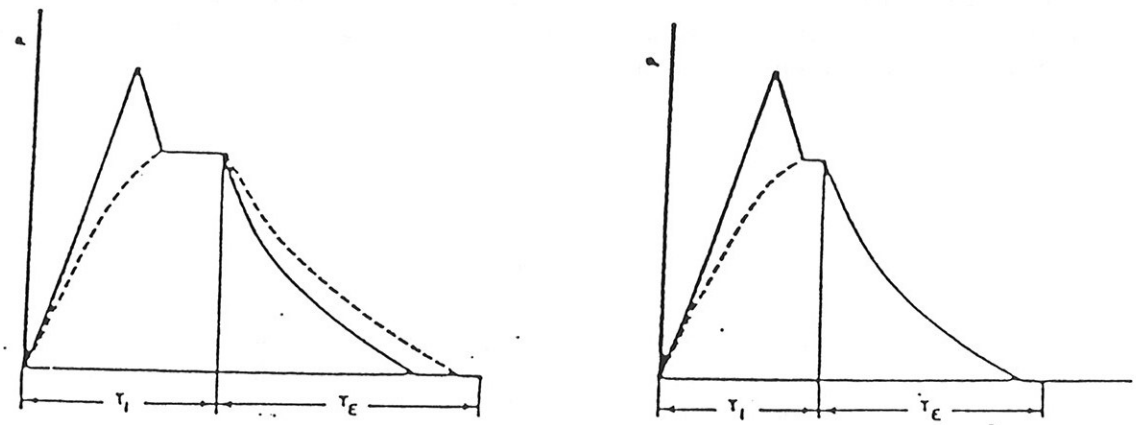

Diagram III-C

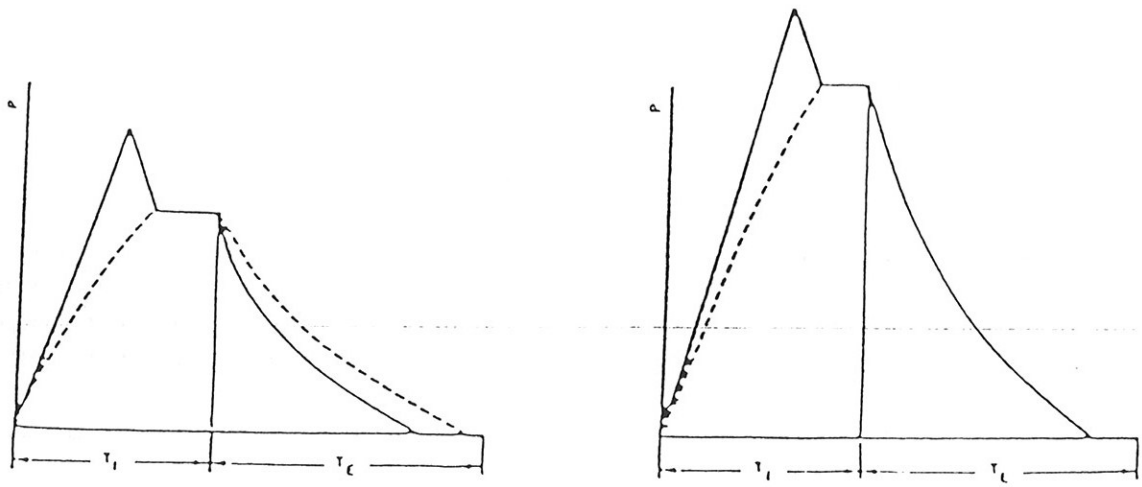

Diagram III-D

III-B

To reduce peak pressure during inspiration to a minimum, the inspiratory flow can be reduced until the difference between the peak pressure and the inspiratory pause pressure indicated at the system pressure gauge becomes a minimum (III-B). With such a performance, the inspiratory pause time becomes also a minimum and an unexpected increase in the airway resistance of the patient or other increase of resistance may result in a decrease of lung ventilation. A similar effect may be noticed when increasing the maximum pressure setting.

III-C

Diagram III-C indicates an increase in frequency. It should be noted that due to independent controls of frequency, flow and tidal volume, the pressure readings during the flow portion of the inspiratory cycle are not effected by a change in the increase of frequency, however, the period of inspiratory pause is shortened in relationship to the increase of frequency. The inspiratory pause may be eliminated completely in the event of a significant increase in frequency which would require an increase of flow in order to re-establish the inspiratory pause. It should also be noted that the respiratory minute volume is increased in exact proportion to the increase of frequency when the tidal volume is kept constant.

III-D

Diagram III-D shows the effect on the system pressure as a result of a change in tidal volume. Both peak pressure and pressure during the inspiratory pause are increased as a result of increased preset tidal volume. An increase of tidal volume will further result in a lengthening of inspiratory flow time and shortening of inspiratory pause time. The generated flow and/or maximum pressure setting may have to be increased in the event of a significant increase of tidal volume.

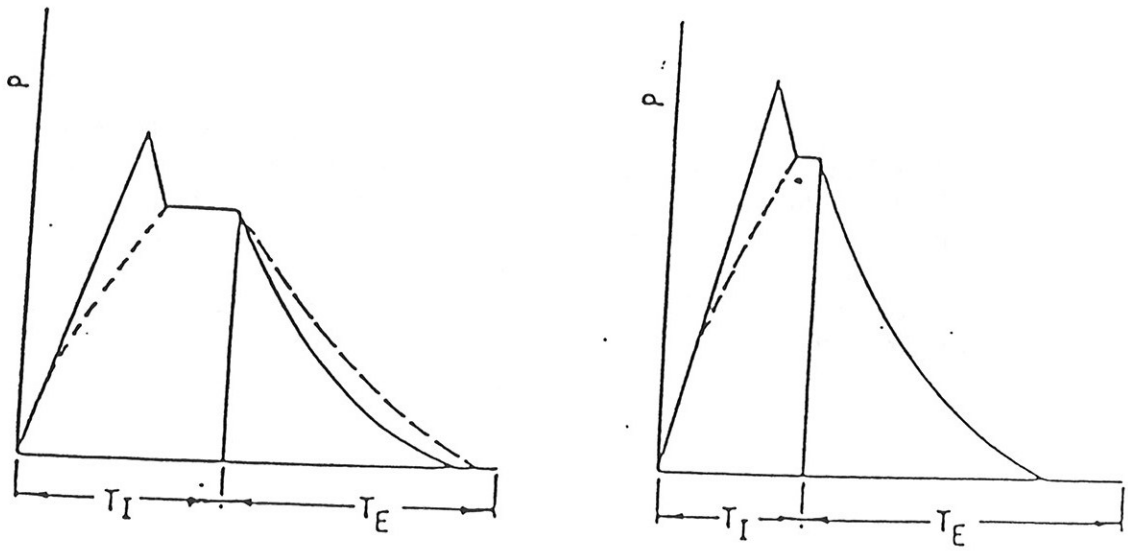

Diagram III-E

III-E

Diagram III-E shows the effect of changing the I:E phase time ratio while maintaining the same frequency. This procedure shortens the inspiratory pause time but prolongs the expiratory pause time by an equal period.

Recommended Sequence of Adjustments

1. Adjust tidal volume to desired setting.
2. Adjust breaths per minute to desired frequency.
3. Set I:E to desired ratio.
4. Turn on power switch.
5. Set manual-automatic valve to AUTO position and adjust flow setting if necessary so that bellows is properly emptied (reaches upper stop).

NOTE: For emergency shut-down, turn power switch to OFF and change manual-selector valve to BAG position.

Improper Functions & Their Causes

1. Ventilator fails to cycle with on-off switch in ON position

   Probable causes & ways of elimination:

1.1 Electrical supply shut off or not connected.
1.2 Driving gas (O_2 or AIR) supply shut off or not connected.
1.3 Frequency control thumbwheel set to "00" position.

2. Ventilator cycles but bellows maintains an expanded condition with little or no movement.

   Probable causes & ways of elimination:

2.1 Leak between bellows dome assembly and bellows housing. Re-seat bellows dome assembly and securely tighten wing nuts holding dome to housing.
2.2 Manual-automatic selector valve not in AUTO position.

3. Ventilator cycles and bellows moves but does not reach inspiratory stop.

   Probable causes & ways of elimination:

3.1 See items 2.1 and 2.2 above.
3.2 Inspiratory flow set to low. With maximum inspiratory flow, the ventilator should be capable of ventilating a respiratory minute volume in excess of 20 liters (frequency multiplied by preset tidal volume).
3.3 Liquid in bellows (hanging bellows only) or in corrugated ventilator hose.

4. Ventilator cycles but bellows does not expand completely.

Probable causes & ways of elimination:

4.1 Fresh gas flow set too low, increase flow as required.
4.2 Small leak in anesthesia breathing system; check for and correct leaks.

The manufacturer or manufacturer's representative should be contacted immediately in all cases when the ventilator does not function properly and the cause of the improper functioning cannot be easily detected and corrected.

Check-Out Procedure

1. Have ventilator connected to anesthesia system.
2. Switch manual-automatic selector valve to AUTO.
3. Close 15mm outlet at Y-piece with thumb.
4. Adjust tidal volume to approximately 1 liter.
5. Turn on power.
6. Adjust frequency to 10 cycles per minute.
7. Adjust flow to maximum of low zone.
8. Set I:E phase time ratio to 1:2.

With the settings above, the system pressure gauge shall indicate a pressure in excess of 25 cm H_2O. If this pressure is not reached, check for leaks.

Warnings

1. The electronic control module of the DRAGER AV-E (Fig. 1 & 2, item 5) is enclosed in a metal shield. The purpose of this shield is to protect the control module from transient electromagnetic radiation. The control module SHALL NOT be removed from the metal shield.

2. The DRAGER AV-E Ventilator is designed for use in conjunction with a disconnect monitor. The Narkomed 2 Anesthesia Machine includes a disconnect monitor. For all other applications the DRAGER AV-E shall be interlocked with a North American Drager DPM-S disconnect monitor.

3. Proper ventilation of the patient shall be observed by the action of the breathing system pressure gauge and by patient chest movement.

4. Never operate ventilator without bellows being properly attached.

5. A rotation of the indicator on the VOLUMETER should not be used as assurance of an adequately connected patient; the downward movement of the bellows may create a flow through the VOLUMETER even in the event of a totally disconnected patient. (hanging bellows)

6. Movement of the bellows shall not be used as an indicator of a tight system or a securely connected patient. (hanging bellows)

7. Fire Hazard: Never oil or grease any anesthesia equipment; oils and greases oxidize readily and will burn violently in the presence of oxygen.

8. Federal Law restricts this device to sale by or on the order of a physician.

9. The DRAGER AV-E is not to be used in the presence of flammable anesthetic gases or agents.

Sterilization

The bellows assembly including the bellows, the bellows dome or plate, and the ventilator relief valve are the only components in contact with the patient's breath. These components may be removed for sterilization by disengagement of two wing nuts holding the assembly to the bellows chamber. These components may be gas sterilized. Follow the sterilizer manufacturers recommended procedure to assure proper aeration of gas sterilized parts

NORTH AMERICAN DRÄGER INFORMS

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OVERCOMING THE DISCONNECT HAZARD

The use of anti-disconnect measures in anesthesia breathing circuits has some similarity to the use of seat belts in automobiles. While their daily routine use may be inconvenient and appear unnecessary, statistics indicate that once in a lifetime their use will prevent a catastrophe.

The average anesthesia breathing circuit contains approximately ten connections which are prone to a disconnect. Almost all of these connections are in configurations recommended by ANSI and ISO.

Industry, standard organizations, and professional operators of anesthesia machines have recognized the hazard of possible disconnects but it appears there is no single solution to the problem. There are three different measures recommended to reduce the risk of accidental disconnects:

1. secure locking of mated components
2. utilization of disconnect alarms
3. education of the operator of anesthesia equipment

Most of the disconnects known are reported to have taken place at the 15 mm tube connector at the Y-piece of a breathing circuit. While the unobserved occurrence of such a disconnect may be disastrous, a disconnect which is recognized by the operator of the life supporting equipment may be a beneficial alternative to the unintended extubation of the patient.

The modification of the 22 mm hose connection and bag connection to a positive locking arrangement would eliminate the use of most of the disposable circuits on the market.

It is, therefore, questionable that the problem of accidental disconnects can be eliminated by additional locking mechanisms at the connection points. There is, however, one exception, a positive locking mechanism at the 15 mm connection for the common fresh gas outlet will not affect the performance of the connection but will significantly increase its security.

Disconnects may be revealed through the use of any of three different kinds of monitors: **pressure monitors, respiratory meters, and CO_2 monitors.**

The most commonly utilized disconnect alarms monitor the pressure amplitude in the breathing system and alarm if the maximum inspiratory pressure does not exceed a predetermined value within a predetermined time. While these pressure sensitive monitors provide a high degree of safety, certain incorrect use or unusual circumstances may "fool" the monitoring device. In the event of a disconnect at the Y-piece, bed sheets or other material may partially or completely occlude the outlet of the Y-piece and thus the inspiratory flow may create a pressure high enough to exceed the monitoring pressure of the device. It is, therefore, essential to adjust the monitoring pressure at the disconnect alarm as close below the peak pressure as possible. This is contrary to the habit of most operators of anesthesia machines who leave the disconnect alarm at the lowest pressure setting. Disconnect alarms incorporated into anesthesia ventilators normally have their pressure sensing point also within the anesthesia ventilator. With such an arrangement the disconnect alarm will be "fooled" if the breathing circuit contains a manual automatic selector valve and such a valve is in the "bag" position when intended to be in the ventilator position (the ventilator operates against the dead-ended valve). It is important that the sensing point for the disconnect alarm be located within the breathing circuit itself. Unfortunately, certain breathing systems, especially the hardware for circuits accepting disposable non-rebreathing systems, do not incorporate either connection terminals for disconnect alarms or oxygen meters.

In order to guarantee the utilization of a disconnect alarm at all times when required it is essential that the on/off switch of the alarm be interfaced with the on/off switch of the ventilator.

Respiratory meters, especially if equipped with an alarm device, are an excellent measure to reveal the disconnect of a patient, however, they cannot be used with ventilators having a descending bellows during expiration. Such bellows would continue to draw room air into the bellows in the event of a disconnect and thus, once again, "fool" the alarm device.

CO_2 monitors, through the absence of CO_2, will reveal the disconnect of a patient in most cases. Unfortunately, the percentage of anesthesia machines equipped with CO_2 monitors is still relatively small.

Due to the fact that none of the recommended measures presents a complete security against disconnects, it is necessary that the operator of an anesthesia machine be familiar with the specifics of the equipment in use and the performance limitations of the incorporated safety and alarm devices.

North American Drager offers the following solutions to curtail the catastrophic results of disconnects:

The DPM-S (breathing circuit pressure monitor)

An Absorber System with disconnect alarm terminal

A Locking Mechanism for fresh gas outlets:
standard with the NARKOMED 2
optional with the NARKOMED, can be retrofitted in the field

A Bain Circuit Mount with disconnect alarm terminal

Reprints of this article, product literature or demonstrations, are available by writing to:

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