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TECHNICAL ISSUE & SERVICE SUPPORT OF 7000 ANESTHESIA VENTILATOR MULTI-VOLTAGE ELECTRONIC

Ioannis Vlachos*

Department Of Medical Physics, School Of Medicine, University Of Patras, Patras 26500, Greece., Department of Biomedical Engineering, University of West Attica, Athens 12243, Greece. *Corresponding Author

ABSTRACT Anaesthesia ventilators are an integral part of all modern anaesthesia workstations. Automatic ventilators in the operating rooms, which were very simple with few modes of ventilation when introduced, have become very sophisticated with many advanced ventilation modes. Several systems of classification of anaesthesia ventilators exist based upon various parameters. Modern anaesthesia ventilators have either a double circuit, bellow design or a single circuit piston configuration. In the bellows ventilators, ascending bellows design is safer than descending bellows. Piston ventilators have the advantage of delivering accurate tidal volume. They work with electricity as their driving force and do not require a driving gas. To enable improved patient safety, several modifications were done in circle system with the different types of anaesthesia ventilators. Fresh gas decoupling is a modification done in piston ventilators and in descending bellows ventilator to reduce th incidence of ventilator induced volutrauma. In addition to the conventional volume control mode, modern anaesthesia ventilators also provide newer modes of ventilation such as synchronised intermittent mandatory ventilation, pressure-control ventilation and pressure-support ventilation (PSV). PSV mode is particularly useful for patients maintained on spontaneous respiration with laryngeal mask airway. Along with the innumerable benefits provided by these machines, there are various inherent hazards associated with the use of the ventilators in the operating room.

KEYWORDS : Education, Anesthesia ventilators, circle system changes, hazards, working principle

IMPORTANT

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⚠CAUTION: Servicing of this product in accordance with this service manual should never be undertaken in the absence of proper tools, test equipment and the most recent revision to this service manual which is clearly and thoroughly understood.

Technical Competence

The procedures described in this service manual should be performed by trained and authorized personnel only. Maintenance should be under-taken only by competent individuals who have a general knowledge of and experience with devices of this nature. No repairs should ever be undertaken or attempted by anyone not having such qualifications.

Genuine replacement parts manufactured or sold by Ohmeda are recommended for all repairs.

Read completely through each step in every procedure before starting the procedure; any exceptions may result in a failure to properly and safely complete the attempted procedure.

List of Illustrations

Precautions

Warnings

Notice: As used in this manual, a WARNING indicates a potentially life threatening situation a CAUTION indicates a condition that may lead to equipment damage or malfunction.

The following WARNINGS and CAUTIONS are used in various places throughout this manual to appropriately inform the reader of possible hazards and problems.

Possible Explosion Hazard. Do not use in the presence of flammable anesthetics.

For protection against shock hazards, connect this equipment only to a three-wire grounded hospital grade receptacle. The three prong plug must be inserted into a properly wired three-wire receptacle. Where a two-wire receptacle is encountered, a qualified electrician must replace it with a properly grounded three-wire receptacle in accordance with the National Electrical Code. Do not, under any circumstances, remove the grounding prong from the power plug. Do not use extension cords or adapters of any type. The power cord and plug must be intact and undamaged.

The information in this manual is intended for use by personnel who have been adequately trained in the use and application of devices of this nature and have been instructed on the use of this specific equipment. Hospital administrative personnel are responsible for making certain that all operators of the instrument(s) described in this manual receive adequate training beforehand and that training courses for operators be scheduled on a regular basis. It is especially important that instruction be given for preventive maintenance as described in this manual.

When mounting the ventilator, use only Ohmeda 7000 Ventilator mounting kits. Inappropriate screws will damage internal components and may create an electrical shock hazard.

If used with an extension cord, the unit may be subject to electro-magnetic interference.

Do not, under any circumstances, perform any testing or maintenance on medical instruments while they are being used to ventilate a patient.

Disconnect power before removing the cover panel. Leave the power disconnected unless specifically instructed otherwise.

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

The alarm circuit check (Section 7.16) must be performed before the ventilator is returned to use after any service procedure.

Never use the ventilator if the jumper plug is missing; the audible alarm will malfunction. Always check to be sure that the audible alarm works before returning a unit to operation.

Electrical Shock Hazard. Do not touch exposed wires or conductive surfaces while the cover panel is removed from the ventilator unless electrical power is disconnected from the unit. Hazardous voltages are present during normal operation. Never wear a grounding wrist strap when working on an energized ventilator.

Do not use the ventilator until all the Preoperative Checkout Procedures have been performed and correct operation has been verified.

Do not connect the ventilator Exhaust directly to a vacuum source. The vacuum may remove required gases from the patient circuit.

Do not use the ventilator if it fails any part of the checkout procedure. Remove for service.

The bellows assembly should be sterilized periodically to minimize the risk of cross-infecting patients. Use a sterilization schedule which complies with the user's infection control and risk management policies.

Liquids or any foreign material trapped within the driving gas circuit of the Pop-off Valve (Port "A", Figure 4-15) and Bellows Base (Port "B" and Ports "C", Figure 4-15) can impair operation of the Pop-off Valve. Do not use the Pop-off Valve or Bellows Base if this is suspected. If complete disassembly is required to remove trapped foreign material, perform Pop-off Valve Performance Test (see Section 3.2) and Bellows Assembly Leak Test (see Section 3.3) before reuse.

Cautions

Always wear a grounding wrist strap when handling static sensitive assemblies except when working on an energized unit. Otherwise, electrostatic discharges can damage electronic components.

Only control boards with assembly revision 14 or higher can be used with this version of the 7000 Electronic Ventilator. Use of earlier version boards will result in malfunction of the ventilator.

Operation must be checked per Section 3 after performing any maintenance procedure.

Those parts suitable for ethylene oxide sterilization should, following sterilization, be quarantined in a well ventilated area to allow dissipation of residual gas absorbed by components. Follow the sterilizer manufacturer's recommendations for special aeration periods required.

Do not apply excessive force to the circuit board when removing it. Overstressing may damage the printed circuit board.

Be sure the proper voltage is selected on the power inlet module before plugging the unit into a mains receptacle.

Do not apply any compound to the pressure switches. Application of such substances may cause damage to the switch and cause malfunction of the switch.

Perform all calibration steps in the order given.

Connecting TP-20 to ground places the ventilator in a continuous gas delivery phase where the exhaust valve is continuously on (closed). If the ventilator is left on in this condition for more than one minute, overheating of the exhaust valve may occur.

1. General Inforamation

1.1 Operational Briefs

⚠WARNING: Possible Explosion Hazard. Do not use in the presence of flammable anesthetics.

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⚠WARNING: When mounting the ventilator, use only Ohmeda 7000 Ventilator mounting kits. Inappropriate screws will damage internal components and may create an electrical shock hazard.

⚠WARNING: If used with an extension cord, the unit may be subject to electro-magnetic interference.

Note: This service manual covers the variation of the 7000 Electronic Ventilator which has selectable mains voltages. Earlier variations of the 7000 Electronic Ventilator are covered in the 7000 Electronic Ventilator Service Manual Stock Number 0178-0125-000.

The Model 7000 Anesthesia Ventilator is an electronically controlled, pneumatically driven device, specifically designed for mechanical ventilation of patients during surgery under general anesthesia. The instrument consists of two major parts:

1. The Bellows Assembly* connects to both the control unit and anesthesia machine by flexible hoses, and isolates the breathing circle system from the driving gas. Provision is made for mounting the bellows assembly on top of the control unit.

   Note: A Kit, (Stock No. 0219-7518-810) is available to be used with the Modulus II Anesthesia System which permits the GMS Absorber to 7000 Ventilator bellows interface. Installation instructions are provided with the kit.

* The revised Bellows Base Assembly has a raised identification mark on the left front corner of the Base Assembly.

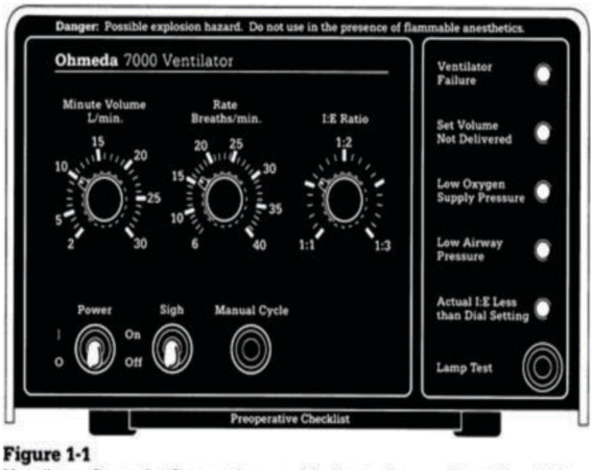

Figure 1-1
Ventilator Controls, Connections and Indicator Lamps Front Panel View

2. The Control Unit contains all the electrical and pneumatic components necessary to drive the bellows assembly according to the selected parameters, and to perform the monitoring alarm functions.

   The controls on the ventilator (Figure 1-1) are calibrated to linear scales, and are non-interactive so that changing one control setting does not affect the other control settings. They are set to the physiological parameters of Minute Volume, Breathing Rate, and Inspiratory/Expiratory ratio. From these settings, the electronic circuitry in the ventilator calculates the Flow and Tidal Volume to deliver to the patient.

Several alarm conditions are monitored by the electronic circuitry:

1. Low Oxygen Supply Pressure
2. Low Airway Pressure
3. High Airway Pressure
4. Ventilator Failure (electronics)
5. Selected Minute Volume not delivered
6. Actual I:E ratio less than dial setting

The ventilator operates from a nominal 50 psig oxygen source, usually delivered from the power outlet of an anesthesia gas machine. The driving gas consumption is approximately the same as the minute volume delivered.

1.2 Specifications

Note: Specifications are subject to change without notice.

Minute Volume:

Adult Bellows Assembly: 2 to 30 L/min.
Pediatric Bellows Assembly: 2 to 12 L/min.
Accuracy: 5% of dial setting ±2% full scale.

Rate:

Calibrated from 6 to 40 Breaths Per Minute (BPM).
Accuracy: 5% of dial setting ±1 Breath.

I:E Ratio:

Calibrated Range from: 1:1 to 1:3.
Accuracy: within 20% of dial setting at sea level.

Sigh:

Switchable On or Off sigh function.
One sigh frequency: every 64 breaths ± 2 breaths.
Sigh-Volume: 150% of tidal volume, with 1.5 liter maximum.

Manual Cycle:

Pushbutton to initiate breathing cycle manually.

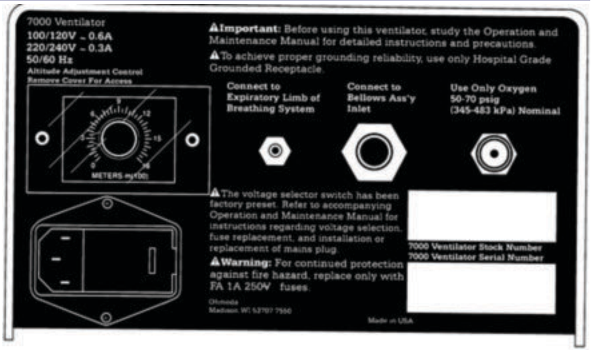

Figure 1-2
Ventilator Controls and Connections, Rear Panel View

Altitude Compensation Range:

0 to 1,800 meters above sea level.

Tidal Volume:

Calculated automatically; limited to 1.5 liter maximum.
Note: The bellows scale is an approximation of the Tidal Volume and should be used only as a guide.

Flow Rate:

4 to 60 L/min.

Alarms:

Set Volume Not Delivered.
Low Oxygen Supply Pressure.
Low Airway Pressure.
Actual I:E Less than Dial Setting.
Ventilator Failure.
Power Failure.

Ventilator Compliance:

With Adult Bellows:
Approximately 3 mL/cm H_2O.
With Pediatric Bellows:
Approximately 1.5 mL/cm H_2O.

Note: Ventilator compliance will vary depending on the length and material of the flexible hose between the control module and bellows assembly.

Driving Gas Requirement:

Oxygen at 50 - 70 psig (345 - 483 kPa) and 70 L/min flow.

Leakage Current:

There must be less than 35 microamps leakage current at 100/120 V ac or less than 70 microamps leakage current at 220/240 V ac under all conditions.
Ground resistance must be less than .15 ohms.

Dimensions:

(in centimeters)

Control unit: 22.1 wide x 23.4 deep x 13.3 high
Bellows housing: 19.0 wide x 19.0 deep x 22.2 high

(in inches)

Control Unit: 8.7 wide x 9.2 deep x 5.2 high
Bellows Housing: 7.5 wide x 7.5 deep x 8.7 high

Weight:

Control unit: 6.3 kilograms (14 pounds)
Bellows housing: 2.2 kilograms (5 pounds)

Electrical Requirements:

53 Watts at 100/120/220/240 V ac ± 10% 50/60 Hz

2. Theory of Operation

2.1 Mathematical Relationships

(Of Breathing Rate, Minute Volume, Tidal Volume, I:E Ratio, and Inspiratory Flow Rates:)

R = Rate, number of breaths per minute.

MV = Minute Volume, number of liters per minute of exchanged gas.

TV = Tidal Volume, the volume of each breath.

I = Inspiration Time, the time during which gas is supplied to the patient lungs.

E = Expiration Time, the time during which gas is exhaled from the lungs of the patient including any end expiratory pause.

I:E = I:E Ratio, the ratio of inspiration and expiration times.

Conventionally expressed as 1: number such as 1:1, 1:2, etc.

F = Flow, the actual inspiratory flow rate at any given instant expressed in liters per minute (L/min).

Given the physiological parameters of MV, R and I:E it is possible to compute TV, F, and E from the following equations:

1. TV = MV/R
2. Avg Flow = MV = (F•I)/(I+E)
   solving for F:
   F = MV(1+E/I)

   Expresses the inspiratory flow rate in terms of minute volume and the I:E ratio, which are set on the front panel.
3. I+E = 60/R
   I(1+E/I) = 60/R
   I = 60/[R(1+E/I)]

   Expresses the inspiration time in terms of the Rate and the I:E ratio, which are set on the front panel.
4. I+E = 60/R
   E = (60/R)-(60/(R(1+E/I)))
   E = 60[1(1/(1-E/I))]/R

   Expresses the expiration time in terms of the Rate and the I:E ratio, which are set on the front panel.

Consider a numerical example:

MV = 8 L/min
R = 12 BPM (Breaths Per Minute)
I:E = 1:2

We have:

TV = 8/12=0.667 liters
F = MV(1+E/I)=8(1+2) = 24 L/min
I = 60/R(1+E/I)=60/12(1+2) = 1.67s
E = 60[1-(1/(1+E/I))]/R=60[1-(1/(1+2))]/12 = 3.33s

The preceding relationships in terms of Minute Volume, Rate, and I:E Ratio are used by the control circuitry of the Ventilator to deliver the appropriate Flow.

2.2 Patient Volumes vs. Ventilator Set Volume

Several factors within the breathing system including the patient affect the delivered patient volume. The extent of these variations depend on the type of breathing system used.

1. Compliance of the breathing system reduces the volume from the ventilator that is delivered to the patient. Compliance can be defined as the volume of gas which when added to a closed system produces a unit increase in pressure. The compliance of any circle absorber system can be a significant factor because of its large internal volume. Because of this large volume, it requires more of the ventilator's delivered volume to produce a unit increase in pressure within the system.

   An approximate compliance factor for a circle absorber system with the 7000 Anesthesia Ventilator is C = 10 mL/cm H_2O. This can be used only as an approximate comparison of measured patient volumes and ventilator set volumes.

   MVpt = Patient Minute Volume
   TVpt = Patient Tidal Volume
   MVv = Ventilator set Minute Volume
   MVc = Minute Volume lost because of compliance of the system
   ΔP = Change in circuit pressure
   C = Compliance of the system
   TVc = Tidal Volume lost because of compliance of the system
   R = Rate, number of breaths per minute

   $MVpt = MVv - MVc = MVv - C \bullet \Delta P \bullet R$

   or:

   $$TVpt = \frac{MVv}{R} - TVc = \frac{MVv}{R} - C \bullet \Delta P$$

2. Fresh Gas Flow into the breathing system during inspiration adds to the volume from the 7000 Anesthesia Ventilator that is delivered to the patient.

   MVpt = Patient Minute Volume
   TVpt = Patient Tidal Volume
   MVv = Ventilator set Minute Volume
   MVfgf = Minute Volume total Fresh Gas Flow
   fgf = Total Fresh Gas Flow
   R = Rate, number of breaths per minute

TVfgf = Tidal Volume total fresh gas flow
(I:E) = I:E ratio 1:2 so E/I = 2

$$MVpt = MVv + MVfgf = MVv + \frac{fgf}{(1 + E/I)}$$

or:

$$TVpt = \frac{MVv}{R} + TVfgf = \frac{MVv}{R} + \frac{fgf}{R(1 + E/I)}$$

3. Leaks in the breathing system during inspiration reduce the volume from the ventilator delivered to the patient. This factor is usually small, however, it should be considered.

MVpt = Patient Minute Volume
TVpt = Patient Tidal Volume
MVv = Ventilator set Minute Volume
MVl = Minute Volume lost to leaks
TVl = Tidal Volume lost to leaks
Vl = Leak rate at peak inspiratory pressure
R = Rate, number of breaths per minute
(I:E) = I:E ratio 1:2 so E/I = 2

$$MVpt = MVv - MVl = MVv - \frac{Vl}{2(1 + E/I)}$$

or:

$$TVpt = \frac{MVv}{R} - TVl = \frac{MVv}{R} - \frac{Vl}{2R(1 + E/I)}$$

Example:

To determine the measured patient Minute Volume or Tidal Volume expected from the 7000 Anesthesia Ventilator attached to a circle absorber breathing system, make the following calculations:

Ventilator Setting: Minute Volume	=	8 L/min
Rate	=	10 min
I:E	=	1:2
Fresh Gas Flow (fgf)	=	4 L/min
Change in Circuit Pressure (ΔP)	=	30 cm H_2O
Breathing Circuit Leak (V)	=	500 mL/min at 60 cm H_2O

Breathing circuit leakage is assumed to be directly proportional to pressure:

$$Vl = \frac{500\ mL/min}{60\ cm\ H_2O}(30\ cm\ H_2O) = 250\ mL/min$$

$$Mvpt = MVv - MVc + MVfgf - MVl$$

$$= MVv - C \bullet \Delta P \bullet R + \frac{fgf}{(1 + E/I)} - \frac{Vl}{2(1 + E/I)}$$

$$= 8\ L/min - \frac{(10\ mL/cm\ H_2O)(30\ cm\ H_2O)(10/min)}{(1000\ mL/L)} + \frac{4\ L/min}{(1 + 2)} - \frac{250\ mL/min}{2(1 + 2)1000}$$

$$= 84\ min - 3\ L/min + 1.33\ L/min - .042\ L/min$$

Patient Minute Volume (MVpt) = 6.29 L/min

or:

$$TVpt = \frac{MVv}{R} - TVc + TVfgf - TVl$$

$$= 800\ mL - 300\ mL + 133\ mL - 4.2\ mL$$

Patient Tidal Volume (TVpt) = 629 mL of each breath.

2-2

2.3 Pneumatic Operation

(See Figure 2-1)

The driving gas (oxygen at 50 psig nominal) connects to the ventilator enroute to the pressure regulator. The output of the regulator is set for 38 psig ± 0.50 psig at 24 L/min flow, and connects directly to the flow control solenoid valves.

The flow control valves are electronically controlled during the inspiratory time to direct gas flow through calibrated orifices. The orifices are calibrated for flows of 2, 4, 8, 16 and 32 L/min. The range of flow selection is 4 L/min to 60 L/min, in 2 L/min increments.

Both the pressure within the patient breathing circuit and the pressure generated from the settings of the control module act upon the bellows. The bellows assembly can be thought of as the interface between the anesthesia gas circuit and the control module driving gas circuit, even though the two circuits are isolated from each other.

Note: The anesthesia machine's oxygen flush valve is used to inflate (extend) the bellows before initiation of patient ventilation. For purposes of discussion, it will be assumed that ventilation begins with the bellows extended.

During the inspiratory phase, the control module delivers its pre-established gas flow into the area between the bellows and the transparent bellows housing. As the volume of gas increases within the bellows housing, pressure is exerted on the bellows which in turn exerts pressure in the patient breathing circuit, including the patient's lungs. When the pre-established gas volume has been delivered into the bellows housing, the process is reversed and the expiratory phase begins.

During the expiratory phase, gas flows from the patient breathing circuit into the inside of the bellows. The flow is a combination of fresh gas flow from the anesthesia machine and patient exhaled gas. The bellows expands, thus exerting pressure on the area between the bellows and the bellows housing.

There are three valves which are of importance during the inspiration-expiration cycle. One of these is the driving gas exhaust valve located in the control module. This valve remains closed during the inspiration phase when gas is being delivered into the bellows housing. It opens, however, during the expiratory phase to provide an outlet for the driving gas being displaced from the bellows housing.

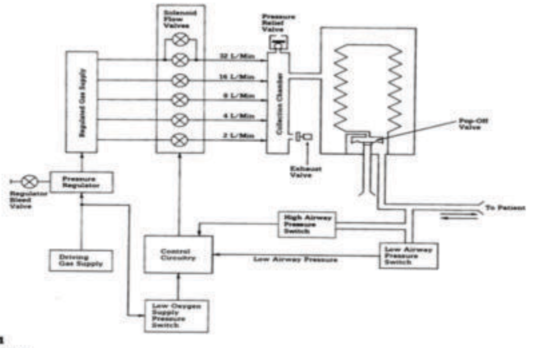

Figure 2-1
Block Diagram

The pressure relief valve is located in the control module. This valve is of the "dead weight" type. A ball is held against a seat by a weight. When the pressure in the driving gas circuit is great enough to overcome the closing force of the weight, the valve opens and gas flows from the driving gas circuit to the atmosphere. This acts to limit the maximum pressure in the driving gas circuit, and therefore limits the maximum pressure that is transferred to the patient circuit.

The other valve is the pop-off valve located within the bellows. This valve remains closed unless the volume of gas delivered into the bellows exceeds the volume which the bellows can hold. When the bellows cannot extend any further and maximum pressure is being exerted within, the pop-off valve opens and the excess gas is vented through the ventilator exhaust tube. The opening pressure of the pop-off valve is approximately 2.5 cm H_2O.

It can be seen then that both gas circuits have a valve mechanism which exhausts excess gas volume. These valves help to keep the gas volume balanced during exhalation and inhalation.

There are three pressure switches located in the control module. The Low Oxygen Supply Pressure Switch monitors the supply pressure. The Low Airway Pressure Switch and High Airway Pressure Switch monitor the patient circuit pressure.

2.4 Electronic Circuit Detailed Description

(Refer also to full schematic in Section 8)

A. Control Circuit

Minute Volume: Refer to Figure 2-2. The MV has a calibrated range of 2-30 L/min. A series arrangement of MV potentiometer RP1 with RJ, R77, and a 2 volt reference voltage, provides a linear signal scaled to 0.067 volts/L/min.

U5D is an amplifier in a noninverting configuration. In the circuit, voltage is applied to the (+) input, and a fraction of the output signal, is fed back to the (-) input through R53 and R54. The resistors R53 and R54 determine the gain of the circuit.

Note: Potentiometers RI, RJ and RK compensate for errors in the control potentiometers.

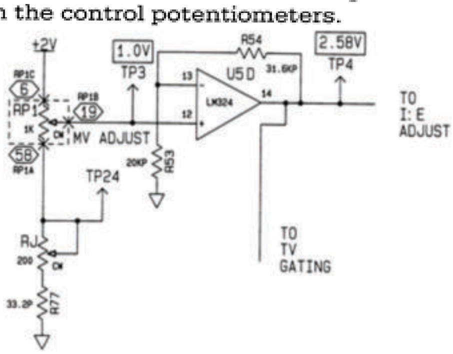

Figure 2-2
Minute Volume Circuit

I:E Ratio: See Figure 2-3. The flow voltage is produced by multiplying MV by (1 + E/I). A series arrangement of I:E potentiometer RP3 with RK, and R112 provides a linear range of I:E from 1:1 to 1:3. The resultant output at TP-13 represents a flow corresponding to the MV and I:E setting.

U22B is an amplifier in an inverting configuration. In the circuit, the (+) input is grounded and the signal is applied to the (-) input through R55, with feedback returned from the output R56. The resistors R55 and R56 determine the gain of the circuit.

Note: Potentiometers RI, RJ, and RK compensate for errors in the control potentiometers.

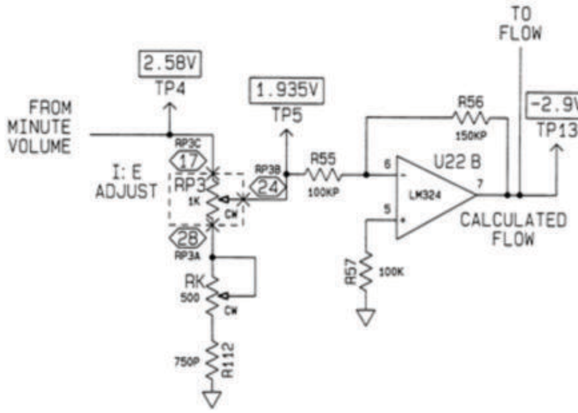

Figure 2-3
I:E Ratio Circuit

Rate: See Figures 2-4, 2-5, and 2-6. The Rate Control has a calibrated range from 6-40 BPM. A series arrangement of the Rate potentiometer RP2 with RI, R111, and a reference of 2 volts provides a linear signal scaled to 0.05 V/BPM.

Note: Potentiometers RI, RJ and RK compensate for errors in the control potentiometers.

U22A is a scaler and multiplier in an inverting configuration. In the circuit, the (+) input is grounded and the signal is applied to the (-) input through R64, with feedback returned from the output through R65. The resistors R64 and R65 determine the gain of the circuit.

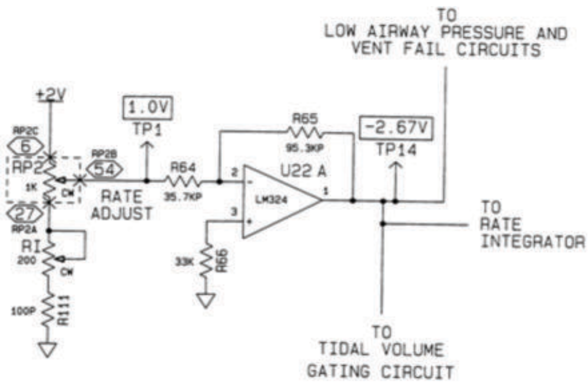

Figure 2-4
Rate Scaler Circuit

Potentiometer RM calibrates the rate of integration. U23 is a solid state switch that resets the integrator. The voltage is integrated on capacitor C12 in the feedback loop of Op-amp U22D.

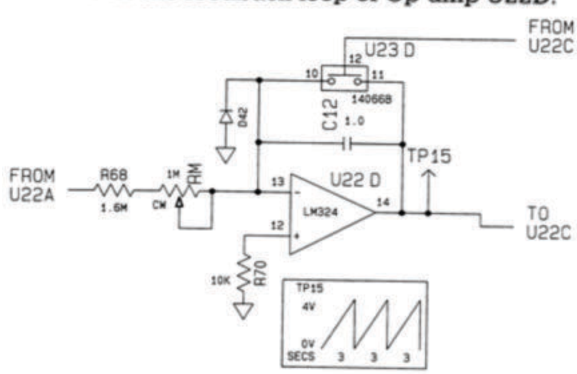

Figure 2-5
Rate Integrator Circuit

U22C compares the ramp voltage from U22D to a fixed voltage of four volts which is set by R73 and R72. When the voltages become equal, the comparator changes state. AND gate U11C adjusts the signal from an analog voltage level to a digital voltage level. The Manual Cycle function can be initiated only during the expiratory phase. Depressing the front panel Manual Cycle pushbutton (SW4) connects a negative voltage to comparator U22C which resets integrators U22D and U17 starting a new rate and flow ramp.

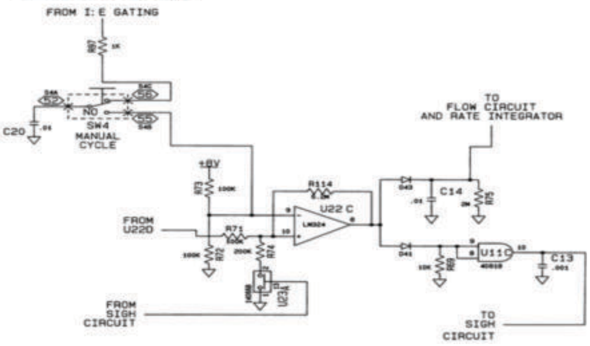

Figure 2-6
Rate Analog to Digital Circuit

Bus: The clock U1 oscillates at approximately 1500 Hz and drives an auto-cycling binary counter U7. The frequency of the clock is adjusted by potentiometer RA. Ten of the counter (U7) outputs are used for the timing functions. Five of the outputs (Q1 to Q5) drive the solenoid valves through latch U8 and transistor array U20. These five outputs correspond to binary counts of 2, 4, 8, 16 and 32, which also correspond to the flow values of 2, 4, 8, 16 and 32 L/min. The 6-low outputs (Q1 to Q6; binary 1, 2, 4, 8, 16, 32) drive a digital to analog converter (DAC) U2C. This converter develops the signal that is used for delivery of the actual flow. The 9 outputs (Q1 to Q9; binary 1, 2, 4, 8, 16, 32, 64, 128, 256) of the counter drive another DAC-U12A (via latch U9 and U14) which is the Tidal Volume generator circuit. Its output is the calculated Tidal Volume. An additional use of the 256th count is to cause the audio and the visual alarms to beep and blink by toggling the alarm pulser/driver circuit U21. The 512th count is used for resetting integrators U5B (Tidal Volume limit check) and U4 (Tidal Volume gating).

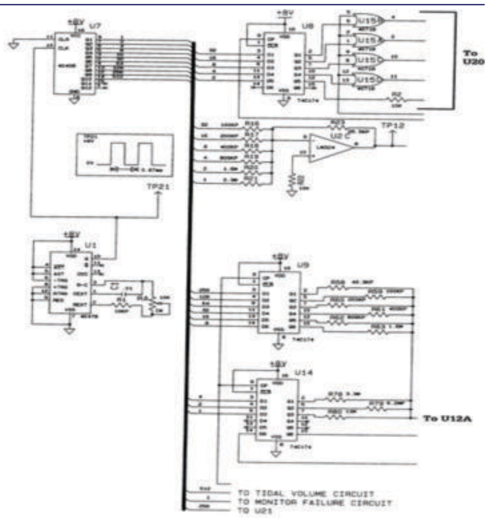

Figure 2-7
Clock Circuit

Flow: See Figure 2-8. Comparator U2D compares the flow voltage against a staircase voltage from DAC U2C. (The output span of the negative staircase is such that the Flow voltage is always limited to the equivalent of 63 L/min as a maximum value). When the two voltages at the inputs of U2D are equal the output of the comparator goes high, enabling latch U8.

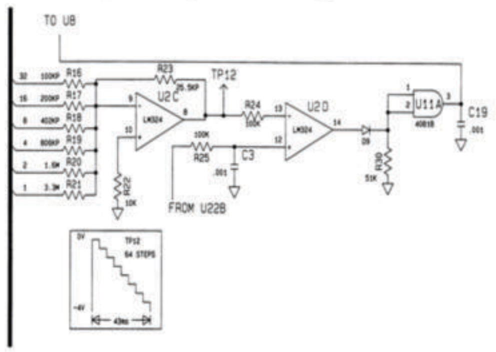

Figure 2-8
Flow DAC Circuit

See Figure 2-9. (There are 5 AND gates and 5 OR gates. One of the OR gates is made up of R2 and D1.) The valves stay open as long as the AND gates are enabled by U2A during the inspiration phase.

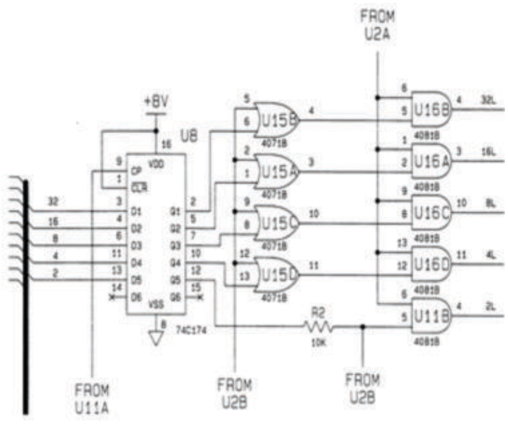

Figure 2-9
Flow Gating Circuit

See Figure 2-10. U20 driver is an array of Darlington pairs that interfaces the low current electronics to the high current solenoid valves. The Darlington Transistor Array has a 10.5 K ohm series input resistor which operates directly from CMOS or PMOS outputs utilizing supply voltages of 6 to 15 V.

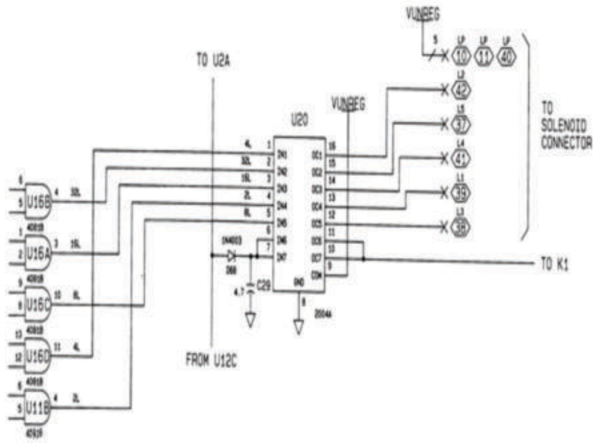

Figure 2-10
Flow Valve Driver Circuit

See Figure 2-11. The ramp rate of the integrator U17 is adjusted by potentiometer RO. For MV = 20, R = 20 and I:E = 1:1, TP-17 (output of comparator U12C) is adjusted for a 50% duty cycle. When the integrated voltage equals the calculated Tidal Volume voltage from DAC U12B, Comparator U12C output goes negative to disable the AND gates and thereby ends the inspiration phase. The output of U12 pin 8 is fed back to U17 as positive feedback to provide hysteresis. When the comparator output switches negative, the positive feedback causes the output of integrator U17 to rise sharply. This ensures that the comparator output will stay low, thereby eliminating glitches. By this action, valves are opened and closed for a duration which compensates for inaccuracies between the settings of the dials, the valves, and their related binary flow control circuitry. Potentiometer RN compensates for tolerance in the altitude potentiometer. The adjustment is such that the voltage at TP-6 is 80% of the voltage at TP-7 with the altitude dial set at 0 meters.

U6B converts the digital flow enabling signals to an analog signal for the altitude compensation scaling.

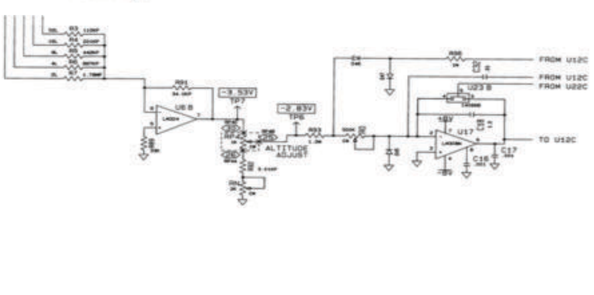

Figure 2-11
Flow DAC and Altitude Adjust Circuit

Tidal Volume: See Figure 2-12. The generation of the Tidal Volume signal is initiated by applying the Rate voltage from U22A pin 1 to integrator U4. The signal is integrated, then compared to the MV voltage from U5D at comparator U5A. When the two voltages are equal, the output of U5A goes high. Through D12 and U11D this enables latches U9 and U14 to load the binary count present at their inputs.

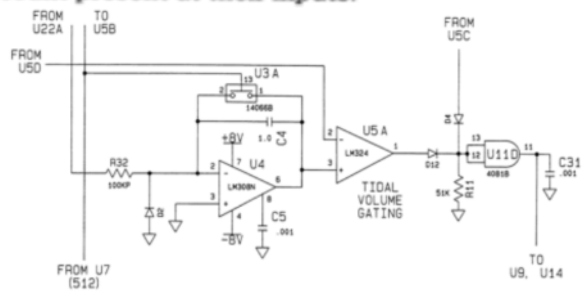

Figure 2-12
Tidal Volume Gating Circuit

See Figure 2-13. Integrator U5B is a free running integrator which is reset by the 512th count of counter U7. The integrator is kept reset until the 1024th count when the line goes low. At this instant a reference voltage begins integrating and is compared at U5C with a second reference voltage. The second reference voltage level corresponds to a 1.5 Liter Tidal Volume voltage level at U12B.

When the integrated voltage at U5B rises above the second reference voltage at U5C, the comparator output (U5C pin 8) goes high.

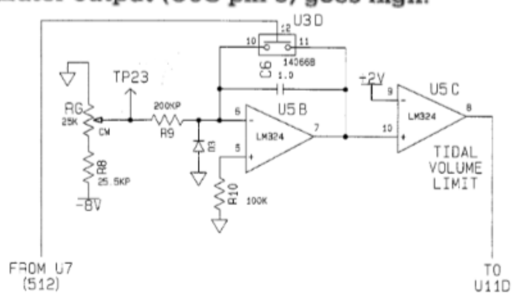

Figure 2-13
Tidal Volume Limit Circuit

See Figure 2-14. If the OR gate (diodes D4, D12) output is not already high, then the binary count from U7 at this instant will be loaded into latches U9 and U14. This count represents the maximum Tidal Volume of 1.5 liters. If the DAC U12A output rises above the reference voltage at comparator U12D an alarm of Set Volume Not Delivered comes on via the alarm pulser/driver U21.

When the two input voltages are equal the comparator U5A output goes high, which through OR gate U11D latches the count from counter U7 into the latch U9 and U14.

This count is a digital representation of the Tidal Volume. The count is converted to an analog signal by the DAC U12A and is used to determine the inspiratory time by comparator U12C.

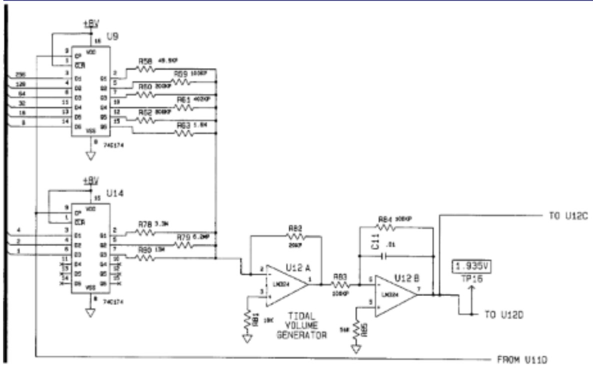

Figure 2-14
Tidal Volume Generator Circuit

See Figure 2-15. If the DAC U12A output rises above the reference voltage at comparator U12D an alarm of Set Volume Not Delivered comes on via the alarm pulser/driver U21. When the two input voltages are equal the output of the comparator U2D enables latch U8. The counts at that instant are latched in and it represents the binary value of the flow rate. This is used to drive the binary weighted valves through the OR gate U15 and AND gate U16. The AND gate is enabled during inspiration time by the output of comparator U12C through level shifter U2A. The binary signal driving the flow valves is also converted to analog signal through DAC U6B. This "flow" signal is compensated for altitude and integrated by integrator U17. This integrated signal corresponding to the "actual volume" is compared by comparator U12C with the calculated Tidal Volume from DAC U12A and when the two are equal the output of the comparator goes low and disables the AND gate U11C, which shuts off the solenoid valves, ending the inspiratory phase. At this point there is no flow (expiratory phase), which continues until the rate comparator U22C resets the flow integrator U17 and a new respiratory cycle is initiated.

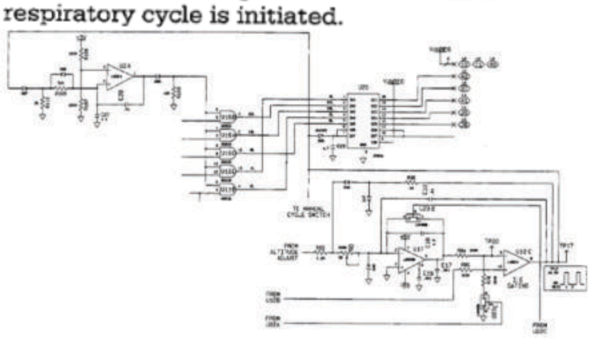

Figure 2-15
I:E Gating Circuit

Exhaust Valve: See Figure 2-16. The start of an inhalation is coincident with the start of integration of rate integrator U22D and flow integrator U17. At this time, the output of comparator U12C is at logic 1. Transistor driver U20 inverts this signal to a low and causes the exhaust valve to energize (close) through the closed contacts of Relays K1 and K2. When the actual Tidal Volume voltage equals the calculated Tidal Volume voltage at comparator U12C, the output of U12C goes low. The exhalation period begins, and the exhaust valve de-energizes (opens). The exhaust valve stays open until integrators U22D and U17 are reset. They are reset by the rate integrator U22D voltage rising above a reference voltage at comparator U22C. This causes a new respiratory cycle to start. During the exhalation phase the output of U20 no longer holds the cathode of zener diode D14 low.

If VUNREG is sufficiently high, approximately 24 V dc or greater, and there is a continuous circuit through the exhaust valve, K1, and K2, integrator U6C is reset by analog switch U3C.

If the reset signal does not appear, the output of integrator U6C continues to increase, causing the output of comparator U6D to go low. When U6D pin 14 goes low, relay K1 de-energizes, opening its contacts and the exhaust valve. This signal through R39 and D18 inhibits the reset pulses from occurring, and through comparator U6A activates the Ventilator Failure alarm after 2 to 3 breaths. These components form the exhaust valve lockout circuity. The rate of increase of integrator U6C is adjusted with potentiometer RH. The waveform at TP-18 (output of integrator U6C) has a rate of increase so that the peak voltage equals 0.50 volts for R = 20 BPM.

If a patient circuit pressure greater than approximately 65 cm H_2O occurs, the contacts of the patient over pressure switch close, energizing the High Pressure Board, the Set Volume Not Delivered lamp and relay K2. When K2 energizes the normally closed contacts open and interrupt the exhaust valve circuit. The exhaust valve opens to relieve the high pressure condition. When the high pressure condition is relieved, the over pressure switch resets and re-energizes relay K2. This stops the alarm condition and reconnects the exhaust valve circuit. The ventilator will now operate normally for the next breath. However if the pressure is not relieved and the alarm condition remains, the Ventilator Failure Alarm will activate after two to three breaths.

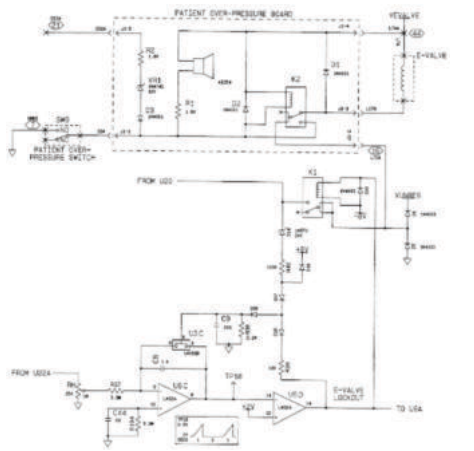

Figure 2-16
Exhaust Valve Lockout Circuit

Sigh: See Figure 2-17. This circuit increases the inspiration and expiration times by 50% when selected. The Sigh Switch on the front panel controls the sigh counter (U13). When the Sigh switch is on, the sigh counter U13 counts 64 pulses, corresponding to 64 respiratory cycles. Every time the output of U11C (Rate) goes high to start a new respiratory cycle, the sigh counter is advanced one count. On the 64th count a logic "1" appears at the output of the sigh counter which enables analog switches U23 A and C. With the analog switches closed, the slope of the Rate and Flow ramps at comparators U22C and U12C (respectively) decreases to sixty-six percent of the normal values. This causes the Rate and Flow comparators to take longer to change state, effectively increasing the length and Tidal Volume of the respiratory cycle. At the end of the inspiratory phase of the 64th breath, U13 is clocked and the outputs go to binary 65, i.e. outputs Q1 and Q7 are both high and therefore R67 pulls the D6 input of U14 high. When the binary values for the next breath are clocked into U9 and U14, the high signal at D6 of U14 is clocked through to the Q6 output of U14 and U13 is reset. With Rate = 40, the time between two sigh breaths is approximately 1 minute 34 seconds.

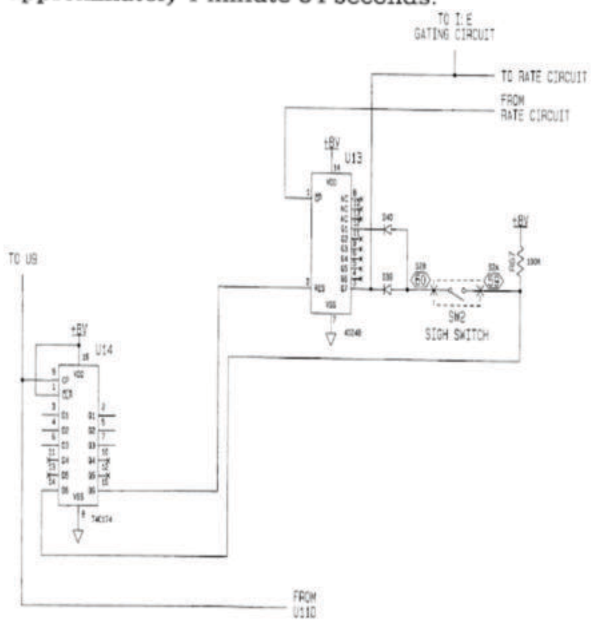

Figure 2-17

Sigh Circuit

Alarm System

See Figure 2-18. All alarms except Actual I:E Less than Dial Setting Monitor Failure and Power Failure are pulsating alarms whose frequency is dependent on the Q9 output of counter U7. Diodes D21-D24 cause this action, by blanking the inputs to invertor U21 every 256th count.

The 512th count is used for resetting integrators U5B (Tidal Volume limit check) and U4 (Tidal Volume gating).

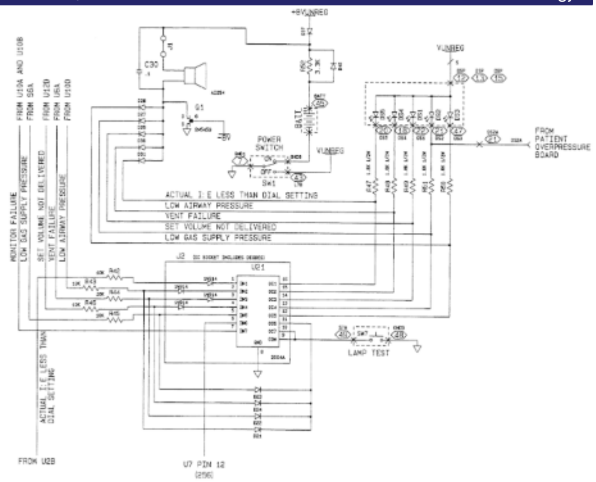

Figure 2-18

Alarm Driver Circuit

Ventilator Failure
(Pulsating red lamp and audio tone)

See Figure 2-19. The alarm is activated if the exhaust valve fails to open during the expiratory phase or the exhaust valve is disabled for 2 to 3 breaths due to continuous high pressure conditions.

Note: See exhaust valve description in this section for additional information.

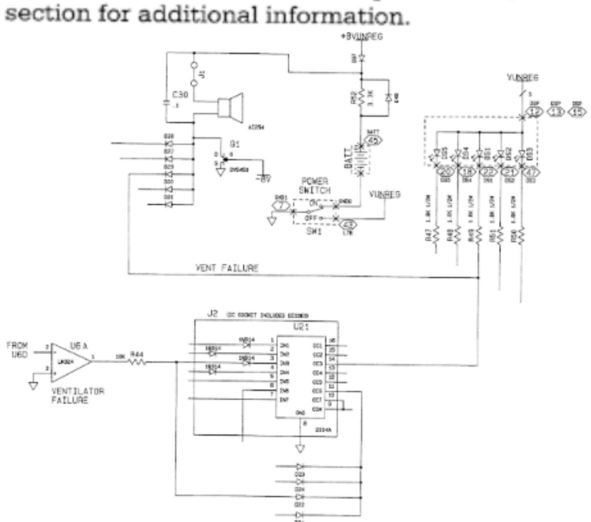

Figure 2-19

Ventilator Failure Alarm Circuit

Set Volume Not Delivered
(Pulsating red lamp and audio tone)

See Figure 2-20. The Tidal Volume is limited to 1.5 liters maximum, but when the Minute Volume and Rate settings call for a Tidal Volume greater than 1.5 liters the output of integrator U5B rises above the reference voltage at comparator U5C, causing the output of U5C to go high. If the output of the OR gate formed by D4 and D12 is not high then the count at counter U7 at this instant will be loaded into latches U9 and U14 by the high signal from U5C. This latched count represents the maximum Tidal Volume. Op amp U12A and U12B are

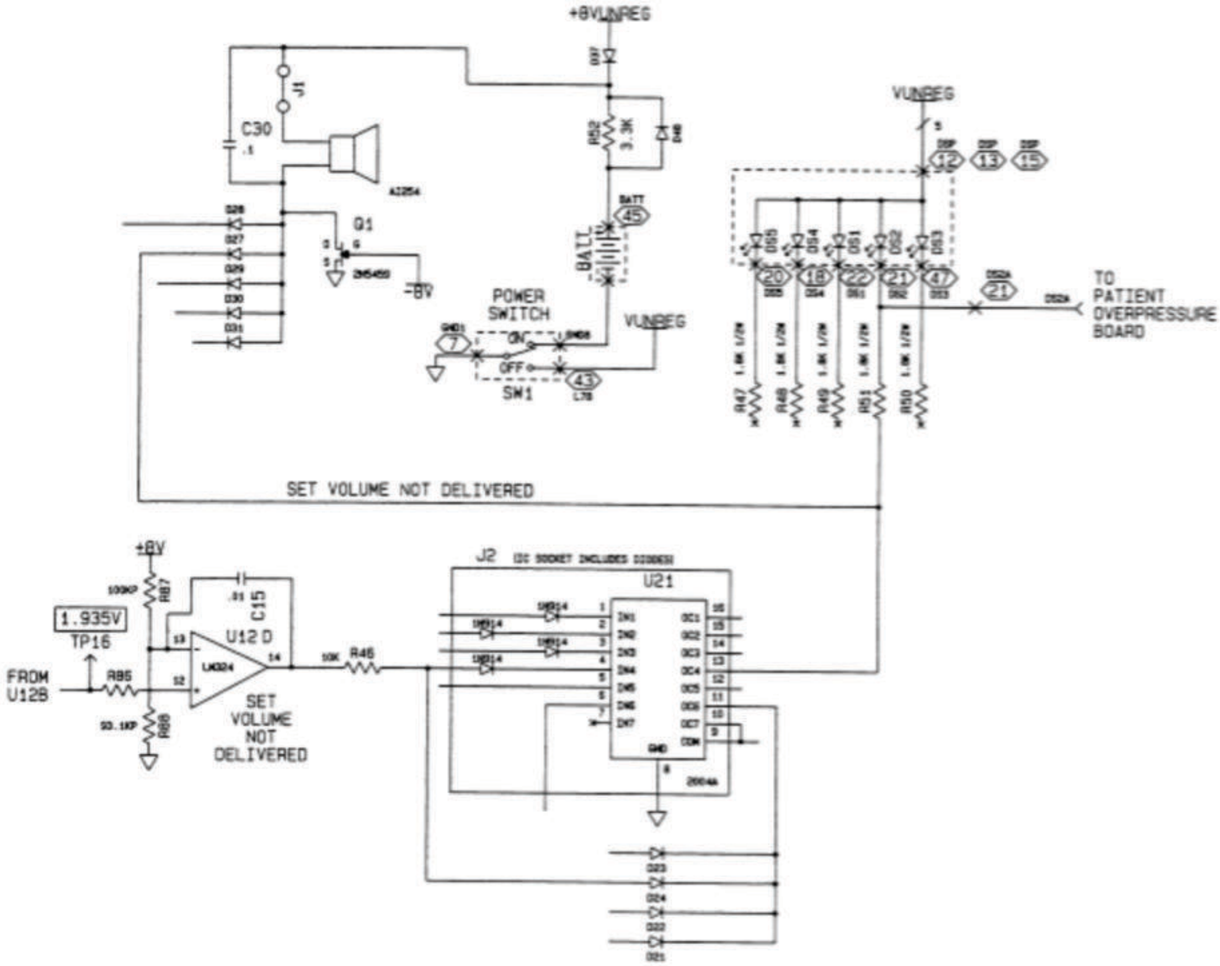

Figure 2-20
Set Volume Not Delivered Alarm Circuit

Actual I:E Less than Dial Setting (Continuous red lamp and audio tone)

See Figure 2-21. If a flow greater than 60 L/min is called for by the control setting, the calculated flow voltage from U22B will exceed the reference voltage at comparator U2B. The output of this comparator via OR gates U15A, B, C, D, and diodes D10, and D1, turns on all solenoid flow valves. This also activates a lamp and audio alarm via the alarm pulser/driver U21.

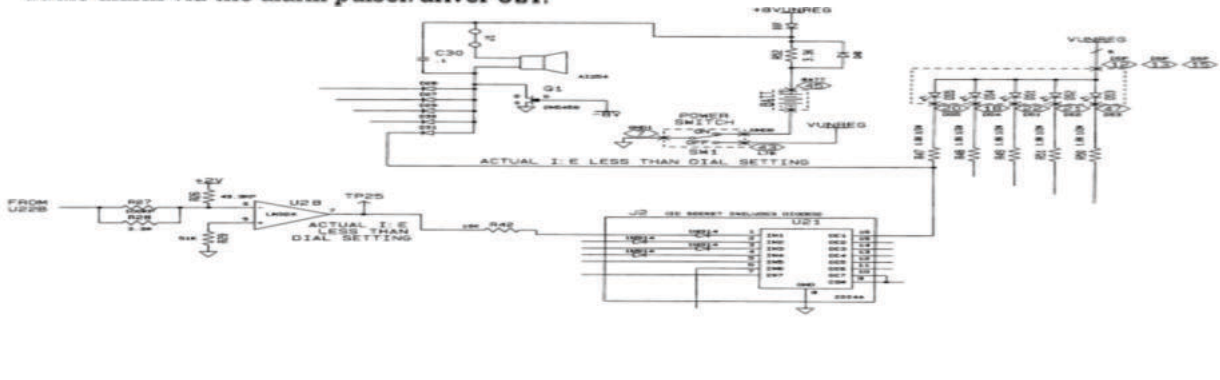

Figure 2-21
Actual I:E Less Than Dial Setting Alarm Circuit

Low Oxygen Supply Pressure (Pulsating red lamp and audio tone)

See Figure 2-22. The pressure regulator operates from a nominal supply pressure of 50 psig. A supply pressure switch SW6 remains closed at this pressure. If the supply pressure drops below approximately 35 psig, the switch opens and activates the Low Oxygen Supply Pressure alarm via the alarm pulser/driver U21.

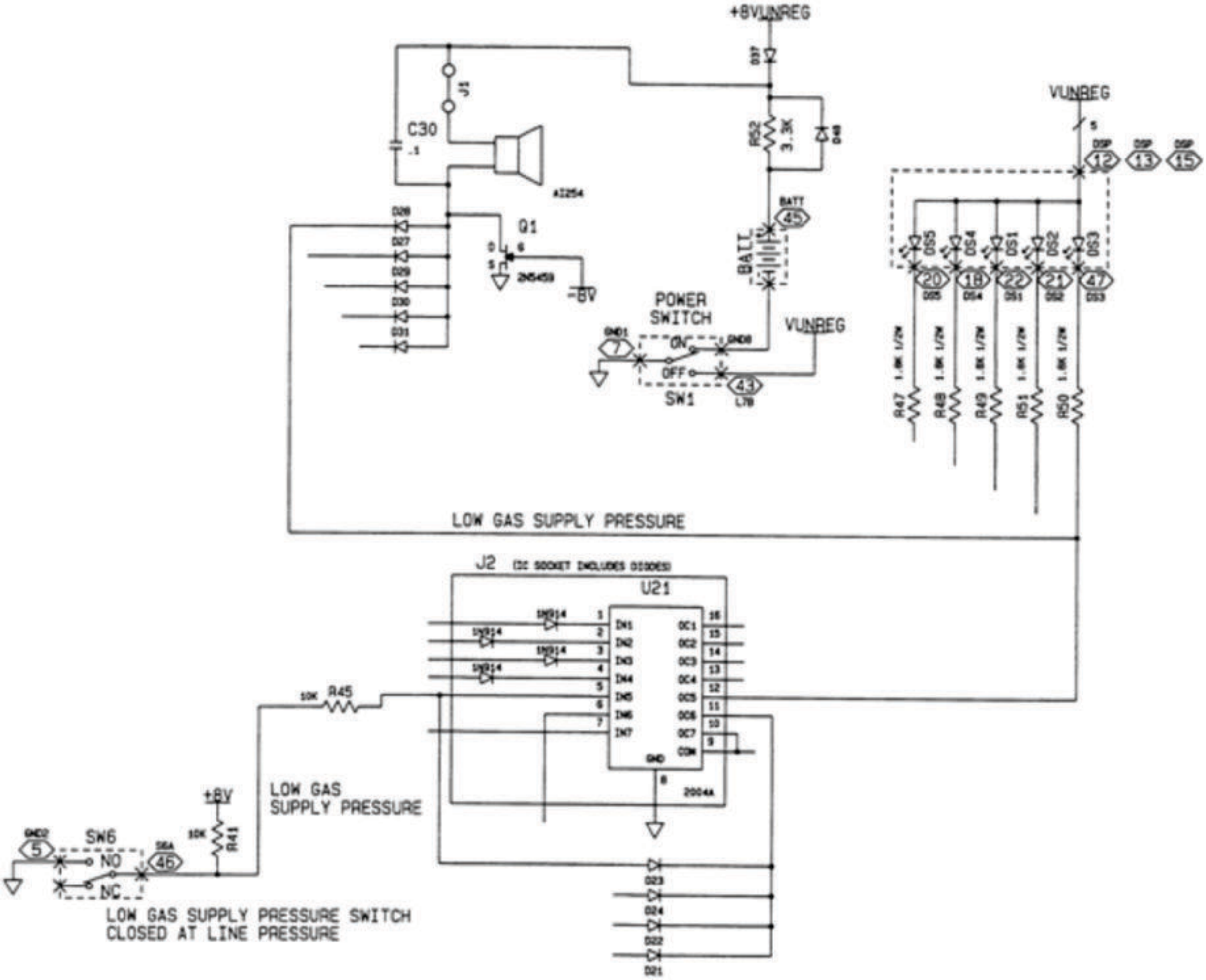

Figure 2-22
Low Oxygen Supply Pressure Alarm Circuit

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Low Airway Pressure
(Pulsating red lamp and audio tone)

See Figure 2-23. The pressure is monitored at a distal sensing tee by a pressure switch in the control unit. At pressures below 7 cm H_2O the switch stays open; otherwise, it is closed and transmits an enable signal to the analog switch U3B which resets integrator U10C. If for two breaths there is no switching action, integrator U10C integrates the Rate voltage to a value above the reference voltage at comparator U10D. This causes the Low Airway Pressure alarm to activate via the alarm pulser/driver U21. The ramp rate of integrator U10C is adjusted by potentiometer RL. The waveform at TP-19 (output of integrator U10C) for Rate 20 has a voltage of 1.0 V at 3 seconds.

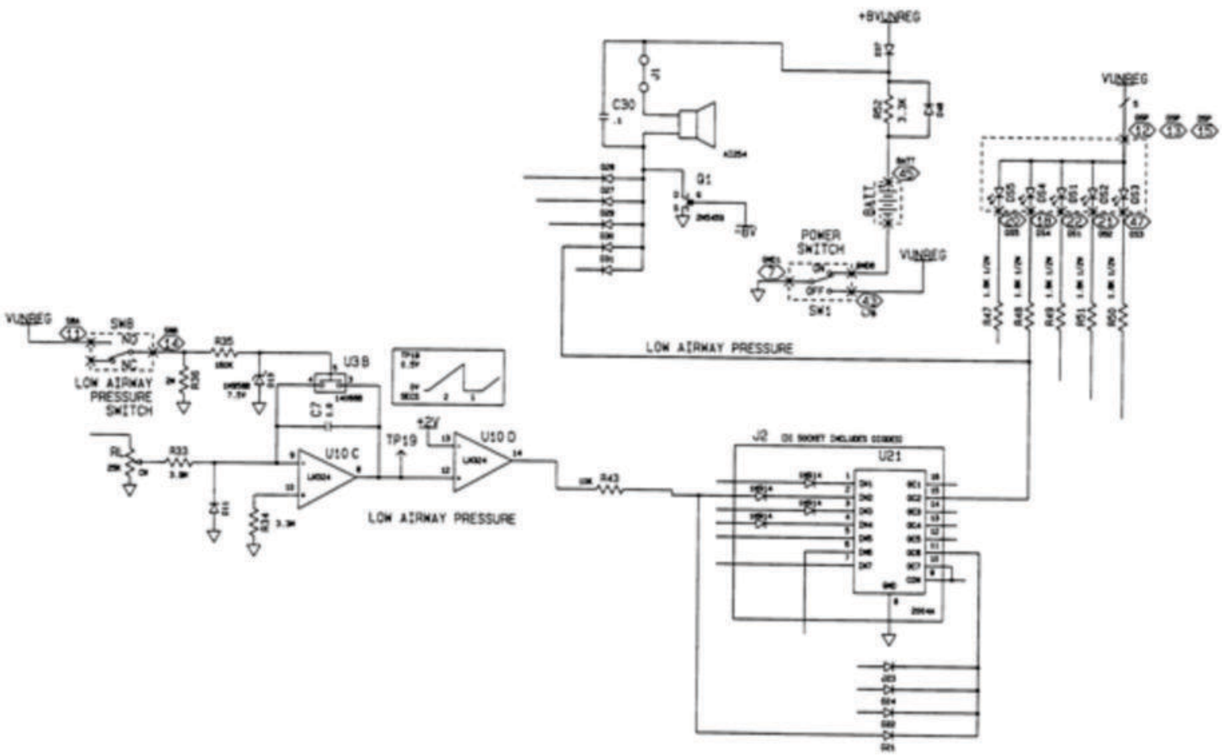

Figure 2-23
Low Airway Pressure Alarm Circuit

Lamp Test
(Continuous red lamp and audio tone)

See Figure 2-24. The front panel lamp test switch (when depressed) causes all the lamps and the audio alarm to turn on. All outputs of the alarm pulser/driver U21 are taken low by the switch to accomplish this.

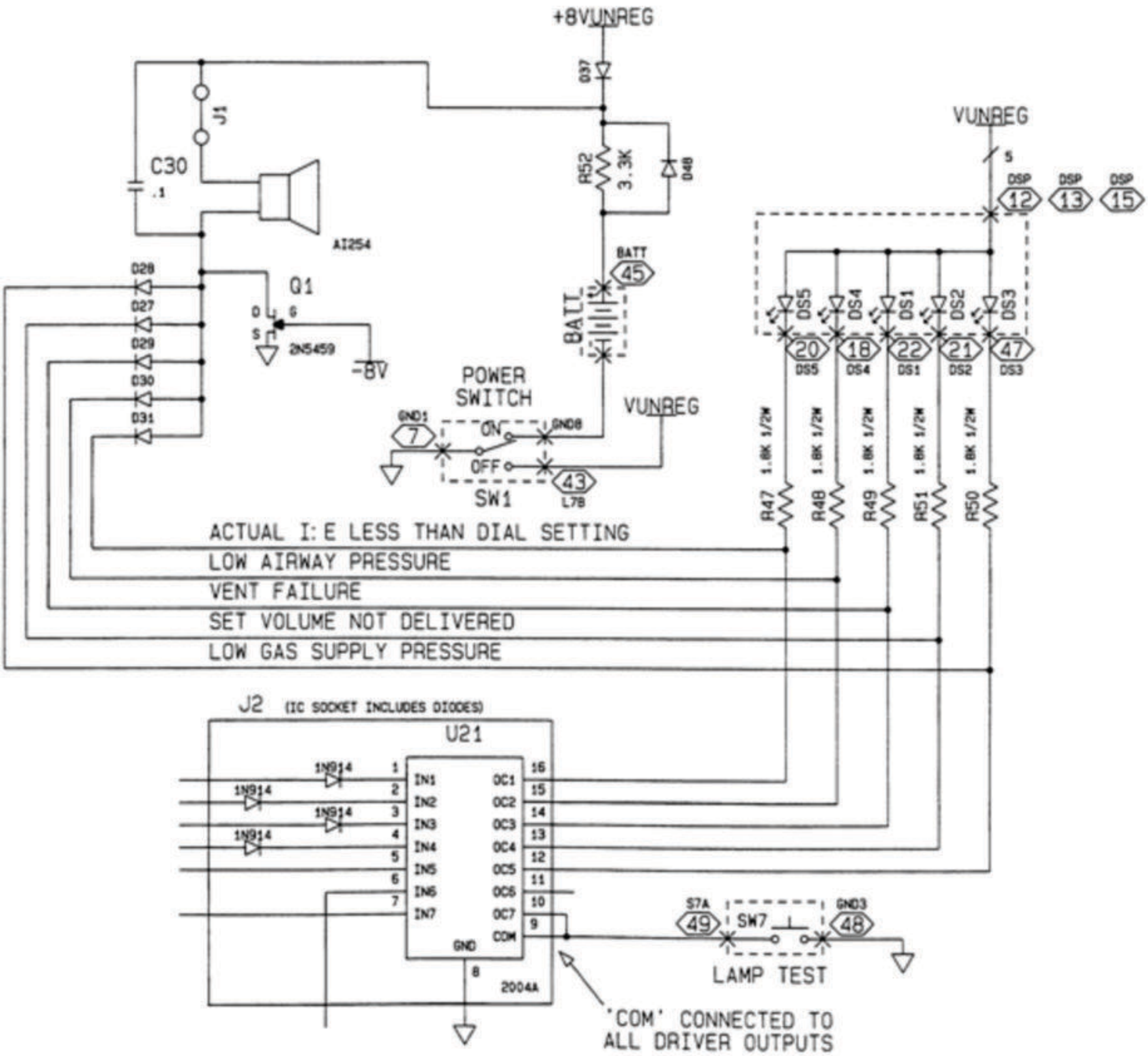

Figure 2-24
Lamp Test Circuit

Monitor Failure
(Continuous red lamp and audio tone)

See Figure 2-25. The pin 9 output of counter U7 is applied to U10B (a low limit 2 V comparator) and U10A (a high limit 6 V comparator) through an RC network. The signal at pin 9 alternates between +8 V and 0 V, and so maintains an average voltage of 4 V at capacitor C2. If counter U7 or the clock U1 fails, the voltage at C2 remains high or low and activates one of the comparators. This causes all the alarms to turn on via the alarm pulser/driver U21.

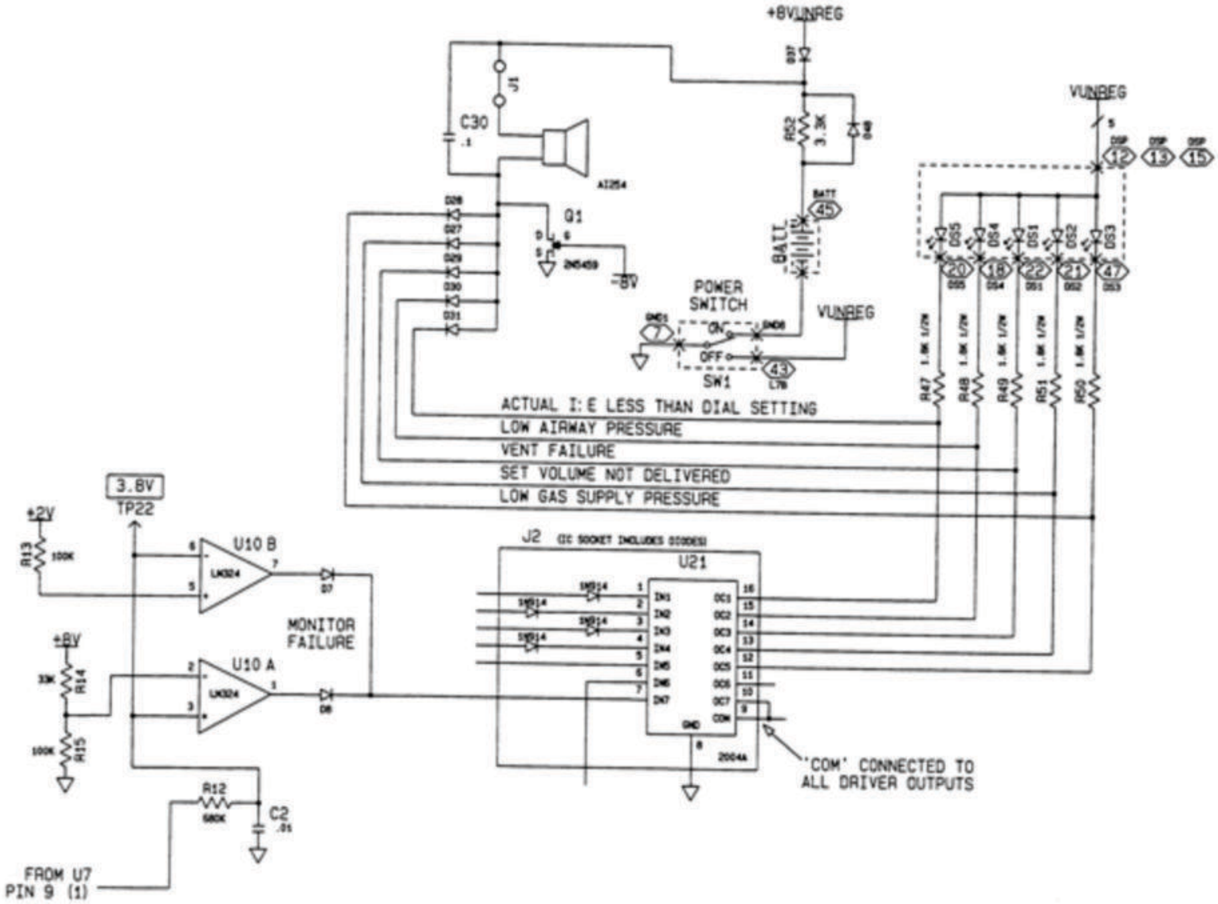

Figure 2-25
Monitor Failure Alarm Circuit

Power Failure
(Continuous audio tone)

See Figure 2-26. In the event of power loss, the -8 V supply will be absent. Transistor Q1 is normally biased off by the negative voltage and if the voltage is absent, Q1 will turn on. This causes the audible alarm to activate, deriving its power from a rechargeable NiCad battery. When the power is On, the battery is recharged from a +8 V unregulated supply.

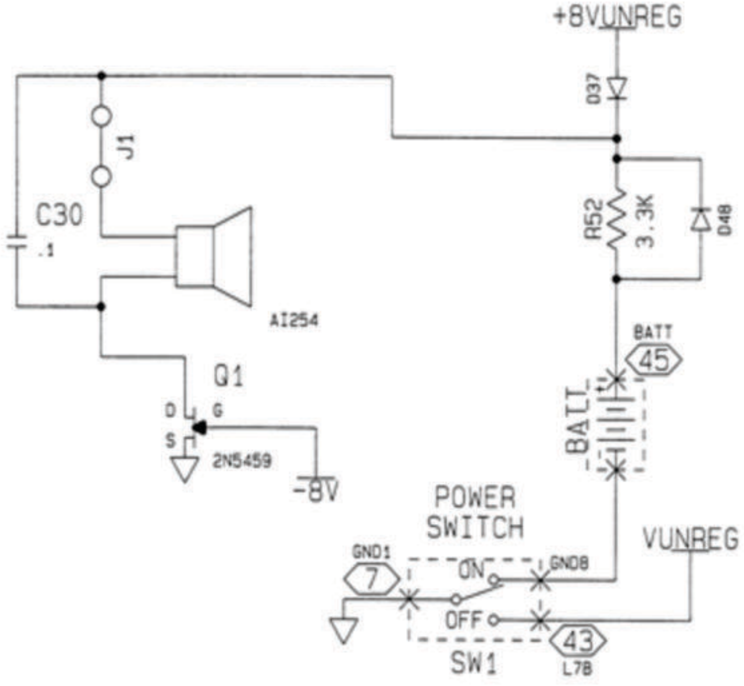

Figure 2-26
Power Failure Alarm Circuit

Power Supply

(Refer to Schematic, Figure 8-4)

Power enters the system through the appliance inlet of the Power Inlet Module where it is filtered for RFI, fused by two fuses on the line and neutral, and routed appropriately by the voltage selector for the transformer T1. The voltage selector can be set for input voltages of 100, 120, 220, or 240 V ac. The transformer provides two AC outputs, 23 V ac at 1.7 A and 27.5 V ac at 100 mA center tapped (CT). The 23 V ac is rectified and filtered to provide 24 V dc unregulated (VUNREG). VUNREG is used to drive the solenoid valves, the exhaust valve, and the LED's. The 27.5 V ac CT is rectified and filtered to provide +8 V dc unregulated (+8 VUNREG) and -8 V dc unregulated (-8 VUNREG). +8 VUNREG is used to drive the audible alarm, charge the NiCd battery, and provide the source for the regulated supplies, +8 V dc and +2.00 V dc. -8 VUNREG is used to provide the source for the -8 V dc regulated supply. Zener diode D57 and potentiometer RP provide regulation to provide the +2.00 V dc reference. The +2.00 V dc reference is amplified by U19 and U18 to provide the +8 V dc and -8 V dc regulated supplies, respectively. The +8 V dc and -8 V dc regulated supplies supply power for the control logic. The bleed valve is driven by +8 VUNREG and -8 V dc regulated.

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3/Functional Test

⚠**WARNING: Do not, under any circumstances, perform any testing or maintenance on medical instruments while they are being used to ventilate a patient.**

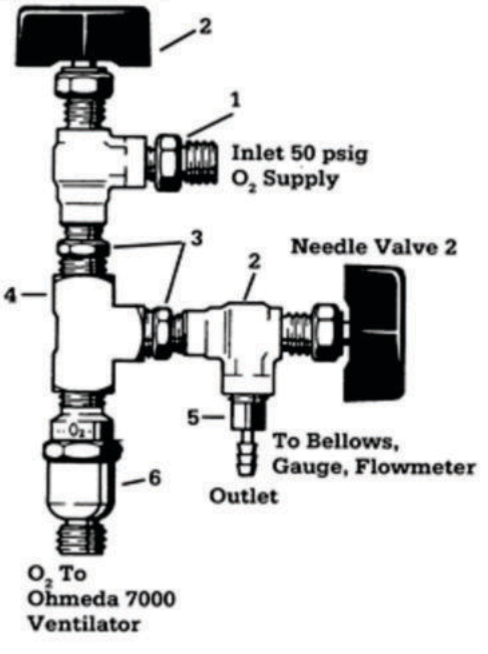
3.1 Bellows Performance Test

Equipment Required:

- Pressure Gauge, 0 - 20 cm H_2O
- Test Fixture
- 2" length of 1/4" OD copper tubing
- #2 rubber stopper w/hole
- Test plug (Stock Number 2900-0001-000)
- Plastic tee
- Flowmeter 0 - 500 mL/min and Needle valve
- Suitable lengths of 1/8" ID tygon or rubber tubing.

1. Connect the test equipment to the bellows assembly as shown in Figure 3-2.
2. Plug the exhaust port on the Bellows Assembly.
3. Close the needle valves on the test fixture then turn on the oxygen supply.
4. Open needle valves 1 and 2 and inflate the bellows to the 100 mL level.
5. If the pressure on the gauge exceeds 1.0 cm H_2O or the bellows drops at a rate exceeding 50 mL/min, replace the bellows and repeat the above steps.
6. Continue inflating the bellows to the top of the housing.
7. At a pressure value shown on the gauge of 15 cm H_2O the bellows must still be correctly located, with the base bellows securing lip still covered by the bellows. (See Note).

   Note: Gas leak is acceptable providing the above conditions are met.
8. If the bellows has slipped off or exposed the securing lip the bellows must be replaced.



Description	Stock Number
1. DISS, O_2, M x 1/4" NPTM Adapter	0204-0490-535
2. Needle Valve, 1/8" NPTF	0207-6067-800
3. Reducing Nipple, 1/8" NPTM x 1/4" NPTM	0213-5017-335
4. Tee, 1/4" NPTF	0213-6115-335
5. Hose Nipple, 1/8" ID x 1/8" NPTM	0204-8877-300
6. Check Unit, DISS, O_2, M x 1/4" NPTM	0221-3900-800

Figure 3-1
Test Fixture

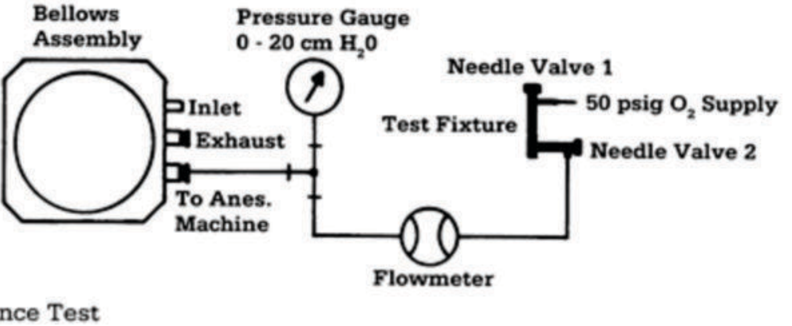


Figure 3-2
Bellows Performance Test

3.2 Pop-off Valve Performance Test

Equipment Required:

- Pressure Gauge, 0 - 20 cm H_2O
- Test Fixture
- 2" length of 1/4" OD copper tubing
- #2 rubber stopper w/hole
- Plastic tee
- Flowmeter 0 - 500 mL/min and Needle valve
- Suitable lengths of 1/8" ID tygon or rubber tubing.

To verify operation of the pop-off valve, perform the following tests.

1. Connect the test equipment to the bellows assembly as shown in Figure 3-3.
2. Close the needle valves on the test fixture then turn on the oxygen supply.
3. Open needle valves 1 and 2 to allow the bellows to rise up against the top of the bellows housing.
4. Adjust needle valve 2 to obtain a flow of 5 L/min (indicated on flowmeter). The pressure within the bellows should not exceed 3.5 cm H_2O.
5. Adjust needle valve 2 to obtain a flow of 200 mL/min. The pressure within the bellows should be at least 1 cm H_2O and sufficient to hold the bellows at the top of the housing.
6. Close needle valves 1 and 2.
7. Monitor the volume lost by observing the height of the bellows against the volume graduations on the housing. The volume loss should not exceed 100 mL in a one minute period.
8. If the leak rate exceeds the above values replace the pop-off valve.

3.3 Bellows Assembly Leak Test

Equipment Required:

- Pressure Gauge, 0 - 100 cm H_2O
- Test Fixture
- 2" length of 1/4" OD copper tubing
- #2 rubber stopper w/hole
- Test plug (Stock Number 2900-0001-000)
- Plastic tee
- Flowmeter 0 - 500 mL/min and Needle valve
- Suitable lengths of 1/8" ID tygon or rubber tubing.

1. Connect the test equipment to the bellows assembly as shown in Figure 3-4.
2. Remove the bellows housing
3. Remove the bellows and replace the housing.
4. Close the needle valves on the test fixture then turn on the oxygen supply.
5. Open needle valves 1 and 2. Adjust needle valve 2 to obtain 300 mL/min fresh gas on flowmeter. Do not readjust the flowmeter during this test.
6. Plug the inlet port on the Bellows Assembly.
7. The pressure should rise to 60 cm H_2O or greater (do not pressurize over approximately 100 cm H_2O).
8. If 60 cm H_2O pressure cannot be maintained with a flow of 300 mL/min or less, place a finger tightly over the "Exhaust" port. If this causes the pressure to rise and/or the flow to decrease, a leak exists through the pop-off valve.
9. If sealing the "Exhaust" port has no effect, check the bellows housing, u-cup seal, and the bellows base assembly for leaks.
10. Any leak must be corrected to achieve at least 60 cm H_2O at 300 mL/min.

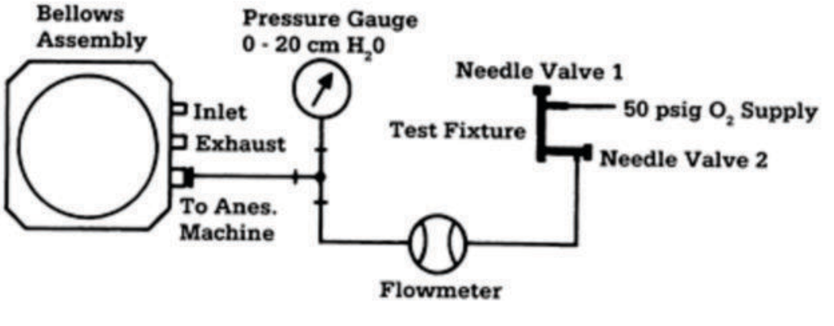


Figure 3-3
Pop-off Valve Performance Test

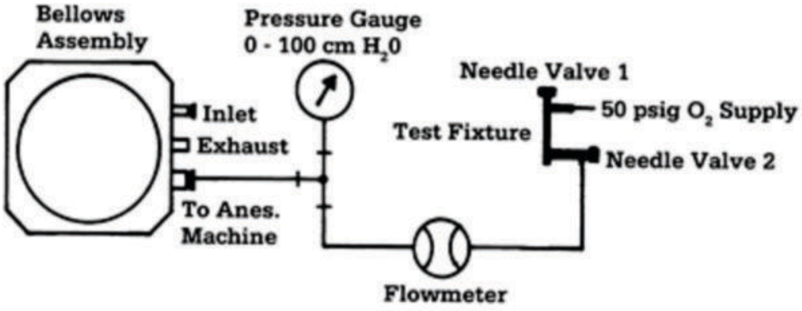


Figure 3-4
Bellows Assembly Leak Test

3.4 Low Oxygen Supply Pressure Alarm Test

Equipment Required:

- Pressure Gauge, 0 - 60 psig
- Pressure Gauge, 100 cm H_2O
- Test Fixture
- Plastic Tee
- Squeeze bulb w/valve
- High pressure O_2 hose, DISS O_2, Female fitting on both ends
- Suitable length of 1/8" ID tygon or rubber tubing.

1. Connect the test equipment to the controller assembly as shown in Figure 3-5.
2. Close the needle valves on the test fixture then turn on the oxygen supply.
3. Using the squeeze bulb, pressurize the distal sensing port to 10 cm H_2O. This will eliminate the Low Airway Pressure Alarm so it will not interfere with the test.
4. Set the ventilator controls as follows:

   Minute Volume = 2 L/min
   Rate = 6 BPM
   I:E = 1:1
5. Turn on the controller unit.
6. Open needle valves 1 and 2.
7. Close needle valve 1 slowly so that during the inspiration phase the pressure on the 0 - 60 psig gauge decreases to 35 psig. The Low Oxygen Supply Pressure Alarm should activate at 35 psig or above.
8. Open needle valve 1 slowly so that during the expiration phase the pressure on the 0 - 60 psig gauge increases to 42 psig. The Low Oxygen Supply Pressure Alarm should deactivate at 42 psig or below.
9. Adjust or replace the pressure switch (Section 6.5.B) if it does not meet the specifications.

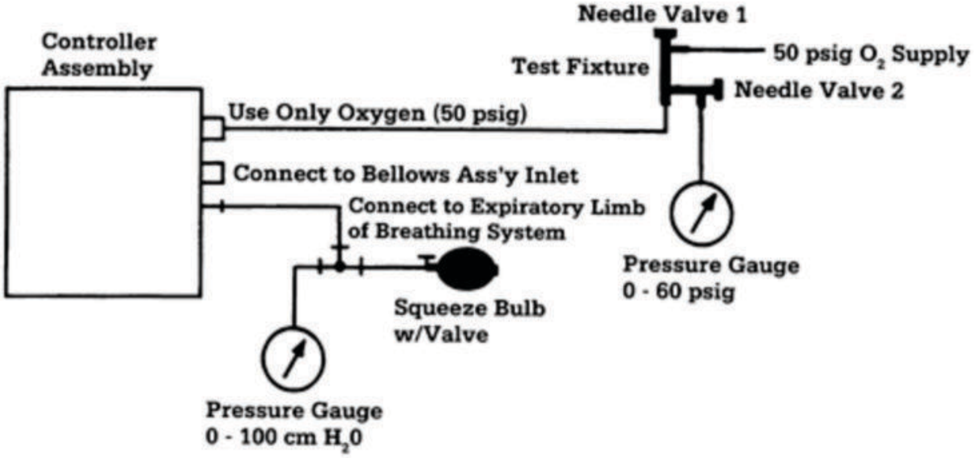


Figure 3-5
Low Oxygen Supply Pressure Alarm Test

3.5 Low Airway Pressure Alarm Test

Equipment Required:

- Pressure Gauge, 0 - 20 cm H_2O
- Squeeze bulb w/valve
- Plastic Tee
- Suitable length of 1/8" ID tygon or rubber tubing

Note: A Low Airway Pressure alarm may occur during testing when the ventilator is operating normally. This can happen when the ventilator is equipped with a test lung and small tidal volumes are selected (less than approximately 200 mL Adult; 100 mL Pediatric).

1. Connect the test equipment to the ventilator as shown in Figure 3-6.
2. Lightly pump the squeeze bulb, then open the valve and bleed until 5 cm H_2O is indicated on the gauge.
3. Set the ventilator controls as follows:

   Minute Volume = 6 L/min
   Rate = 6 BPM
   I:E = 1:1
4. Turn the ventilator on.
5. The "Low Airway Pressure" alarm should activate after the second breath.
6. Lightly squeeze the hand bulb to bring the pressure over 10 cm H_2O. The alarm must silence.
7. If either of the above alarm conditions do not occur, adjust or replace the Sensor Pressure switch as necessary. If problems remain, perform unit calibration.

3.6 Pressure Relief Valve Test

Equipment Required:

- Pressure gauge 0 - 100 cm H_2O
- Pressure Gauge, 0 - 20 cm H_2O
- Test Fixture
- Plastic Tee (2 required)
- #2 Rubber Stopper w/hole
- Squeeze bulb w/valve
- High pressure O_2 hose, DISS O_2, Female fitting on both ends
- Suitable length of 1/8" ID tygon or rubber tubing
- Corrugated driving gas tubing
- #2 length of 1/4" OD copper tubing

1. Connect the test equipment to the bellows and control assembly as shown in Figure 3-7.
2. Close the needle valves on the test fixture then turn on the oxygen supply.
3. Open needle valves 1 and 2 to inflate the bellows to the 500 mL level.
4. Close needle valve 2 when the 500 mL is obtained.
5. Set the ventilator controls to:

   Minute Volume = 10 L/min
   Rate = 10 BPM
   I:E = 1:1
6. Using the squeeze bulb, pressurize the distal sensing port to 10 cm H20. This will eliminate the Low Airway Pressure Alarm so it will not interfere with the test.
7. Turn on the ventilator.
8. The gauge will indicate varying pressures during inspiration and expiration, but the

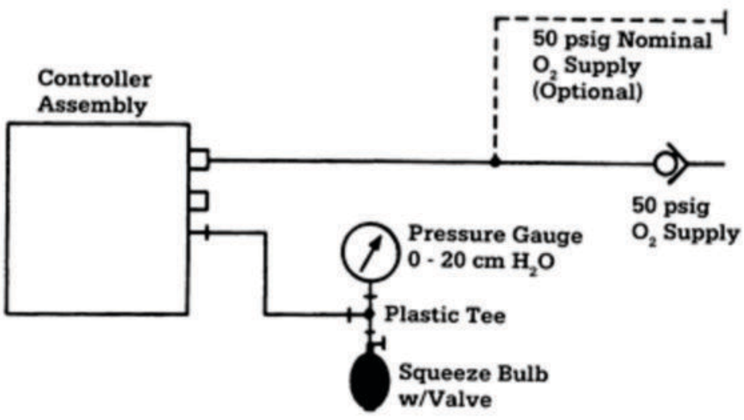


Figure 3-6
Low Airway Pressure Alarm Test

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maximum pressure indicated on the 0 - 100 cm H_2O gauge must be between 65 and 75 cm H_2O.

9. If the valve fails, replace the entire flow control unit. This is necessary because the valve cannot be replaced without disturbing the tuned flow tubes.

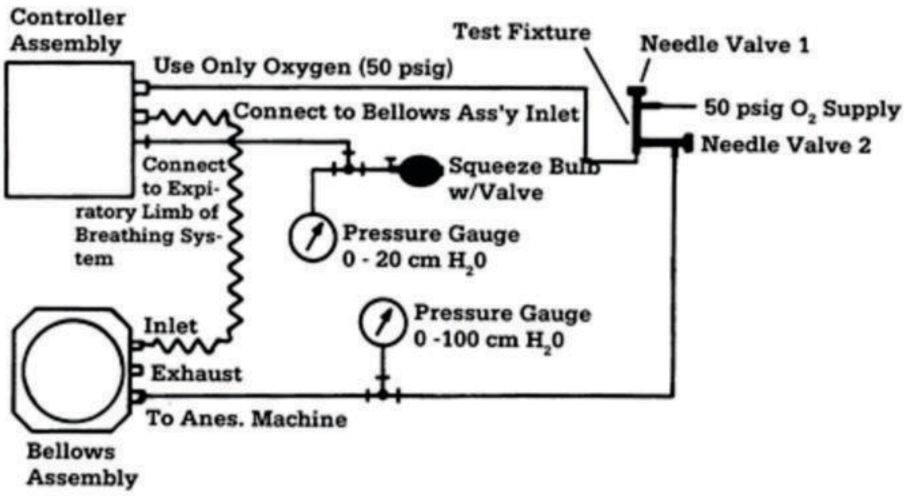

Figure 3-7
Pressure Relief Valve Test

3.7 Controller Assembly Leak Test

Equipment Required:

- Pressure Gauge, 0 - 100 psig
- Test Fixture
- High pressure O_2, DISS O_2, Female fitting on both ends

1. Connect the test equipment to the controller assembly as shown in Figure 3-8.
2. Close the needle valves 1 and 2 on the test fixture then turn on the oxygen supply.
3. Open needle valve 1 and 2.
4. Pressurize the controller assembly to 50 psig.
5. Close needle valve 1 and monitor the pressure in the controller assembly. The pressure drop should not exceed 1 psig in 90 seconds.
6. If pressure in assembly cannot be maintained check for loose hose fittings or holes in the hoses.

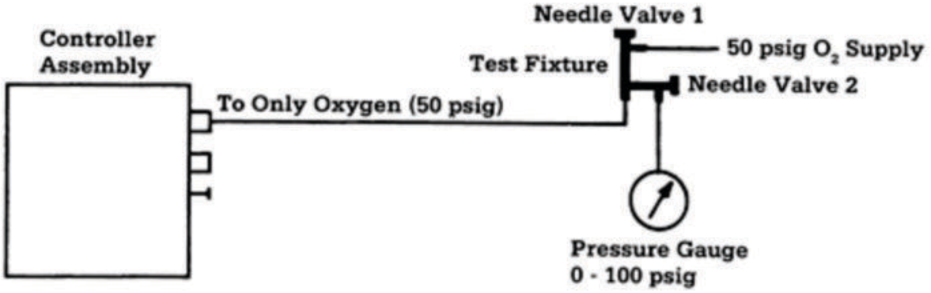

Figure 3-8
Control Assembly Leak Test

3.8 Ground Resistance Checks

Perform a ground resistance check on the ventilator. Use a low range ohmmeter or electrical safety analyzer to measure the resistance between the ground pin on the line cord plug and the controller unit. Tug and flex each end of the power cord during the measurement. The ground resistance must be less than 0.15 ohms. Higher readings may indicate loose or oxidized connections in the power cord or the ventilator grounding circuits.

Measure the leakage current in all wiring configurations both On and Off, grounded and ungrounded, and normal and reverse polarities.

Use the leakage current tester Stock No. 0175-2284-000 and digital multimeter (DMM) for the following procedure:

1. Connection (Figure 3-9)
   a. Connect the device under test to the outlet on the leakage current tester.
   b. Make sure the polarity switch on the leakage tester is in the Off Position then plug the line cord into an appropriate grounded mains wall outlet.
   c. Connect the positive lead of the DMM to the positive (+) Meter Out output.
   d. Connect the negative lead of the DMM to the negative (-) Meter Out output.
   e. Set the DMM on the AC millivolt scale.
   f. Connect one end of the test cable (needle probe tip) to contact the External Ground jack on the Leakage Current Tester.
   g. Use the other end of the test cable (needle probe tip) to contact the exposed conductive surface of the device under test.

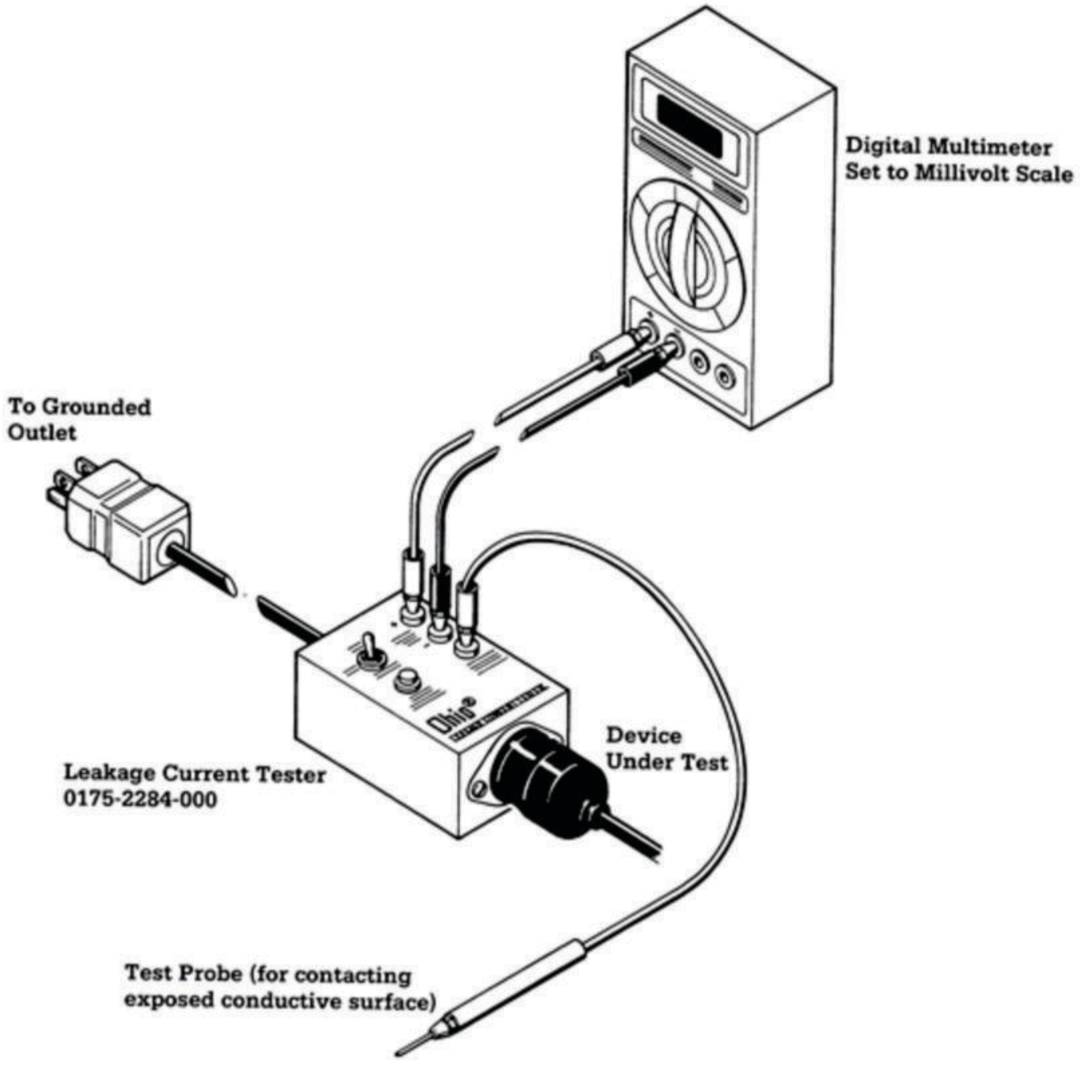

Figure 3-9
Leakage Current Tester Setup

2. Normal Polarity Leakage Current Test
   a. Place the polarity switch of the Leakage Current Tester in the Normal position. (This is in the grounded mode.)
   b. Switch On the power of the device under test.
   c. Measure the voltage on the DMM in millivolts. The millivolt reading is directly related to leakage current in microamps (i.e., 100 mV is equivalent to a leakage current of 100 microamps).
   d. Push the Ground Disconnect switch to measure the ungrounded leakage current.
   e. Switch the power switch of the device under test Off and then repeat steps 2c through 2d.
3. Reverse Polarity Leakage Current Test
   a. Place the polarity switch on the Leakage Current Tester in the Reverse position. (This is the grounded mode.)
   b. Switch On the power of the device under test.
   c. Measure the voltage on the DMM in millivolts. The millivolt reading is directly related to leakage current in microamps, (i.e., 100 mV is equivalent to a leakage current of 100 microamps).
   d. Push the Ground Disconnect switch to measure the ungrounded leakage current.
   e. Switch the power switch of the device under test Off and then repeat steps 2c through 2d.

3.9 Leakage Current Test

Use approved equipment and techniques to test the ventilator's leakage current and ground continuity. There must be less than 35 microamps leakage current at 100/120 V ac or less than 70 microamps leakage current at 220/240 V ac under all conditions.

3.10 High Airway Pressure Switch Test

Equipment Required:

- Pressure Gauge, 0 - 100 cm H_2O
- Squeeze bulb w/valve
- Plastic Tee
- Suitable lengths of 1/8" ID tygon or rubber tubing.

1. Connect the test equipment to the controller assembly as shown in Figure 3-10.
2. Lightly pump the squeeze bulb, then open the valve and bleed until 15 cm H_2O is indicated on the gauge.
3. Set the ventilator controls as follows:

   Minute Volume = 6 L/min
   Rate = 6 BPM
   I:E = 1:1
4. Turn on the oxygen supply and the ventilator.
5. Slowly Squeeze the hand bulb to bring the pressure above 60 cm H_2O. The Set Volume Not Delivered alarm must occur between 65 and 75 cm H_2O as pressure is increased.
6. Check that with the pressure maintained at a level to provide a constant alarm, the Ventilator Failure alarm occurs after 2 to 3 breaths.
7. If either of the above alarms conditions do not occur, adjust/replace the Pressure Switch or High Pressure board. If problems remain, perform unit calibration.

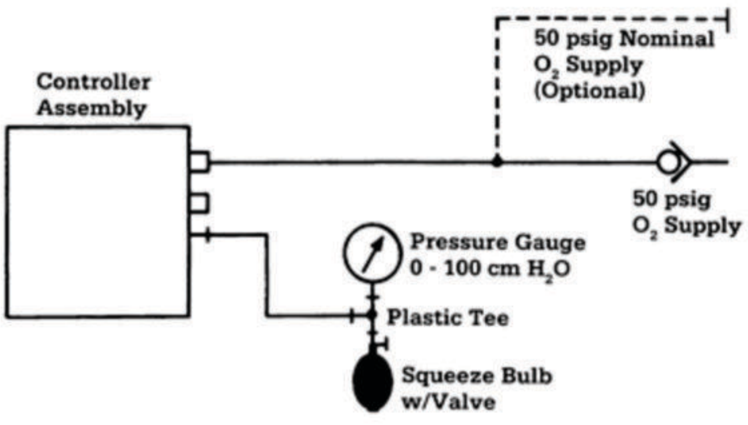

Figure 3-10
High Airway Pressure Switch Test

4/Maintenance

⚠**WARNING:** Disconnect power before removing the cover panel. Leave the power disconnected unless specifically instructed otherwise.

⚠**WARNING:** Fire Hazard. Never oil or grease any anesthesia equipment. In general, oils and greases oxidize readily, and in the presence of oxygen they will burn violently.

⚠**WARNING:** Do not, under any circumstances, perform any testing or maintenance on medical instruments while they are being used to ventilate a patient.

⚠**WARNING:** The alarm circuit check (section 6.16) must be performed before the ventilator is returned to use after any service procedure.

⚠**WARNING:** Never use the ventilator if the jumper plug is missing; the audible alarm will malfunction. Always check to be sure that the audible alarm works before returning a unit to operation.

⚠**WARNING:** Always wear a grounding wrist strap when handling static sensitive assemblies except when working on an energized unit. Otherwise, electrostatic discharges can damage electronic components.

⚠**WARNING:** Operation must be checked per Section 3 after performing any maintenance procedure.

4.1 Scheduled Maintenance

The items listed in the chart must be checked at the specified intervals by a competent technician to help ensure that the ventilator remains in optimum working condition. If these items are not checked, performance may eventually deteriorate and the warranty may be void under the terms of the user's responsibility set forth in the operation manual (1502-0008-000).

Item	Procedure	See Section	Recommended Intervals
Altitude Control	Adjust	4.2	yearly or when relocated
Battery	Replace	4.3	two years
Bellows	Replace	4.4	yearly
Hoses, Internal	Inspect	4.5	yearly
Inspect Unit	Inspect	4.6	six months
Regulator	Check	4.7	yearly
Valve, Exhaust	Inspect	4.10	yearly
Bellows Assembly	Check	4.12	six months
Pop-Off Valve	Check	4.13	six months
Bellows	Check	4.13	six months

4.2 Altitude Adjustments

(See Figure 4-1)

Tool Required:

- 3/32 inch hex key wrench.

1. Check the altitude adjustment once a year and whenever the unit is moved to a new location.
2. Determine the location's altitude above sea level.
3. Remove the cover from the altitude adjustment.
4. Set the control to the altitude in meters. Note that the adjustment is set in 50 meter increments.
5. Replace the cover over the control.

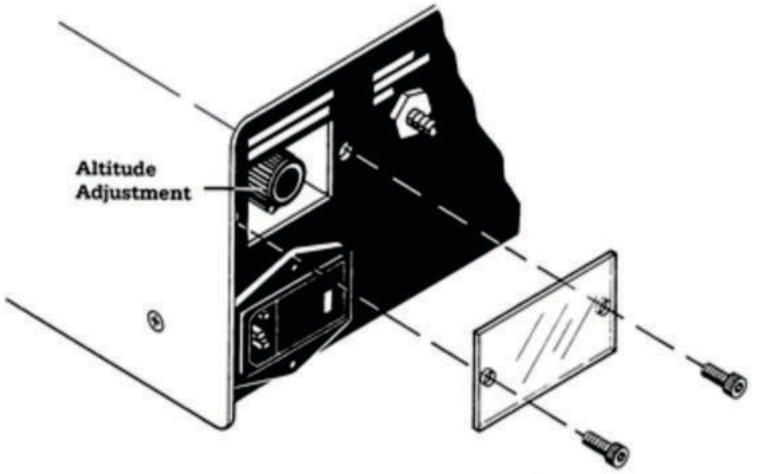

Figure 4-1
Altitude Adjustment

Note: When using the Ohmeda 7000 Ventilator at altitudes above the altitude set on the back of the unit, the minute volume delivered will be greater than the setting. At altitudes above 6,000 feet or 1,800 meters the following correction will convert the dial setting of minute volume to the delivered minute volume.

First set the altitude compensation knob to 6,000 feet or 1,800 meters. In the equation, "A" is the altitude in units of the number of feet above 6,000 feet or number of meters above 1,800.

$$\frac{610}{610-(.02)A} \times \sqrt{\frac{2576-(.02)A}{2576}} \times \text{Minute Volume Set} = \text{Minute Volume Delivered}$$

For example, assume an altitude of 12,159 feet then:

$$\frac{610}{610-(.02)6159} \times \sqrt{\frac{2576-(.02)6159}{2576}} \times \text{MV Setting} = \text{MV Delivered}$$

$$1.19 \times \text{MV Setting} = \text{MV Delivered}$$

Therefore, at an altitude of 12,159 feet with the altitude compensation knob set to 6,000 feet and a set minute volume of 10 L/min, the 7000 will deliver a minute volume of 12.23 L/min.

For ventilators with Altitude Adjustment Control in meters assume an altitude of 3,648 meters then:

$$\frac{610}{610-(.02)1848} \times \sqrt{\frac{2576-(.02)1848}{2576}} \times \text{MV Setting} = \text{MV Delivered}$$

$$1.19 \times \text{MV Setting} = \text{MV Delivered}$$

Therefore, at an altitude of 3,648 meters with the altitude compensation knob set to 1,800 meters and a set minute volume of 10 L/min, the 7000 will deliver a minute volume of 10.57 L/min.

4.3 Battery Replacement

Tools Required:

- #2 Phillips Screwdriver
- 1/8" Flat-tip Screwdriver

1. Unplug the line cord from the electrical outlet.
2. Remove the four screws that fasten the white cover panel in place, and lift off the panel. Do Not unfasten the ground wire between the cover panel and the chassis, (Figure 4-2).
3. The battery mounting clip is located underneath the circuit board plate, (Figure 4-3). Pry the battery out of the clip and install the replacement. Use only a 7.2 V rechargeable battery for a replacement. Stock No. 1502-3016-000.
4. Reassemble the unit.

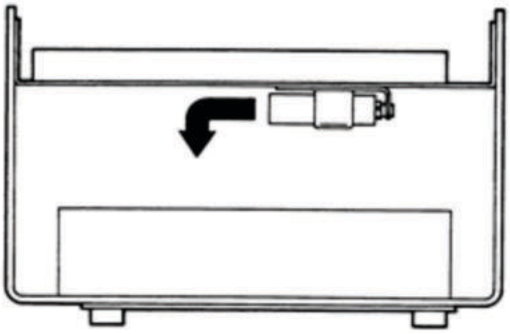

Figure 4-3
Battery Replacement

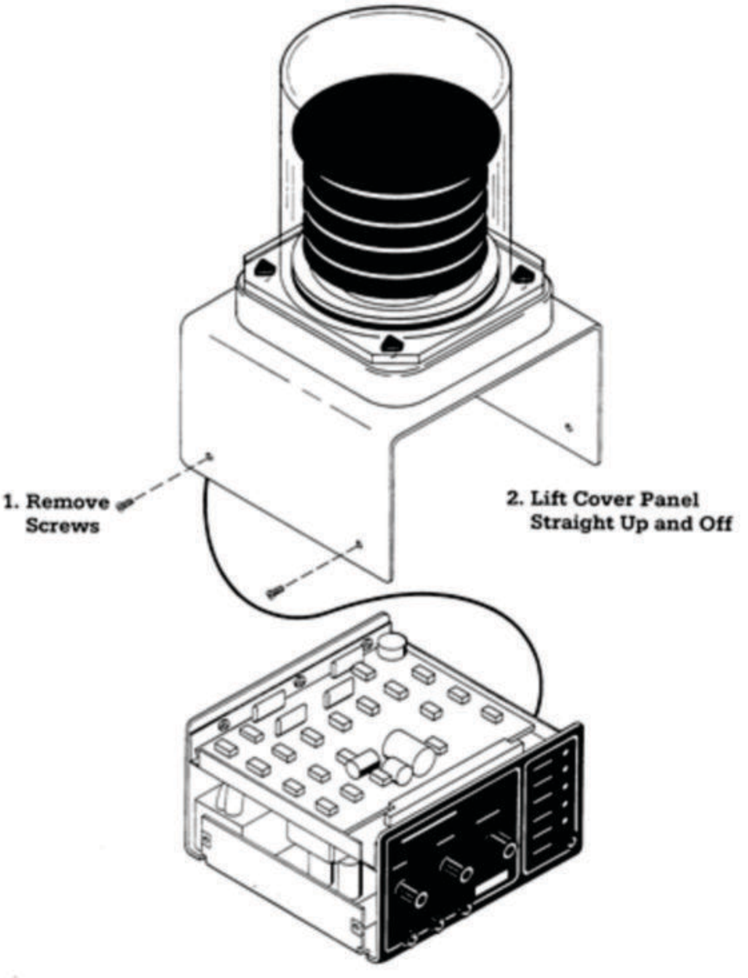

Figure 4-2
Cover Panel Removal

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4.4 Bellows Replacement

(See Figure 4-4)

1. Remove the four thumbscrews that fasten down the transparent bellows housing.
2. Lift the housing off the bellows assembly.
3. Pull the bellows off its mounting flange.
4. Stretch the replacement bellows over the mounting flange. Remove any wrinkles and make sure of a uniform fit.
5. Replace the bellows cover on the assembly. Be sure the U-cup seal around the base of the assembly does not come out of its groove when the cover is replaced. Otherwise, the assembly will leak.
6. Fasten the cover on with the four thumb-screws.
7. Test the ventilator for correct operation per Section 3.

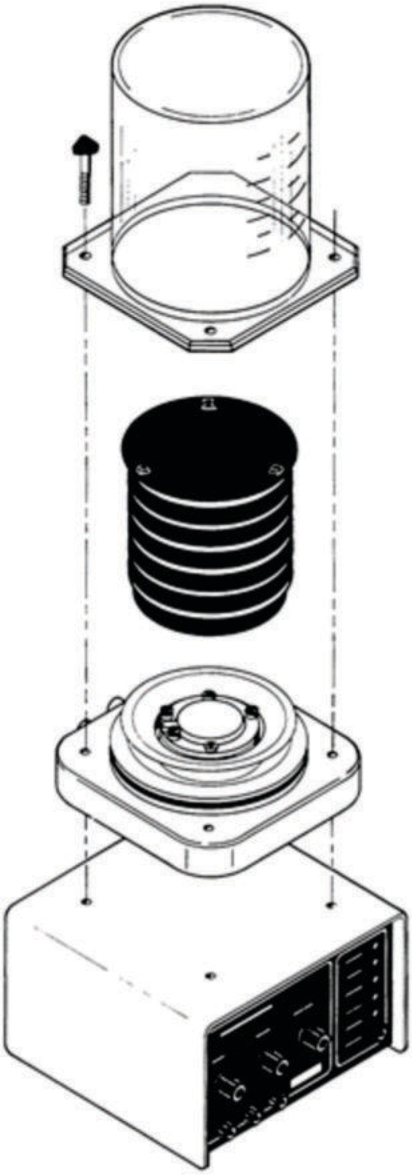


Figure 4-4
Bellows Replacement

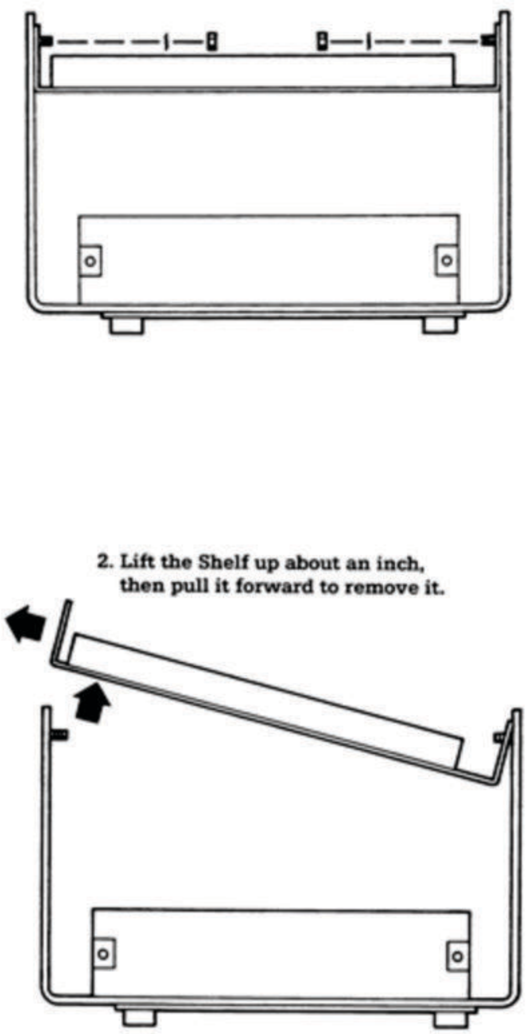


Figure 4-5
Circuit Board Shelf Removal for Maintenance

4.5 Hose Check and Replacement (Internal)

Tools Required:

- #2 Phillips screwdriver
- 5/16" open-end wrench
- 5/16" nut driver
- Needle nose pliers
- Sharp knife

Note: When ordering hose, specify length in units. That is, one unit of 0995-6439-010 would be one foot long, five units would be five feet, etc.

1. Unplug the line cord and remove the four screws that fasten the cover panel in place. Lift off the cover panel (see Figure 4-2).
2. Remove the four nuts that fasten the circuit board mounting plate to the chassis. Tilt the front of the plate up, slide it forward and out of the chassis. Lay it to the side, (Figure 4-5). Inspect the hoses for cracking or general deterioration. If they are OK, reassemble the unit. Otherwise, continue with this procedure to replace all hoses.
3. Loosen the hose clamps and remove all of the hoses attached inside the ventilator.
4. Refer to Figure 4-6 for hose connections throughout the following procedure.
5. Connect TB7 (6 inch length) between the regulator bleed outlet and the solenoid bleed valve inlet.
6. Connect TB6 (6 inch length) between the solenoid bleed valve outlet and the exhaust manifold.
7. Connect TB8 (4 inch length) between the 35 psi pressure switch and the regulator inlet.
8. Connect TB1 (8.25 inch length) between the regulator inlet and the rear panel O_2 supply connection.
9. Connect TB4 (1 inch length) between the middle barb of the Tee fitting and the 7 cm H_2O pressure switch.
10. Connect TB2 (4.75 inch length) between the regulator outlet and the flow control unit inlet.
11. Connect TB9 (2.75 inch length) between the flow control unit outlet and the rear panel connector.
12. Attach TB3 (1.75 inch length) from the distal sensing connection on the rear panel to the Tee fitting.
13. Connect TB 5 (1.75 inch length) between the Tee fitting and the 65 cm H_2O pressure switch.
14. Attach TB10 (5 inch length) between the flow control unit relief valve outlet and the exhaust manifold.
15. Test the ventilator for correct operation per Section 3.

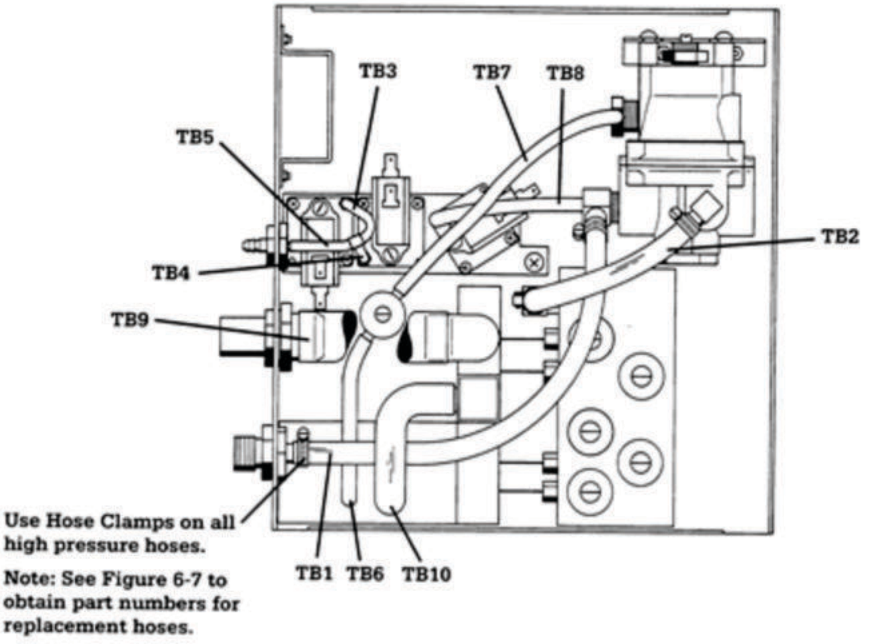


Figure 4-6
Internal Hose Connections

4.6 Inspections

Equipment Reguired:

- Leakage Current Tester
- Operational Anesthesia Machine

1. Check that none of the control dials or switches are loose.
2. Plug in the line cord, and switch on the ventilator. Disregard any alarms.
3. Depress the Lamp Test button. All of the alarm lamps must light and the audible alarm must sound.
4. Check the breathing circuit, including the bellows assembly, for cracking or dryness of the rubber. Replace defective items.
5. Set the Altitude dial to the correct elevation (in meters) for the operational location.
6. Inspect the bellows housing for cracks or chips.
7. Using approved equipment and techniques, check that the leakage current is under 35 microamps (70 microamps on 220/240 volts AC). Also test ground continuity to specified values.
8. Examine the physical condition of the unit. Units that appear to have been abused should be tested for correct function per Section 3.
9. Connect the ventilator to an anesthesia machine as if for normal operation. Check that the ventialtor's controls function correctly.

4.7 Pressure Regulator and Bleed Valve Test and Adjustment

Tools Required:

- #2 Phillips screwdriver
- 5/8" open-end wrench
- 7/8" flat-tip screwdriver
- 5/16" open-end wrench
- 5/16" nutdriver
- 0 - 60 psig pressure gauge ± 0.25% full scale accuracy
- 50 ± 2 psig oxygen supply
- 5 mm nutdriver

1. Unplug the line cord. Remove the four Phillips-head screws that fasten the cover panel in place, then lift off the cover panel, (Figure 4-7).
2. Remove the four nuts that fasten the circuit board assembly in place. Lift the front of the assembly up an inch and a half, then slide it forward off its mounting studs and out of the unit. Lay it down next to the chassis, (Figure 4-5).
3. Remove the manifold plug, (Figure 4-8). Connect an accurate pressure gauge to the manifold where the plug was. The gauge must have a length of tubing attached between it and the manifold such that the gauge will rest on the table beside the ventilator.

⚠WARNING: Electrical Shock Hazard. Do not touch exposed wires or conductive surfaces while the cover panel is removed from the ventilator unless electrical power is disconnected from the unit. Hazardous voltages are present during normal operation. Never wear a grounding wrist strap when working on an energized ventilator.

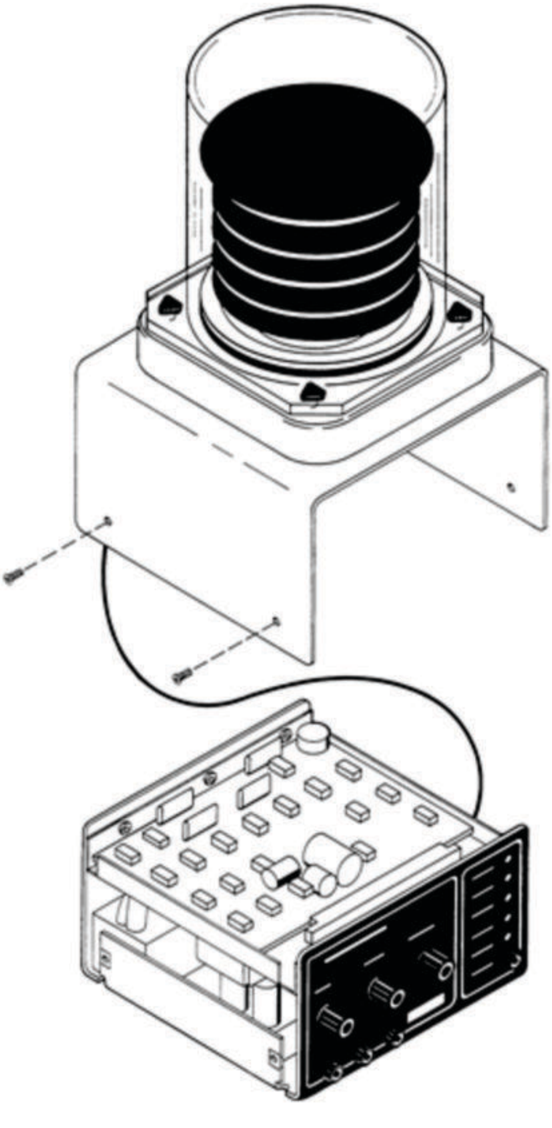


Figure 4-7
Cover Panel Removal

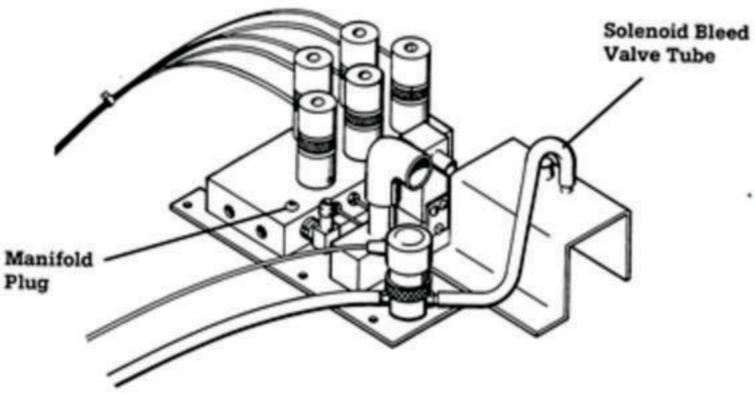


Figure 4-8
Manifold Plug Location for Regulator Adjustment

4. Remove the solenoid bleed valve's tube from its connection to the exhaust chamber cover.

5. Connect the 50 psig O_2 supply to the ventilator, connect the line cord to the power source, and switch on the unit in that order. (Disregard any alarms).

6. A maximum gas flow of 3 L/min out of the bleed tube must be observed. If the flow is greater than 3 L/min, replace the regulator.

   If there is no flow out of the bleed valve, disconnect the bleed valve tube from the fitting on the regulator. Flow some gas through the bleed valve to verify that it is open. If the bleed valve is not open, check the circuit board and bleed valve solenoid for correct operation.

7. Turn off the ventilator. Then, reconnect the bleed tube to the exhaust chamber cover.

   Note: During this test ignore the Set Volume Not Delivered alarm.

8. Replace the circuit board assembly but do not fasten it in place. Turn the ventilator back on.

9. Set the ventilator controls to:

   Minute Volume = 12 L/min
   Rate = 6 BPM
   I:E = 1:1

10. Check for 38 ± 0.50 psig during inspiration. If necessary, adjust the regulator using a 5 mm nutdriver, (Figure 4-9).

11. Set the ventilator controls to:

    Minute Volume = 30 L/min
    Rate = 6 BPM
    I:E = 1:1

12. Check that the regulator output pressure is 36.75 psig or higher during inspiration. If not, readjust it and repeat steps 6 through 9. Replace the regulator if it cannot be adjusted to meet the specifications.

13. Set the ventilator controls to:

    Minute Volume = 12 L/min
    Rate = 6 BPM
    I:E = 1:1

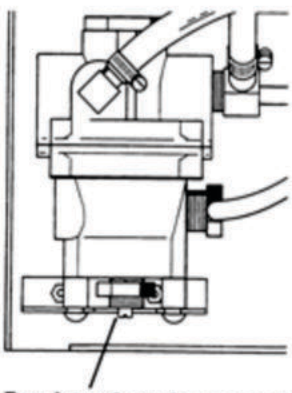
14. Check for 38 ± 0.50 psig during inspiration. If necessary, adjust the regulator using a 5 mm nutdriver, (Figure 4-9).

15. Check the static pressure during expiration. It must be less than 39 psig; if not, adjust the regulator and repeat steps 6 through 10. Replace the regulator if it cannot be adjusted to meet the specification.

16. Any regulator that develops an oscillation in the output pressure should be replaced.

17. Switch off the ventilator and disconnect the O_2 supply.

18. Reinstall the manifold plug, then reassemble the unit.



Adjust Regulator through access hole in side of chassis. Secure adjustment with thread-locking compound when finished. (Loctite #242).

Figure 4-9
Regulator Adjustment

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4.8 Fuse Replacement

1. Remove the power cord from the AC power source receptacle.
2. Remove the power cord anti-disconnect bracket by removing the two socket head cap screws. Refer to figure 4-11.
3. Remove the power cord plug from the power inlet module.
4. Place the end of a small flat edge screwdriver into the tab on the right hand side of the power inlet module and pry open the cover.
5. Refer to Figure 4-10. Use the end of the screwdriver to lift out the fuse drawers. Replace both of the fuses with fuses of the same type and rating.
6. Check voltage selector drum so that the desired voltage is facing forward.
7. Close the cover and push firmly to snap the module cover into place. Check to insure that the desired voltage is displayed in the window.
8. Reinstall the power cord and the power cord anti-disconnect bracket.

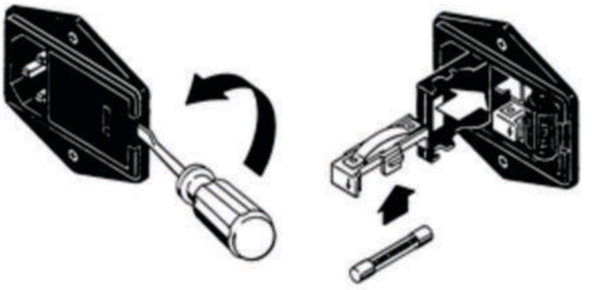


Figure 4-10
Fuse Replacement

4.9 Changing Input Voltage

1. Remove the power cord from the AC power source receptacle.
2. Remove the power cord anti-disconnect bracket by removing the two socket head cap screws. Refer to figure 4-11.
3. Remove the power cord plug from the power inlet module.
4. Refer to Figure 4-12. Place the end of a small flat edge screwdriver into the tab on the right hand side of the power inlet module and pry open the cover.
5. Remove the voltage selector drum and rotate the drum so that the desired voltage faces forward. Reinsert the drum back into the slots in the module.
6. Close the cover and push firmly to snap the module cover into place. Check to insure that the desired voltage is displayed in the window.
7. Reinstall the power cord and the power cord anti-disconnect bracket.

⚠CAUTION: The input voltage to the ventilator from the mains outlet must be the same as that indicated in the window on the power inlet module on the rear panel of the control module. Operating the ventilator with an incorrect input voltage may damage the ventilator or cause it to malfunction.

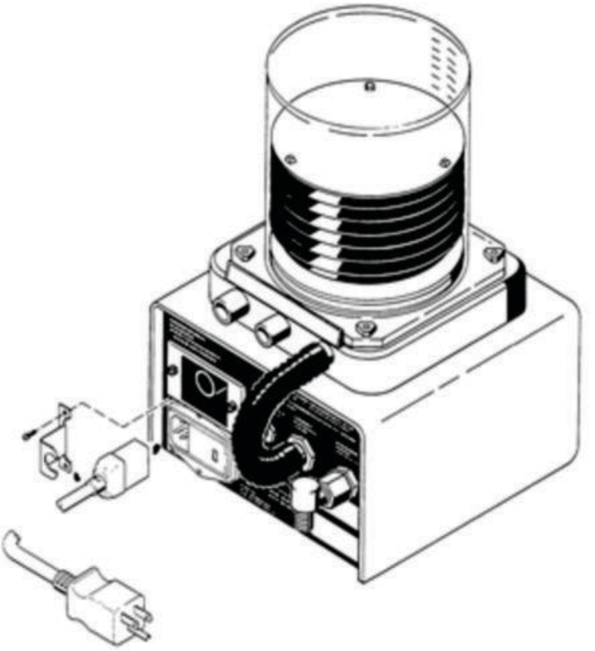


Figure 4-11
Anti-Disconnect Bracket Removal

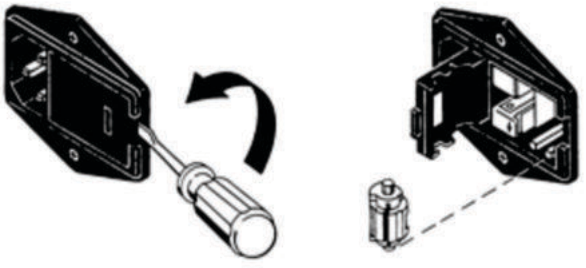


Figure 4-12
Changing the Input Voltage

4.10 Exhaust Valve Inspections

Tools Required:

- #2 Phillips screwdriver
- 5/16" open-end wrench
- 7/8" open-end wrench
- 5/16" nutdriver

1. Unplug the ventilator's line cord from the wall outlet and disconnect the O_2 power source.
2. Remove the four Phillips head screws that fasten the cover panel in place. Lift off the cover panel, (Figure 4-7).
3. Unbolt the circuit board mounting plate from the chassis (four nuts) and set it to the side, (Figure 4-5).
4. Disconnect the gas hose from the rear panel gas supply inlet connector.
5. Remove the rear panel gas supply inlet connector, (Figure 4-13).
6. Referring to Figure 4-6, disconnect tubes TB6 and TB10.
7. Remove the exhaust valve cover, (Figure 4-14).
8. Examine the seal on the exhaust valve. If it is deteriorated or worn replace the exhaust valve (refer to Section 6.2A).

   Examine the exhaust valve plunger for debris or corrosion. Replace if debris or corrosion is present.
9. Reassemble the unit, then perform all of the tests in Section 3 before returning the unit to operation.

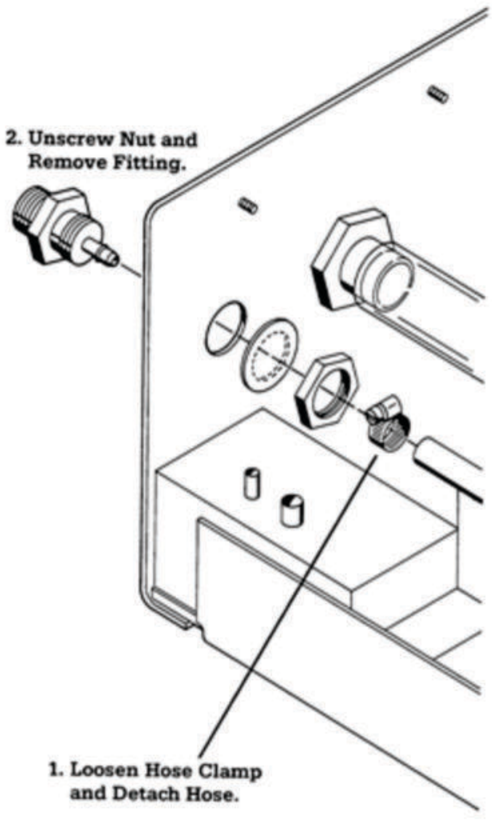


Figure 4-13
Rear Panel Gas Supply Inlet Connector Removal

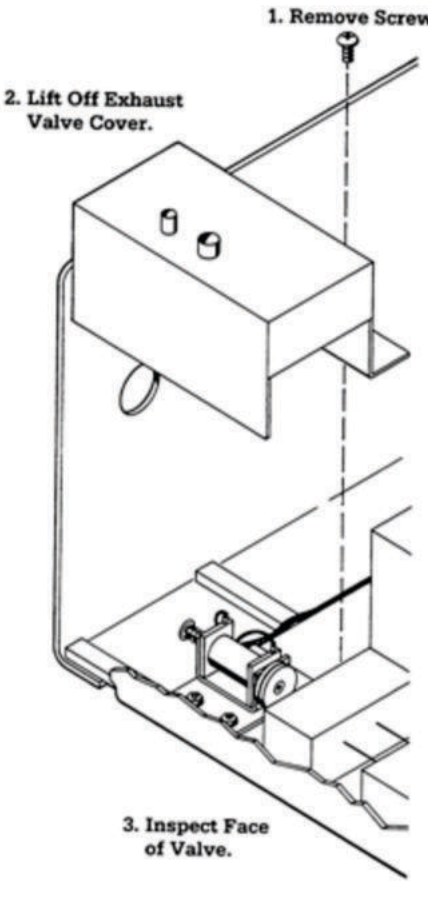


Figure 4-14
Exhaust Valve Inspection

4.11 Preoperative Checkout Procedures

⚠WARNING: Do not use the ventilator until all the Preoperative Checkout Procedures have been performed and correct operation has been verified.

Perform these procedures after cleaning and sterilizing the bellows assembly and before each case.

1. Verify that the proper hose connections have been made between the bellows assembly and the control module.
2. Verify that the proper hose connections have been made between the bellows assembly and the patient breathing circuit.
3. Verify that the correct driving gas (Oxygen Only) is securely connected to the control module.
4. Verify that the electrical power cord is plugged into a properly grounded outlet.
5. Verify that a properly functioning scavenging system is connected to the ventilator's 19 mm Exhaust port or interface manifold 19 mm connector. Do not connect the ventilator Exhaust directly to a vacuum source.

   ⚠WARNING: Do not connect the ventilator Exhaust directly to a vacuum source. The vacuum may remove required gases from the patient circuit.
6. Verify that the alarm lamps light and alarm tone sounds when the Lamp Test button is pressed (the Power switch must be On (I). If not, perform the Functional Tests in Section 3 to isolate the problem.
7. Verify that the Sigh switch is in the desired position.
8. Verify that the low airway pressure sensing tube is properly connected to the barb on the control module back panel labeled Connect to Expiratory Limb of Breathing System and to the pressure sensing tee (or Circuit Pressure fitting secured in the GMS Absorber).
9. Verify that the Low Airway Pressure Alarm and high pressure relief are functioning by doing the following:

   Verifying Low Airway Pressure

   a. Fit a rebreathing bag onto the Y connector.

   b. Fill the bellows using the anesthesia system's oxygen flush and set a gas flow of 2 L/min. Keep the bellows inflated.

   c. Switch the ventilator on.

   d. Set ventilator control dials so that no alarms activate.

   e. Remove the bag from the Y connector. The Low Airway Pressure Alarm should activate after the second ventilation cycle. If not, perform the Functional Tests in Section 3 to isolate the problem. If the alarm is functional, continue with step f.

   Verifying High Pressure Relief

   f. Keep the ventilator cycling and set the control dials for a tidal volume of 1 liter.

   g. Plug the Y connector with the test plug.

   h. During the next inspiration phase, the Set Volume Not Delivered Alarm should activate and the bellows should reinflate before the 1 liter tidal volume is reached. If not, perform the Functional Tests in Section 3 to isolate the problem.

Note: An abbreviated version of these procedures is printed on the Preoperative Check List card which slides out from under the control module. Its purpose is to remind the operator of the checks which must be made, not to give instruction. To learn safe operation of the ventilator, read the 7000 Electronic Anesthesia Ventilator's Operation and Maintenance Manual.

4.12 Bellows Assembly Leak Test

Perform this procedure after cleaning and sterilizing the bellows assembly and before each case.

1. Perform the leak test recommended for the absorber in use (consult the absorber operation and maintenance manual). The absorber must pass the leak test before performing the following steps.
2. Shut off all fresh gas flow.
3. Plug the Y connector with the test plug.
4. Fill the bellows using the anesthesia system's oxygen flush.
5. Observe the bellows. If it drops more than 100 mL in one minute, it has a leak. Tighten loose patient circuit connections, then repeat the test.

   If the leak cannot be corrected, perform the Functional Tests (Section 3) to isolate the problem.

⚠WARNING: Do not use the ventilator if it fails any part of the checkout procedure. Remove for service.

4.13 Cleaning and Sterilizing the Bellows Assembly

⚠WARNING: The bellows assembly should be sterilized periodically to minimize the risk of crossinfecting patients. Use a sterilization schedule which complies with the user's infection control and risk management policies.

Note: Because of the temperature difference between exhaled patient gases and the breathing circuit, condensation may form in the circuit. Water droplet formation is particularly noticeable in the bellows and bellows base. This is a normal occurrence. Periodic cleaning and sterilization helps keep the ventilator in proper working order.

Remember to perform the above Preoperative Checkout Procedures and Bellows Assembly Leak Test after cleaning and sterilizing the bellows and before each case.

To clean and sterilize the bellows assembly do the following:

Disassembly

Perform Step 1 if the bellows assembly is attached to the control module.

Perform Step 2 if the bellows assembly is attached to the GMS Absorber.

1. To detach the bellows assembly from the control module:
   a. Remove all hose connections from the bellows assembly.
   b. Remove the four thumbscrews which attach the bellows assembly, and carefully lift the bellows assembly from the control module.
2. To detach the bellows assembly from the GMS Absorber:
   a. Remove all hose connections from the bellows assembly.
   b. Loosen the locking knob until the locking rod is released. Hold the entire assembly firmly and pull it free from the absorber.
   c. Remove the four thumbscrews which attach the bellows assembly to the mounting assembly. Separate the bellows assembly from the mounting assembly.
   d. Remove the interface manifold from the bellows assembly ports.
3. Use Figure 4-15 as a guide for further disassembly.

Cleaning

Except for the control module, those parts shown in Figure 4-15 may be washed with a mild soap and water solution. Make sure to dry the parts thoroughly.

4. To clean the plastic bellows housing, bellows, pressure sensing tube, Pop-off Valve, bellows base and Interface Manifold do the following:
   a. Wash the plastic bellows housing with mild soap and water solution. Rinse thoroughly with cold water making sure that all soap is removed. Dry thoroughly with a soft cloth.
   b. Wash the bellows with mild soap and water solution. Rinse thoroughly with cold water making sure that all soap is removed. Remove excess water and hang the bellows up to dry overnight, suspended by its top disc.

   Note: Moisture remaining in the folds of the bellows can cause tackiness and interfere with normal operation.

   Note: Rubber materials deteriorate over a period of time and should be considered an expendable item, subject to periodic replacement. Check rubber parts often for swelling, tackiness, holes or cracking. When any of these conditions are evidence, replace the affected parts.
   c. Wash the pressure sensing tube with mild soap and water solution. Rinse thoroughly with cold water making sure that all soap is removed. Dry thoroughly.
   d. Do not submerse the Pop-off Valve. Liquids can become trapped within the valve. Clean the exterior surfaces with a soft cloth dampened in a solution of warm water and mild liquid detergent. Do not allow liquid to enter the Drive Gas Port (see Figure 4-15 Port "A"). Rinse the cloth in clean cold water and wipe the valve to remove all soap. Dry thoroughly before use and before sterilization.

   ⚠WARNING: Liquids or any foreign material trapped within the driving gas circuit of the Pop-off Valve (Port "A", Figure 4-15) and Bellows Base (Port "B" and Ports "C", Figure 4-15) can impair operation of the Pop-off Valve. Do not use the Pop-off Valve or Bellows Base if this is suspected. If complete disassembly is required to remove trapped foreign material, perform Pop-off Valve Perform-

ance Test (see Section 3.2) and Bellows Assembly Leak Test (see Section 3.3) before reuse.

e. Do not submerse the Bellows Base. Liquids can become trapped within the base. Clean the exterior surfaces with a soft cloth dampened in a warm water and mild liquid detergent solution. A bottle brush may be used to clean the 22 mm "To Anesthesia Machine" (patient) port and 19 mm "Exhaust" port. The 17 mm "Inlet" port is normally exposed only to the oxygen driving gas and should not require cleaning. Rinse the cloth and bottle brush in clean cold water and repeat cleaning procedure to remove all soap. Dry thoroughly before use and before sterilization.

⚠WARNING: Liquids or any foreign material trapped within the driving gas circuit of the Pop-off Valve (Port "A", Figure 4-15) and Bellows Base (Port "B" and Ports "C", Figure 4-15) can impair operation of the Pop-off Valve. Do not use the Pop-off Valve or Bellows Base if this is suspected. If complete disassembly is required to remove trapped foreign material, perform Pop-off Valve Performance Test (see Section 3.2) and Bellows Assembly Leak Test (see Section 3.3) before reuse.

Note: When disassembling the Bellows Base, remove the retaining screws and carefully separate the individual components. Remove the foreign material and reassemble in reverse order. Do not over-tighten screws.

f. Wash the Interface Manifold in a solution of warm water and mild liquid detergent. Rinse thoroughly in clean cold water removing all soap. Dry thoroughly before use and before sterilization.

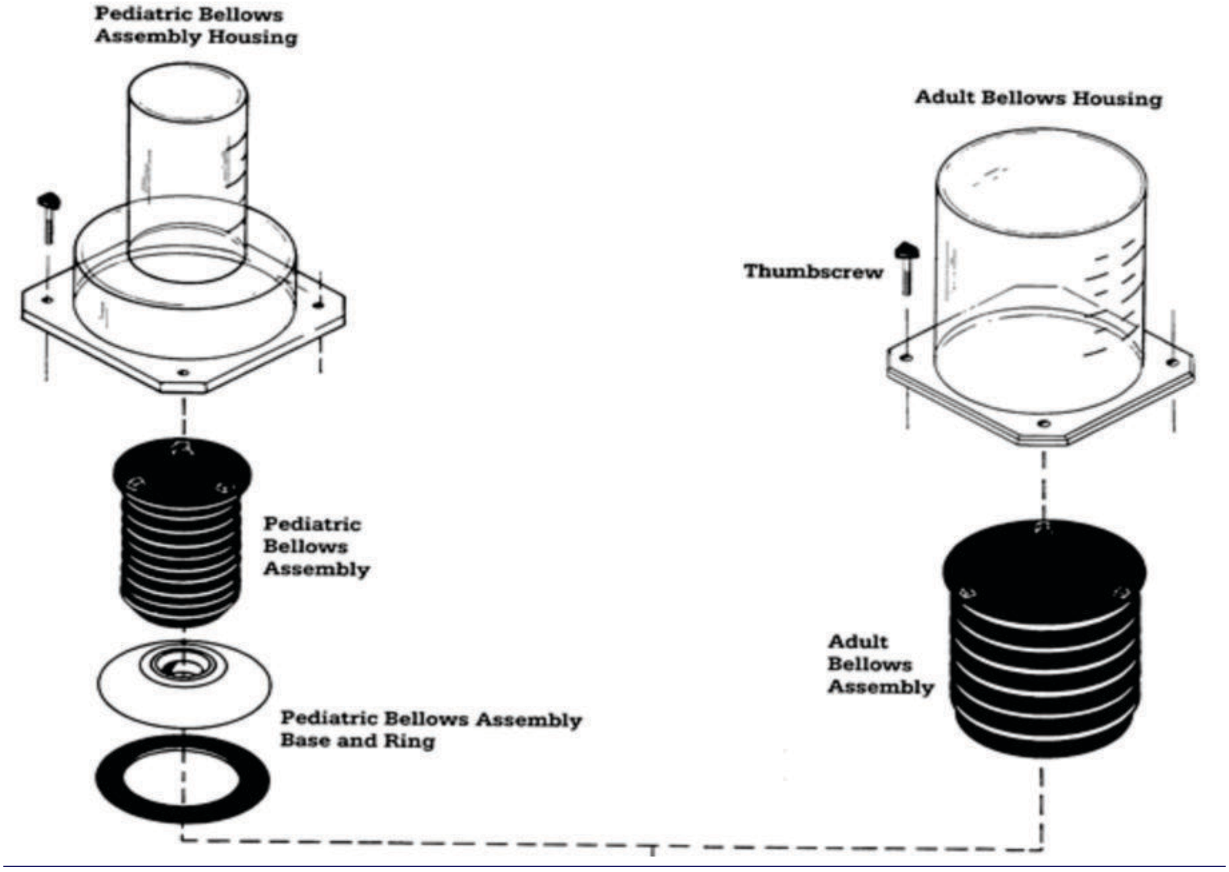
Sterilization

Except for the control module, those parts shown in Figure 4-15 may be washed with a mild soap and water solution. Make sure to dry the parts thoroughly.

Note: The clear plastic bellows housing (adult and pediatric) requires sterilization only if the bellows has torn or leaked. Normally the bellows exterior is exposed to the driving gas only. The control module is exposed to the driving gas only and does not require sterilization.

Ethylene Oxide Sterilization: After cleaning and thorough drying, all components may be sterilized using an ethylene oxide mixture not exceeding 135 degrees Fahrenheit. Follow sterilizer manufacturer's recommendations for sterilization and aeration of rubber and plastic parts.

⚠CAUTION: Those parts suitable for ethylene oxide sterilization should, following sterilization, be quarantined in a well ventilated area to allow dissipation of residual gas absorbed by components. Follow the sterilizer manufacturer's recommendations for special aeration periods required.



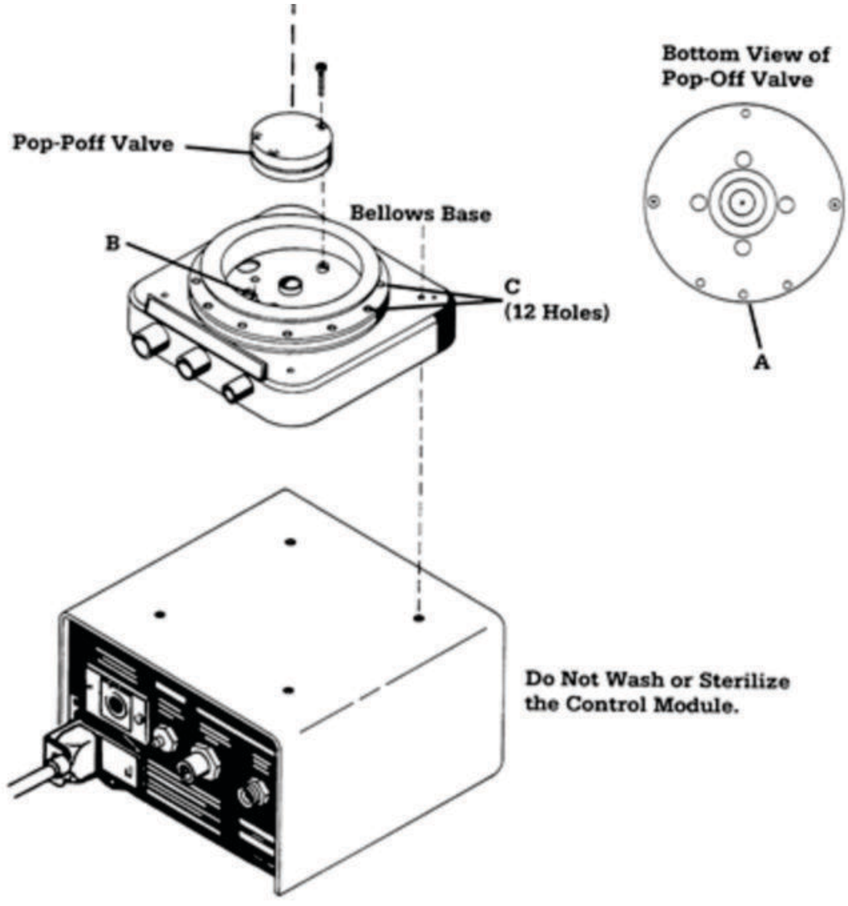


Figure 4-15
Bellows Disassembly

5.1 Troubleshooting (Basic)

Troubleshooting Guide

This troubleshooting guide is intended to isolate the cause of the most basic problems only. If after using this guide, the ventilator continues to malfunction, an Ohmeda Service Representative should be called to repair the unit.

Problem	Probable Cause	Check
Bellows does not expand during ventilation or tends to collapse.	1. Leak in the breathing circuit.	Check breathing circuit and absorber for leaks.
	2. Bellows not installed properly.	Check the bellows to base attachment.
	3. Tear or leak in bellows.	Check the entire surface of the bellows. Pay close attention to the angles in the convolutions (see Section 3).
	4. Insufficient fresh gas flow.	Check that settings on flowmeters are adequate.
	5. Improperly functioning Pop-off valve.	Check Pop-off valve (see Section 3).
Bellows distended and/or slips off base.	1. Bellows retention problem.	Check bellows (see Section 3).
	2. Bellows assembly exhaust restricted.	Check the scavenging system for high vacuum or blockage.
	3. Ventilator Pop-off valve.	Control port plugged (see Section 3) or drive gas inlet hose blocked.
Audible power failure alarm activates when turning the ventilator on.	1. Power cord disconnect or power failure.	Check the power cord connection to the wall outlet. Make sure the wall outlet has power.
	2. Fuse blown.	Check fuses.

Set Volume not Delivered alarm activates.	1. The Minute Volume and/or Rate dials are set to exceed Tidal Volume limits. 2. High pressure condition in patient circuit.	Check the Minute Volume and Rate dial settings. Make sure they allow function within the ventilator limits. See Section 2. Check patient circuit for obstruction.
Low Oxygen Supply Pressure alarm activates.	1. High pressure hose connections may be leaking. 2. Anesthesia machine power outlet circuit pressure may be low. 3. Hospital oxygen pipeline supply pressure may be low. 4. Flow restriction in the oxygen supply line.	Check high pressure hose connections at ventilator and oxygen source. Check pressure in power outlet circuit. Check pressure of hospital oxygen pipeline supply. Check oxygen supply line on hose for restrictions.
Ventilator cycles normally but Low Airway Pressure alarm activates.	The tube from the ventilator port labeled Connect to Expiratory Limb of Breathing System to the distal LowPressure Alarm tee or connector is disconnected, plugged or kinked.	Check the connections at the ventilator control module and at the sensing tee or connector.
Actual I:E Ratio Less than Dial Setting alarm activates.	The Minute Volume and I:E Ratio dials are set to exceed ventilator functional limits.	Check the Minute Volume and I:E Ratio dial settings. Make sure they allow function within the ventilator limits. See Section 2.1.
Continuous flow of supply gas before machine is turned on.	1. Valve plate assembly. 2. Internal hose leak. 3. Bleed valve failure.	Manually hold exhaust valve closed and check for gas flow from control unit driving gas outlet. Check hose. Check bleed valve outlet for gas flow.
Bellows does not descend during inspiration.	Failure of exhaust valve.	Check exhaust valve.
Ventilator Failure Alarm activates.	1. High pressure condition in patient circuit. 2. Failure in critical area of control module.	Check patient circuit for obstruction. Contact Ohmeda Service for ventilator repair.

5.2 Troubleshooting (Extended)

This troubleshooting guide is intended to isolate the cause of most problems. If after using this guide, the ventilator continues to malfunction, an Ohmeda Service Representative should be called to repair the unit.

Problem	Probable Cause	Check
Power failure	Transformer, board connector or power switch	a. Check ac to board at cathode D-50.
	PC board	b. Check for +8 ± 0.15 volts at TP8.
	PC board	c. Check for -8 ± 0.15 volts at TP9.
Ventilator failure	PC board	a. Check for flow gate TP17, see Figure 7-4. (If present go to C).
	PC board	b. Check for rate at TP15, see Figure 7-3.
	PC board	c. Check junction D16, 17 and 18 for exhaust valve lockout reset pulse.
	PC board	d. Check for ramp at TP18, see Figure 7-5.

Low supply pressure	Pressure switch	a. Check supply pressure to SW6 pressure switch to be above 35 psi.
	Pressure switch or PC board	b. Check pin 46 for zero volts.
Patient pressure alarm	Bellows not installed properly	a. Check pressure connection from bellows base to control unit.
	Pressure switch or PC board	b. Check cathode of D13 for reset pulse each time the bellows is driven.
	PC board	c. Check ramp at T19 see Figure 7-6.
Actual I:E less than setting	PC board	a. Check TP13 for 1.933 ± 0.10 volts.
	PC board	b. Check U2 pin 7 for 7.65 ± 0.5 volts.
Low Tidal Volume	PC board	a. Check TP4 for 0.34 ± 0.02 volts.
	Leaking in the breathing circuit	b. Check driving gas to bellows assembly is within 1 L/min of set Flow Rate.
	Breathing circuit compliance	c. Perform bellows assembly tests (see Section 3).
		d. Check breathing system and absorber for leaks.
		e. See Section 2 on compliance.

6/Repairs and Parts

⚠**WARNING: Fire Hazard. Never oil or grease any anesthesia equipment. In general, oils and greases oxidize readily, and in the presence of oxygen they will burn violently.**

⚠**WARNING: The alarm circuit check (section 7-16) must be performed before the ventilator is returned to use after any service procedure.**

⚠**WARNING: Disconnect power before removing the cover panel. Leave the power disconnected unless specifically instructed otherwise.**

⚠**WARNING: Electrical Shock Hazard. Do not touch exposed wires or conductive surfaces while the cover panel is removed from the ventilator unless electrical power is disconnected from the unit. Hazardous voltages are present during normal operation. Never wear a grounding wrist strap when working on an energized ventilator.**

⚠**CAUTION: Always wear a grounding wrist strap when handling static sensitive assemblies except when working on an energized unit. Otherwise, electrostatic discharges can damage electronic components.**

Note: Check operation of the unit after any service procedure is performed.

Note: Assembly is the reverse of disassembly except where noted.

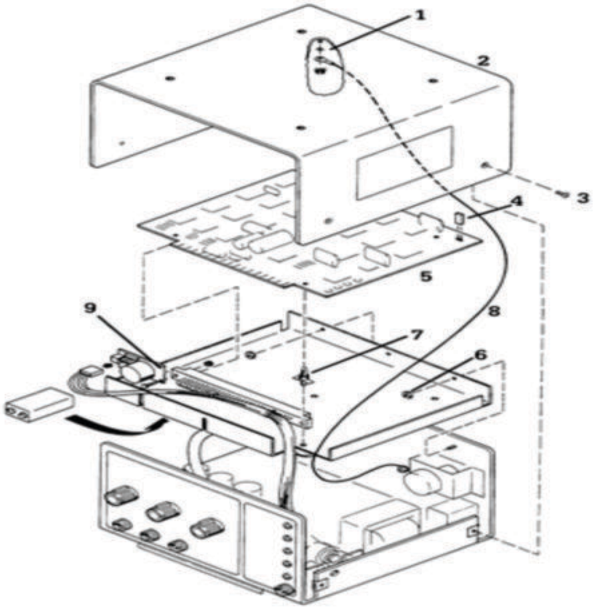
6.1 Circuit Board Assembly

⚠**CAUTION: Only control boards with assembly revision 14 or higher can be used with this version of the 7000 Electronic Ventilator. Use of earlier version boards will result in malfunction of the ventilator.**

Tools Required:

- #2 Phillips screwdriver
- 5/16" open-end wrench
- 5/16" nutdriver
- Solder gun and solder
- needle nose pliers
- 1/8" flat-tip screwdriver
- wire cutting/stripping tool
- 5 mm nutdriver

1. Unplug the ventilator's line cord from the wall outlet and disconnect the O_2 power source.



Description	Stock Number
1. Washer	0202-3200-300
2. Cover Panel	0229-1001-710
3. Screw	0140-6224-106
4. Alarm Jumper Plug	0690-1563-315
5. Circuit Board (Calibrated)	0208-6349-700
6. Nut	0202-1130-300
7. Stand-off, Circuit Board mtg	0602-2088-300
8. Wire, Grounding, Cover Panel	1502-7016-000
9. Over Pressure PC Board	0208-6341-300
Not Shown	
Audio Alarm	0690-1100-301

Figure 6-1
Circuit Board Assembly Removal

2. Remove four screws fastening the cover panel onto the chassis then set the panel aside, (Figure 6-1).

3. Gently lift the circuit board while releasing it from its five mounting pegs.

   ⚠CAUTION: Do not apply excessive force to the circuit board when removing it. Over-stressing may damage the printed circuit board.

4. Unplug the circuit board from the harness connector to replace it.

5. Unplug the connector from the over pressure board.

6. Remove the four nuts that fasten the circuit board mounting plate into position.

7. Lift the front of the circuit board mounting plate about an inch and a half then slide it forward off the rear panel mounting studs.

8. Any of the following components can now be replaced.

A. Transformer

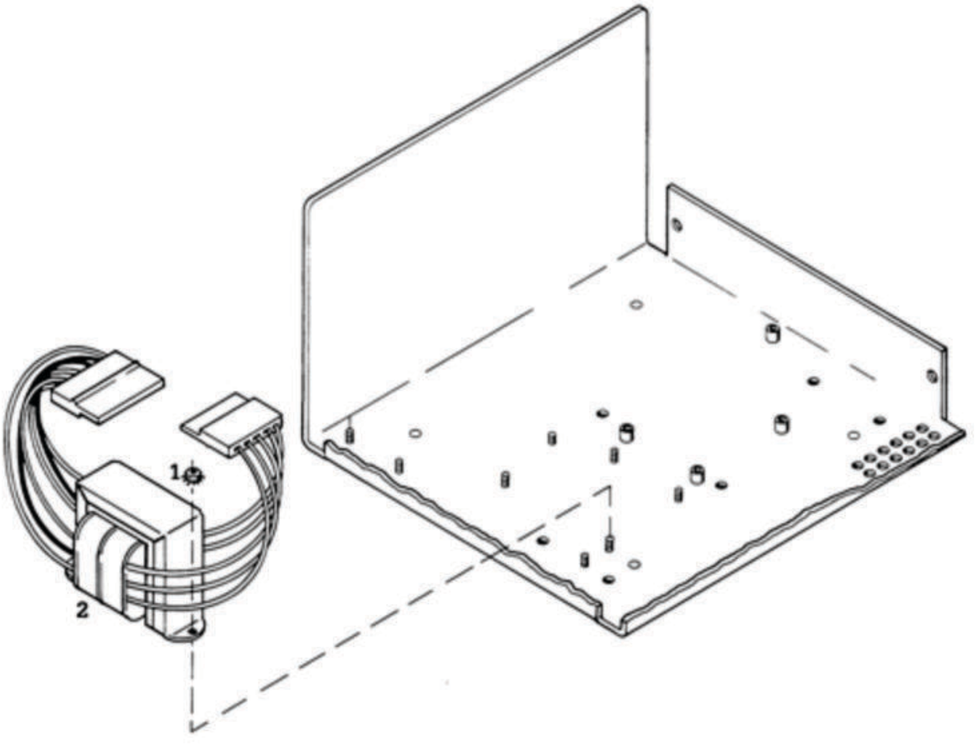
(See Figure 6-2)

1. Disconnect the two connectors from the transformer from their mating connectors.

2. Remove the two nuts retaining the transformer and remove the old transformer.

3. Mount the new transformer onto the main-frame of the ventilator.

4. Connect the two connectors from the transformer to the mating connectors.



Description	Stock Number
1. Nut	0202-1130-300
2. Transformer	1502-3000-000

Figure 6-2
Transformer

B. Battery Clip

(See Figure 6-3)

1. Pry the battery out of the clip.
2. Unfasten the old battery clip then install the replacement.
3. Transfer the wire connections from the old clip to the replacement, working one wire at a time. Use shrink wrap insulation over both solder joints.
4. Fasten the battery to the clip.

C. Board Mounting Plate

(See Figure 6-3)

1. Remove the battery and unfasten the battery clip from the plate.
2. Install the battery clip on the new mounting plate. Orient the component as shown in Figure 6-3.

6.2 Flow Control Unit

⚠WARNING: Never tamper with or disassemble the flow control solenoid valves. Such actions will compromise the calibration of the Flow Control Unit, which must then be replaced as an assembly.

Tools Required:

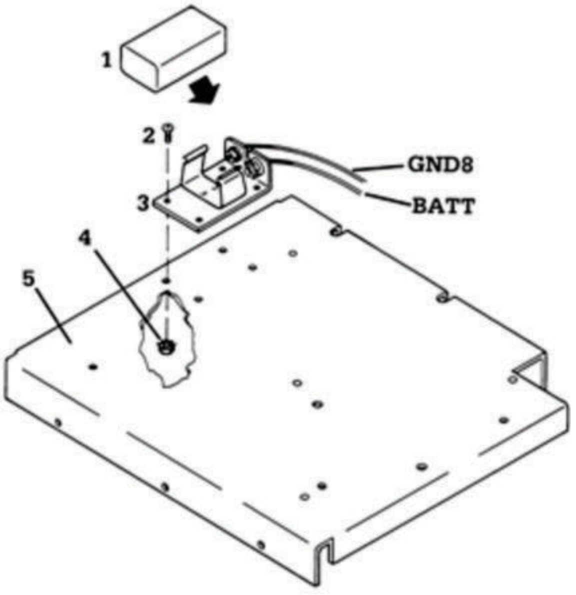
- 5/16" nutdriver
- 5/16" open-end wrench
- #2 Phillips screwdriver
- needle nose pliers
- 7/8" open-end wrench
- Pin extractor (Molex #11-03-002) (Ohmeda #0175-2355-000)
- 1/4" open-end wrench

1. Unplug the ventilator's line cord from the wall outlet and disconnect the O_2 power source.
2. Remove the Circuit Board Assembly per Section 6.1. Disregard steps 3 through 5 of Section 6.1 as the circuit board itself is not being replaced.
3. Disconnect all internal hoses. See Figure 6-7 for internal hose connections.
4. Remove the pressure regulator per Section 6.5.

   Note: It may also be necessary to remove the Lamp Test switch in order to remove the regulator. (See Section 6.3C).
5. Take off the rear panel oxygen supply connector. (See Figure 6-4).

See Figure 6-5.

6. Unplug both wiring harness connections to the solenoid valves.



Description	Stock Number
1. Battery	1502-3016-000
2. Screw	0140-6617-103
3. Clip, Battery	1502-3015-000
4. Nut	0144-3717-312
5. Board Mounting Plate	0234-0210-500

Figure 6-3
Battery Clip and Shelf

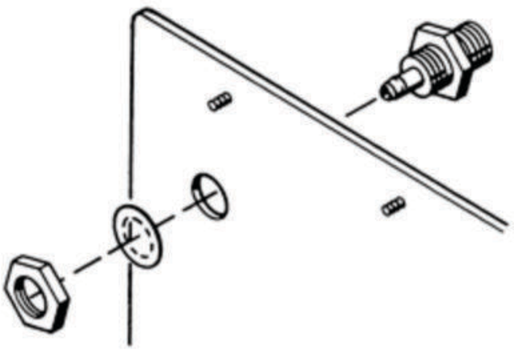
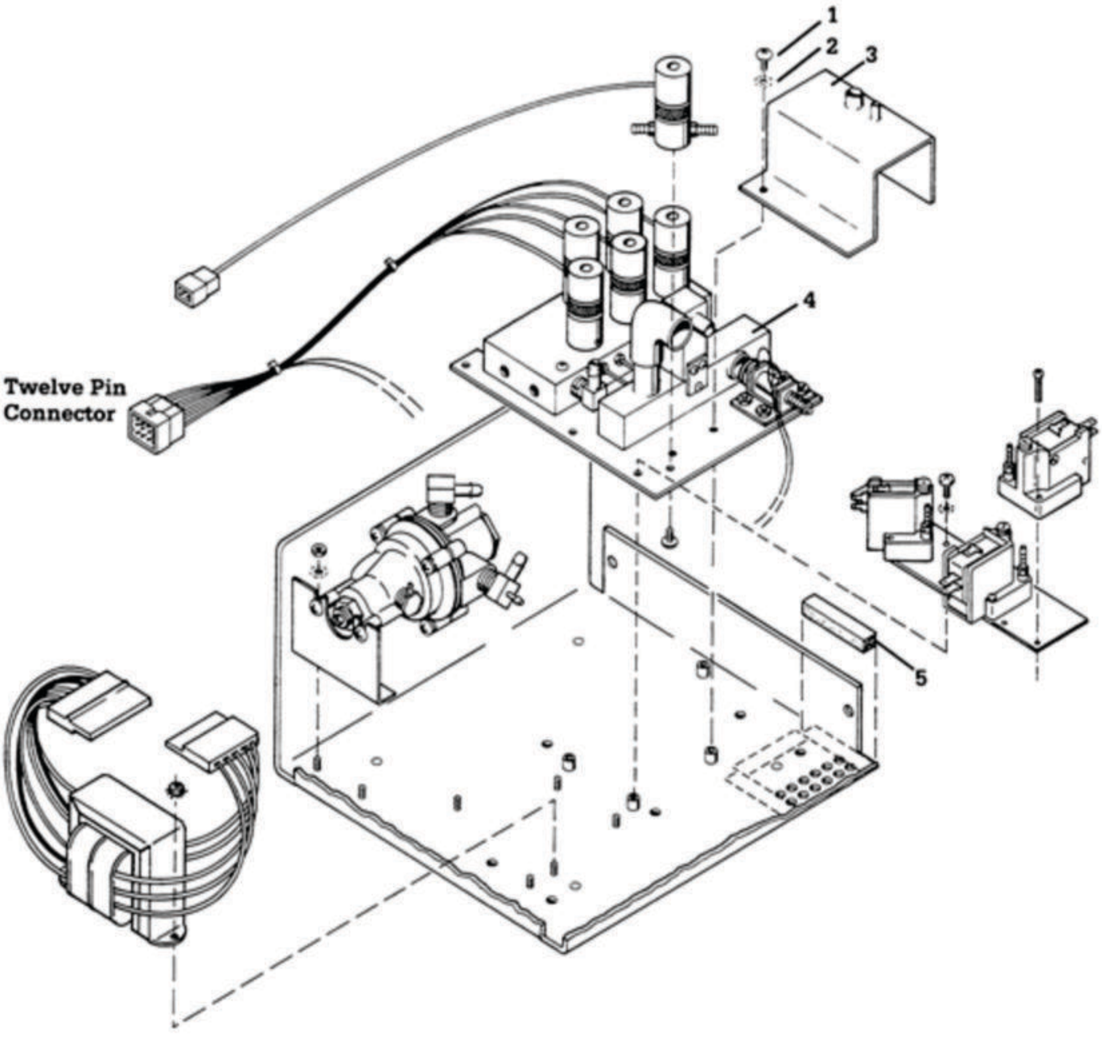


Figure 6-4
Removing the Rear Panel Gas Supply Connector Before Removing the Flow Control Unit

7. Remove all five mounting screws from the flow control unit, then lift it out of the chassis.

8. With the Flow Control Unit removed from the chassis, any of the following components can be replaced.



Description	Stock Number
1. Screw	0140-6124-105
2. Washer	0202-3200-300
3. Cover, Exhaust	0229-1000-742
4. Flow Control Unit, Calibrated, Less Regulator Bleed Valve	1502-8001-000
5. Seal, Exhaust (1 Section Required; Cut to Length)	0999-1116-010

Figure 6-5
Flow Control Unit

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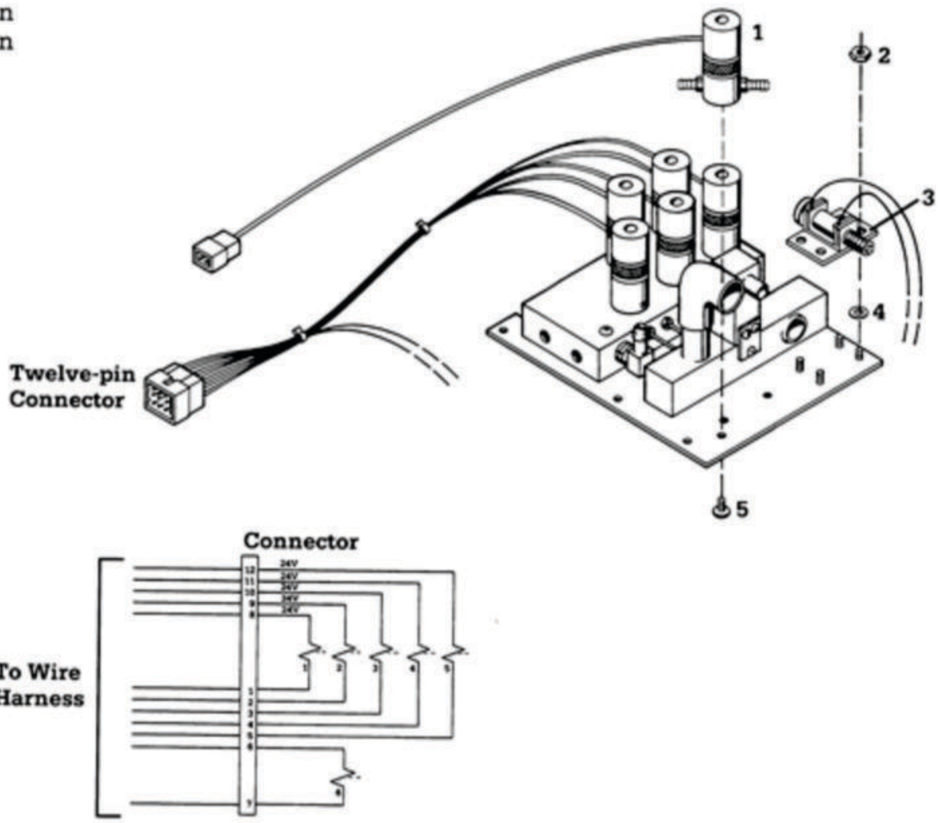
A. Exhaust Valve

1. Unbolt the old exhaust valve.
2. Referring to Figure 6-6, locate the exhaust valve wiring connections to the valve wire connector.
3. Using a pin extractor, transfer the wire connections of the replacement valve to the connector.
4. Loosely screw the replacement valve into position.
5. Manually extend the valve stem as far as it will go. Slide the assembly in the slots until the pad is compressed about 1/32 of an inch against the low pressure manifold seat. Tighten the exhaust valve assembly (4 places).
6. Reconnect the gas hose to the rear panel gas supply inlet connector.
7. Connect 50 psig O_2 supply to the ventilator.
8. Set front panel controls as follows:

   MV 30 L/min
   Rate 6 B/min
   I:E 1:1

9. (Disregard any alarms: jumper TJ1 maybe removed to silence alarms). Apply power to the ventilator.
10. Occlude the bellows assembly inlet port at rear of chassis.
11. Visually watch to see that the exhaust valve seats properly and that there are no leaks or blow by. A small amount of water maybe used to check for leaks. Drive Gas (O_2) should only be relieving through the pressure relief valve.

    If exhaust valve functions properly reassemble the unit then test it for leaks and correct operation. See Service Manual, Section 3. If proper operation is not achieved, readjust the exhaust valve assembly or if necessary replace it and retest.
12. Remove power from the ventilator.
13. Reassemble the unit then test it for leaks and correct operation (Section 3). See Figure 6-7 for hose connections.



Wiring Schematic

Valve Number	Flow
1	2 L/min
2	4 L/min
3	8 L/min
4	16 L/min
5	32 L/min

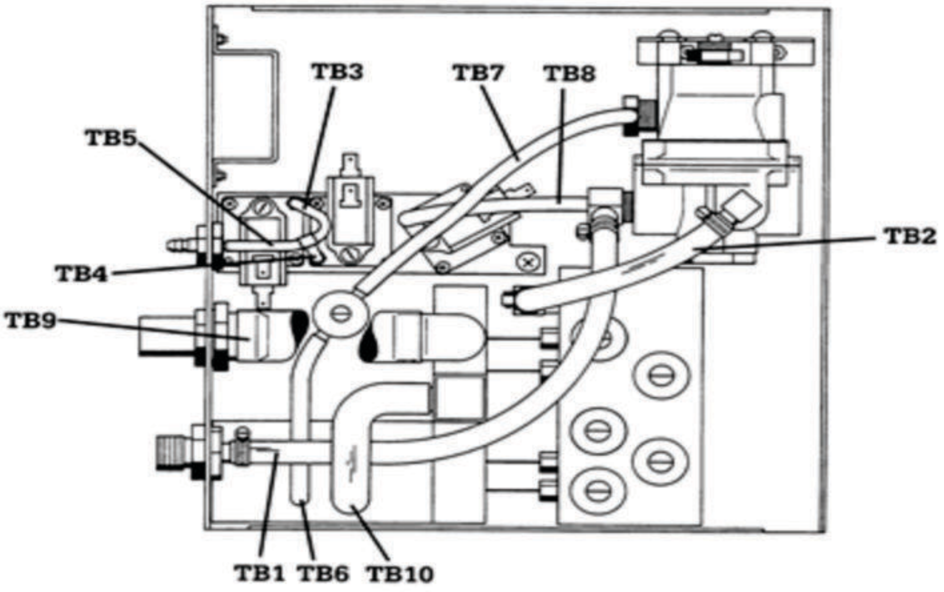
Description	Stock Number
1. Valve, Bleed, Regulator	0229-1034-700
2. Nut	0202-1130-300
3. Valve, Exhaust	0229-1014-700
4. Spacer	0144-1006-131
5. Screw	0140-6124-104

Figure 6-6
Exhaust Valve Regulator Bleed Valve

B. Regulator Bleed Valve

(See Figure 6-6)

1. Remove the two valve mounting screws from underneath the flow plate.
2. Fasten the replacement valve into position. Orient it with the valve outlet towards the exhaust valve.
3. Reassemble the ventilator. (See Figure 6-7 for internal hose connections.) Check that the valve opens to bleed the regulator when the ventilator is switched on, and closes to prevent the regulator from leaking when the ventilator is switched off.



Description	Stock Number
1. Tee	0204-8847-300
2. Hose Clamp	0690-1240-322

Tubing No.

TB 1	0995-6439-010
TB 2	0995-6439-010
TB 3	0994-6370-010
TB 4	0994-6370-010
TB 5	0994-6370-010
TB 6	0994-6370-010
TB 7	0994-6374-010
TB 8	0994-6374-010
TB 9	0994-6499-010
TB 10	0994-6435-010

Figure 6-7
Internal Hose Connections

6.3 Front Panel Components

Tools Required:

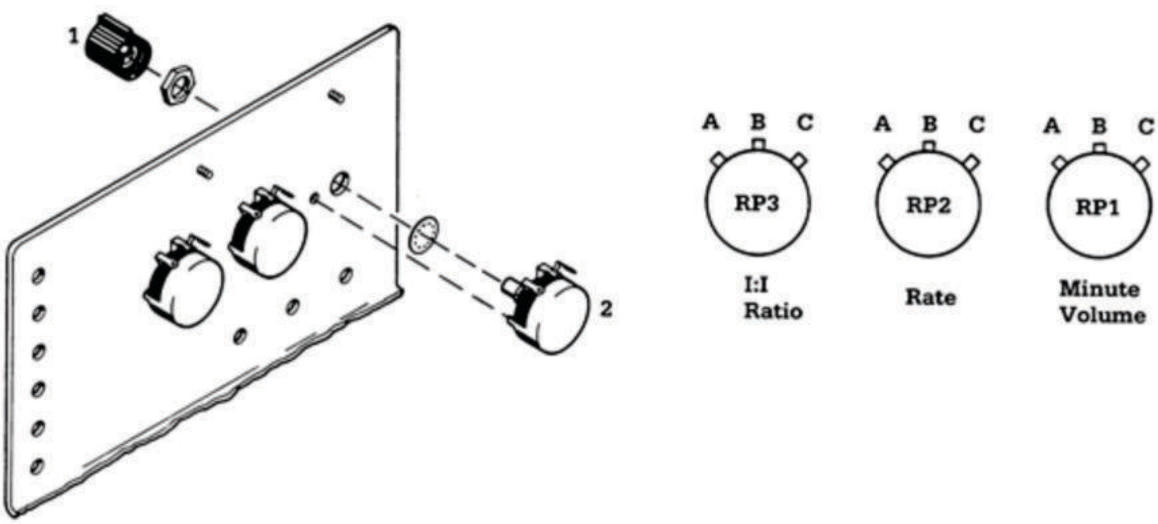
- #2 Phillips screwdriver
- 5/16" open-end wrench
- 1/2" open-end wrench
- 5/16" nutdriver
- 1/16" hex key wrench
- soldering tool and solder
- needle nose pliers
- wire cutting/stripping tool
- ordinary pliers
- pin extractor

1. Remove the Circuit Board assembly per Section 6.1. Disregard steps 3 through 5 of Section 6.1 as the circuit board itself is not being replaced.
2. With the chassis exposed, any of the following front panel components can be replaced. Reassembly is the reverse of disassembly except as noted.

A. Potentiometer Replacement

(See Figure 6-8)

1. Use a hex key wrench to remove the control knob from the old pot.
2. Remove the mounting nut from the front of the old pot.
3. Remove the old pot and insert the replacement in the front panel.
4. Fasten the replacement in position with the mounting nut. The tab on the face of the pot must set into the alignment hole provided in the front panel.
5. Working one wire at a time, transfer the electrical connections from the old pot to the replacement. Insulate all solder joints with heat-shrink tubing.
6. Reassemble the ventilator, leaving the cover panel off. Calibrate the potentiometer per Section 7.6.



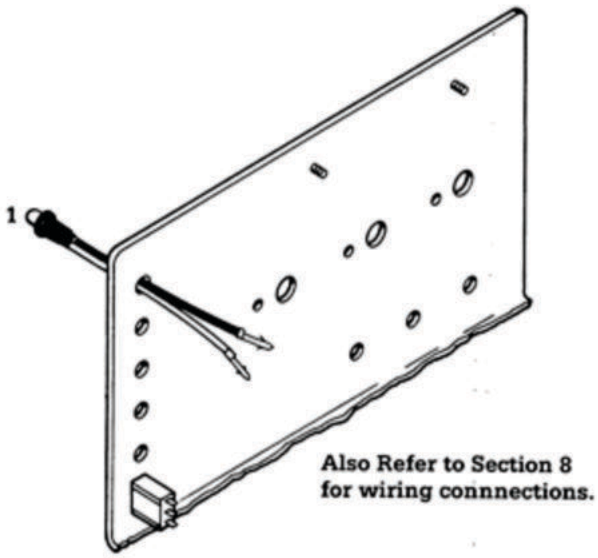
Description	Stock Number
1. Knob, Control	0212-1945-300
2. Potentiometer, w/Mounting Hardware	0681-0800-000

Figure 6-8
Potentiometers

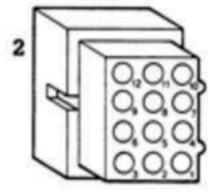
B. Alarm Lamps

(See Figure 6-9)

1. Extract the wires of the burned out lamp from the wiring harness connector. Note which sockets the wires came out of.
2. Push the old lamp forward, out of the front panel.
3. Feed the wires of the replacement lamp through the front panel hole from the front. Press the lamp into place.
4. Insert the wires from the replacement lamp into the wiring harness connector. Make sure the wires go into the correct sockets.



Description	Stock Number
1. Lamp	0683-9017-700
2. Socket, Wiring	0690-1565-306



Pin	Name	Color
1	DS1	Blk
2	DS2	Blk
3	DS3	Blk
4	DS4	Blk
5	DS5	Blk
6	NC	Blk
7	DSP2	Blk
8	DSP1	Blk
9	NC	Blk
11	DSP3	Blk
12	DSP5	Blk
13	DSP4	Blk

Figure 6-9
Indicator Lamp Replacement

C. Switches

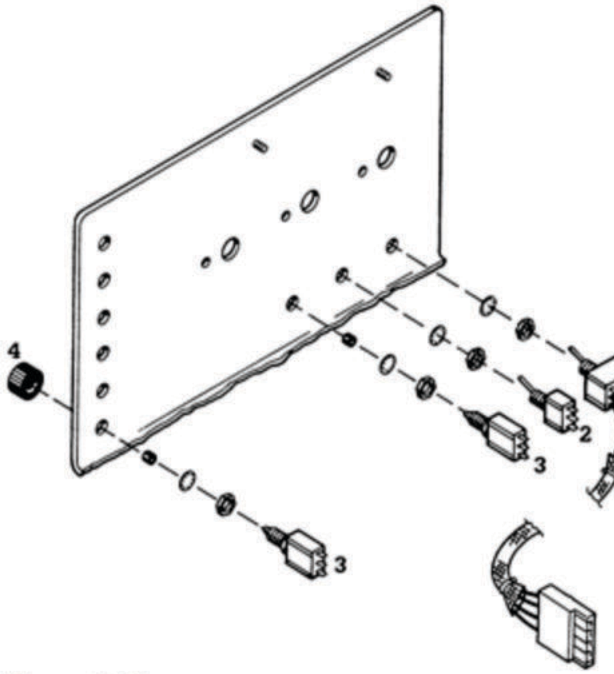
(See Figure 6-10)

1. Remove the bezel nut from the switch that is to be replaced.
2. Slide the switch back out of the front panel. If necessary, cut some of the harness ties to allow the switch to be moved into a position where its terminals are readily accessible.
3. Working one wire at a time, transfer the control harness wires from the old switch to the replacement. Cover all solder joints with heatshrink.

   For power switch only (a. and b.):

   a. Disconnect the four wire harness of the old switch from the four pin connector from the power inlet module.

   b. Route the four wire harness of the new switch s/a along the bottom in the front and right side of the chassis. Connect the switch s/a harness to the four pin connector from the power inlet module.
4. Insert the replacement switch in the front panel and fasten it into position with the bezel nut. Use medium strength thread-locking compound on the nut. (Loctite #242).
5. Check the switch for correct operation.



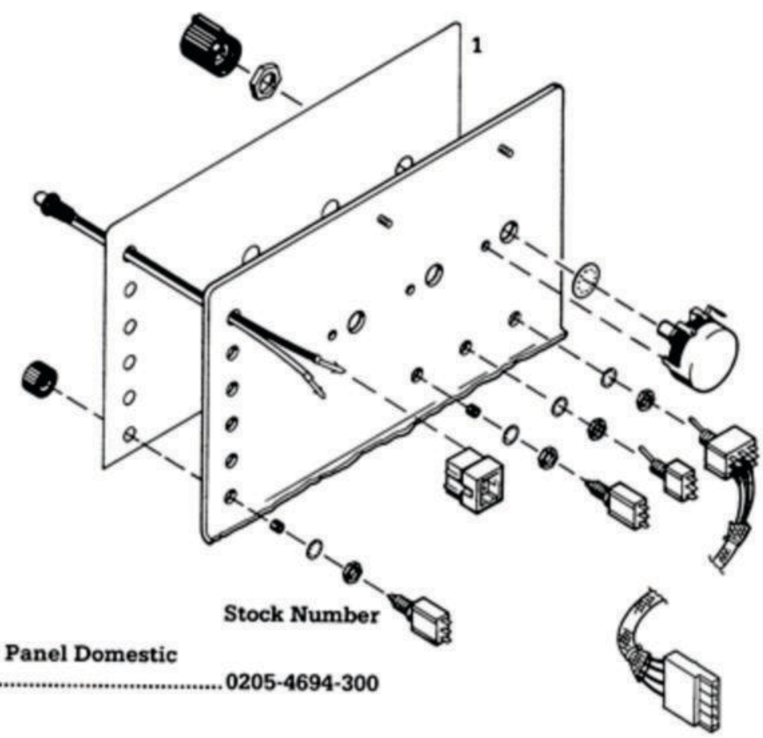
Description	Stock Number
1. Switch, On/Off, w/mtg Hardware ..	0690-2500-345
2. Switch w/mtg Hardware	0690-2500-346
3. Switch w/mtg Hardware	0690-2500-343
4. Knob	0690-2500-344

Figure 6-10
Front Panel Switches

D. Front Panel Overlay

(See Figure 6-11)

1. Remove the bezel nuts from all four of the switches and push them back out of the panel.
2. Remove the alarm lamp wire connections from their wiring harness connector.
3. Push all five of the lamps forward out of the front panel.
4. Remove the knobs and mounting nuts from the potentiometers. Push the potentiometers back out of the front panel.



Description	Stock Number
1. Overlay, Front Panel Domestic (English)	0205-4694-300

Figure 6-11
Front Panel Overlay

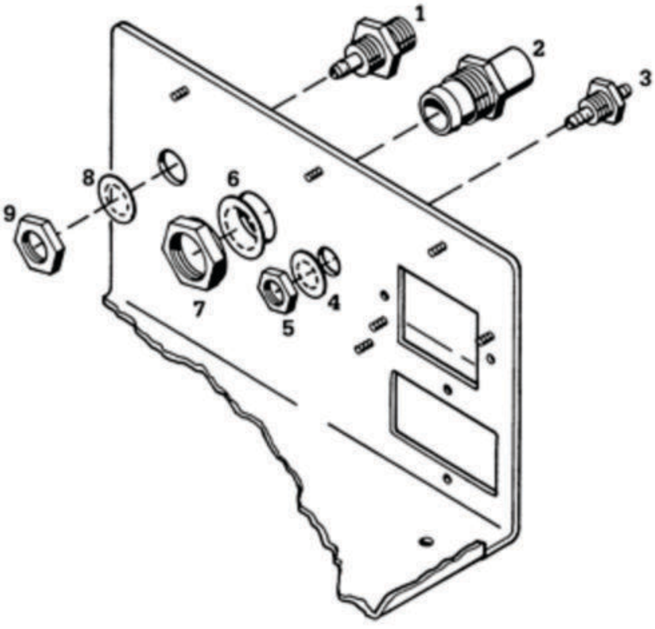
5. Insert a sharp knife into the crack between the front panel and the overlay. Peel off the overlay.
6. Clean the surface of the front panel with a suitable solvent or rubbing alcohol.
7. Remove the backing from the new panel overlay. Position the overlay carefully then press it into place.
8. Reassemble the ventilator leaving the cover panel off. Refer to Figure 6-9 when inserting the alarm lamp wire connections into the wiring harness connector. Calibrate all three potentiometers per Section 7.6.

6.4 Rear Panel Components

Tools Required:

- #2 Phillips screwdriver
- 5/16" open-end wrench
- 5/16" nutdriver
- 7/8" open-end wrench
- 1/2" open-end wrench
- needle nose pliers
- 1/16" hex key wrench
- soldering tool and solder
- wire cutting/stripping tool

1. Remove the Circuit Board assembly per Section 6.1. Disregard steps 3 through 5 of Section 6.1 as the circuit board itself is not being replaced.
2. With the chassis exposed, any of the rear panel gas connectors can be disengaged from the internal hoses and replaced. (Figure 6-12).



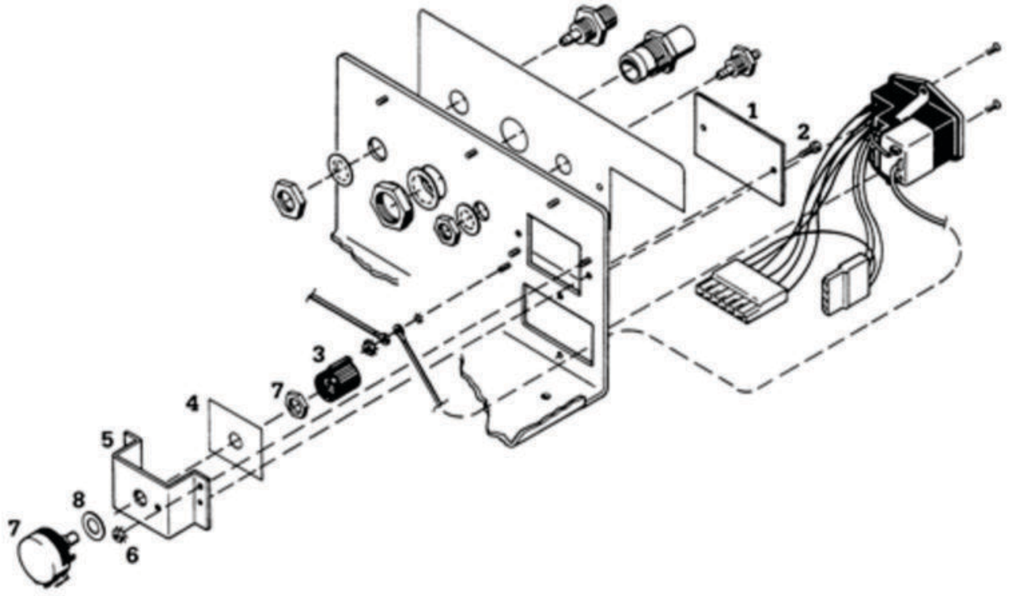
Description	Stock Number
1. Adapter, Inlet, O_2 DISS	0229-0004-535
2. Connector, 15 mm	0229-0005-535
3. Connector, 1/8 inch barbed hose	0229-0006-535
4. Washer	0202-3422-340
5. Nut	0402-1683-535
6. Washer	0202-3432-300
7. Nut	0402-1779-535
8. Washer	0144-1126-131
9. Nut	0402-1544-535

Figure 6-12
Rear Panel Connectors

A. Altitude Adjustment Potentiometer Replacement

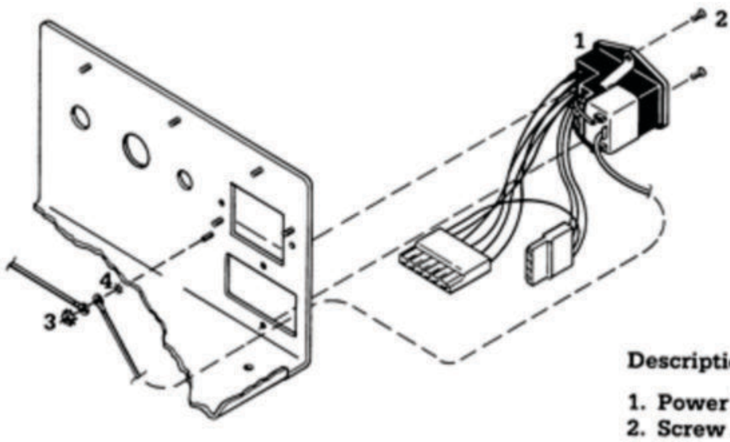
(See Figure 6-13)

1. Remove the adjustment cover panel.
2. Remove the knob from the pot.
3. Remove the pot from the mounting bracket.
4. Working one wire at a time, transfer the wire connections from the old pot to the replacement. Cover all solder joints with heat-shrink insulation.
5. Mount the replacement pot on the mounting bracket. Orient the pot with the alignment tab in the alignment hole provided in the bracket.
6. Calibrate the control per Section 7.6 then reassemble the ventilator.



Description	Stock Number
1. Plate	0229-0029-300
2. Screw	0144-2124-206
3. Knob	0212-1945-300
4. Label	0205-4696-300
5. Bracket, mtg	1502-5000-000
6. Nut	0202-1130-300
7. Potentiometer (Includes Bezel Nut)	0681-0800-000
8. Washer	0402-6224-105

Figure 6-13
Altitude Adjustment Potentiometer Replacement



Description	Stock Number
1. Power Entry Module S/A	1502-7002-000
2. Screw	0400-3153-300
3. Nut	0202-1130-300
4. Washer	0202-3200-300

Figure 6-14
Power Entry Module Replacement

B. Power Entry Module Replacement

(See Figure 6-14)

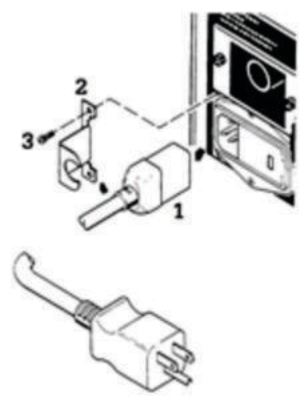
1. Remove the power cord from the AC power source.
2. Remove the two socket head screws and remove the power cord anti-disconnect bracket. See figure 6-15.
3. Disconnect the six position connector of the transformer from the mating connector of the power entry module.
4. Disconnect the four position connector of the On/Off switch from the mating connector of the power entry module.
5. Disconnect the ground wires to the chassis.
6. To remove the power entry module, remove the two phillips mounting screws and pull the module out from the chassis.
7. Place the new power entry module into the chassis and secure with the mounting screws.
8. Connect the ground wires from the power entry module and from the cover to the chassis ground stud.
9. Connect the four position connector to the mating connector from the On/Off switch.
10. Connect the six position connector to the mating connector from the transformer.
11. Install the fuses and set the input voltage as per sections 4.8 and 4.9.
12. Reinstall the power cord and the power cord anti-disconnect bracket.

C. Anti-Disconnect Bracket and Power Cord Plug Removal

(See Figure 6-15)

To remove the anti-disconnect bracket and the power cord plug from the ventilator control module:

1. Remove the power cord from the ac power source.
2. Remove the two socket head screws and remove the power cord anti-disconnect bracket. The power cord plug can now be disconnected.



Description	Stock Number
1. Power Cord	1502-3020-000
2. Anti-Disconnect Bracket	1502-5000-000
3. Screw, Socket Head Cap	0144-2124-206

Figure 6-15
Anti-Disconnect Bracket and Power Cord Plug Removal

6.5 Chassis Components

Tools Required:

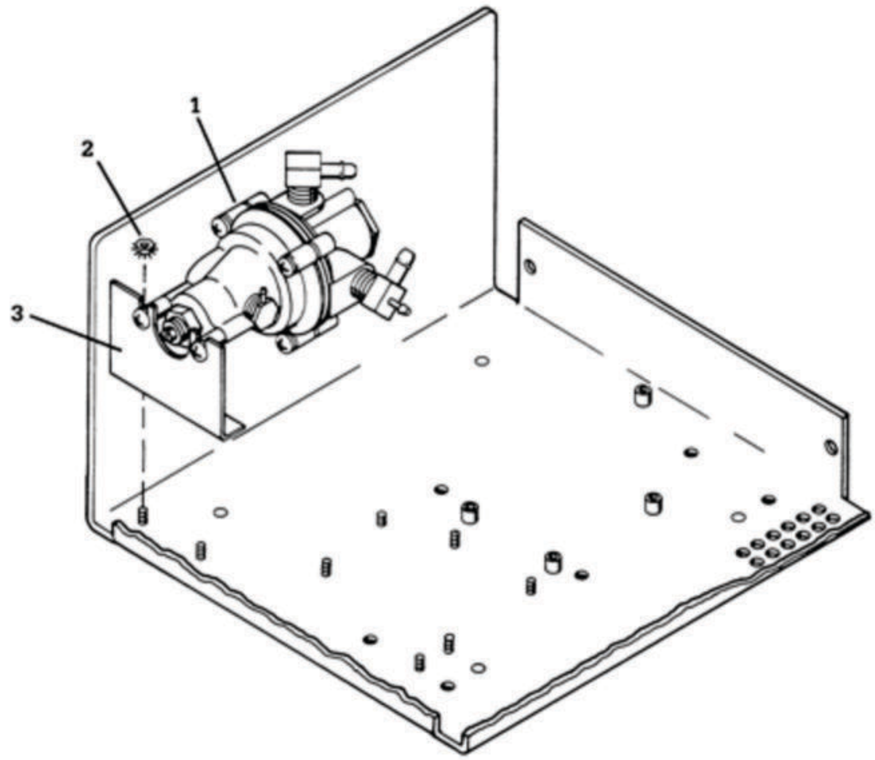
- #2 Phillips screwdriver
- #1 Phillips screwdriver
- 1/8" flat tip screwdriver
- 5/16" open-end wrench
- 5/8" open-end wrench
- 5/16" nutdriver
- needle nose pliers
- soldering tool and solder
- wire cutting/stripping tool
- 5 mm nutdriver

1. Remove the Circuit Board assembly per Section 6.1. Disregard steps 3 through 5 of Section 6.1, as the circuit board itself is not being replaced.
2. With the chassis exposed, the following components can be replaced.

A. Regulator Replacement

(See Figure 6-16)

1. Remove the Lamp Test switch from the front panel (See Section 6.3 C).
2. Unclamp and disconnect the high pressure hoses from the regulator.
3. Disconnect the bleed valve tube from the regulator.
4. Unbolt the regulator mounting bracket from the chassis.
5. Lift the regulator out of the chassis.
6. Install the replacement regulator. Adjust the regulator per Section 4.9 before placing the cover panel on the unit.



Description	Stock Number
1. Regulator, w/mtg Bracket, Hose Connections	0306-0618-800
2. Nut	0202-1130-300
3. Bracket, Regulator mtg (*)	0234-0202-500
(*) Included with Regulator Kit	0306-0618-800

Figure 6-16
Regulator Replacement

B. Low Supply Pressure Switch

(See Figure 6-17)

Adjustment Procedure

1. To adjust the Low Supply Pressure switch, connect the ventilator to the test equipment specified in section 3.4.
2. Perform the test in section 3.4.
3. Adjust the switch. Turning the adjustment screw counterclockwise reduces the pressure trip point.
4. Repeat the test from section 3.5. Repeat adjustments and tests until the switch trips at the specified points or clearly cannot be made to do so.
5. Replace the switch if it is defective.

C. High and Low Airway Pressure Switches

Adjustment Procedure

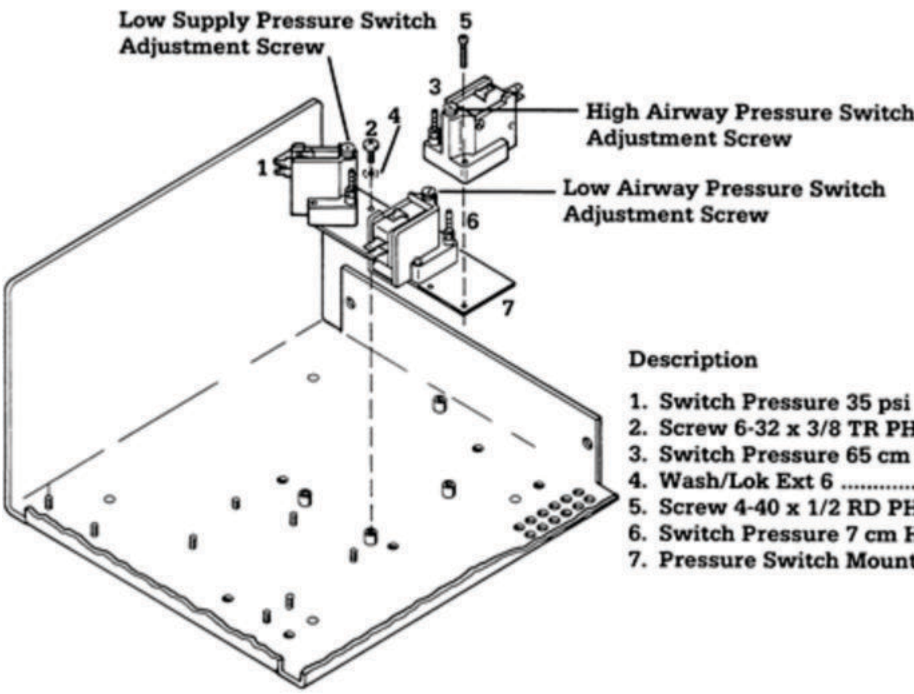
(See Figure 6-17)

1. To adjust the Low and High Airway Pressure switches, connect the ventilator to the test equipment specified in Section 3.5 or 3.10 as required.
2. Perform the test in Sections 3.5 or 3.10 as required.
3. Adjust the pressure switches. Turning the adjustment screw counterclockwise to reduce the pressure trip point.
4. Repeat the test from Section 3.5 or 3.10 as required. Repeat adjustments and tests until the switch trips and the alarm is silenced at the specified points or clearly cannot be made to do so.
5. Replace the switch if it is defective.

D. Pressure Switch Replacement

(See Figure 6-17)

1. Unscrew the switch that is to be replaced from the mounting plate.
2. Disconnect the hose from the switch that is to be replaced.
3. Transfer the electrical connections from the old switch to the replacement, working one wire at a time.
4. After reassembling the ventilator, check the operation of the replaced switch per Section 3.



Description	Stock Number
1. Switch Pressure 35 psi Oxygen	0208-5175-300
2. Screw 6-32 x 3/8 TR PH HD (2)	0140-6624-106
3. Switch Pressure 65 cm H_2O	0208-5174-300
4. Wash/Lok Ext 6	0202-3200-300
5. Screw 4-40 x 1/2 RD PH HD (6)	0140-6117-108
6. Switch Pressure 7 cm H_2O	0208-5176-300
7. Pressure Switch Mounting Plate	1502-5002-000

Figure 6-17
Pressure Switches

E. Preoperative Checklist Card Replacement

(See Figure 6-18)

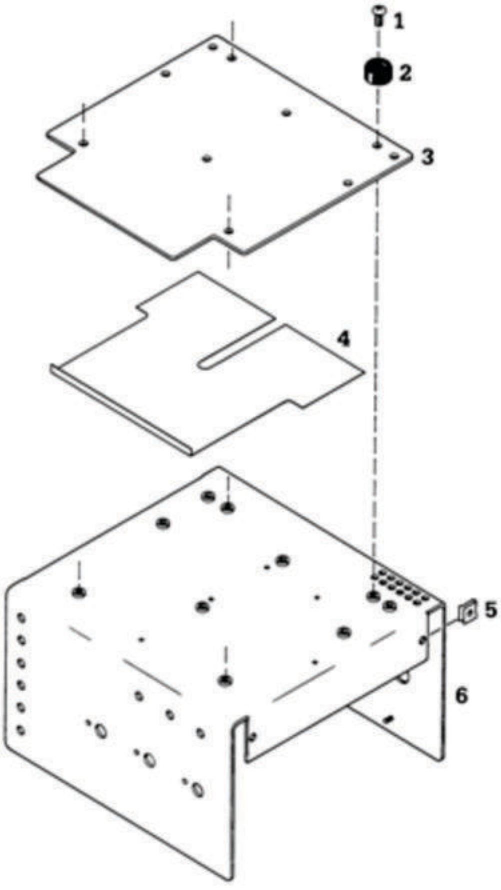
To replace the Preoperative Checklist Card from the ventilator control module:

1. Remove the power cord from the ac power source.
2. Remove the mounting screws for the two front rubber feet on the control module. The Preoperative Checklist Card can now be pulled forward and out.
3. Install the replacement Preoperative Checklist Card (in the correct orientation), the two rubber feet and the mounting screws.

6.6 Bellows Unit Disassembly

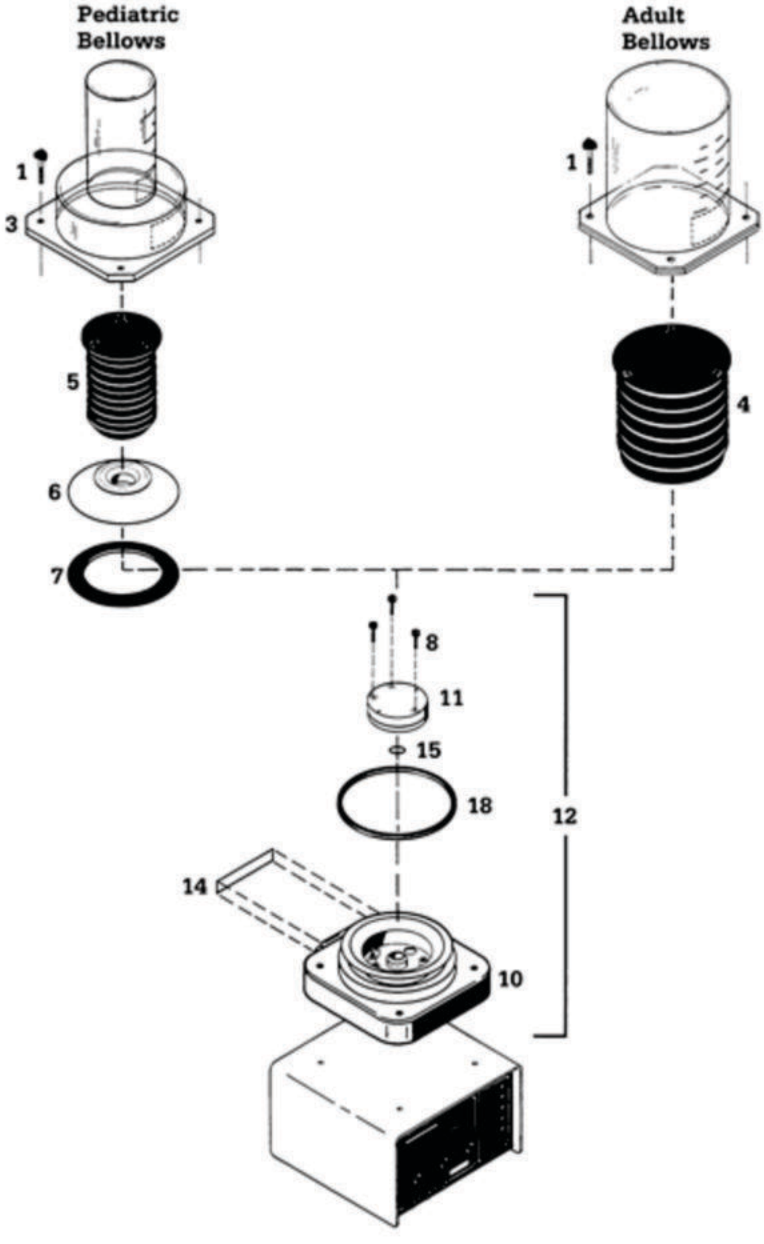
(See Figure 6-19)

1. Remove the four thumbscrews that fasten the bellows assembly to the control unit.
2. Lift off the transparent bellows cover.
3. Pull the bellows off the base unit.
4. (Pediatric bellows only) Stretch the retaining ring and remove the pediatric bellows mounting ring.
5. Remove the three thumbscrews that fasten the popoff valve into the base unit and lift off the valve.



Description	Stock Number
1. Screw	0140-6531-106
2. Foot, Rubber	0411-1959-100
3. Plate	0234-0214-552
4. Card, Preoperative Checklist Domestic (English)	1502-3025-000
5. Nut	1502-3018-000
6. Chassis	1502-7000-000

Figure 6-18
Preoperative Checklist Card Replacement

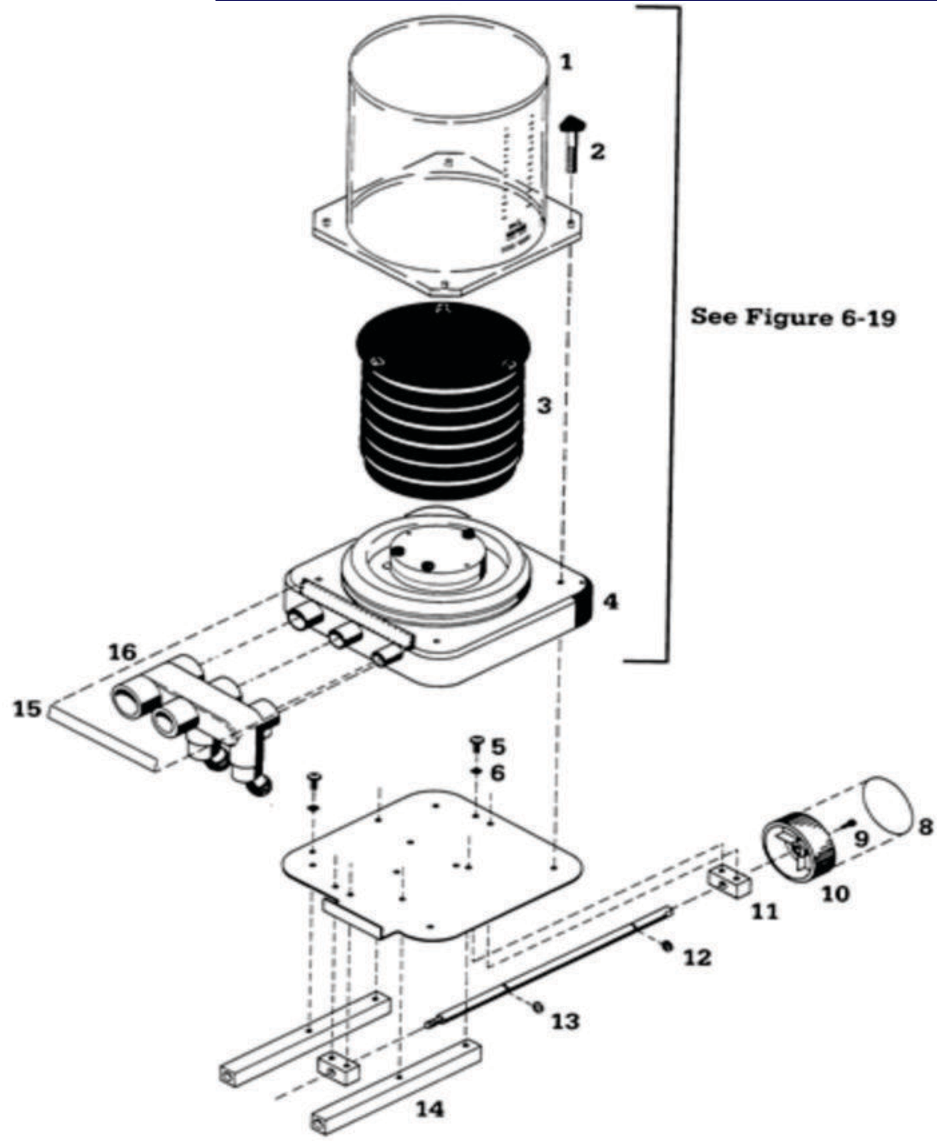


Description | **Stock Number**

1. Thumbscrew 10-32 x 2.25" 0400-3524-300
2. Housing, Bellows, Adult 0229-0014-300
3. Housing, Bellows, Pediatric 0229-0034-300
4. Bellows, Adult 0229-1013-700
5. Bellows, Pediatric 0229-1018-700
6. Ring, Ped. Bellows Mounting (Includes #7) 0229-1023-700
7. Ring, Retaining, Ped. Bellows 0229-0036-300
8. Thumbscrew, 6-32 x 1.19" 0400-3507-300
9. Seal, U-cup, 6.00" OD x 5.44" ID 0210-0784-300
10. Base (Not Sold Separately)
11. Pop-Off Valve Assembly* 0229-1029-800
12. Base Assembly (English) 0229-1032-880
13. Complete Pediatric Bellows Attachment Kit (Includes Items 1, 3, 5, 6, 7 & 12) 0219-7520-871
14. Label, Port ID/ English 0205-6200-949
15. O-ring 0210-0463-300

* ⚠**WARNING:** Only use the new style Pop-off Valve Assembly as a replacement part for a Base Assembly pre-viously fitted with the new style Pop-off Valve. Do Not use the new style Pop-off Valve on bases that Do Not have a raised identification mark on the left front corner of the Base Assembly.

Figure 6-19
Bellows Assembly Components



Description	Stock Number
1. Housing	See Fig. 6-19
2. Thumbscrew	See Fig. 6-19
3. Bellows	See Fig. 6-19
4. Base*	See Fig. 6-19
5. Screw 10-32 x 1/2 (Qty. 8)	0140-6631-108
6. Lock Washer Ext. #10 (Qty. 8)	0202-3210-300
7. Bellows Mtg. Plate	0234-1078-700
8. Knob Label	0205-4903-300
9. Screw 8-32 x 3/8	0144-2127-206
10. Selector Knob	0212-1954-100
11. Lock Support (Qty. 2)	0236-0453-552
12. Truarc Ring .375 Shaft (Qty. 2)	0203-5314-300
13. Locking Bellows Rod	0236-0450-500
14. Bellows Support Guide (Qty. 2)	0236-0451-552
15. Label	See Fig. 6-22
16. Manifold	0236-0478-700

* The revised Bellows Base Assembly has a raised identification mark on the left front corner of the Base Assembly.

Figure 6-20
Bellows Assembly w/Manifold and Mounting for GMS Absorber

7/Calibration

⚠WARNING: Do not, under any circumstances, perform any testing or maintenance on medical instruments while they are being used to ventilate a patient.

⚠WARNING: The alarm circuit check (section 7.16) must be performed before the ventilator is returned to use after any service procedure.

Tools Required:

- #2 Phillips screwdriver
- 5/16" open-end wrench
- 5/16" nutdriver
- 1/8" flat-tip screwdriver
- variac (0 - 240 volts ac)
- digital voltmeter (DVM) 4 digit
- oscilloscope, storage type
- jumper wire (12 inches long)
- 50 psig oxygen supply (nominal)
- test lung
- stop watch
- 3/32" hex key wrench
- 1/16" hex key wrench
- pneumatic tester ±1% accurate, capable of measuring Minute Volume, Tidal Volume, Flow Rate, Breath Rate and I:E Ratio

Note: Failure in any step is cause for rejection. Ignore all visible and audible alarms until mentioned. For convenience, a jumper plug has been provided (TJ1) on the circuit board which, when removed, disables the audible alarm. Make sure the jumper plug is reinstalled before returning the ventilator to operation. If the plug is lost, order Stock No. 0690-1563-315 for a replacement.

⚠WARNING: An Electrical Shock Hazard exists at the fuse receptacle under the circuit board shelf.

⚠WARNING: Never use the ventilator if the jumper plug is missing; the audible alarm will malfunction. Always check to be sure that the audible alarm works before returning a unit to operation.

⚠WARNING: Electrical Shock Hazard. Do not touch exposed wires or conductive surfaces while the cover panel is removed from the ventilator unless electrical power is disconnected from the unit. Hazardous voltages are present during normal operation. Never wear a grounding wrist strap when working on an energized unit.

⚠CAUTION: Perform all calibration steps in the order given.

7.1 Setup

1. Turn off the power switch.
2. Turn off the sigh switch.
3. Remove the cover panel.
4. Remove the printed circuit board. (See Section 6.1)
5. Connect the power cord to a variac set at 0 V.

7.2 Wiring Checks

1. Set the variac voltage according to the voltage selected on the power entry module on the rear panel of the ventilator:

   120 volts ac - set variac voltage to

   120 volts ac at 60 Hz.

   100 volts ac - set variac voltage to

   100 volts ac at 50 Hz.

   220 volts ac - set variac voltage to

   220 volts ac at 50 Hz.

   240 volts ac - set variac voltage to

   240 volts ac at 50 Hz.
2. Turn on the power switch.
3. Test the leakage current. It must be less than 35 microamps at 100/120 V ac or less than 70 microamps at 220/240 V ac.
4. Set a voltmeter to read volts ac rms and perform the following voltage checks. All pins are referenced to the 60 pin wire harness connector. All voltages should be taken during expiration.
   a. The voltage between pins 9 and 35 should read 15.7 ± 0.5 V ac
   b. The voltage between pins 4 and 9 should read 26.5 ± 1.0 V ac.
   c. The voltage between pins 4 and 35 should read 15.7 ± 0.5 V acC.
   d. The voltage between pins 3 and 8 should read 31.5 ± 1.0 V ac.
5. If these readings are incorrect, the transformer, its associated components, and the wiring should be checked.
6. Turn off the power switch.

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7.3 DC Power Supply

Note: To help service personnel locate test points on the circuit board, all test points are labeled. Refer to the component diagram (Figure 8-1) for the circuit board.

1. Connect the printed circuit board.
2. Record the variac setting.
3. Connect a Digital Volt Meter (DVM) between TP-2 and ground.

   Note: Use only TP26, TP27, TP28 or the negative side of capacitor C21 as a ground.
4. Turn on the power switch.
5. Adjust potentiometer RP until the DVM indicates +2 ± 0.005 V dc.
6. Vary the variac ± 10%. The voltage at TP-2 should remain +2 ± 0.005 V dc.
7. Return the variac setting to that recorded in step 2.
8. Connect the DVM between TP-8 and ground; it should read +8 ± 0.15 V dc.
9. Connect the DVM between TP-9 and ground; it should read -8 ± 0.15 V dc.

   Note: If the unit fails step 8 or step 9, go back and repeat steps 5 thru 9. If recalibration of potentiometer RP doesn't work, the circuit board must be replaced (Section 6.1).
10. In Steps 11 and 12, the voltages are loaded voltages. Take measurements with the rate control fully counterclockwise, minute volume fully clockwise, I:E ratio fully counterclockwise, and when the solenoids are on (inhalation).
11. Connect the DVM between TP-10 and ground. The voltage should be +32 ± 3 V dc.
12. Connect the DVM between TP-11 and gound. The voltage should be +28 ± 3 V dc.
13. If the readings cannot be obtained, the circuit board, LED's, solenoids, and transformer should be checked out.

7.4 Lamp Test

1. Press the Lamp Test button. All lamps shall light and the audio alarm must sound.
2. If this does not happen, check the LED's, circuit board, wiring, and power supply.

7.5 Monitor Circuit

1. Connect an oscilloscope between TP-21 (U1 pin 10) and ground. Adjust the oscilloscope for 2 V/division vertical scale and 0.2 ms/division horizontal scale. There must be a square wave of approximately 850 to 2300 Hz (time period of 0.43 to 1.2/ms). The waveform should look like Figure 7-1. Adjust potentiometer RA if necessary to obtain the specified time period.
2. Connect a DVM to TP-22 (U10 pin 6). Check for +3.8 ± 0.8 V dc.
3. Connect the oscilloscope to TP-12 and set it for 1 V/division vertical scale and 5 ms/division horizontal scale. Check for a negative staircase waveform having 64 steps. The waveform should look like Figure 7-2.
4. Replace the circuit board if these adjustments cannot be made or the proper waveforms cannot be obtained.

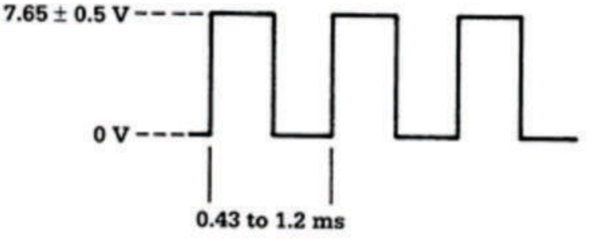

Figure 7-1
Oscillator Waveform

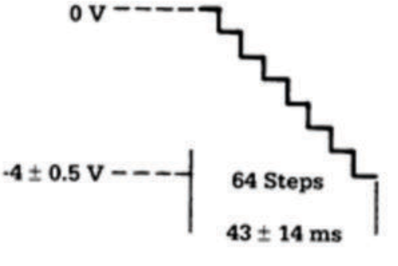

Figure 7-2
Staircase Waveform

7.6 Mounting and Calibrating the Control Dials, Front and Rear Panel

1. Remove the front and rear panel dials if installed.
2. Turn the Minute Volume, Rate, I:E Ratio and Altitude Adjustment potentiometer shafts fully counterclockwise.
3. If any of these adjustments cannot be made, the circuit board wiring and potentiometers should be checked, recalibrated, and replaced if necessary.
4. For correct positioning of the dials, the potentiometers first have to be moved out of their dead band area by moving their shafts as follows:

A. Mounting the Minute Volume Dial

1. Connect the DVM between TP-3 and ground. (A convenient ground is TP28.)
2. Move the Minute Volume potentiometer shaft slightly to produce about 4 to 15 mV voltage change.
3. Place the dial on the potentiometer shaft, with the pointer set to the 2 L/min position, and tighten the dial into place.
4. Adjust potentiometer RJ to obtain 0.133 ± 0.003 V.
5. Check for 0.340 ± 0.020 V at TP-4.

B. Mounting the Rate Dial

1. Connect the DVM between TP-1 and ground.
2. Move the RATE potentiometer shaft slightly clockwise to produce about 2 to 5 mV voltage change.
3. Place the dial on the shaft with the pointer set to the 6 BPM position, and tighten the dial into place.
4. Adjust potentiometer RI until the DVM indicates 0.3 ± 0.003 V.

C. Mounting the I:E Dial:

1. Connect the DVM between TP-5 and ground.
2. Move the I:E Ratio potentiometer shaft slightly clockwise to produce about 4 to 15 mV voltage change.
3. Place the dial on the shaft, with the pointer set to the 1:1 position, and tighten the dial in place.
4. Make sure the Minute Volume dial is set to 2 L/min. Record the voltage at TP-4.
5. Connect a DVM to TP-5 and adjust potentiometer RK until the voltage at TP-5 is one-half the voltage at TP-4 (within ± 0.003 V).

D. Mounting the Altitude Adjustment Dial, Rear Panel:

⚠CAUTION: Connecting TP-20 to ground places the ventilator in a continuous gas delivery phase where the exhaust valve is continuously on (closed). If the ventilator is left on in this condition for more than one minute, overheating of the exhaust valve may occur.

1. Using a jumper wire, connect TP-20 to ground.
2. Connect the DVM between TP-6 and ground.
3. Move the Altitude potentiometer shaft slightly clockwise to produce about 1 to 4 mV change in voltage at TP-6.
4. Place the dial on the pot shaft with the pointer set to the 0 meters position, and tighten the dial in place.
5. Set the ventilator controls to read:

   Minute Volume = 25 L/min
   Rate = 10 BPM
   I:E Ratio = 1:2
6. Measure the voltage at TP-7. It should be -4.76 ± 0.20 V. Record this voltage for use in the next step.
7. Connect a DVM to TP-6 and adjust potentiometer RN until the voltage at TP-6 is 0.8 of the voltage at TP-7 (within ± 0.006 V).
8. Remove the jumper wire between TP-20 and ground. Turn off the unit, then turn it back on to reinitialize it.

7.7 Multiplier and Scaler Circuits

Note: The dials may be turned one half division from the specified settings to meet specification in this procedure.

1. Set the ventilator controls to:

   Minute Volume = 10 L/min
   Rate = 20 BPM
   I:E = 1:2
2. Connect a DVM to TP-13. Check for 1.933 ± 0.10 V.
3. Check for 2.66 ± 0.08 V at TP-14.
4. Set the ventilator controls to:

   Minute Volume = 15 L/min
   I:E = 1:1

5. Check U8 pin 2 for 0 to +0.05 V and U8 pins 5, 7, 10 and 12 for 7.65 ± 0.5 V. This corresponds to the flow valves for 2, 4, 8 and 16 L/min being open.
6. As the minute volume is varied between 15 and 16 L/min only U8 pin 2 should be high (7.65 ± 0.5 V). All other output pins 5, 7, 10 and 12 should be low (0 to ± 0.05 V). This corresponds to the flow valve for 32 L/min being open.
7. If these readings cannot be obtained, recalibrate the ventilator's controls (section 7.6) and replace the potentiometers or circuit board as necessary.

7.8 Flow Limit Circuits

1. Set the ventilator controls to:

Minute Volume = 19 L/min

I:E = 1:2

2. Connect a DVM to TP-25 (U2 pin 7). Check for -7.65 ± 0.5 V. Increasing the Minute Volume to 20 ± 1.5 L/min must change the voltage to 6.8 ± 0.5 V.
3. If these readings cannot be obtained, recalibrate the ventilator's controls (Section 7.6) and replace the potentiometers or circuit board as necessary.

7.9 Rate Circuits

1. Set the Rate control to 30 BPM.
2. Connect an oscilloscope to TP-15 and set it for 1 V/division vertical scale and 0.5 s/division horizontal scale. Adjust potentiometer RM until the oscilloscope displays a sawtooth waveform having a 2 ± 0.04 second ramp. The waveform should look like Figure 7-3.
3. If these readings cannot be obtained, recalibrate the ventilators controls (section 6.6) and replace the potentiometers or circuit board as necessary.

7.10 Tidal Volume Limit Circuits

1. Connect a DVM to TP-23 and adjust potentiometer RG counterclockwise until the DVM indicates 0 V.
2. Set the ventilator controls to:

   Minute Volume = 20 L/min
   Rate = 20 BPM

3. Connect a DVM to TP-16 and adjust potentiometer RA until the DVM indicates 2.58 V (2.55 to 2.60 V). This calibrates the oscillator.
4. Set the front panel controls to:

   Minute Volume = 16 L/min
   Rate = 10 BPM

5. Record the voltage at TP-16. It should be 4 ± 0.2 V.
6. Set the Minute Volume control to 25 L/min.
7. Adjust potentiometer RG to obtain at TP-16 the voltage recorded in Step 5. Set the voltage to within ± 0.02 V.
8. If these readings cannot be obtained, recalibrate the ventilator's controls (section 7.6) and replace the potentiometers or circuit board as necessary.

7.11 Inspiration/Expiration Time Circuit

1. Set the ventilator controls to:

   Minute Volume = 20 L/min
   Rate = 20 BPM
   I:E = 1:1
   Altitude Adjustment = 0

2. Connect an oscilloscope to TP-17 and set it for 5 V/division vertical scale and 0.5 s/division horizontal scale. Adjust potentiometer RO until the displayed waveform has a 50% duty cycle. The waveform should look like Figure 7-4.
3. If these readings cannot be obtained, recalibrate the ventilator's controls (section 7.6) and replace the potentiometers or circuit board as necessary.

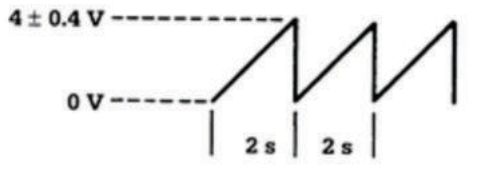

Figure 7-3
Rate Circuit Waveform

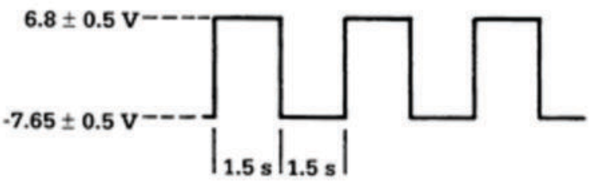

Figure 7-4
I:E Circuit Waveform

7.12 Manual Cycle Circuit

1. Connect an oscilloscope to TP-17 and set it for 5 V/division vertical scale and 0.5 s/division horizontal scale. Press the Manual Cycle pushbutton when the square wave of Step 7.11-2 is high (7 V nominal). There should be no change in the waveform.
2. Repeat Step 1, but this time depress Manual Cycle when the square wave is low (-8 V nominal). On pressing the switch, there should be a positive transition to + 7 V nominal.
3. Check for a defective switch or circuit board if the correct results are not observed. Replace the Manual Cycle switch or circuit board if defective.

7.13 Exhaust Valve Circuit

⚠CAUTION: Connecting TP-20 to ground places the ventilator in a continuous gas delivery phase where the exhaust valve is continuously on (closed). If the ventilator is left on in this condition for more than one minute, overheating of the exhaust valve may occur.

1. Set the ventilator controls to:

   Rate = 20 BPM
   I:E = 1:1

2. Connect an oscilloscope to TP-18 and adjust potentiometer RH until the displayed waveform has a peak ramp voltage of 0.5 V. The waveform should look like Figure 7-5.
3. Connect TP-20 to ground. The Ventilator Failure alarm must activate within 3 to 7.5 seconds and the exhaust valve must remain open. (Listen for a click, indicating that the valve might have closed, signifying malfunction.) The alarm is a blinking LED and an intermittent audible tone. The voltage at the cathode of D14 should stay at less than 1 V.
4. Remove the short between TP-20 and ground. The alarm should stay on and the exhaust valve should remain open. The voltage at the cathode of D14 should stay at less than 1 V.
5. Turn the unit Off, then On. There should be no Ventilator Failure alarm and the exhaust valve should function normally. The voltage at the cathode of D14 should alternate between 0 and 32 volts (nominal).
6. If these results cannot be obtained, recalibrate or replace the controls, circuit board, and exhaust valve as necessary.

7.14 Low Airway Pressure Alarm Circuit

1. Set the ventilator controls to:

   Rate = 20 BPM
   I:E = 1:1

2. Connect an oscilloscope to TP-19 and set it for 0.2 V/division vertical scale and 0.5 s/division horizontal scale. Adjust potentiometer RL until the displayed waveform reaches a ramp voltage of 1.0 V at 3 seconds. For this adjustment the ventilator will have to be turned Off and On. When the ventilator is turned On measure the ramp and adjust RL for a 1 ± 0.05 V ramp at 3 seconds. The waveform should look like Figure 7-6.
3. Check the low airway pressure switch, and the circuit board if the correct results are not observed.

Figure 7-5
Exhaust Valve Ramp Waveform

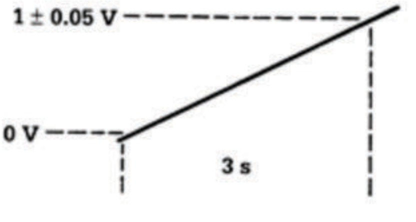

Figure 7-6
Low Airway Pressure Alarm Ramp Waveform

7.15 Sigh Circuit

1. Connect the bellows assembly Inlet port to the port labeled Connect To Bellows Ass'y. Inlet at the back of the ventilator.
2. Connect the To Anesthesia Machine outlet port of the bellows assembly to a test lung.
3. Connect the Connect To Expiratory Limb of the Breathing System port at the back of the ventilator to the test lung using a tee connector.
4. Connect a 50 psig oxygen supply line to the back of the ventilator. Inflate bellows to top of housing.
5. Set the front panel controls to:

   Minute Volume = 30 L/min
   Rate = 40 BPM
6. Turn On the Sigh Switch and count the number of breaths, starting when the first sigh is detected. On the 64th breath (±2 breaths) or in approximately 1 minute 36.5 seconds, a larger breath must be delivered which should be 150% ± 15% of the normal breath.

   Note: When the sigh breath is delivered there is a high logic level voltage that is delivered across pin 3 of U-13.
7. In case of malfunction, check and replace the circuit board or switch as necessary.

7.16 Alarm Circuit Check

⚠WARNING: The alarm circuit check (Section 7.16) must be performed before the ventilator is returned to use after any service procedure.

Note: Jumper plug TJ1 must be in place on the circuit board during this test.

1. Set up the unit as in Section 7.15, Figure 7-7. Set the ventilator controls to:

   Minute Volume = 14 L/min
   Rate = 10 BPM
2. Increase the Minute Volume; the Set Volume Not Delivered alarm must activate when the Minute Volume reaches 15 breaths/minute ± 1 breath. The alarm is a blinking light and an intermittent audible tone.
3. Set the ventilator controls to:

   Minute Volume = 20 L/min
   Rate = 15 BPM
   I:E = 1:1
4. Increase the I:E ratio; the Actual I:E Less Than Dial Setting alarm must activate at an I:E of approximately 1:2 ± 0.2. The alarm is a continuous light and audible tone.
5. Set the Rate control to 6 breaths/minute and the Minute Volume dial to 10 L/min.
6. Remove the patient circuit connection between the test lung and the distal sensing tee. The Low Airway Pressure alarm must activate in 18.5 to 30 seconds. The alarm is a blinking light and an intermittent audible tone.
7. Shut off the oxygen supply line. The Low Oxygen Supply alarm shall activate. The alarm is a blinking light and an intermittent audible tone.
8. Pull the power plug from the variac. A continuous audible alarm shall activate.

   Note: If the power disconnect alarm does not sound, try recharging the battery (leave unit on for 21 hours to fully recharge the battery). If the alarm still malfunctions do not use the ventilator until it has been repaired.
9. Reconnect the power plug to the variac.
10. Turn the ventilator Off.
11. Remove all external pneumatic connections except line pressure.
12. Consult the appropriate calibration or maintenance section if any of these tests fail.

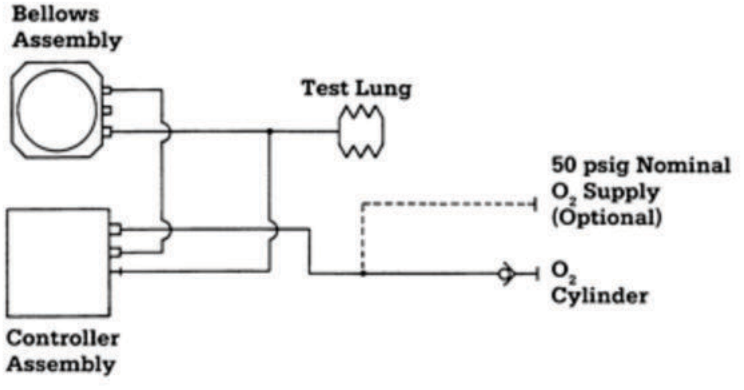

Figure 7-7
Sigh and Alarm Circuit Check

7.17 Valve Assembly Calibration Check

⚠CAUTION: Connecting TP-20 to ground places the ventilator in a continuous gas delivery phase, where the exhaust valve is continuously on (closed). If the ventilator is left in this condition for more than one minute, overheating of the exhaust valve may occur.

Note: The pressure regulator must be checked and adjusted per section 4.7 before attempting valve assembly calibration.

1. Place a short across capacitor C8.
2. Connect TP-20 (U-12 pin 9) to ground.
3. Connect TP-24 (Minute Volume potentiometer) to ground.
4. Connect the port labeled connect To Bellows Ass'y Inlet port at the back of the ventilator to a flow measuring device (Figure 7-8).
5. Turn on the ventilator and set its controls to:

   Minute Volume = 2 L/min
   Rate = 6 BPM
   I:E = 1:1
6. Vary the Minute Volume control dial from its low to high settings and observe that the solenoids operate in a binary sequence. Record the flow when only the 2 L/min valve is On. Record the same when the 4, 8, 16 and 32 L/min valves are On.
7. Compare the flows recorded in the previous step with the following limits:

   Note: Normalize all flow readings to a barometric pressure of 730 mm Hg. Otherwise, test specifications will not be met.

Flow L/Min	Maximum Allowable	Minimum Allowable
2	2.10	1.90
4	4.20	3.80
8	8.40	7.60
16	16.80	15.20
32	33.60	30.40

8. Turn Off the ventilator.
9. Remove the connections made in Steps 1 through 5.

   Note: The components of the Flow Control Unit are matched and calibrated as an assembly and must not be replaced on an individual basis. Malfunctioning flow units must be replaced as an assembly except where otherwise noted in this manual.

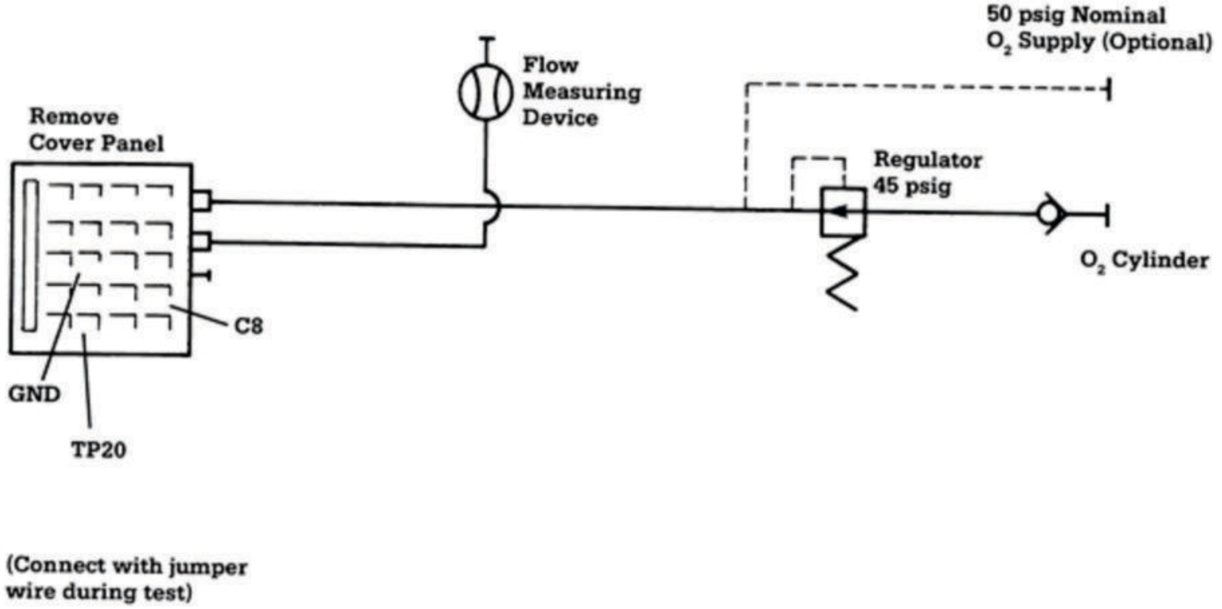

Figure 7-8
Valve Assembly Calibration Check

Corporate Office

EC REP

GE Healthcare Finland Oy
Kuortaneenkatu 2
Helsinki, Finland
FI-00510
Tel 358 10 394 11
Fax 358 9 146 3310

North America

United States

Customer Service, Technical Support and Distribution Center
Datex-Ohmeda, Inc.
PO Box 7550
Madison, WI
53707-7550, USA
Tel 1 800 345 2700
Fax 1 608 221 4384

Equipment Service Center
GE Healthcare
100 Marquette Drive
Jupiter FL 33458
USA
Tel 1 561 575 5000
Fax 1 561 575 5070

Canada
Datex-Ohmeda
(Canada) Inc.
c/o GE Canada
2300 Meadowvale
Boulevard
Mississauga, Ontario
L5N 5P9
Canada
Tel 800 268 1472
Fax 905 858 6208

Asia/Pacific

China
Datex-Ohmeda Pte. Ltd.
Room B416,
COFCO Plaza
8 Jianguomennei
Avenue
Beijing 100005, PR China
Tel 86 10 6526 9773
Fax 86 10 6526 0653

Datex-Ohmeda Pte. Ltd.
Room 1708, Yunlong
Mansion
No. 122 Luoguo Street
Chengdu 610017, PR
China
Tel 86 28 661 4424
Fax 86 28 676 2703

Datex-Ohmeda Pte. Ltd.
403 Huan Shi Dong Road
Room 1602, GIE Tower
Guangzhou, 510095, P R
China
Tel 86 20 8732 2521
Fax 86 20 8732 2518

Datex-Ohmeda Pte. Ltd.
Room 2509 Lippo Plaza
No. 222
Huaihai Road (M)
Shanghai 200021, P.R.
China
Tel 8621 5382 5657
Fax 8621 5382 1691

Datex-Ohmeda Pte. Ltd.
Room 809, Truroll Plaza
Wusheng Road
Wuhan 430033, P R China
Tel 86 27 8571 2536
Fax 86 27 8571 2655

India
Datex-Ohmeda (India)
Pvt. Ltd.
Block EP & GP, Sector V
Plot XI-16, Salt Lake City
Calcutta 700091
India
Tel 91 33 3574002
Fax 91 33 3574001

Indonesia
Datex-Ohmeda Pte. Ltd.
Wisma Danamon Aetna
Life 19th Floor
Jln. Jend Sudirman Kav.
45-46 Jakarta 12930,
Indonesia
Tel 62 21 575 0864
Fax 62 21 575 0865

Japan
GE Yokogawa
Medical Systems
TRC Annex 9F
6-1-1 Heiwajima,
Ohta-ku,
Tokyo 143-0006
Japan
Tel 81 3 5763 6801
Fax 81 3 5763 6838

GE Yokogawa
Medical Systems
Technical Center
TRC A Bldg. AE 4-8
6-1-1 Heiwajima
Ohta-ku,
Tokyo 143-0006
Japan
Tel 81 3 5763 6850
Fax 81 3 5763 6852

Korea
Datex-Ohmeda Pte. Ltd.
10th Floor,
Sam Sung Building
36 - 1, Yoido-Dong, Young-
deungpo-Ku
Seoul, Korea
Tel 82 2 786 7421
Fax 82 2 786 7420

Malaysia
Datex-Ohmeda Pte. Ltd.
Level 2 Bangunan
O'Connor
13 Jalan 223
46100 Petaling Jaya
Selangor, West Malaysia
Tel 60 3 754 7872
Fax 60 3 757 6948

Singapore
Datex-Ohmeda Pte. Ltd.
152 Beach Road
#12-05/07 Gateway East
Singapore 189721
Tel 65 391 8618
Fax 65 291 6618

Taiwan and Philippines
Datex-Ohmeda Pte. Ltd.
2nd Floor, No. 85,
Chien-Kuo North Road,
Sec. 2
Taipei, Taiwan
Republic of China
Tel 886-2 2515-0457
Fax 886-2 2501-9136

Thailand
Datex-Ohmeda Pte. Ltd.
12th Floor (Unit F) Grand
Amarin Tower
1550 New Petchburi
Road, Makasan,
Rajathevi,
Bangkok 10320,
Thailand
Tel 66 2 2071012/13
Fax 66 2 207 1014

Vietnam
Datex-Ohmeda Pte. Ltd.
522G Nguyen
Tri Phuong St.
Ho Chi Minh City, Dist. 10
Vietnam
Tel 848 865 5875
Fax 848 862 5501

Australia

Datex-Ohmeda Pty. Ltd.
Units 1
149 Arthur Street
Locked Bag 356
Homebush
NSW 2140
Australia
Tel 61 1300 722 229
Fax 61 2 9746 1796

Europe

CIS/Baltics
Datex-Ohmeda
Regional Head Office
PO Box 70071
GR-16610 Glyfada -
Athens
Greece
Tel +30 10 9625136-7
Fax +30 10 9623687

France
Datex-Ohmeda S.A.S.
ZAC de Sans-Souci
1211 Chemin de la
Bruyère
F-69760 Limonest
France
Tel 33 (0) 4 78 66 62 10
Fax 33 (0) 4 78 43 26 58

Germany
Datex-Ohmeda GmbH
Munzinger Strasse 3
79111 Freiburg
Germany
Tel +49 761 4543 0
Fax +49 761 4543 233

GE Service Center
T: 0800 434325842273
T: 0800 GEHealthcare

Italy
Datex-Ohmeda S.p.A.
Via Cassanese 100
20090 Segrate, Milan
Italy
Tel 39 2 21693431
Fax 39 2 26926226

Netherlands
Datex-Ohmeda B.V.
De Wel 18
Post Box 22
3870 CA Hoevelaken
Netherlands
Tel 31 33 2541 222
Fax 31 33 2541 223

Spain
Datex-Ohmeda S.L.
C/Manuel Tovar 26
28034 Madrid
Spain
Tel 34 1 334 26 00
Fax 34 1 358 12 84

United Kingdom
Datex-Ohmeda Ltd.
Ohmeda House
71 Great North Road
Hatfield Hertfordshire
AL9 5EN England
Tel 44 1707 263570
Fax 44 1707 260191

Latin America, Caribbean

Datex-Ohmeda
9155 South
Dadeland Blvd.
Suite 1218
Miami, FL 33156, USA
Tel 1 305 670 8540
Fax 1 305 670 2316

Middle East/ Africa

Datex-Ohmeda
Regional Head Office
PO Box 70071
GR-16610 Glyfada -
Athens
Greece
Tel +30 10 9625136-7
Fax +30 10 9623687

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8/Schematics

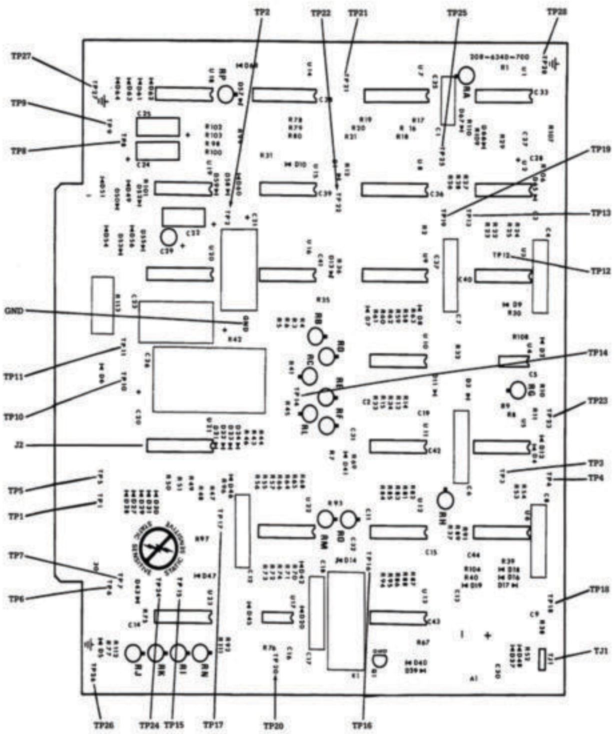
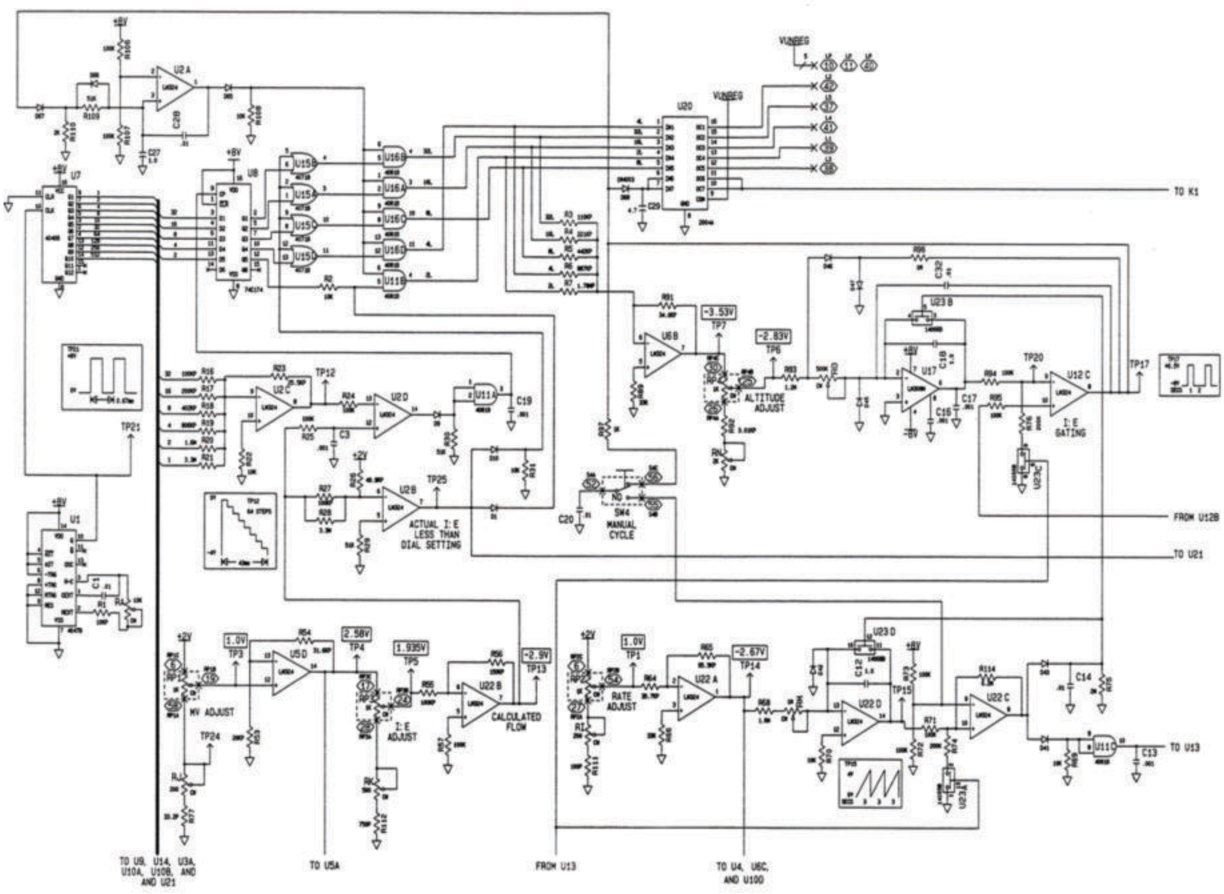


Figure 8-1
Circuit Board Component Layout

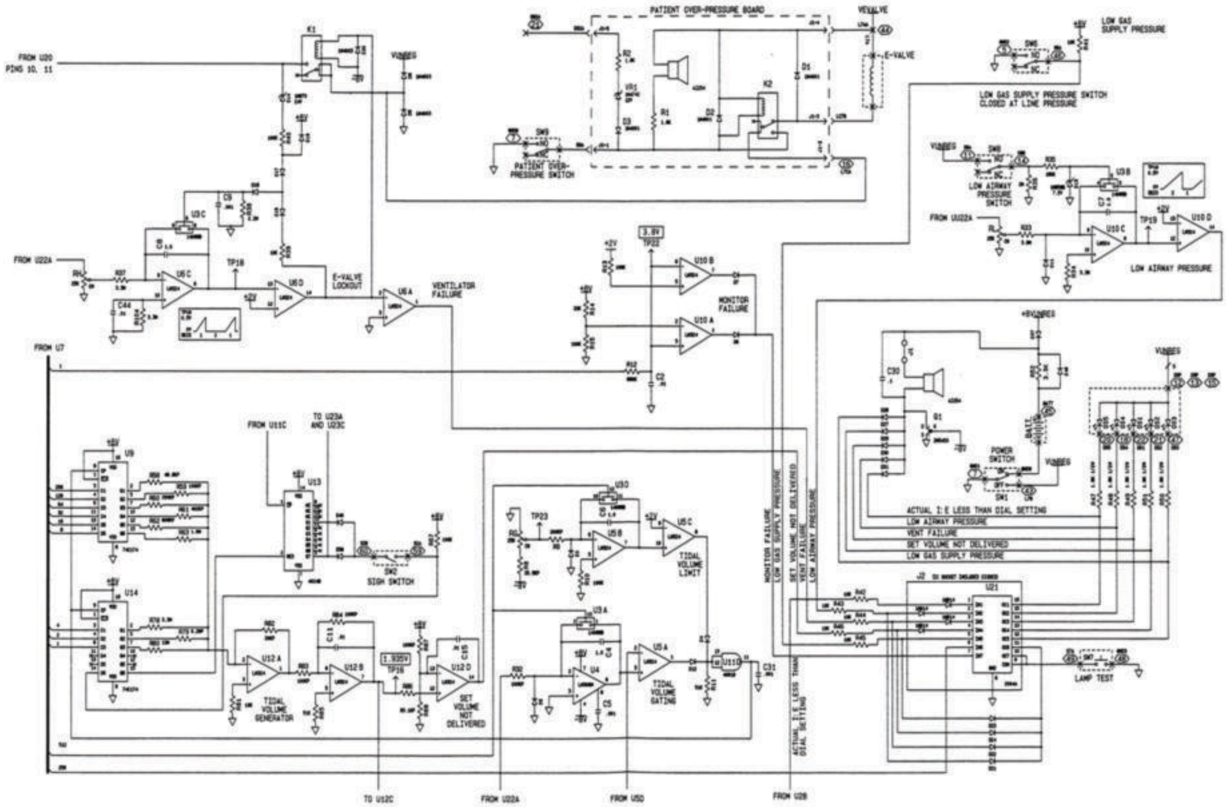
8-1



Voltage and Wave shapes valid for the condition
Rate = 20
MV = 15
IE = 1:2
Alt. Adj. = 0

Note: The letter "P" after the resistor value indicates ±1% precision.

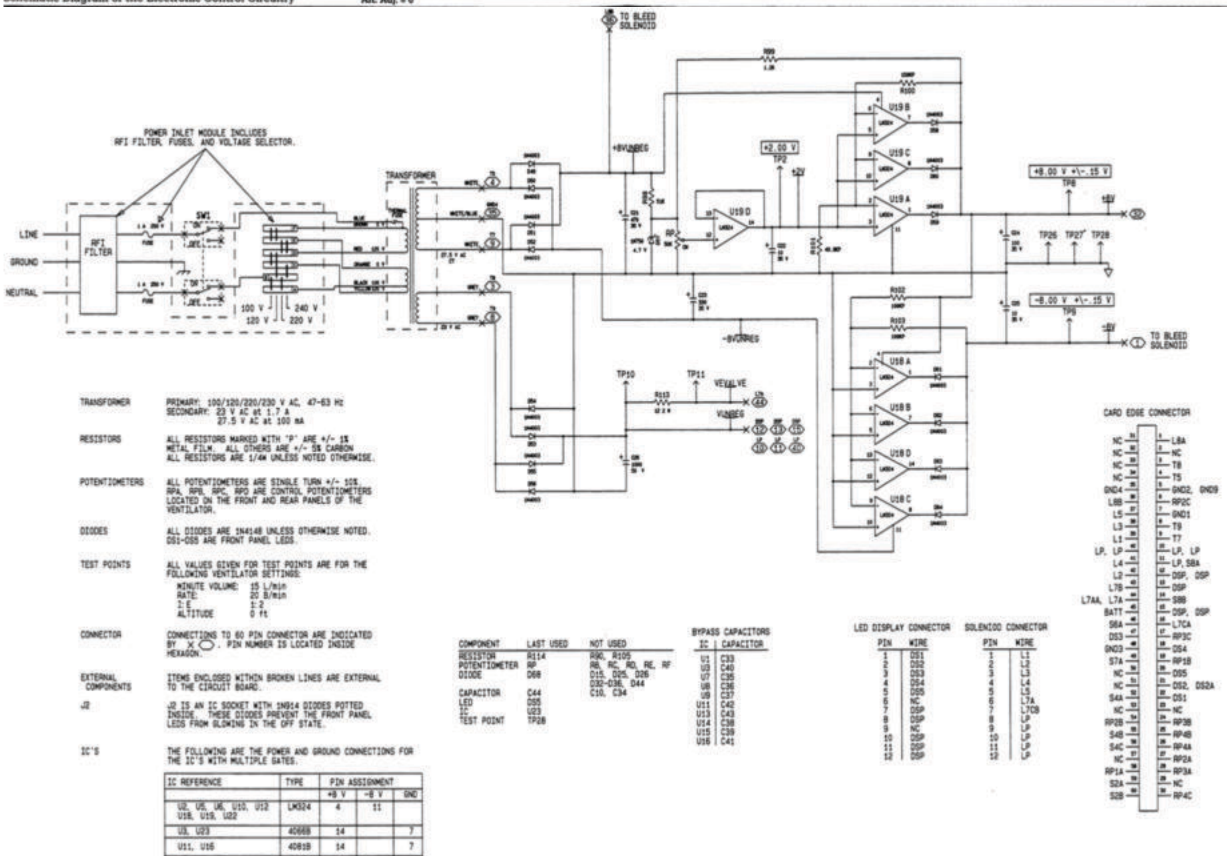
Figure 8-2A
Schematic Diagram of the Electronic Control Circuitry



Voltage and Wave shapes valid for the condition
Rate = 20
MV = 15
IE = 1:2
Alt. Adj. = 0

Note: The letter "P" after the resistor value indicates ±1% precision.

Figure 8-2B
Schematic Diagram of the Electronic Control Circuitry



Note: The letter "P" after the resistor value indicates ±1% precision.

Figure 8-3
Power Supply Schematic

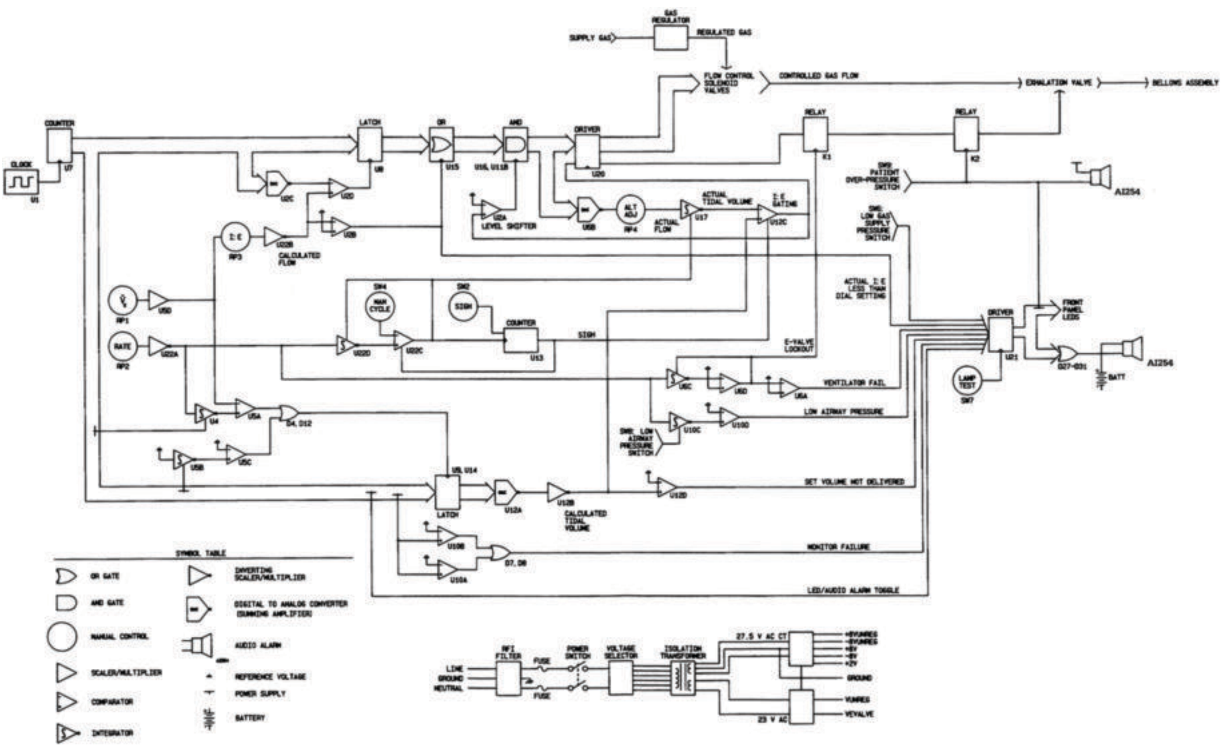


Figure 8-4
Block Diagram of the Electronic Control Circuitry

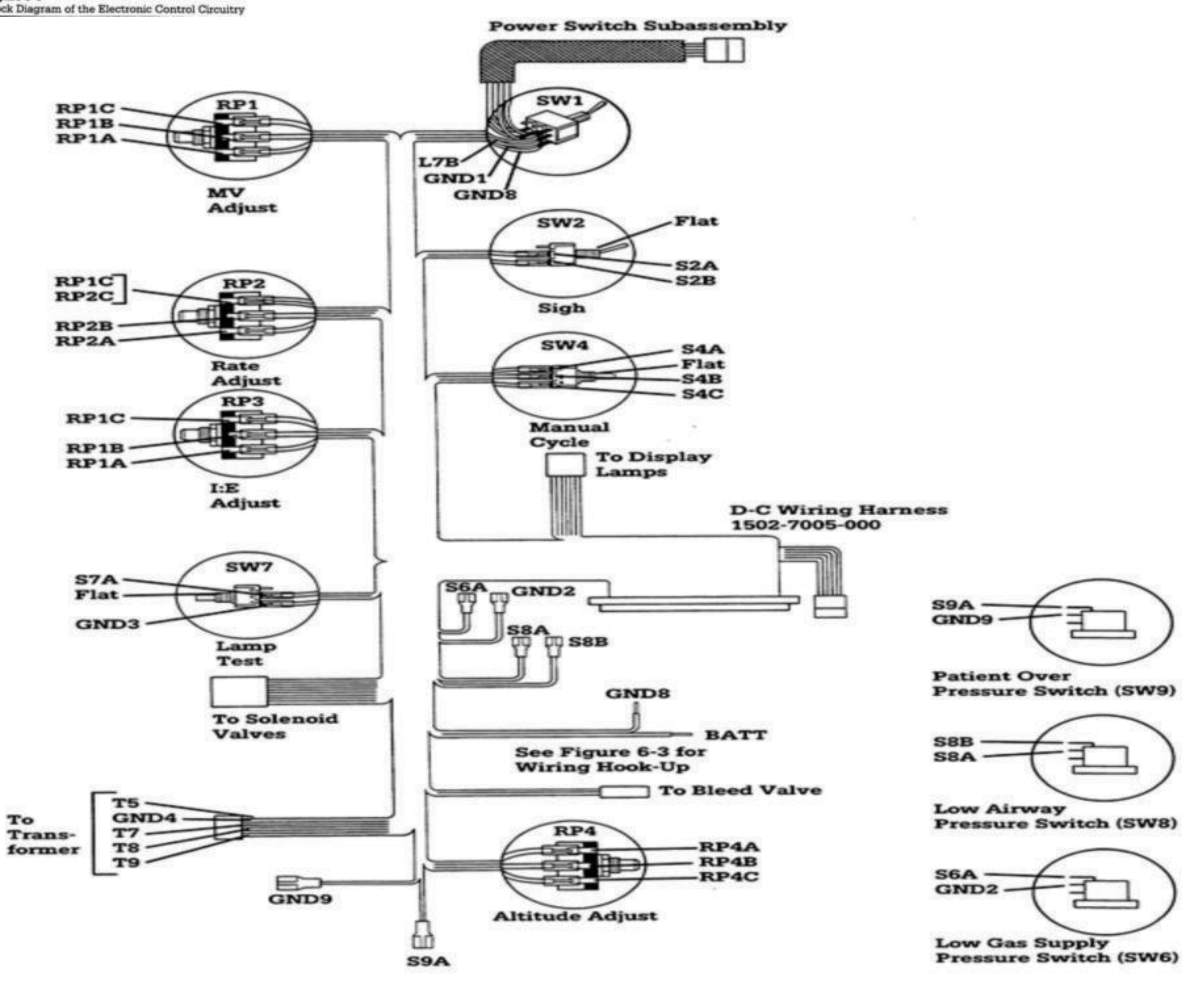


Figure 8-5
DC Wiring Diagram

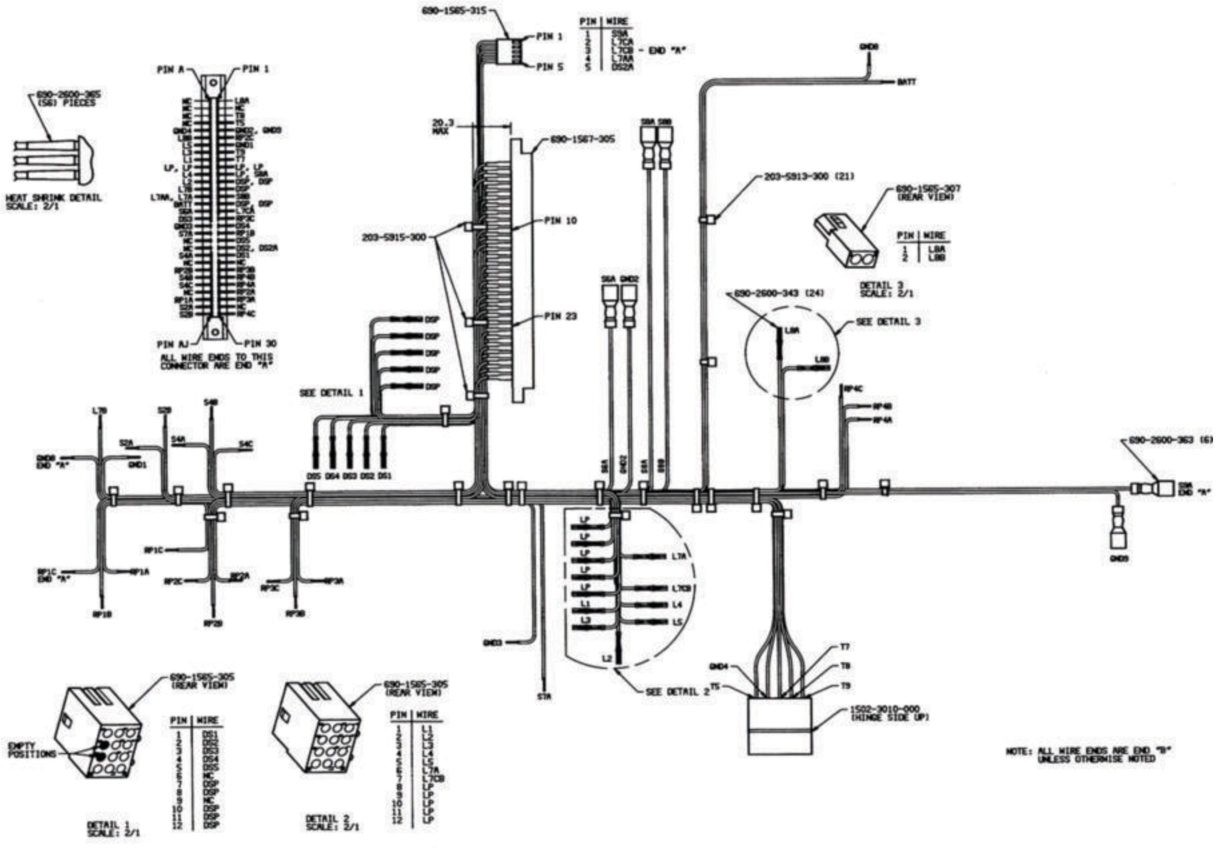


Figure 8-6
Wiring Harness 1502-7005-000

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