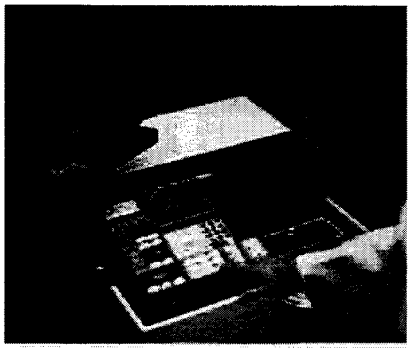


Puritan Bennett 7200AE

Ventilatory System

Manual

- Training Overview
- Self Test
- Error Codes
- 10,000 Hour Service Procedure

Contents

Physiology and Ventilation

Chris Thompson 2003

VENTILATION

INTRODUCTION

Normally, Alveolar Ventilation is unconsciously regulated to maintain constant arterial blood gas tensions, despite variable levels of oxygen consumption and CO2 production.

Many drugs and techniques used in anaesthesia interfere with control or mechanics of ventilation, and it is the Anaesthetists responsibility to ensure the adequacy of ventilation during the perioperative period.

Equipment related to ventilation is consequently of great importance to the Anaesthetist and Anaesthetic Technician. Correct use of the equipment relies on a good understanding of basic respiratory physiology as well as how the individual ventilator operates.

NORMAL PHYSIOLOGY

Basic Principles

Venous blood always has a lower PaO2 (40 mmHg or 75% saturated or 15 ml O2/100ml blood) and higher PaCO2 (46 mmHg) than inspired gas (PiO2 150 mmHg, PiCO2 usually 0), so that there is normally a partial pressure gradient driving Oxygen in and CO2 out of the pulmonary capillary blood.

Ventilation of the lungs with inspired gases results in mixing of the inspired gases with alveolar gas.

If there is no ventilation at all, there will be no replenishment of oxygen and no removal of CO2, so the PAO2 will fall and PACO2 will rise towards the venous O2 and CO2 tensions.

If the ventilation is much greater than is needed, then the alveolar gas tensions will be much closer to inspired gas.

Definitions

Ventilation is the process by which Oxygen and CO2 are transported to and from the Lungs.

Tidal Volume (VT) is the amount of gas expired per breath - typically 500ml at rest.

Deadspace Volume (VD) is the sum of the Anatomic Deadspace, due to the volume of the airways (typically 150ml), and Physiologic Deadspace, due to alveoli which are ventilated but not perfused (usually insignificant).

Minute Volume (VE) is the amount of gas expired per minute.

Alveolar Ventilation (VA) is the amount of gas which reaches functional respiratory units (ie, alveoli) per minute. VA = (Tidal Volume - Deadspace) x Respiratory rate

Lung Volumes

- FRC (Functional Residual Capacity) 2.2l.(supine)
- TLC (Total Lung Capacity) 6.2l.
- Maximum Inspiratory Volume 4.0l. above FRC.
- ERV (Expiratory Reserve Volume) 1.0l. below FRC.
- RV (Residual Volume) 1.2l.
- MVV (Maximal Voluntary Ventilation) 150 l/m.

Lung Mechanics

Inspiration

An active process requiring musular effort; 75% diaphragmatic at rest; intercostals used on exertion.

Inspiratory effort causes:

- Fall in intrapleural pressure
- Fall in Alveolar pressure
- Pressure gradient from mouth to alveoli
- Gas flow down pressure gradient

Maximum inspiratory force sometimes used as an index of resp. effort; if < 20 cmH2O most patients have difficulty

Expiration

Usually a passive process due to lung recoil:

- Relaxation of inspiratory muscles causes:
- Intrapleural pressure becomes less negative
- Alveolar pressure rises
- Pressure gradient from alveoli to mouth
- Gas flow down pressure gradient

Airway Resistance

- Limits gas flow down airways
- Due mostly to airway/ETT diameter (fourth power of radius)
- Normal response to increased resistance is increased effort
- GA's increase resistance and decrease response, causing hypoventilation

Intrapleural Pressure

- Normally -10 cmH2O, due to elastic recoil of lung opposed by chest wall.
- Becomes more negative on inspiration.
- Less at the dependent regions of the lung, reducing alveolar size.

Compliance

"Static" Compliance is a measure of the "stiffness" of lung and chest wall, typically 50 ml/cmH2O in adults and proportionally less in kids. It is usually due equally to lung and chest wall compliances (100 ml/cmH2O each).

Surfactant improves lung compliance, especially at low lung volumes; its absence as in ARDS, results in stiff

lungs and a tendency for the alveoli to collapse and fill with fliud.

"Dynamic" compliance includes the extra pressure needed to overcome resistance to airflow, inertia of chest wall, and viscoelasticity of tissues.

Total compliance varies from person to person and from time to time. A ventilator with pressure limited inspiration will deliver varying tidal volumes during an anaesthetic and from patient to patient. Most modern anaesthesia ventilators are of the "Volume Preset" type to minimise this problem.

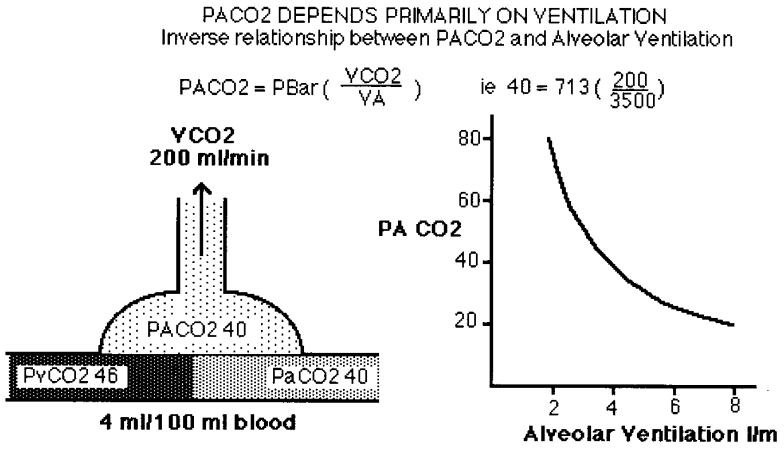
Work of Breathing

Work = Pressure x Volume

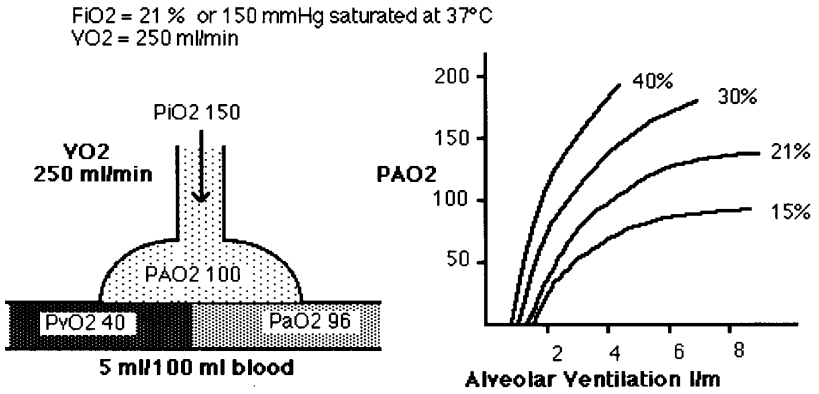
Respiratory work at rest or during exercise is seldom responsible for more than 5% of the total body work. Most of this is used to overcome the lung and chest wall stiffness during inspiration. Work to overcome airway resistance is usually very small, except during exercise or in athsmatics.

Patients with most respiratory diseases have increased respiratory workloads, which may be due to high respiratory rates, stiff lungs, or high airway resistances. When the patient becomes so exhausted that they can no longer keep up the workload, respiratory failure ensues. Anaesthetic machine tubing, one-way valves, and ETTs all increase total resistance and respiratory work, while drugs will diminish respiratory effort, so that the patient with poor respiratory function usually requires ventilating both during and after the operation.

CO2 Elimination



Oxygen Transport



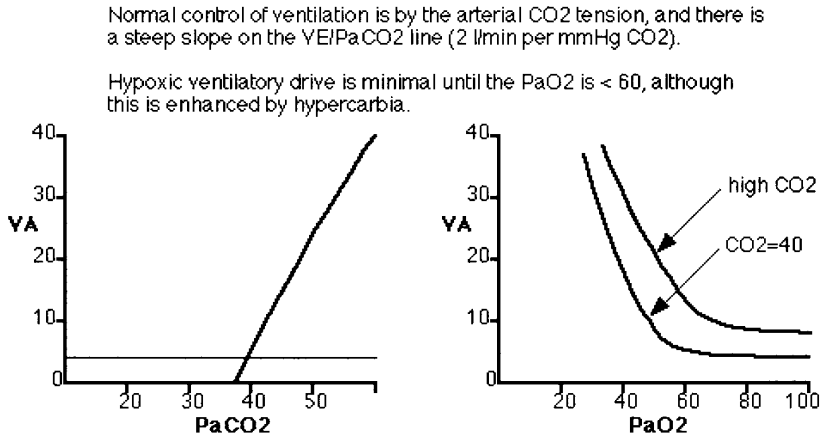
Effect of Shunts

Some venous blood passes through the lungs without equilibration with Alveolar gas. This "Venous Admixture" or "Shunt" subsequently mixes with oxygenated blood in the pulmonary veins, and has the effect of reducing PaO2 and elevating PaCO2.

While the slight rise in PaCO2 can be overcome easily by increasing the ventilation to normal alveoli, the same is not true for PaO2. For example, a 50% shunt needs 100% inspired oxygen to get a PaO2 of about 60 mmHg, but only a doubling of ventilation for normocarbia.

This is because the normal alveoli can blow off lots more CO2 than normal, but can never saturate the Hb any more than 100%.

Control of Ventilation



Effects of Anaesthesia

- Impaired control of ventilation; volatile agents almost totally abolish hypoxic responses, narcotics, sedatives, anaesthetics impair CO2 responses
- Increased Deadspace (equipment and physiological)
- Increased work of ventilation due to:
- Increased circuit and airway resistance
- Decreased lung compliance
- Increased Shunt, leading to hypoxia, due to:
- Atelectasis of dependent parts of the lung

- Impaired sputum clearance (cilia, atropine, sedation, pain)
- Decreased FRC

VENTILATION

Classification

- Mouth-to-Mouth/mask/ett etc
- IPPV - "Conventional" Mechanical Ventilation
- PCV - Pressure Control Ventialtion
- IMV - Intermittent Mandatory (Volume) Ventilation
- MMV - Mandatory Minute Ventilation
- SIMV -- Synchronised IMV ("Assisted")
- PRVC - Pressure Regulated Volume Controlled (volume preset pressure ventilation; machine alters pressure on a breath by breath basis to generate the tidal volume set by the user)
- BiPAP - Two-level CPAP (pt can breathe during inspiration and expiration)
- J et Ventilation (Sanders Injector)
- HFV - High-Frequency Ventilation
- HFO - High-Frequency Oscilation
- HFJV - High-Frequency Jet Ventilation
- PEEP - Positive End-Expiratory Pressure
- CPAP - Constant Positive Airway Pressure (pt can breathe duting expiration)
- NPV - Negative Pressure Ventilation
- TRIO - Tracheal Insufflation of Oxygen
- Apnoeic oxygenation

Effects of IPPV/PEEP

Respiratory:

- Decreased PaCO2 due to increased Alveolar Ventiilation
- Improved PaO2 (see previous graphs)
- Intrapleural Pressure less negative
- Work of breathing reduced
- Decreased lung water
- Optimum PEEP increases alveolar size, FRC, compliance, etc
- Hazards associated with intubation, paralysis or sedation, equipment failure.

Cardiovascular:

- Pressure gradient for venous return decreased whenever intrathoracic pressure rises
- CVP and peripheral venous pressure rise
- Reduced RV filling and increased RV afterload; opposite effects on LV
- May cause fall in Cardiac Output, particularly in hypovolaemic patients, causing reflex increase in contractility, heart rate, MVO2, vasoconstriction to augment venous pressure, reduced mixed venous oxygen tension, which may worsen aterial PO2

Renal

- Decreased renal function due to fall in Cardiac Output & Renal perfusion
- Increased ADH due to decreased central venous wall tension

Effects of CPAP/IMV or BiPAP

- Patient can breathe spontaneously; paralysis not always required
- Optimum CPAP and a low-resistance circuit reduces work of breathing
- Intrapleural pressure not as high as for IPPV so less depression of C.O.

But most IMV/CPAP systems do not maintain CPAP well and finding "Optimal" CPAP is difficult.

Ventilators

Classification

- TYPE OF VENTILATION
- Positive/Negative
- OTHER CAPABILITIES
- PEEP/CPAP/IMV/MMV/HFV/HFO/HFJV etc
- CYCLING (reason inspiration commences)
- a) Automatic
- Time (Campbell, Bird)
- Pressure
- Other
- b) Manual c) Patient-Triggered
- INSPIRATION LIMIT
- Automatic
- Volume +/- Pressure limit (Bird with Bellows)
- Time (Campbell)
- Pressure (Bird)
- Flow
- Manual
- INSPIRATORY FLOW PATTERN
- Constant (Bird with Air-Mix control closed)
- Decelerating (Venturi-type, ie Campbell)
- Programmable
- Sinusoidal (Piston driven)
- CONTROL MECHANISM
- Pneumatic +/- Magnetic (Bird)
- Electronic (Servo)
- Fluidic Logic (Campbell)
- PATIENT CIRCUIT
- Single or Dual
- POWER REQUIREMENTS CONTROLS

Use in Anaesthesia

- Aim for normocarbia or slight hypocarbia
- Usually Volume preset IPPV devices
- Tidal volume and rate adjusted to suit patient (CO2 analysers useful)

With CO2 absorber ON:

- All inspired gas is free of CO2
- Effective ventilation depends only on Ventilator settings
- Very low Fresh Gas Flows may be used in the circle circuit

With the CO2 Absorber off:

- Provided that the ventilator settings deliver normal alveolar ventilation, the effective ventilation depends on Fresh Gas Flow.
- CO2 rebreathing occurs

Hazards

- Disconnection from circuit
- Failure to deliver ventilation
- Barotrauma

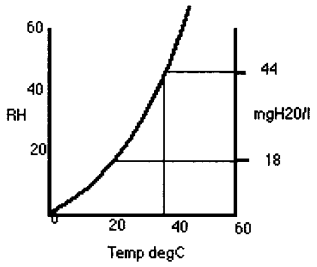
Monitoring Ventilation

- Colour of the Patient
- Watching the chest move
- Precordial/Oesophageal Stethoscope +/- telemetry
- Listening to sound of ventilator
- Measurement of Circuit Parameters, such as pressure or tidal volume
- Measurement of Patient Parameters, such as ETCO2, SpO2, chest wall impedance,etc

HUMIDIFICATION

Physics

- Vapour - Gas Phase of a liquid below boiling point
- Aerosol/Mist - suspension of fine droplets of a liquid in a gas
- Absolute Humidity - amount of water vapour per unit of gas (mg/l)
- Relative Humidity - Absolute humidity of the sample as a % of the absolute humidity of fully saturated gas at the same temperature



NOTE
1] Exponential rise in absolute humidity with increasing temperature.
2] At 37 degC fully sat is 44mg/l
3] At 20 degC fully sat is 18mg/l

Measurement of Humidity

- Dew Point Hygrometer
- Hair Hygrometer
- Wet/Dry thermometer
- Humidity Sensors
- Measurement of water used by humidifier

Physiology

The nose is a very efficient humidifier:

- 60% RH at the post-nasal space
- 5% RH in the mouth
- 100% at 37 degC in the bronchi

Mouth-breathing is less efficient (60% RH in the upper trachea)

Heat and water loss through the nose is minimised by cooling on inspiration and warming on expiration.

Humidification is required to maintain of ciliary activity, prevent squamous epithelial changes (Mucosal changes in 2-3 hours), prevent dehydration and thickening of secretions and possible ETT obstrucion, minimise atelectasis and tracheitis, and to decrease heatloss

Methods

ANAESTHETIC CIRCUIT CONSIDERATIONS

- Cylinder gas is completely dry, and tracheal intubation bypasses the nose
- Waters CO2 absorber heats and humidifies gas very effectively
- Circle CO2 absorbers are of slight benefit only
- Bain circuit allows some warming but very little humidification

HEAT AND MOISTURE EXCHANGERS

- Relatively cheap
- 70%-80% effective humidification
- Increased deadspace, resistance, risk of disconnection

HUMIDIFIERS

Up to 100% humidification, essential for longterm respiratory care. Modern types heat both the water bath and patient hose to prevent rainout. Disadvantages:

- Cost
- Potential for leaks, disconnection
- Drowning if tipped
- Source of infection
- Unreliable
- Airway burns
- Increased airway resistance

EQUIPMENT

FISHER & PAYKEL

- Water heated to 37 degC , servo controlled hose heaters in newer units

GRANT - NICHOLAS

- Water heated to 45 degC , hose servo to 37 degC. Inefficient at >10l/min flows

BOURNS

- Basic Kettle type

NEBULISERS

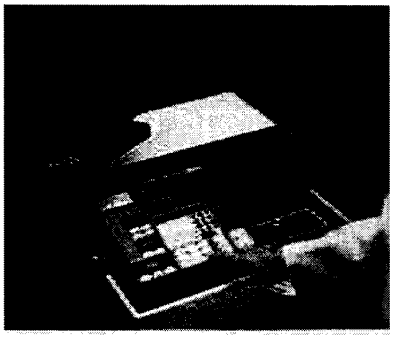
- Produce aerosols with humidity depending on temperature.
- Air is usually cooled by the droplets ->cold wet air
- Most useful for drug delivery

Comments? please use this form.

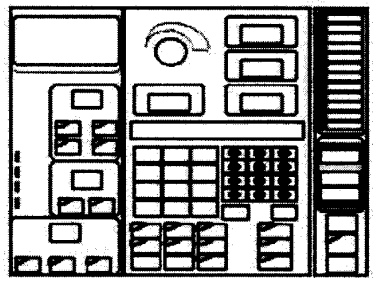
Overview of the Puritan Bennett 7200 Series Ventilatory System

The University of Kansas
Respiratory Care Education

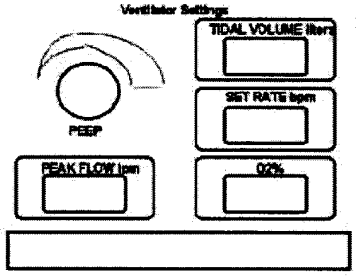
7200



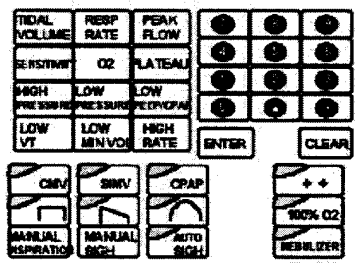
'he 7200 is pneumatically driven, electronically (microprocessor) and ıeumatically controlled with CMV, SIMV, and CPAP available in volume ontrolled or pressure controlled modes. Volume control is more correctly alled flow control, and as such, is therefore time-cycled rather than volume ycled. Pressure control is time cycled. Pressure support and flow-by are vailable options as are many other functions accessible via the [++] key. 'ressure support is pressure or flow triggered and flow cycled when the flow alls to 5 LPM.



'he 7200's control panel is divided into 3 sections: Patient Data shown in ;reen above, Ventilator Settings shown in blue, and Ventilator Status shown ı black. The same panel is illustrated on the right. Each section will be nlarged and discussed starting with the the center section.



'he keypad is used to input values for the ventilator and alarm settings. Each 'entilator setting has its own separate display window to show the current etting for Tidal Volume, Rate, Oxygen %, and Peak Flow.



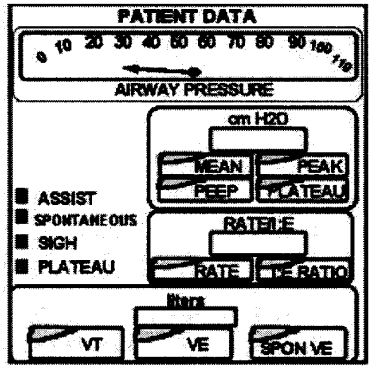
'o change any of the 6 ventilator settings or 6 ventilator alarms, press the .esired parameter pad. The value is displayed in the long message display vindow (MDW) in the middle of the section. The new value is entered on the :eypad and the <ENTER> pad is pressed.To change modes or flow vaveforms or activate manual breath or manual sigh, simply press the desired ıad. Before a manual sigh can be given, however, sigh parameters must be set .sing the Automatic Sigh pad, whether Automatic Sigh is

)N or not. Accessing functions using the [++] key usually requires pressing the <ENTER> pad until <UPDATE 'ARAMETERS> is viewed in the MDW. The last <ENTER> actually implements the change. The [CLEAR] ıad makes the MDW blank to correct mistakes made while using the keypad. [CLEAR] will also change various unctions accessed through the [++] key.

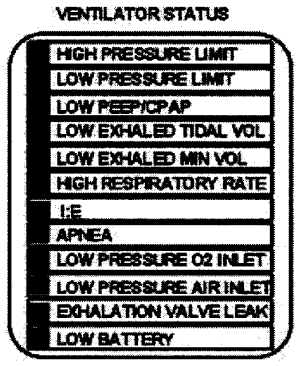
he [++] pad is used to access Pressure Control (Function 80), Apnea Ventilation in PC (81), and Fixed I:E Ratio r Fixed Inspiratory Time (82). To access the parameter settings under Function 80, "Function 80 Select" must ɔpear in the MDW. Pressing <ENTER> will then allow the operator to set the Inspiratory Pressure level and

ıspiratory Time or I:E Ratio. Inspiratory Time should be fixed unless inverse ratio ventilation is desired. Pause ime cannot be set in Pressure Control. If "80 Pressure Control" appears in the MDW, pressing <ENTER> will mply scroll through all the 20+ possible functions. To open a particular function if "Select" is not displayed, ress any of the 12 parameter pads first, and then press <ENTER>. Input "80" if it does not read "Function 80 elect" and begin entering values for pressure control that are displayed in the MDW. Note that while in Pressure ontrol mode, the TIDAL VOLUME and PEAK FLOW displays will still show the values set in VOLUME ONTROL. There are **no parameter settings** for tidal volume or peak flow in pressure control mode!

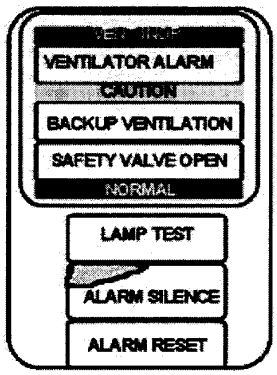
.ctivating the [100% SUCTION] pad will deliver 100% oxygen for 2 minutes. The [NEBULIZER] pad will eliver 10 LPM during inspiration to the nebulizer port as long as the peak flow is over 10 LPM. The nebulizer ·ill automatically end after 30 minutes. Nebulization will occur during any type of breath as long as the flow is 0 LPM or more. The nebulizer FIO2 will be AIR if the ventilator FIO2 is less than 0.60. It will use 100% xygen if the FIO2 is 0.60 or more. The 6 ventilator alarms are functional in all modes. When switching from MV to SIMV, the LOW TIDAL VOLUME and LOW MINUTE VOLUME alarms monitor all breaths which ıclude spontaneous in SIMV, so the alarm settings might require adjustment when changing modes. EEP/CPAP is set with the control knob located in the top of the section.



'he Patient Data section (green) has the Airway Pressure monitor, and a ·isplay window for PEAK, PLATEAU, PEEP, and MEAN AIRWAY pressur, ·epending on which pressure pad indicator is illuminated. Set the PEEP/CPAP ·evel according to the AIRWAY PRESSURE monitor and not the LED 'EEP/CPAP display. There is also a display window for RATE or I:E RATIO. \t the bottom of the section, exhaled TIDAL VOLUME, MINUTE /OLUME, or SPONTANEOUS MINUTE VOLUME can be displayed in ıters.



n the Ventilator Status Section, the indicators illuminate together with an audible ·arning when any of the alarm conditions have been met. In addition to the 6 larms in the Ventilator Settings section, there are built-in alarms which include ·ow Battery, Exhalation Valve Leak, I:E Ratio, Low Air, and Low O2. The 7200 tores the last ventilator settings in memory, which are used on initial power up, and equires battery power for the Vent Inop alarm. Low Battery indicates that battery ·ower is too low to sustain one hour of memory. The Exhalation Valve Leak alarms ·hen 10% of the delivered volume or 50 mL pass through the expiratory flow ·ansducer during inspiration. The Apnea indicator illuminates when there has been ıo breath sensed at the expiratory flow transducer for the length of time determined ·y the Apnea Interval setting (Function 1 in volume control and Function 81 in ·ressure control).



n the bottom half of the Ventilator Status section, the Alarm Summary Display has ıree indicator lights. When an alarm condition occurs, the red indicator illuminates, n audible alarm sounds, the specific alarm indicator above flashes, and the alarm ondition is identified in the MDW. If the condition corrects itself, the indicator hanges from red to yellow, the audible stops, and the specific alarm indicator stops lashing and shines continuously. When the alarm condition has been RESET, the ıdicator changes to blue for NORMAL function.

'he BACKUP VENTILATION indicator illuminates when 3 system errors have been detected in a 24 hour ·eriod. The ventilator must be changed out immediately. SAFETY VALVE OPEN illuminates during the initial ·ower up when the Power-On-Self-Test is running. Alarm Silence will stop the audible alarm for 2 minutes, fter which time the audible will resume if the alarm condition is not corrected.

;o back to ventilator table.

C Ed WebMaster

The University of Kansas
Respiratory Care Education

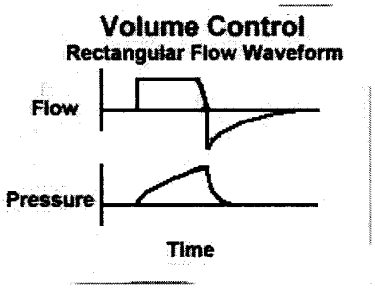
Waveforms of the 7200

200

1. Waveforms

Identify pressure and flow waveforms of volume controlled ventilation

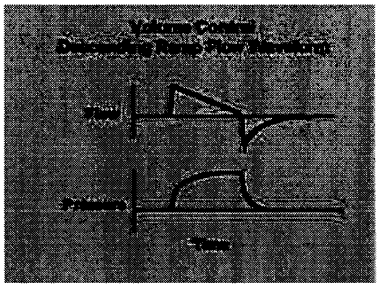
Rectangular Flow Waveform



Highest Peak Pressure

Lowest Mean Airway Pressure

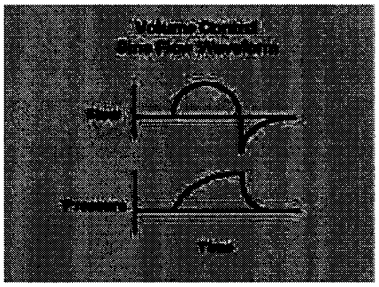
Descending Ramp Flow Waveform



Lowest Peak Pressure

Highest Mean Airway Pressure

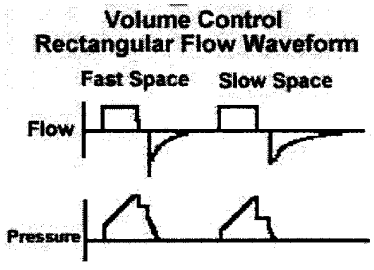
Sine Flow Waveform



Peak pressure less than rectangular waveform and higher than descending.

Mean Airway Pressure is higher than rectangular waveform but lower than descending.

Rectangular Flow Waveforms Comparing Fast and Slow Space Ventilation



Inspiratory flow wave remains constant. Expiratory flow takes longer to return to baseline with slow space.

Plateau pressures are greater with fast space. The peak minus plateau pressure difference is greater in slow space due to the increased airway resistance and normal or increased compliance.

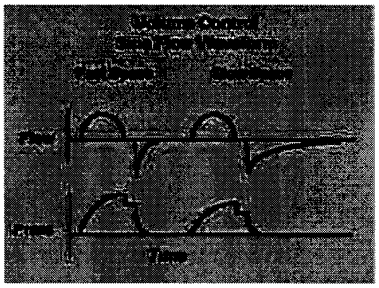
Ramp Flow Waveforms Comparing Fast and Slow Space Ventilation

Changing to a ramp flow waveform lengthens inspiration and may cause air-trapping in slow space lung units. Expiratory flow

takes longer to return to baseline during slow space ventilation.

Peak and plateau pressures essentially equal each other in a ramp waveform since inspiratory flow has dropped to zero at end inspiration. Airway pressures are higher in fast space ventilation. The increase in airway pressure from high airway resistance in slow space ventilation is minimized with a ramp flow waveform.

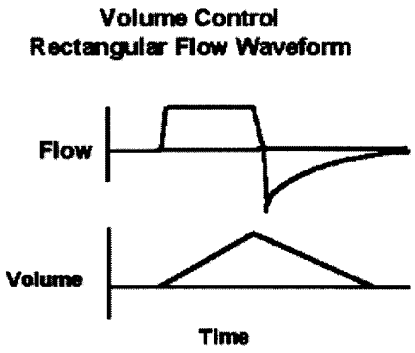
Sine Flow Waveforms Comparing Fast and Slow Space Ventilation

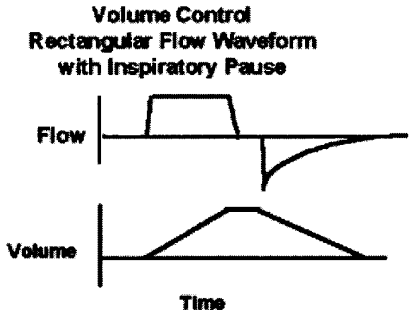


Changing to a sine flow waveform lengthens inspiration and may cause air-trapping in slow space lung units. Expiratory flow takes longer to return to baseline in slow space.

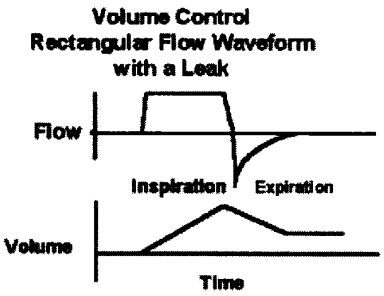
Peak pressures are less than a rectangular waveform but more than a descending ramp. The peak minus plateau pressure difference is less than a rectangular waveform but more than a descending ramp in slow space ventilation due to the lower flowrates at the beginning and end of inspiration.

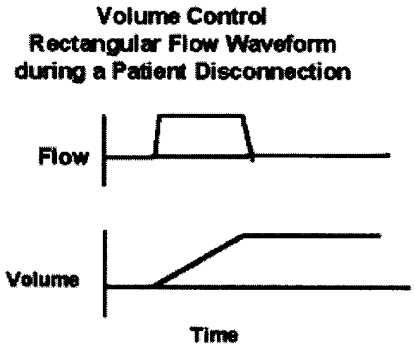
Certain conditions may be easier to detect viewing volume waveforms. The first graphic shows flow/time and volume/time waveforms of a volume controlled breath during normal function. The second graphic shows the same breath with a pause added.

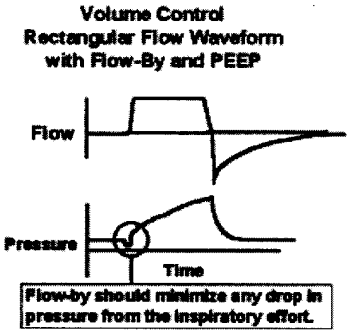




The next graphic is an example of what a leak in the circuit would look like in a volume waveform. The last set shows a volume waveform during a patient disconnection.

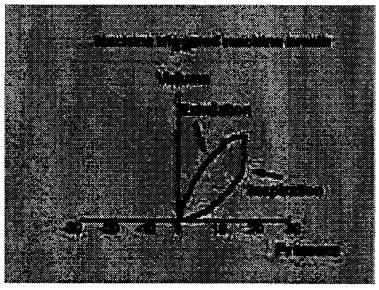






Pressure waveforms can be used to adjust Flow-by. In Flow-by, the patient's inspiratory effort creates a drop in flow, rather than a drop in pressure, to trigger a breath. If the flow sensitivity and base flow are adjusted properly, there should be little, if any, drop in pressure when the patient triggers a breath.

Interpret pressure/volume loops of volume controlled ventilation
Set the volume and pressure ranges appropriately.



The volume axis should touch the pressure axis at the pressure baseline.

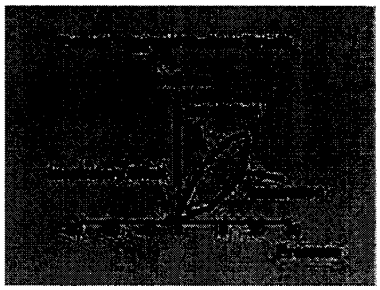
The portion of the curve to the right (positive pressure side) of the volume line represents the work performed by the ventilator. Low compliance will decrease the slope and flatten the loop.

The bottom part of the curve is inspiration and the upper part is exhalation.

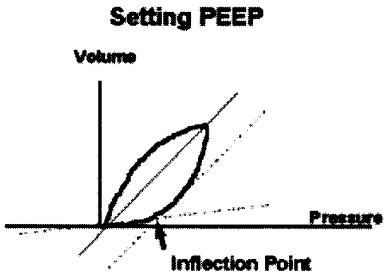
An assisted volume controlled breath shows the patient's inspiratory effort to the left of the volume axis.

The area of the loop to the left is displayed as Inspiratory Area in the upper left portion of the Graphics screen. The inspiratory area is the patient's work of breathing in joules/liter. Normal work of

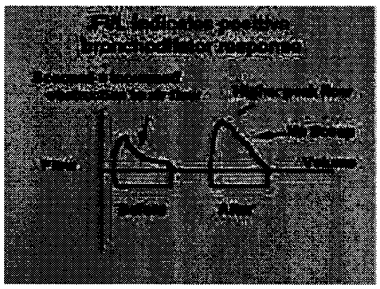
breathing is 0.3 to 0.8 joules/liter. Respiratory muscle fatigue is likely to occur if the work of breathing exceeds 1.5 j/l.



Pressure/volume loops can also be used to determine the appropriate PEEP level. If an inflection point appears on the inspiratory limb, the PEEP should be set at that level of pressure. The inflection point represents an improvement in compliance from alveolar recruitment. The dashed lines represent the change in slope (compliance) on either side of the arrow (inflection point).



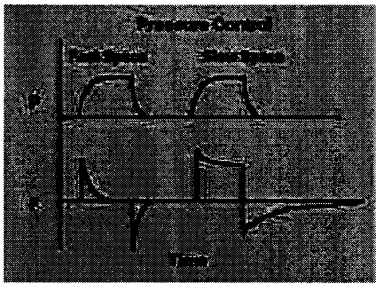
Flow/volume loops help in evaluating whether airway obstruction lessens after bronchodilator therapy. Improvement would result in a higher peak expiratory flow (top half). Keep in mind that these breaths are not forced exhalations. If there are higher expiratory flows from a reduction in airway obstruction, there would be less of a scooped appearance during mid to end exhalation.



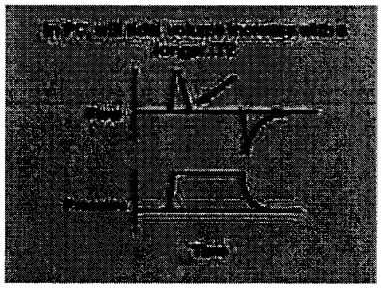
Remember that exhalation and the following inspiration are from different breaths. An exhalation may be from a ventilator breath followed by a spontaneous inspiration if the patient is in SIMV mode.

Interpret pressure and flow waveforms of pressure controlled ventilation

In pressure controlled ventilation, volume delivery can be drastically different at any given level of pressure control, depending on the patient's compliance and resistance.

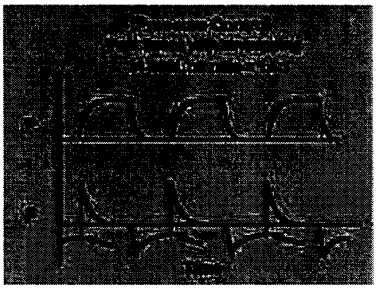


When ventilating fast spaces with pressure control, lengthening inspiratory time will not increase tidal volume if inspiratory flow returns to baseline as indicated by the arrow. In this case the tidal volume can only be increased with an increase in the level of pressure control.

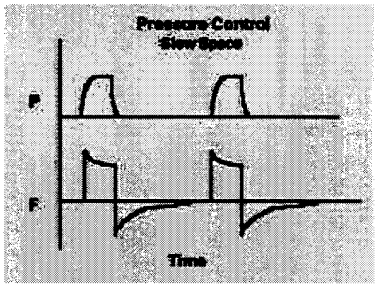


Since expiratory flow quickly returns to baseline in fast space,

much higher respiratory rates can be tolerated without air-trapping. If air-trapping is desired as in inverse ratio ventilation, inspiratory time should be lengthened while observing flow waveforms. It is better to fix the I:E ratio rather than the inspiratory time when providing inverse ratio ventilation. Otherwise, it is preferable to fix the Inspiratory Time to minimize fluctuations in volume delivery.

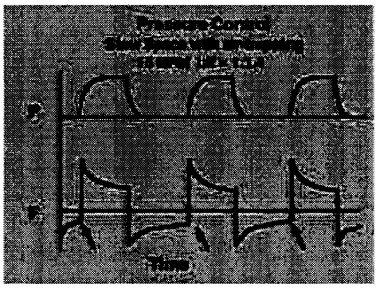


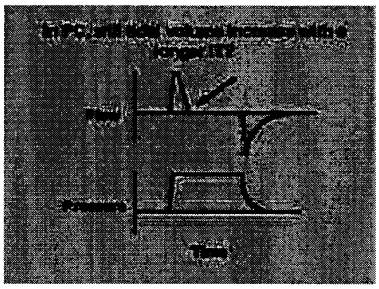
When ventilating slow spaces, inspiration typically ends before inspiratory flow has returned to baseline. Lengthening inspiratory time will increase volume delivery. However, greater inspiratory volumes will require more time for exhalation and lower respiratory rates are necessary to prevent unwanted air-trapping.



In CMV mode, slight increases in the respiratory rate may lead to air-trapping in cases of predominantly slow space lung units as in patients with COPD.

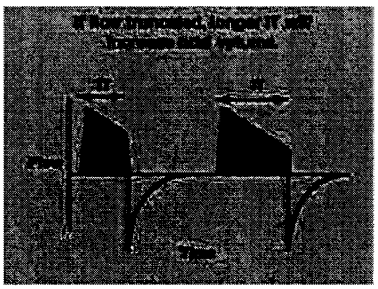
Note in *all* the air-trapping examples, that whether or not the airway pressure in the pressure/time waveform returns to baseline at end-exhalation is NOT important. The airway pressure in this case IS NOT a measurement of Auto-PEEP. There needs to be an end-expiratory pause in order for airway pressure to equal alveolar pressure and measure Auto-PEEP.





No. The arrow indicates that the inspiratory flow has returned to baseline and maximal volume delivery at that level of pressure control has occurred. Lengthening inspiratory time or going to a larger I:E ratio will not increase the tidal volume.

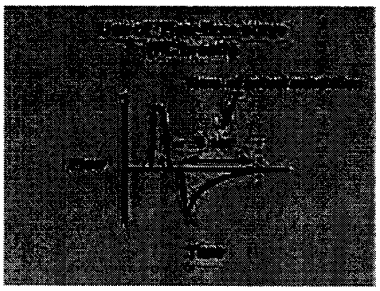
Increasing inspiratory time will increase tidal volume if flow waveform truncated at end of inspiration.

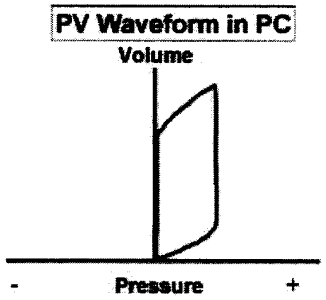


Can observe actual expiratory time to estimate time constant

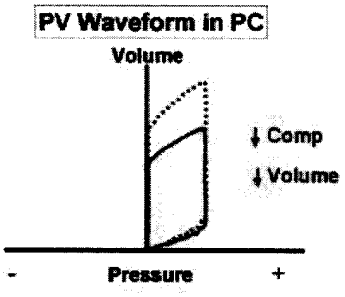
and determine whether tc fast or slow (normal tc = .5 seconds). Fast space occurs when compliance is decreased and airway resistance is normal or decreased as in ARDS. Slow space occurs when the airway resistance is increased and compliance is normal or increased as in COPD.

3 seconds/ 5 = 0.6 for one tc. Slightly slower.





The pressure/volume loop on the right is in pressure control ventilation. The straight vertical line represents the inspiratory pressure level.



When compliance decreases, the tidal volume will decrease. The pv loop changes as shown in red. Since inspiratory pressure is controlled, there will be no over-inflation spikes or flattening of the curve.

Go back to ventilator table.

>BACK

The University of Kansas
Respiratory Care Education

7200 Questions

1. What performance check of the 7200 would you do if you don't have time to run a Quick EST before the patient is due in the SICU?

2. What should you do when you first connect the ventilator to the patient's ETT and the high pressure limit alarms? (You have a 10 ml/kg tidal volume set in VC and a High Pressure Limit of 50 cm H_20?)

3. In VC, should the exhaled tidal volume approximately equal the set tidal volume? Give 3 examples of patient situations when it won't.

4. Why do you need to set the Function 1 Apnea Ventilation for VC, even though you are in PC and you've set Function 81 PC Apnea Ventilation?

5. In VC, what do you change if you have an actual inspiratory time of 0.5 seconds and an I:E ratio of 1:5?

6. In #5, why may you decide not to make that change?

7. Will an increase in 5 cm H_20 in the patient's plateau pressure increase the mean airway pressure to the same extent as a 5 cm H_20 increase in peak inspiratory pressure? How could you test this in the lab?

8. In VC, if your PIP = 42, plateau pressure = 32, and PEEP = 5, what pressure would you use to set in PC?

9. When measuring Auto-PEEP with the Braschi valve, when do you remove the cap? When do you note the presence of Auto-PEEP? What function measures Auto-PEEP?

10. In VC, if the patient's plateau pressure is too high, what setting do you need to decrease?

11. In VC, if you have to decrease the tidal volume due to the patient's decreased compliance, what setting do you need to increase if possible?

12. In PC, if your pressure control setting is already at 35 cm H_20, what else might you do to increase tidal volume? What can you do if inspiratory flow has returned to baseline before the end of inspiration?

13. What maneuver is required to measure Auto-PEEP? What condition is necessary?

C Ed WebMaster

Self Tests

SECTION 5. SELF-TESTS

Two diagnostic programs, the Power-On Self-Test (POST) and the Extended Self-Test (EST), are used to test and troubleshoot the 7200 Series Ventilator. POST, which is executed each time power is applied to the ventilator, can detect faults in the electronics even while a patient is attached to the system. EST, which requires that the patient be disconnected from the ventilator, more completely tests the hardware. Together, the two diagnostic programs provide a confidence check each time a patient is connected to the ventilator.

This section describes how to run these self-tests. Refer to Section 6 for a listing of the POST and EST tests and error codes.

5.1 Power-On Self-Test (POST)

The following subsections describe POST, its operation and test routines, and the meaning of the error information POST conveys.

5.1.1 Introduction

POST verifies the integrity of the ventilator electrical system. Using POST, it is possible to quickly detect and isolate most electronic failures.

Structure of POST

POST can diagnose electronic problems using a minimal amount of system hardware, that is, the CPU kernel. The kernel is located on the CPU PCB. The kernel includes the microprocessor, an EPROM containing the POST software, and LEDs (eight in the 80188-based ventilator, three in the 8088-based ventilator).The test routines within POST are generally ordered so that each routine requires successively more operational hardware than the last, permitting electronic components to be systematically eliminated as possible causes of ventilator malfunction.

The first test routines check the CPU kernel. The next set of routines tests the entire CPU PCB. Finally, the last set of test routines checks circuitry off the CPU PCB. The routines that comprise POST differ somewhat depending on whether the ventilator has an 80188 or 8088 Microprocessor.

When Is POST Invoked

POST starts automatically (1) any time power is applied to the ventilator, including after a power interruption; (2) immediately before EST is run; and (3) after a software watchdog timeout.

What If POST Fails

If one of the POST routines considered critical for proper ventilation fails, the ventilator activates back-up ventilation (BUV) or the safety valve open mode. If a noncritical test fails, it may be possible to run EST and ventilate a patient, as described later in this section.

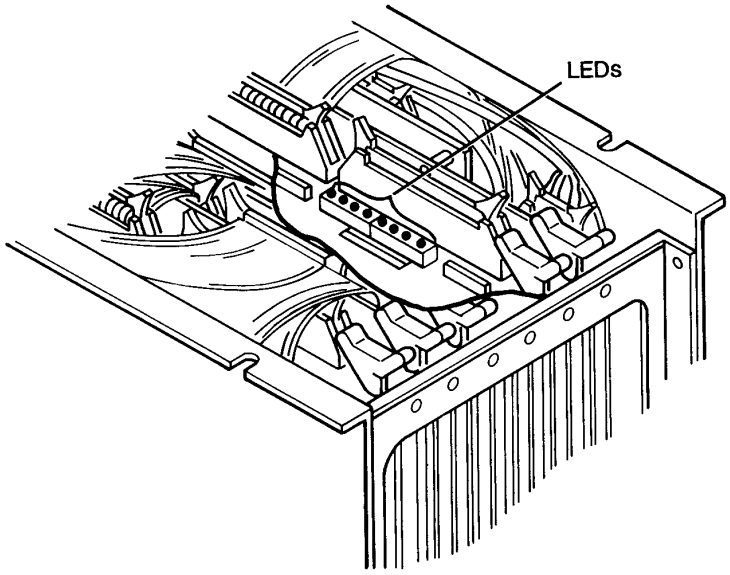
5.1.2 Running POST

To run POST for diagnostic purposes, do the following:

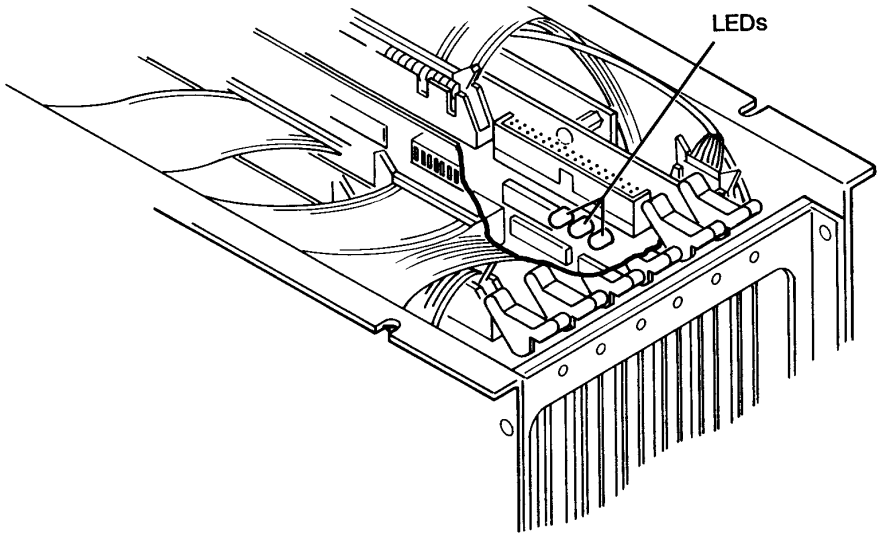
1. Expose the card cage. LED indicators (eight in 80188-based ventilators, three in 8088-based ventilators) should be visible at the upper edge of the CPU PCB (see Figure 5-1).

2. Turn on ventilator power.
3. Observe the LED indicators and the 20-character display. The LED indicators and the 20-character display should show codes corresponding to the test being run, as indicated in Section 6. Be aware that some codes may appear and disappear quickly.
4. If a code corresponding to an error condition is continuously displayed by the CPU PCB LEDs and/or the 20-character display, an error has been detected. Refer to Section 6 for troubleshooting information. The ventilator will not resume normal operation until the fault is located and repaired.

If POST passes, program control is passed to the ventilator applications software.



a. 80188 CPU PCB



b. 8088 CPU PCB

Figure 5-1. LED Indicators on the CPU PCB

5.1.3 Error Handling

POST may report error information through LED indicators on the CPU PCB and the 20-character display. Refer to Section 6 for specific error information.

How POST Reports Errors

POST reports errors differently depending on which test routine is being executed. When a kernel test fails, the LEDs on the CPU PCB display the error code. When a later test (a CPU PCB or offboard test) fails, these LEDs and the 20-character display provide error information. In any case, the error code is stored in battery-backed RAM, where the six most recent POST and EST error codes are retained.

In 80188-based ventilators, eight LEDs display error information. The three left-hand LEDs display the test section number, while the five right-hand LEDs display the binary test code, as follows:

●OO OOOOO Section 1 - CPU kernel
●●O OOOOO Section 2 - CPU PCB
●●● OOOOO Section 3 - Offboard and displays

Test section — Binary test code

In 8088-based ventilators, three LEDs display error information, as follows:

OOO

Binary test code:
- 0-5 Kernel and CPU PCB tests (no 20-character display)
- 6 Offboard and display tests (should have 20-character display)
- 7 POST passed

If an error is detected during one of later tests, an error code and message are displayed as follows:

ERR xxyz

Refer to Tables 6-1 or 6-2 to interpret these error codes.

How the Ventilator Responds to Errors

The ventilator responds differently to errors depending on whether it considers the failure critical (capable of compromising safe ventilation). In any case, the ventilator attempts to log the error code into battery-backed RAM and it sounds the alarm.

Critical errors. When the ventilator detects an error that could compromise safe ventilation (a critical error), POST stops testing and continuously displays the error message, but strobing of the watchdog timer continues. In addition to sounding the audio alarm, the ventilator turns on the ALARM and VENTILATOR INOPERATIVE alarm summary lights. Putting the ventilator into BUV is attempted, but if that fails, the ventilator is put into the safety valve open mode, permitting the patient to breathe room air.

An exception to this is the 80188 CPU PCB test 3 (ac power test). POST waits for a period of time for ac power to reach an acceptable level. If power levels then become acceptable, POST resumes operation. During a low power condition, the ventilator is put into the BUV or safety valve open mode.

Noncritical errors. When the ventilator detects an error that would not compromise safe ventilation (a noncritical error), POST displays the error message and continues testing. This message is displayed until the next error is detected or until the end of POST. If only noncritical errors are detected by POST, the ventilator allows the operator to run EST at the end of POST. Examples of such errors are the watchdog umpire, the battery-backed RAM checksum, and SPST connection check.

5.2 Extended Self-Test (EST)

This subsection describes the Extended Self-Test (EST), its operation, test routines, and the meaning of the error information it conveys. This information applies to Total EST, the full set of EST routines, as well as an abbreviated version, Quick EST. Quick EST is intended to verify that a new patient system is connected and matched to the ventilator.

5.2.1 Introduction

EST is a set of software routines, which, in conjunction with POST, thoroughly tests the integrity of the ventilator. These routines ensure the integrity of ventilator parts such as the pneumatics, battery-backed RAM, the back-up ventilator, and the front panel controls and indicators. EST also calculates the system compliance and the exhalation valve area ratio and detects possible leaks.

When To Run EST

EST was designed to be performed by a therapist before connecting a new patient to the ventilator or after replacing the patient tubing system, or by a service technician after servicing the ventilator. Unlike POST, EST must be run without a patient attached to the ventilator. Therefore, EST performs tests that POST cannot perform. When the <EST> button is pressed to start EST, the ventilator automatically runs POST first. It will not invoke EST until POST is completed with no critical errors (see Section 5.1.3).

Hardware Requirements

High-pressure air (either an external source or the compressor) and oxygen are required to run EST. If these are not available, EST will fail. EST will also fail unless a leak-tight patient tubing circuit is used.

What If EST Fails

If an EST test fails, the operator can continue EST execution, although EST will not pass until the error conditions are corrected.

If EST fails, Puritan-Bennett recommends that the ventilator be repaired before it is returned to service. The ventilator does offer limited capability to override EST errors and resume normal operation, however.

WARNING

Do not use a ventilator that has failed EST without verifying its operational integrity by means other than EST and determining that the patient will not be placed at risk.

Quick EST

Quick EST is an abbreviated version of EST, designed to be run when only the patient tubing system is being replaced. Quick EST, which tests the ventilator in approximately 1-1/2 minutes, runs six tests that ensure that the new patient service system is connected and matched to the ventilator. These tests are as follows:

Test	Function
52	Autozeroes pressure transducers
53	Checks for patient attached
54	Leak test
57, step 2	Calculates compliance
57, step 7	Autozeroes proportional solenoid valves (PSOL1 and PSOL2)
58	Calculates area ratio

5.2.2 Starting EST

WARNING

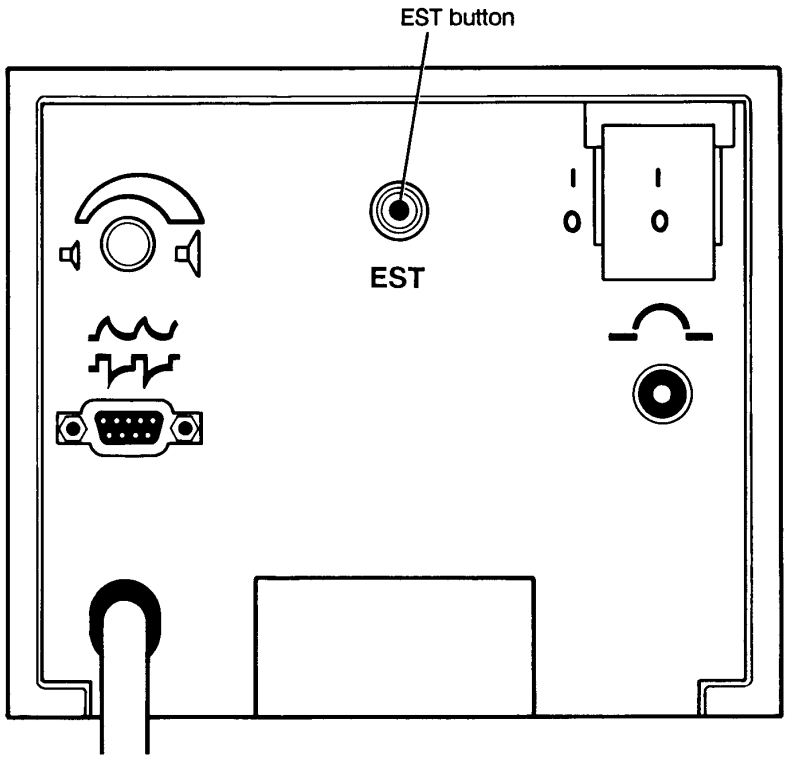
Never press the EST button while a patient is connected to the ventilator.

Before starting EST, make sure that the patient is disconnected from the ventilator. Start EST as follows:

1. Make sure ventilator power is on and that a patient is not attached to it.
2. Press the <EST> button on the utility panel (Figure 5-2), holding it for 1 to 2 seconds. Prompts requiring your response will be displayed by the 20-character display.

NOTE

To cancel an EST request after the <EST> button is pressed but before test routine execution begins, press <ALARM RESET>, <CLEAR>, or any ventilator setting or status key.



31052-034F

Figure 5-2. Location of EST Button

3. Respond to the following 20-character display prompts by pressing the keys indicated. If you do not respond to one of the following prompts within the allotted time, the EST request will be canceled.

Prompt	Response
START EST-ENTER	Make sure the patient is disconnected from the ventilator and the wye is blocked. Press <ENTER>.
PAT TUBING OFF-ENTER	Press <ENTER> if patient is disconnected and wye is blocked.
QUICK EST	Respond as follows: • **Run Quick EST** by pressing <ENTER>. • **Run Total EST** by pressing <++> and <ENTER>.

Prompt	Response
TOTAL EST (displayed only if Total EST selected)	Respond as follows: • **Run Total EST** by pressing <ENTER>. • **Run Quick EST** by pressing <ALARM SILENCE>. **NOTE** **Puritan-Bennett recommends you make a practice of reviewing error codes and other data from the most recent EST run before continuing with EST.** • **Review the six most recent error codes** by pressing a number between <1> and <6> (see Section 5.2.9). • **Clear an error code from memory** by pressing a number between <1> and <6>, <LAMP TEST>, then <ENTER> (see Section 5.2.10). • **Review data (other than errors) from the most recent EST run** by pressing <0> (see Section 5.2.8). If a 7202 Display is present, the error codes and other data from the most recent EST run are now displayed (Figures 5-3 and 5-4). • **View the ventilator model, software revision level, and option code** by pressing <I:E RATIO> (see Section 5.2.11). • **Repeat last test step** by pressing <*> twice, followed by <ENTER>. • **Repeat last test sequence** by pressing <*>and <ENTER>. Use these keys to scroll backwards to any test. • **Continue testing at beginning of EST** by pressing <ALARM SILENCE>. • **Exit EST** by pressing <ALARM RESET>. Continue pressing <ENTER> until <OVERRIDE-ENTER> is displayed, then press <ENTER>.

5.2.3 Running EST Test Routines

The EST routines begin running when the previous prompts are answered. As the ventilator executes the test routines, it displays the test number, followed by [TESTING]. The EST routines run sequentially, stopping only to prompt the operator to perform certain actions. The 7202 Display, if present, lists the tests and their pass/fail status as they are run. (See Figures 5-3 and 5-4.)

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Figure 5-3. 7202 Display during Total EST

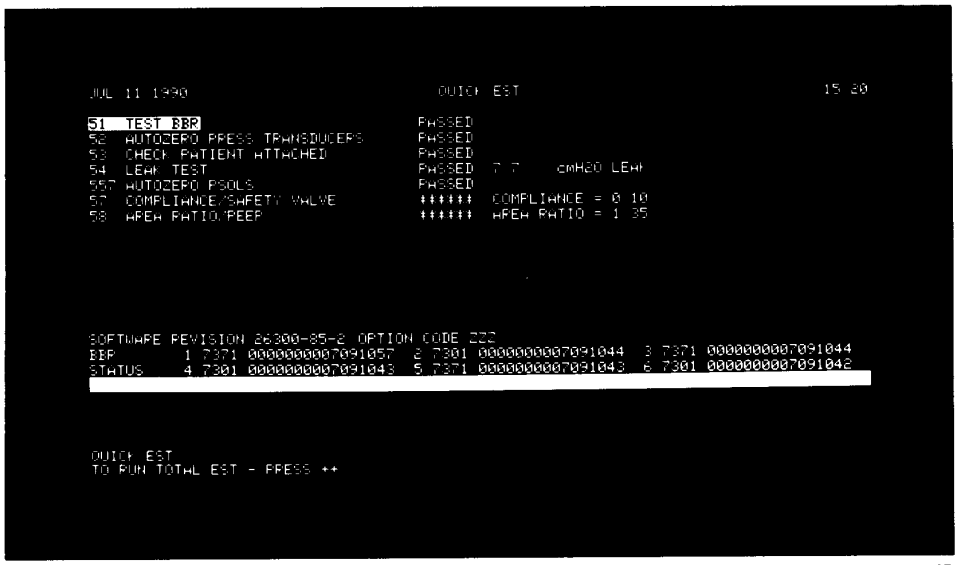

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Figure 5-4. 7202 Display during Quick EST

Prompts

The ventilator displays the following prompts in the approximate order given after the previous prompts are answered appropriately. Only the first four prompts are displayed during Quick EST. Respond to each prompt as indicated. Failing to respond to a prompt within an allotted time results in the test failing.

Prompt	Response
BLOCK WYE	Insert a stopper into the patient wye. Press <ENTER>.
CONNECT O2	Connect the ventilator to the oxygen supply. Press <ENTER>.
SET PEEP = 0	Turn <PEEP/CPAP> control counterclockwise until the 20-character display shows 0.0 cmH_2O. Press <ENTER>.
SET PEEP = xx	Turn <PEEP/CPAP> control clockwise to increase PEEP. Observe that the value in the cmH_2O display equals xx cmH_2O. **NOTE** **Three short beeps signal you to turn the knob and a long string of beeps signals you to fine-tune PEEP/CPAP to exact setting.**
UNBLOCK WYE	Remove stopper from patient wye.
CONNECT AIR	Connect ventilator to external air supply. Verify that ventilator compressor (if attached) is turned off.
DISCONNECT AIR	Disconnect ventilator from external air supply.
DISCONNECT O2	Disconnect ventilator from oxygen supply.
PUSH xxx	Press requested key within 10 seconds.
591 NEB ATTACH/	Press <ENTER> if patient tubing circuit includes a nebulizer. Press <CLEAR> to skip this test if tubing circuit does not have nebulizer.
601 COMPR ATTACH/	Press <ENTER> if the ventilator is equipped with a compressor. Press <CLEAR> to skip this test if the ventilator does not have a compressor.

Operator Errors

If EST detects an operator error, it may display one of the following messages. Respond as indicated.

Message	Meaning
INVALID KEY	You responded to a prompt by pressing an incorrect key. Retry key entry. Pressing an incorrect key twice causes [xxxyz ERR] to be displayed. Repeat test by pressing <*> twice, then <ENTER>.
OPERATOR RESPONSE TIMED OUT. PLEASE RESPOND TO THE PROMPT.	You did not enter requested information within the allotted time.
TIME OUT	Either you did not enter requested information *or* the ventilator could not respond correctly to the action (for example, this message displayed during PEEP/CPAP level setting may mean the PEEP circuit cannot achieve the desired PEEP). Repeat test by pressing <*> twice, then <ENTER>.

Power Loss During EST

If the ventilator is turned off or loses power during EST, [RUN EST-DO NOT USE] is displayed when power is restored. The ventilator then goes into BUV. The ventilator cannot be used until EST is rerun and passed or overridden.

Displays

EST uses the ventilator displays to display various parameters. Figures 5-5 and 5-6 and Table 5-1 provide information on these EST displays.

Table 5-1. Displays Used in EST Operation

Display	Function
Pressure (cmH_2O) display	Displays pressure measurement of type indicated by LED.
RATE/I:E display	Displays area ratio.
Volume (liters) display	Displays tubing system compliance.
TIDAL VOL liters display	Displays oxygen volume (test 614), lift-off current (test 557), or inspiratory oxygen flow rate.
PEAK FLOW lpm display	Displays air volume (test 613), take-off current (test 557), or inspiratory air flow rate.
O_2% display	Displays exhalation flow rate.
Alarm summary display:	
NORMAL	Indicates EST is running by operator election and that EST has not detected any error conditions during current run.
CAUTION	Indicates one of these conditions: • A noncritical POST or EST error was detected. • EST is being rerun after it failed once. • A test was skipped. This light is turned off and NORMAL lit if an EST test is failed, then subsequently passed. The ALARM light is lit if EST fails while CAUTION is lit.
ALARM	EST detected an alarm condition during current run. This light is turned off and CAUTION is lit if EST is restarted.
20-character display	Displays operator prompts, error codes, and other messages.

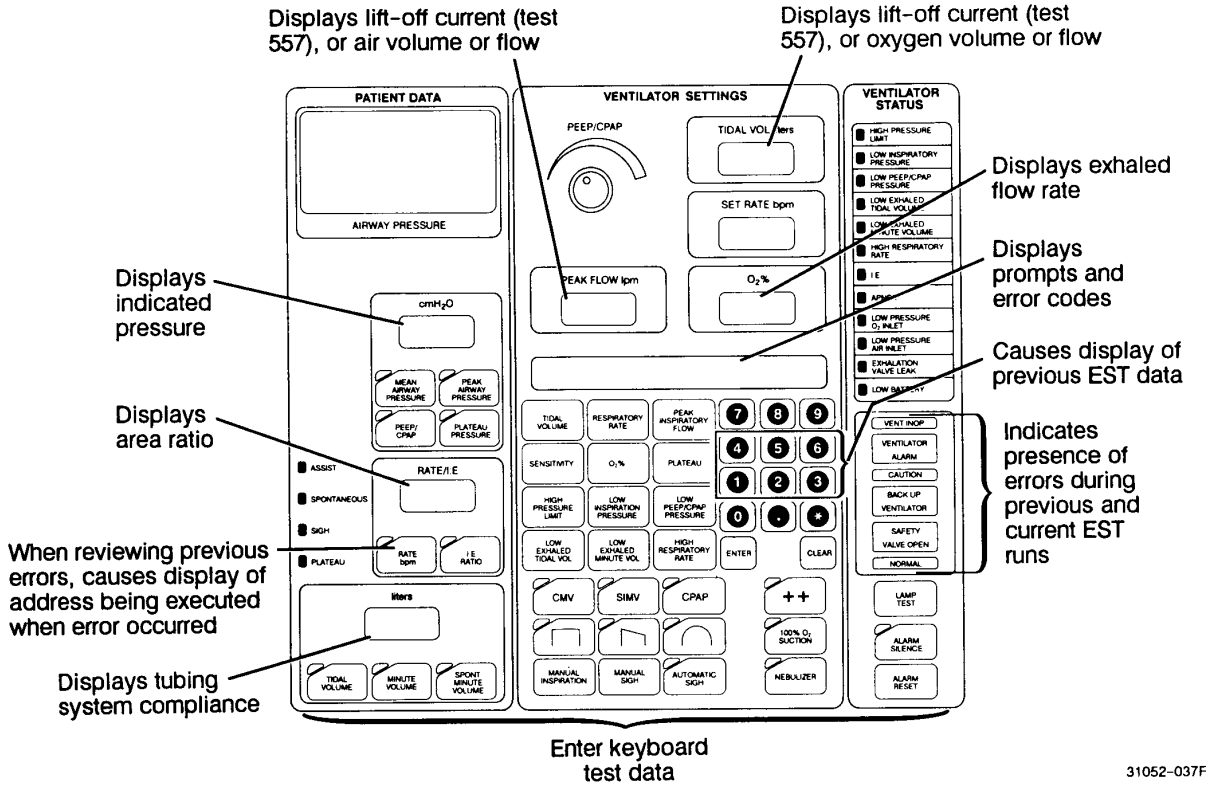


Figure 5-5. Enhanced Keyboard Controls and Indicators Used in EST

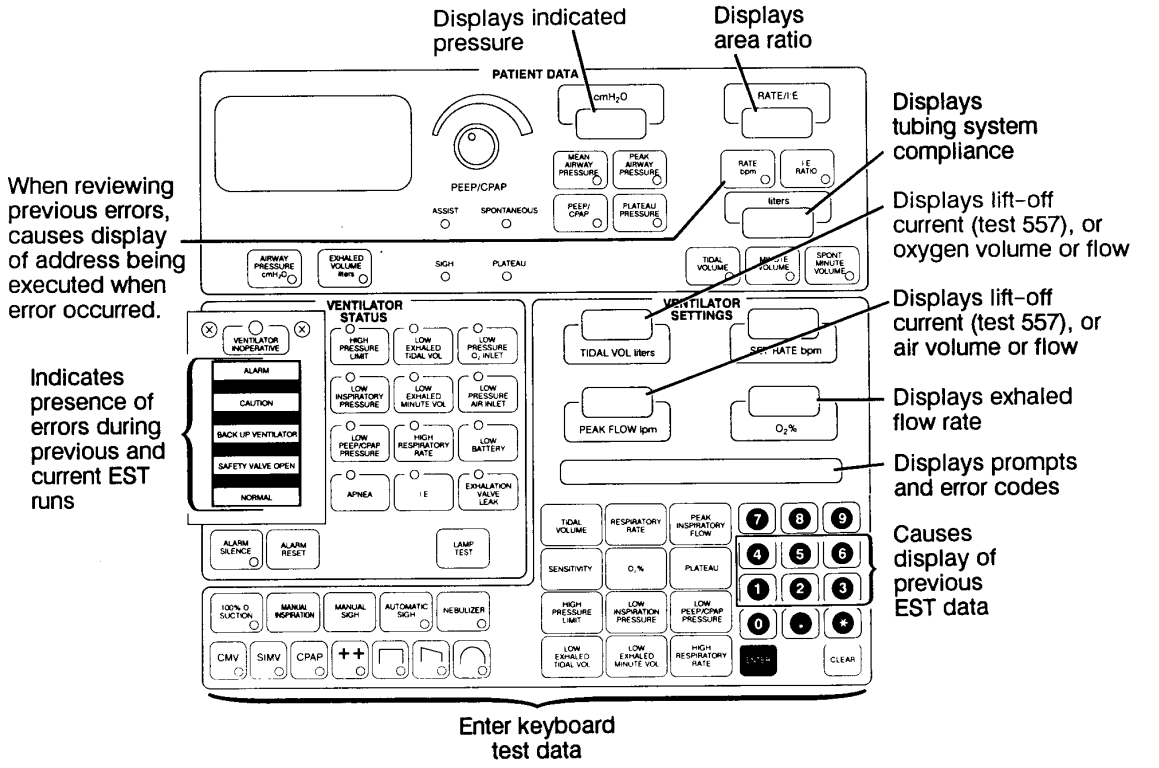


Figure 5-6. Basic Keyboard Controls and Indicators Used in EST

5.2.4 Error Handling

Follow these procedures if an EST test fails or if the entire EST fails.

After an EST Test Fails

When EST detects a hardware malfunction, it displays

xxyz ERR

Take one of these actions:

- **Stop error message from scrolling** by pressing <∗> or <ENTER> after the message has begun scrolling. This causes just the error code to be displayed.
- **Exit EST** by pressing <ALARM RESET>. Continue pressing <ENTER> until error message display is completed. Correct the problem and rerun EST by powering up the ventilator. (Refer to Section 6 for information on interpreting and responding to error codes.)
- **Repeat last test step** by pressing <∗> twice, followed by <ENTER>.
- **Repeat last test sequence** by using the <∗> key to scroll backwards to any test, then pressing <ENTER>.
- **Resume testing after a failure** by pressing <∗> or <ENTER>, then <ENTER>.
- **Continue testing at beginning of EST** by pressing <ALARM SILENCE>.

After the Entire EST Fails

WARNING

Do not use a ventilator that has failed EST without verifying its operational integrity by means other than EST and determining that the patient will not be placed at risk.

After EST fails, it displays one of these messages. Respond as indicated.

Prompt	Response
EST FAIL	EST failed one or more critical tests. Do one of the following: • **Rerun EST at the beginning** by pressing <ALARM SILENCE>. • **Repair the ventilator** by checking errors in battery-backed RAM (Section 5.2.9), powering down the ventilator, repairing the malfunction, and powering up the ventilator to reinvoke EST. • **Resume ventilation** by pressing <ENTER> after verifying the operational integrity of the ventilator by means independent of EST. [OVERRIDE-ENTER] will be displayed. Press <ENTER>.
EST COMPLETE	Either EST passed all critical tests, but failed one or more noncritical tests or EST was exited at operator request (<ALARM RESET>). Press <ENTER>. [OVERRIDE-ENTER] will be displayed. You may press <ENTER> to resume ventilation.

5.2.5 Exiting EST

You can exit EST either after its completion or while it is running.

During Test Routine Execution

Exit EST while it is running by pressing <ALARM RESET> then <ENTER>, either during operator prompting or during error message display.

If there are no unresolved errors, normal ventilator operation resumes.

If there are unresolved errors, take one of these actions:

- **Resume ventilation** by pressing <ENTER> in response to the [OVERRIDE-ENTER] prompt. Press <ENTER> again.The bypass condition and codes of all errors detected during this pass of EST are logged into battery-backed RAM.

- **Continue EST at the beginning** by pressing a key other than <ENTER> in response to the [OVERRIDE-ENTER] prompt.

After Its Completion

When EST is completed, it displays one of the following messages. Respond as indicated.

Prompt	Response
EST PASS	All EST tests were passed. Resume normal ventilator operation by pressing <ENTER>.
EST FAIL or EST COMPLETE	EST failed one or more tests or it was exited at operator request. See Section 5.2.4 to respond to this prompt.

5.2.6 Restarting EST

Restart EST as follows:

- **If the [RUN EST-DO NOT USE] message is displayed,** press <EST>. The [RUN EST-DO NOT USE] message indicates EST was interrupted for some reason. When this message is displayed, the ventilator also goes into BUV.
- **During a test fail condition or during error code review,** press <ALARM SILENCE>, then <ENTER>. The ALARM light, if lit, will be turned off; and the CAUTION light will be lit.

5.2.7 Printing an EST Status Report

Ventilators with the Digital Communications Interface (DCI) option active and a printer properly connected can generate an EST status report, shown in Figure 5-7. The report can be printed either after EST is completed or at any time during normal ventilator operation.

What the Report Includes

The report contains information on the most recent EST execution. This information includes:

- test number, title, pass/fail status, and error codes for tests that failed
- tubing compliance
- area ratio of the exhalation valve at selected pressures
- current status codes in battery-backed RAM
- overall result of the most recent EST: whether the ventilator passed or failed the test.

Generating The Report

To generate the report, press the keys and respond to the messages indicated below:

Press	The 20-character display reads:	Comments
<++>	FUNCTION SELECT	
<26>	26 EST STATUS	
<ENTER>	PRNT EST STAT-ENTER	Press <ENTER> to request a printout of the EST status report. Press <CLEAR> to return to the [26 EST STATUS] message
<ENTER>		Press <++> to step to another DCI function, or press any VENTILATOR SETTINGS key to return to current settings.

For additional information on using the DCI option, see the *Digital Communication Interface (DCI) Appendix* to the *7200 Series Ventilatory System Operator's Manual.*

```
TIME: 08:50          VENTILATOR SERIAL #                  DATE:  JUL 11 1990
********** EST RESULTS **********************************
-------------------------------------------------------------------------------
    TEST                                      CONDITION       ERROR CODE
-------------------------------------------------------------------------------
51  TEST BBR                                  PASSED
52  AUTOZERO PRESS TRANSDUCERS                PASSED
53  CHECK PATIENT ATTACHED                    PASSED
54  LEAK TEST                                 PASSED
55  TEST Q2 VS Q3                             PASSED
56  TEST Q1 VS Q3                             ******
57  COMPLIANCE/SAFETY VALVE                   PASSED
58  AREA RATIO/PEEP                           PASSED
59  TEST NEBULIZER                            ******
60  TEST COMPRESSOR                           ******
61  TEST BUV                                  ******
62  TEST FRONT PANEL                          ******
63  TEST DIGITAL COMMUNICATIONS               ******

TUBING COMPLIANCE          4.10    ml/cmH2O        ****** = TEST NOT RUN
TUBING LEAK                7.7     cmH2O/10 SEC             (QUICK EST)

AREA  RATIO
  35 cmH2O                 1.42
  30 cmH2O                 1.44
  20 cmH2O                 1.48
  15 cmH2O                 1.51
  10 cmH2O                 1.52
   5 cmH2O                 1.54
   2 cmH2O                 1.54
  AVERAGE                  1.49

BBR STATUS
  1     0000    000000000000  00000000
  2     0000    000000000000  00000000
  3     0000    000000000000  00000000
  4     0000    000000000000  00000000
  5     0000    000000000000  00000000
  6     0000    000000000000  00000000

      EST LAST RUN          JUL 11 1990    08:50
*****  EST  PASSED  *****
```

31052-039F

Figure 5-7. EST Status Report

5.2.8 Viewing Data from Most Recent EST Run

Follow the procedures below to view data from the most recent EST run. The data includes the date and time (24-hour clock) when EST was last run, the EST status (pass, complete, or fail), leak data, the exhalation valve area ratio, and tubing compliance.

On a ventilator with a 7202 Display, this information is part of the screen that automatically comes up when EST is invoked (Figures 5-3 and 5-4).

On a ventilator without a 7202 Display, view this data by pressing <0> while the [QUICK EST] or [TOTAL EST] prompt is displayed. This data scrolls across the 20-character display until you press another key.

EST may report error information, both about test errors and operator errors, using the 20-character message display and the 7202 Display, if present.

5.2.9 Viewing Previous Error Codes

NOTE

To invoke EST at its beginning while you are reviewing error codes, press <ALARM SILENCE>.

The ventilator can store data on the six most recent errors detected by EST. This error data is stored in battery-backed RAM. It includes the error codes and the date and time the errors were detected. The error code display takes this form:

xxyz ERR mmdd

where:	xxyz	is	the error code
	mmdd	is	the month and day the error was detected
	hhmm	is	the hour and minute the error was detected

On a ventilator with 7202 Display, this information is part of the screen that automatically comes up when EST is invoked (Figures 5-3 and 5-4).

On a ventilator without a 7202 Display, view this error data by pressing a number in the range <1> through <6> in response to the [QUICK EST] or [TOTAL EST] prompt. <1> stands for the most recently detected and <6> stands for the least recently detected error. If no errors were detected, [NULL ERR] is displayed.

When certain errors, such as some soft errors (3xxx - 4xxx), are detected, the address being executed when the error occurred is also stored in battery-backed RAM. These addresses may prove helpful in diagnosing the origin of the problem.

To make use of these addresses, get to the [QUICK EST] prompt, then press <1> and the <RATE bpm> key in the upper right-hand corner of the keyboard. Make note of the 12-digit number in the 20-character display. Do this for locations 1 through 6. If two or more of the addresses you retrieve are identical, do the following:

1. Break the address into three sets of four digits. (For example, [40A361010100] would be broken into 40A3/6101/0100).
2. Multiply the first set by 10H. (For example, 40A3H x 10H = 40A30H.)
3. Add the second set to this value. (For example, 40A30 H + 6101H = 64B31H.)
4. Look at the appropriate memory map in Table 5-2 or 5-3 to determine the corresponding suspect part. (For example, if the ventilator is 80188-based, 64B31H could represent a faulty CPU PCB.)

Table 5-2. 80188-Based Ventilator Memory Map

Address range	Suspected hardware location
00000 - 7FFFF	CPU PCB
80000 - 8FFFF	CPU PCB
90000 - 903FF	Conversion PCB
90400 - 90FFF	Reserved for future expansion
91000 - 91FFF	DCI-display controller PCB
92000 - 92FFF	DCI-display controller PCB
93000 - 93FFF	Reserved for future expansion
94000 - 943FF	Front panel display PCB
94400 - 947FF	Pulse oximetry PCB
98000 - 9FFFF	Pulse oximetry PCB
A0000 - A7FFF	CPU PCB
B0000 - BFFFF	CPU PCB
C0000 - CFFFF	Reserved for future expansion
D0000 - EFFFF	Reserved for future expansion
F0000 - FFFFF	CPU PCB

Table 5-3. 8088-Based Ventilator Memory Map

Address range	Suspected hardware location
00000 - 5FFFF	CPU PCB or software
60000 - 13FFF	Non-existent
14000 - 15FFF	CPU PCB
16000 - 17FFF	Non-existent
18000 - 27FFF	Memory PCB
28000 - 28FFF	CPU PCB
29000 - 2FFFF	Q1 and Q2
30000 - 8FFFF	Memory PCB or software
90000 - 9003F	Conversion PCB
90040 - 93FFF	Conversion PCB
94000 - 97FFF	Display controller PCB
98000 - FF7FF	Display controller PCB
FF800 - FFFFF	CPU kernel or other CPU PCB

5.2.10 Clearing Error Codes from Battery-Backed RAM

EST error codes may be cleared from battery-backed RAM either when the code is first displayed or while error codes are being reviewed. To clear an error code, do the following while the [QUICK EST] or [TOTAL EST] prompt is displayed.

1. Press a key in the range <1> through <6> to display the applicable code.
2. Press <LAMP TEST>.
3. Press <ENTER>. The error code and any associated information, such as a memory address, will be cleared.

5.2.11 Viewing Ventilator Model, Software Revision, and Option Code

To view the ventilator model, software revision level, and option code during EST, press the <I:E RATIO> key while the [QUICK EST] or [TOTAL EST] prompt is displayed. The display takes one of these forms

{ REV / SB / SE / SP / SPI / TB / TE } nnnnn-85-x abc

where:

REV	indicates	ventilator is a 7200a (basic keyboard only)
SB	indicates	ventilator is a 7200spe with basic keyboard
SE	indicates	ventilator is a 7200spe with enhanced keyboard
SP	indicates	ventilator is a 7200sp (basic keyboard only)
SPI	indicates	ventilator is a 7200spi (enhanced keyboard only)
TB	indicates	ventilator is a 7200ae with basic keyboard
TE	indicates	ventilator is a 7200ae with enhanced keyboard
nnnnn	is	the software part number
x	is	the software revision level
abc	is	the option code associated with the customer's installed option. (See Appendix A to interpret option code.)

NOTE

During non-EST operation, the software revision level and option code can be viewed by pressing <LAMP TEST>.

Error Codes

SECTION 6. ERROR CODES

Refer to this section to interpret these types of error codes:

- Those generated by the **Power-On Self-Test (POST)**
- Those generated by the **Extended Self-Test (EST)**
- Those displayed during ventilation and representing **soft errors**, **communications errors**, and **faults**

NOTE

When replacing the memory PCB in an 8088-based ventilator, always remove and reinstall the flow sensor EPROMs and option PAL in the replacement PCB. Additionally, remove the six program EPROMs from the CPU PCB, and install the replacement EPROMs in the CPU PCB.

When replacing the CPU PCB in an 8088-based ventilator, always remove and reinstall the six program EPROMs in the replacement PCB.

When replacing the DCI-display controller PCB in an 80188-based ventilator, always remove and reinstall the flow sensor EPROMs, option PAL, and jumpers in the replacement PCB.

6.1 POST Error Codes

POST reports error information by lighting LED indicators on the CPU PCB. For some POST tests, an error code is also displayed by the 20-character display and the 7202 Display, if present. Because POST differs depending on whether the ventilator is based on the Intel 80188 Microprocessor or the Intel 8088 Microprocessor, separate error code tables are given for 80188-based units (Table 6-1) and 8088-based units (Table 6-2).The lettered procedures corresponding to each error code are sequenced to correct the most probable malfunction or to present the most efficient corrective action first.

Within the error code tables, the LED representations of the error codes are shown, with a darkened circle indicating an LED is lit. Those POST tests that use the 20-character display show an error code and message as follows:

xxyz ERR

where

xx is the number of the test that failed

yz is the number of the test step that failed

6.2 EST, Soft, and Communications Error Codes and Fault Codes

The ventilator displays error codes during EST testing as well as during ventilator operation. Table 6-3 lists soft error codes,Table 6-4 lists EST error codes, Table 6-5 lists communications error codes, and Table 6-6 lists faults. The lettered procedures corresponding to each error code are sequenced to correct the most probable malfunction or to present the most efficient corrective action first.

6.2.1 Definitions

An *EST* error code is displayed when EST detects a ventilator problem.

A *soft* or *system* error code is displayed when a problem is detected during normal ventilator operation. If three soft errors are detected within 24 hours, the ventilator goes into back-up ventilation. These error codes take the format 3xxx or 4xxx.

In the case of some soft errors, it may be extremely difficult to pinpoint the exact problem. For these codes, the table merely suggests a variety of possible hardware solutions. You may need to call Puritan-Bennett Technical Support if your attempts to remedy one of these errors fail.

A *communications* error code is displayed whenever a problem is detected that interferes with the ventilator's ability to communicate with an external device, such as a printer. Because this problem should not compromise the ventilator's ability to ventilate the patient, normal ventilator operation continues, although the error is stored in battery-backed RAM.

A *fault* code is displayed when a problem detected during normal operation is serious enough to compromise patient ventilation. As a result, back-up ventilation begins when the ventilator is powered off and on.

6.2.2 Interpreting Codes

When an error is detected during EST or during normal operation, the 20-character display shows an error code and message as follows:

ERR **xxyz** DO NOT USE

where

xx is the number of the test that failed.

y is the number of the test step that failed.

z indicates a specific error. In EST only, **z** may indicate a failure of a specific hardware subassembly, as follows:

- **1** Varies for each test. See error description for applicable test.
- **2** Not used.
- **3** Operator time out. See error description for applicable test.
- **4** Faulty PEEP/CPAP pressure transducer (P1 < 0). Invalid P1 voltage was read.
- **5** Faulty absolute pressure transducer (P2). Invalid P2 voltage was read.
- **6** Faulty differential pressure transducer (DP). Invalid DP voltage was read.
- **7** Faulty oxygen flow sensor (Q1) or temperature sensor (T1). Invalid Q1 or T1 voltage was read.
- **8** Faulty air flow sensor (Q2) or temperature sensor (T2). Invalid Q2 or T2 voltage was read.
- **9** Faulty exhalation flow sensor (Q3) or temperature sensor (T3). Invalid Q3 or T3 voltage was read.
- **A** Faulty oxygen proportional solenoid valve (PSOL1). Current value needed to establish oxygen flow is out of range. See error description for applicable test.
- **B** Faulty air proportional solenoid valve (PSOL2). Current value needed to establish air flow is out of range. See error description for applicable test.

Table 6-1. POST Error Codes (80188-Based Units)

Test	Error Code	Error Description	Corrective Action
POST kernel test 1 (instruction set): Performs limited test of instruction set, including data transfer, arithmetic, bit manipulation, string manipulation, control transfer, and processor control. The test makes sure all microprocessor registers are working. This test does not check any instructions that use the stack.	●○○○○○●	Microprocessor failed to properly execute instructions.	1. Replace CPU kernel. 2. Replace CPU PCB.
POST kernel test 2 (connection of PCB tester): Verifies whether a PCB tester used at the factory is connected, and if so, whether it is connected properly.	●○○○○●○	The bus timeout expected when CPU attempted to access tester memory location did not occur.	1. Replace CPU kernel. 2. Replace CPU PCB.
POST kernel test 3 (flag RAM): Verifies integrity of flag area RAM by writing a pattern to it, then reading contents, and comparing it to original pattern.	●○○○○●●	Mismatch between flag RAM (U705) pattern read and expected pattern.	1. Replace CPU PCB.
POST kernel test 4 (watchdog): Verifies that watchdog timer times out within acceptable interval.	●○○○●○○	Watchdog timer failed to time out within 60 to 260 ms.	1. Replace CPU kernel. 2. Replace CPU PCB.
POST kernel test 5 (stack RAM): Verifies integrity of stack RAM by writing a unique pattern to each byte, then reading contents, and comparing it to original pattern.	●○○○●○●	Mismatch between stack RAM (U806) pattern read and expected pattern.	1. Replace CPU kernel. 2. Replace CPU PCB.
POST kernel test 6 (extended instruction): Performs a test of the stack instructions.	●○○○●●○	Microprocessor failed to properly execute instructions.	1. Replace CPU PCB.
POST kernel test 7 (bus timeout): Verifies bus timeout (timer 1) operation by writing to a non-existent memory location, then reading bus timeout flag to evaluate subsequent interrupt sequence. This test is executed only if the power fail flag indicates adequate ac. (When power is low, a bus timeout cannot generate a non-maskable interrupt.)	●○○○●●●	Expected bus timeout did not occur.	1. Replace CPU kernel. 2. Replace CPU PCB.

Table 6-1. POST Error Codes (80188-Based Units) (continued)

Test	Error Code	Error Description	Corrective Action
POST kernel test 8 (system clock): Verifies system clock (timer 2) operation by initializing timer and verifying that timer interrupt service routine has set timer test flag to proper value within 20 ±1 ms.	●○○○●○○○	Integral CPU timer 2 (system clock) did not time out within 20 ± 1 ms after being initialized.	1. Replace CPU kernel. 2. Replace CPU PCB.
POST kernel test 9 (kernel checksum): Verifies kernel EPROM by performing checksum on EPROM contents.	●○○○●○○●	Checksum mismatch between kernel EPROM and POST-supplied value.	1. Replace CPU kernel. 2. Replace CPU PCB.
POST CPU PCB test 1 (POST re-entry test): Checks POST re-entry flag for value >2.	●●○○○○○●	More than two attempts were made to restart POST most likely due to repeated power failures.	1. Check ac power. 2. Replace CPU PCB.
POST CPU PCB test 2 (display initialization): Initializes front panel displays, so they can be used to relay messages.	●●○○○○●○	Unable to initialize displays.	1. Replace CPU PCB. 2. Replace DCI-display controller PCB.
POST CPU PCB test 3 (ac power check): Checks power fail flag.	●●○○○○●● LOW AC POWER	ac voltage has declined to power fail module trip point. POST will continue to perform this check until power reaches threshold value.	1. Check ac power. 2. Check power supply.
POST CPU PCB test 4 (digital I/O initialization): Initializes digital I/O ports on CPU PCB, including clearing DAC values, setting all solenoids (except SOL6 and SOL8) off, and opening safety and exhalation valves.	●●○○○●○○	Unable to initialize digital I/O ports.	1. Replace CPU PCB. 2. Replace conversion PCB.
POST CPU PCB test 5 (CPU PCB RAM): Verifies integrity of CPU PCB RAM by writing a unique pattern to each byte, then reading contents, and comparing it to original pattern.	●●○○○●○● 050x	Mismatch between RAM pattern read and expected pattern. Press <++> to determine which RAM device failed.	1. Replace CPU PCB.
POST CPU PCB test 8 (CPU PCB EPROM checksum): Verifies EPROM set on CPU PCB by performing checksum on EPROM contents.	●●○○●○○○ 080x	EPROM checksum failure. Press <++> to determine which EPROM failed. Press <++> again for expected and actual checksum values.	1. Replace CPU PCB.

Table 6-1. POST Error Codes (80188-Based Units) (continued)

Test	Error Code	Error Description	Corrective Action
POST offboard test 9 (Multibus RAM): Verifies integrity of Multibus RAM by writing a unique pattern to each byte, then reading contents, and comparing it to original pattern.	●●●○●○○● 0901	Mismatch between Multibus RAM pattern read and expected pattern. Press <++> for a descriptive error message.	1. Verify proper seating of and secureness of connections between DCI-display controller PCB and CPU PCB. 2. Replace DCI-display controller PCB. 3. Replace CPU PCB.
POST offboard test 10 (air flow EPROM): Verifies air flow sensor (Q2) EPROM by performing checksum on its contents.	●●●○●○●○ 1001	EPROM checksum failure. Press <++> for a descriptive error message.	1. Verify that air flow sensor EPROM (U504) and oxygen flow sensor EPROM (U406) are not reversed. 2. Replace Q2/T2 and air flow sensor EPROM (U504). 3. Replace DCI-display controller PCB. 4. Replace CPU PCB.
POST offboard test 11 (oxygen flow EPROM): Verifies oxygen flow sensor (Q1) EPROM by performing checksum on its contents.	●●●○●○●● 1101	EPROM checksum failure. Press <++> for a descriptive error message.	1. Verify that air flow sensor EPROM (U504) and oxygen flow sensor EPROM (U406) are not reversed. 2. Replace Q1/T1 and oxygen flow sensor EPROM (U406). 3. Replace DCI-display controller PCB. 4. Replace CPU PCB.
POST offboard test 12 (A/D reference voltages): Checks for ground and +10 V reference for analog-to-digital converter. Verifies ground tolerance of +49 mV. Verifies +10 V tolerance of -54 mV.	●●●○●●○○ 120x	Reference or ground channel out of tolerance. Press <++> to determine whether ground or +10 V reference out of range. Press <++> again to see measured and expected values.	1. Verify proper operation of ±15 V power supply. 2. Replace conversion PCB. 3. Replace interface PCB. 4. Install surge suppressor if missing. 5. Replace front panel display PCB. 6. Replace interconnect cable between CPU PCB and conversion PCB. 7. Verify connections of Q1/T1, Q2/T2, Q3/T3, and pressure transducer PCB.

Table 6-1. POST Error Codes (80188-Based Units) (continued)

Test	Error Code	Error Description	Corrective Action
POST offboard test 13 (A/D and D/A converters): Loops output of digital-to-analog converter DAC3 through multiplexer (channel 3) to input of analog-to-digital converter. Checks analog output for a tolerance of ± (0.6% of digital input + 20 counts).	●●●○●●○● 13xx	Voltage comparison between DAC output and A/D input out of range. Press <++> to determine which pattern failed. Press <++> again to see measured and expected values.	1. Verify proper operation of ±15 V power supply. 2. Replace conversion PCB. 3. Replace interface PCB. 4. Replace CPU PCB.
POST offboard test 14 (battery-backed RAM checksum): Verifies battery-backed RAM by performing checksum on contents. **NOTE** **This code will appear if you have disconnected battery-backed RAM for any reason.**	●●●○●●●○ 1401	Battery-backed RAM checksum failure.	1. Rerun POST. (Battery-backed RAM may simply have been disconnected.) 2. Check continuity of CR2 on motherboard. 3. Verify that voltage of each battery is 2.0 V. If not, replace batteries. 4. Replace motherboard. 5. Replace CPU PCB.
POST offboard test 15 (three watchdog timeouts in 24 hour): Checks EST and power fail flags to monitor watchdog timeout activities.	●●●○●●●● 1501	Three unexpected program interruptions occurred within past 24 hours.	1. Check for any soft error codes (3000-4000 series) in memory. Refer to that error code description. 2. If there were recent power problems, replace power supply. 3. Replace DCI-display controller PCB. 4. Replace CPU PCB. 5. Replace interface PCB. 6. Replace motherboard.
WARNING **Error 1501 is indicative of an intermittent fault that may or may not be repeatedly detected by Total EST. The error can be cleared and normal operation restored by running Total EST. It is important that the operator make note of this condition and call a Puritan-Bennett representative.**			
POST offboard test 16 (BUV): Checks back-up ventilator with respect to power fail signal.	●●●●○○○○ 1601	BUV is on and a power fail has not occurred. Press <++> for a descriptive error message.	1. Replace interface PCB. 2. Replace CPU PCB. 3. Replace conversion PCB. 4. Replace DCI-display controller PCB.
POST offboard test 20 (system tester connection): Verifies whether a system tester used in the factory is connected to the ventilator, and if so, whether it is connected properly.	●●●●○●○○ 2001	Possible system tester communication link failure.	1. If a system tester is connected, check connection between CPU PCB connector J100 and tester connector J100. Ensure that the tester is operational before powering up the ventilator. Replace local bus extension cable (P/N 4- 019694-00) if necessary. 2. If a tester is not connected, replace CPU PCB.

Table 6-2. POST Error Codes (8088-Based Units)

Test	Error Code	Error Description	Corrective Action
POST kernel test 0: Verifies proper functioning of CPU registers and flags, kernel checksum, and proper bus timeout operation.	○○○	Improper functioning of CPU registers or flags, kernel checksum failure, or bus timeout failure.	1. Replace CPU PCB.
POST kernel test 1: Verifies proper operation of CPU PCB RAM by writing a pattern to RAM, reading pattern from RAM, and comparing it to original pattern.	○○●	Mismatch between pattern read and expected.	1. Replace CPU PCB.
POST kernel test 2: Verifies proper operation of Intel 8253 Programmable Interval Timer (PIT) and Intel 8259 Programmable Interrupt Controller (PIC). The PIT is tested by comparing its performance against a software-implemented timing loop.	○●○	Failure of PIT or PIC.	1. Replace CPU PCB.
POST kernel test 3: Selectively sets and reads I/O ports of Intel 8755 EPROM-I/O to perform limited operational check.	○●●	EPROM-I/O read operation unsuccessful.	1. Replace CPU PCB.
POST kernel test 4: Checks all EPROMs on CPU PCB for proper contents and positioning.	●○○	CPU PCB EPROM checksum failure.	1. Reseat CPU PCB EPROMs or CPU PCB.
POST kernel test 5: Verifies proper operation of RAM by writing a pattern to RAM, reading pattern from RAM, and comparing it to original pattern.	●○●	Mismatch between pattern read from and expected.	1. Reseat CPU PCB RAM devices or CPU PCB.
POST test 060 (digital I/O): Selectively sets and reads Intel 8255 Parallel Peripheral Interface I/O ports to perform limited operational check.	●●○ 0601	Pattern read was invalid. I/O access was unsuccessful.	1. Replace CPU PCB.
POST test 070 (Multibus access): Verifies Multibus performance by reading and writing a pattern to RAM locations on memory and display controller PCBs. Program EPROM access is verified by reading a fixed location within EPROM memory space.	●●○ 0701	Pattern read operation was invalid. Memory access was unsuccessful.	1. Replace memory PCB. 2. Replace display controller PCB. 3. Replace CPU PCB.

Table 6-2. POST Error Codes (8088-Based Units) (continued)

Test	Error Code	Error Description	Corrective Action
POST test 080 (memory PCB EPROM checksum): Verifies EPROM set on memory PCB by performing checksum on EPROM contents.	●●○ 0801	EPROM checksum failure.	1. Check connection of/or replace EPROMs on memory PCB and the six EPROMs on CPU PCB. 2. Replace memory PCB.
POST test 090 (memory PCB RAM): Verifies Multibus RAM using pattern-type test.	●●○ 0901	Pattern test failure.	1. Replace memory PCB.
POST test 100 (air flow sensor EPROM): Verifies air sensor EPROM by performing checksum on EPROM contents.	●●○ 1001	Checksum invalid.	1. Replace Q2/T2 and air flow sensor EPROM, U403. 2. Replace memory PCB.
POST test 110 (oxygen flow sensor EPROM): Verifies Q1 EPROM by performing checksum on EPROM contents.	●●○ 1101	Checksum invalid.	1. Replace QI/T1 and oxygen flow sensor EPROM, U302. 2. Replace memory PCB.
POST test 120 (A/D reference voltages): Verifies ground and reference channels of A/D converter on conversion PCB. Tests for ground tolerance of ± 14 LSB (± 34 mV) and reference tolerance of ± 14 LSB (± 34 mV).	●●○ 1201	Reference or ground channel out of range.	1. Verify proper operation of ±15 V power supply. 2. Check Q3/T3 electrical connection. 3. Replace conversion PCB. 4. Replace interface PCB. 5. Replace interface and conversion PCB. 6. Replace ±15 V power supply. 7. Install surge suppressor if not present. 8. Replace front panel display PCB. 9. Replace interconnect cable between CPU PCB and conversion PCB.
POST test 130: Tests A/D and D/A converters' breakpoint values throughout their voltage range. Channels DAC output to the A/D converter and ramps through its voltage range. The analog meter will respond during this test.	●●○ 1301	Voltage comparison between DAC output and A/D input out of range.	1. Replace conversion PCB 2. Replace interface PCB. 3. Replace CPU PCB. 4. Check flow sensor EPROM pin connections.

Table 6-2. POST Error Codes (8088-Based Units) (continued)

Test	Error Code	Error Description	Corrective Action
POST test 140: Verifies performance and contents of battery-backed RAM. Performs checksum of battery-backed RAM contents and determines battery condition. **NOTE** **This code will appear if you have disconnected battery-backed RAM for any reason.**	●●○ 1401	Battery-backed RAM pattern test failed.	1. Check continuity of CR2 on motherboard. 2. Replace motherboard. 3. Verify that voltage of each battery is 2.0 V. 4. Replace batteries. 5. Replace memory PCB.
POST test 150: Determines whether ventilator has had three unexpected system interruptions within past 24 hours.	●●○ 1501	Three unexpected program interruptions occurred within past 24 hours.	1. Check if there are soft error codes (3000-4000 series) in memory. If there are, refer to that error code. 2. Check power fail module fuse on power supply fuse block. 3. Replace power fail module. 4. Replace display controller PCB. 5. Replace interface PCB. 6. Replace motherboard.
WARNING **Error 1501 is indicative of an intermittent fault that may or may not be repeatedly detected by Total EST. The error can be cleared and normal operation restored by running Total EST. It is important that the operator make note of this condition and call a Puritan-Bennett representative.**			
POST test 160: Verifies that BUV system has been properly initialized during POST.	●●○ 1601	BUV initialization failure.	1. Replace interface PCB. 2. Replace CPU PCB. 3. Replace conversion PCB.
Display controller and/or front panel display PCB test	●●○ No message	Indeterminate.	1. Verify security of display cable connections. 2. Replace display controller PCB. 3. Replace front panel display PCB.
POST initialization: Attempts to invoke POST.	●●● Unit will go into BUV	POST initialization failure.	1. Verify proper operation of +5 V power supply. 2. Replace display controller PCB. 3. Replace CPU PCB.
POST passed	●●●	POST passed.	Ventilator operation will continue automatically.

Table 6-3. Soft Errors

Test	Error Code	Error Description	Corrective Action
Test 02x: Prepares ventilator to run EST.	02xx	System error; problem occurred between time <EST> button was pressed and POST was begun.	1. Replace CPU PCB or memory PCB.
Test 30x: Executes Schedule-Total EST-Task.	30xx	System error; task aborted.	1. Run Total EST. 2. See error 1501.
Test 31x: Executes Declare-Apnea-Task.	31xx	System error; task aborted.	1. Run Total EST. 2. See error 1501. 3. Replace CPU PCB or memory PCB. 4. Replace pressure transducer PCB.
Test 32x: Delivers breath.	32xx	System error; task aborted.	1. Run Total EST. 2. See error 1501.
Test 33x: Strobes watchdog timer.	3301	System error; task aborted.	1. Run Total EST. 2. See error 1501. 3. Replace CPU PCB or memory PCB.
Test 34x: Autozeroes pressure sensors.	34xx	System error; task aborted.	1. Run Total EST. 2 Faulty P1. Replace pressure transducer PCB. 3. Replace CPU PCB, memory PCB, pressure transducer PCB, SOL6 and SOL8, or interface PCB.
Test 35x: Controls breath delivery.	35xx	System error; task aborted.	1. Run Total EST. 2. See error 1501. 3. Replace CPU PCB or memory PCB. 4. Check motherboard Multibus strip.
Test 36x: Controls pulse oximetry.	36xx	System error; task aborted.	1. Run Total EST. 2. See error 1501. 3. Replace CPU PCB, memory PCB, or pulse oximetry PCB.
Test 37x: Checks system pressures.	37xx	System error; task aborted.	1. Run Total EST. 2. See error 1501. 3. Replace CPU PCB, memory PCB, SOL3, or pressure transducer PCB.
Test 38x: Calculates pressures.	38xx	System error; task aborted.	1. Run Total EST. 2. See error 1501. 3. Replace CPU PCB, memory PCB, pressure transducer PCB, SOL4, SOL6, SOL8, or interface PCB.

Table 6-3. Soft Errors (continued)

Test	Error Code	Error Description	Corrective Action
Test 39x: Keyboard interrupt service routine.	39xx	System error; task aborted.	1. Run Total EST. 2. See error 1501. 3. Replace CPU PCB, memory PCB, DCI-display controller or display controller PCB, keyboard, or front panel display PCB.
	39BE	Option PAL failed. System defaults to operation with all options inactive.	1. Install new option select device. 2. Replace memory PCB or DCI-display controller PCB.
Test 40x: Controls apnea timing and declaration.	40xx	System error; task aborted.	1. Run Total EST. 2. See error 1501. 3. Replace CPU PCB or memory PCB.
Test 41x: Checks task execution.	41xx	System error; task aborted.	1. Run Total EST. 2. See error 1501. 3. Replace CPU PCB or memory PCB.
Test 42x: Performs spirometry.	42xx	System error; task aborted.	1. Run Total EST. 2 See error 1501. 3 Replace Q3/T3, interface PCB, conversion PCB, CPU PCB, or memory PCB.
	4201	System error; task aborted.	1. Run Total EST. 2. See error 1501.
	4205	Excess tidal volume detected. Tidal volume greater than 8 liters.	1. Verify that externally sourced nebulizer is not being used. 2. Replace Q3/T3 and interface PCB. 3. Replace Q3/T3 harness.
Test 43x: Activates alarm LEDs, status lights, and nurse's call signal.	43xx	System error; task aborted.	1. Run Total EST. 2 See error 1501. 3 Replace front panel display PCB, display controller PCB, DCI-display controller PCB, interface PCB, CPU PCB, or memory PCB.
Test 44x: Controls analog meter.	44xx	System error; task aborted.	1. Run Total EST. 2 See error 1501. 3 Replace conversion PCB, CPU PCB, or memory PCB.
Test 45x: Monitors timed functions.	45xx	System error; task aborted.	1. Run Total EST. 2. See error 1501. 3. Replace SOL1, SOL2, CPU PCB, or memory PCB.

Table 6-3. Soft Errors (continued)

Test	Error Code	Error Description	Corrective Action
Test 46x: Gathers and averages DCI trending information.	46xx	System error; task aborted.	1. Run Total EST. 2. See error 1501. 3. Replace CPU PCB, memory PCB, or DCI-display controller PCB.
Test 47x: Monitors options 30 and 40.	47xx	System error; task aborted.	1. Run Total EST. 2. See error 1501. 3. Replace CPU PCB or memory PCB.
Test 480: Opens and closes safety valve.	4801	System error; task aborted.	1. Run Total EST. 2. See error 1501.
Test 48F: Executes interrupt service routines.	48F8	Illegal front panel interrupt.	1. Run Total EST. 2. Replace front panel display PCB. 3. Replace DCI-display controller or display controller PCB.
	48F9	Unexpected bus timeout.	1. Run Total EST. 2. Verify power supply voltages. 3. Verify all ac and dc connections. 4. Verify that all PCBs are properly seated. 5. Replace CPU PCB.
	48FA	Overflow interrupt.	1. Run Total EST. 1. Replace CPU PCB. 2. Replace memory PCB.
	48FB	Breakpoint interrupt.	1. See error 48FA.
	48FC	Single-step interrupt.	1. See error 48FA.
	48FD	Divide-by-zero interrupt.	1. See error 48FA.
	48FF	Unexpected interrupt.	1. See error 48FA.

Table 6-4. EST Errors

Test	Error Code	Error Description	Corrective Action
Test 511: Checks battery-backed RAM using a variable pattern-type test. The contents of battery-backed RAM are restored at end of test.	5111	Battery-backed RAM pattern test failed.	1. **8088:** Replace memory PCB. **80188:** Replace CPU PCB.
Test 512: Verifies integrity of battery-backed RAM contents by performing checksum.	5121	Checksum mismatch.	1. Check/replace battery if low battery indicator is showing. 2. Verify battery charging voltage. 3. **80188:** Replace CPU PCB. **8088:** Replace memory PCB. 4. Replace motherboard. 5. Visually check traces and connections on motherboard.
Test 521: Autozeroes P1 by venting transducer to atmosphere by energizing SOL8.	5211	P1 failed to attain zero level.	1. Check pressure transducer PCB connector J4. 2. Check connection of SOL8. 3. Replace pressure transducer PCB. 4. Replace SOL8. 5. Replace interface PCB.
	5213	Operator response to block wye timed out. Operator did not respond to prompt within 30 seconds.	1. Continue Total EST as described in Section 5.
Test 522: Vents P2 to atmospheric pressure. Autozeroes P2, de-energizes SOL5.	5221	P2 failed to attain zero level.	1. Check pressure transducer PCB connector J4. 2. Replace pressure transducer PCB. 3. Replace interface PCB.
Test 523: Autozeroes DP. Energizes SOL6.	5231	DP failed to attain zero level.	1. Check pressure transducer PCB connector J4. 2. Check SOL6 connection. 3. Replace pressure transducer PCB. 4. Replace SOL6. 5. Replace interface PCB.

Table 6-4. EST Errors (continued)

Test	Error Code	Error Description	Corrective Action
Test 524: Verifies that oxygen supply is connected to ventilator. Prompts operator to connect oxygen.	5241	Oxygen supply not connected to the ventilator.	1. Check that oxygen supply is connected to ventilator and supply pressure is at least 35 psig (241.33 kPa). 2. Check pneumatic harness connection J10 on motherboard. 3. Check connections to PS1. 4. Replace interface PCB. 5. Replace conversion PCB interconnection cable (P/N 4-019231-00) connected to J4 on interface PCB. 6. Replace pneumatic harness (P/N 4-0 19238-00). 7. Replace PS1 (P/N 4-019068-00).
	5243	Operator response timed out. Operator did not respond to prompt within 30 seconds.	1. Continue Total EST as described in Section 5.
Test 525: Verifies connection of air supply	5251	Air supply not connected to ventilator.	1. Check that air supply is connected to ventilator and supply pressure is at least 35 psig (241.33 kPa). 2. Check pneumatic harness connection J10 on motherboard. 3. Check connections to PS2 and PS3. 4. Replace interface PCB. 5. Replace conversion PCB interconnection cable (P/N 4-019231-00) connected to J4 on interface PCB. 6. Replace pneumatic harness (P/N 4-019238-00). 7. Replace PS2 and PS3.
	5253	Operator response timed out. Operator did not respond to prompt within 30 seconds.	1. Continue Total EST as described in Section 5.

Table 6-4. EST Errors (continued)

Test	Error Code	Error Description	Corrective Action
Test 531: Verifies that an operator-requested PEEP pressure of zero was established. This test assumes that test 521 has passed and P1 can be autozeroed.	5311	PEEP pressure of zero was not established. This test assumes the PEEP autozero test was passed.	1. Operator did not turn PEEP/CPAP control to zero within 15 seconds. Refer to Section 5 to continue Total EST. 2. Block patient wye. 3. Replace REG5. 4. Replace pressure transducer PCB. 5. Replace SOL8. 6. Replace interface PCB.
	5313	Operator time elapsed before zero PEEP was established.	1. Operator did not respond to [SET PEEP = 0] prompt within 15 seconds. Refer to Section 5 to continue Total EST. 2. Replace/adjust REG5 and jet venturi. 3. See test 521.
	5314	Invalid P1 reading. PEEP pressure action assumes that test 521 has been successfully run.	1. Replace pressure transducer PCB. 2. Replace interface PCB. 3. Verify actuation of SOL8. 4. Replace SOL8.

Table 6-4. EST Errors (continued)

Test	Error Code	Error Description	Corrective Action
Test 532: Before Total EST continues with active portions of testing, patient connection is evaluated. The air flow subsystem is set to establish 10 lpm flow, and measured air flow (Q2) is compared to Q3 exhaled flow. The patient must be disconnected, the wye properly plugged, and Q3 properly connected.	5321	Flow reading discrepancy between Q2 and Q3. Air flow controller unable to establish desired flow rate after 30 seconds.	1. Check patient system is properly connected and Q3/T3 properly inserted. Check for obstructions. 2. Check air supply for given flow rate. 3. Check for leaks in Q2/T2 couplings. 4. Adjust REG2 to between 10 and 11 psi (68.95 to 75.85 kPa) or replace. 5. Replace Q3/T3. 6. Replace Q2/T2 and air flow sensor EPROM, U504 (80188) or U403 (8088). 7. Replace Q3/T3 harness. 8. Replace CV6 and CV7. 9. Replace interface PCB. 10. Replace proportional valve group.
	5328	Temperature-compensated air flow reading invalid.	1. Check Q2/T2 connection (J6) on interface PCB. 2. Replace Q2/T2 and air flow sensor EPROM, U504 (80188) or U403 (8088). 3. Replace interface PCB. 4. Allow unit to warm up if it has been sitting in cold storage.
	5329	Exhalation flow reading from Q3 invalid.	1. Check Q3/T3 electrical and tubing connections within exhalation compartment. 2. Check Q3/T3 connection (J1) on interface PCB. 3. Replace Q3/T3. 4. Replace interface PCB 5. Replace Q3/T3 and interface PCB.
	532B	PSOL2 drive current out of range.	1. Check for leaks in air Q2/T2 couplings. 2. Adjust or replace REG2. 3. Replace proportional valve group. 4. Replace Q2/T2 and air flow sensor EPROM, U504 (80188) or U403 (8088). 5. Replace interface PCB.

Table 6-4. EST Errors (continued)

Test	Error Code	Error Description	Corrective Action
Test 533: Verifies patient tubing compliance to check that patient is not connected. The anticipated compliance of the tubing system is 0.3 to 5.6 ml/ cmH_2O; if a patient is attached, it is anticipated that a change in the tubing volume will occur during patient breathing. This change will be reflected as a failure of the compliance test. Patient tubing system is pressurized to 30 cmH_2O during this test.	5331	Excessive patient tubing compliance detected. SOL4 energized and DP sampled until DP reading is 30 cmH_2O.	1. Check that patient is disconnected from ventilator. 2. Check that patient system is properly installed and that wye is blocked. 3. Check for exhalation valve leaks. 4. Replace exhalation pilot network (P/N 4-018290-00). 5. Check that bacteria filters are not clogged. 6. Check for an obstruction or disconnect in patient circuit. 7. Replace pressure transducer PCB.
If test fails, ventilator uses default compliance value of 0.01 l/cmH_2O.	5336	DP reading invalid. DP pressure action assumes that test 521 was passed.	1. Check for leaks in patient system. 2. Check pressure transducer PCB connector J4. 3. Replace pressure transducer PCB. 4. Replace interface PCB.
Test 534: Leaving patient tubing system pressurized from test 533, takes stable reading of DP to check lack of patient connection.	5341	Stable reading of DP not obtained. Pressure fluctuations were detected at patient wye.	1. Check that patient is disconnected from ventilator. 2. Check that wye is properly blocked, exhalation valve is active, and patient system does not leak. 3. Patient wye was moved during testing. Continue Total EST as described in Section 5. 4. Check for leaks out vent port on safety/check valve CV3. 5. Replace internal exhalation valve. 6. Replace CV7. 7. Replace conversion PCB.
	5346	DP reading invalid. DP pressure action assumes that test 521 was passed.	1. Check for leaks in patient system. 2. Check pressure transducer PCB connector J4. 3. Replace pressure transducer PCB. 4. Replace interface PCB.

Table 6-4. EST Errors (continued)

Test	Error Code	Error Description	Corrective Action
Test 535: Compares values of DP and P2 while patient tubing system remains pressurized. This test assumes transducers were autozeroed successfully during tests 522 and 523.	5351	Cross checks of P2 and DP out of range.	1. Check patient is disconnected and patient system is properly installed. 2. Check pneumatic connection between P2 and CV3. 3. Replace pressure transducer PCB. 4. Replace SV/CV3. 5. Replace SOL6.
	5355	P2 reading invalid. P2 pressure action assumes that test 521 was passed.	1. Check pressure transducer PCB connector J4. 2. Replace pressure transducer PCB. 3. Replace interface PCB.
	5356	DP reading invalid. DP pressure action assumes that test 521 was passed.	1. Check pressure transducer PCB connector J4. 2. Replace pressure transducer PCB. 3. Replace interface PCB. 4. Replace SOL6.
Test 541: System leak test. Pressurizes patient system to 90 cmH_2O using air flow rate of 10 lpm and checks for leaks. This test assumes that patient detection tests 533, 534, and 535 passed; that patient wye is blocked; and that patient tubing system is properly installed.	5411	Patient system failed to achieve desired pressure.	1. Check patient tubing for leaks, check exhalation valve operation and humidifier connection, check patient bacteria filter, and check patient wye for blockage. 2. Check that patient system is connected and patient pressure water trap is not leaking. 3. Replace exhalation valve. 4. Check SOL6 actuation. 5. Check SOL4 actuation.
	5416	DP reading invalid. DP pressure action assumes that test 521 was passed.	1. Check pressure transducer PCB connector J4. 2. Replace pressure transducer PCB. 3. Replace interface PCB.
	5418	Air flow reading from Q2 invalid.	1. Check Q2/T2 connection (J6) on interface PCB. 2. Check Q2/T2 fittings. 3. Replace Q2/T2 and air flow sensor EPROM, U504 (80188) or U403 (8088). 3. Replace interface PCB.
	541B	PSOL2 drive current out of range.	1.Check for leaks in Q2/T2 couplings. 2. Adjust or replace REG2. 3. Check air source pressure. 4. Check high-pressure hose diameter.

Table 6-4. EST Errors (continued)

Test	Error Code	Error Description	Corrective Action
Test 542: Monitors 90 cmH_2O pressure obtained in test 541 for leaks and verifies that patient tubing system does not lose more than 15 cmH_2O over 10 seconds.	5421	Patient system failed to maintain constant pressure. The system pressure at which leak was detected is displayed beside error code. A 5421 error that occurs during Quick EST does not cause Total EST to fail.	1. Check that the patient system is properly connected and free of leaks. 2. Check exhalation valve operation and connection. 3. Replace exhalation valve. 4. Replace SV/CV3. 5. Check for leaks in CV7. If it is leaking, replace. 6. Check for leaks in tubing from SV/CV3 to P2. 7. Replace outlet connector (P/N 4-019353-00) if cracked. 8. Replace SOL6. **NOTE** **If ventilator continues to pressurize after achieving 90 cmH_2O, replace PSOLs.**
	5426	Reading from differential pressure transducer DP invalid.	1. Check connection of patient system at patient wye and water trap. 2. Check pressure transducer PCB connector J4. 3. Replace pressure transducer PCB. 4. Replace SOL6.
Test 543: Cross-checks DP and P2 for accuracy while patient system remains pressurized. This test assumes pressure transducers were autozeroed successfully during test 535.	5431	Cross check of DP and P2 out of range.	1. Check pneumatic connection between P2 and CV3. 2. Replace pressure transducer PCB. 3. Replace SV/CV3. 4. Check that R5 is not blocked.
	5435	P2 reading invalid. P2 pressure action assumes that test 521 was passed.	1. Check pressure transducer PCB connector J4. 2. Replace pressure transducer PCB. 3. Replace interface PCB. 4. Check that R5 is not blocked.
	5436	DP reading invalid. DP pressure action assumes that test 521 was passed.	1. Check pressure transducer PCB connector J4. 2. Replace pressure transducer PCB. 3. Replace interface PCB.

Table 6-4. EST Errors (continued)

Test	Error Code	Error Description	Corrective Action
Test 551: Compares Q2 reading with Q3 reading at steady-state flow of 0 lpm.	5511	Flow rate comparison out of range (+0.6 lpm) or air flow controller unable to establish desired flow rate after 15 seconds.	1. Check air supply for given flow rate. 2. Check for leaks in Q2/T2 couplings. 3. Replace Q2/T2 and air flow sensor EPROM, U504 (80188) or U403 (8088). 4. PSOL2 leaks at zero flow. Replace proportional valve group. 5. Replace interface PCB. 6. Check for leaking CV6 at 0 lpm.
	5518	Air flow reading from Q2 invalid.	1. Check Q2/T2 connection (J6) on interface PCB. 2. Replace Q2/T2 and air flow sensor EPROM, U504 (80188) or U403 (8088). 3. PSOL2 leaks at zero flow. Replace proportional valve group. 4. Replace interface PCB.
	5519	Air flow reading from Q3 invalid.	1. Check Q3/T3 electrical and tubing connections within exhalation compartment. 2, Replace Q3/T3. 3. Check Q3/T3 connection (J1) on interface PCB. 4. Replace interface PCB.
	551B	PSOL2 drive current out of range.	1. Check for leaks in Q2/T2 couplings. 2, Adjust or replace REG2. 3. Replace proportional valve group. 4. Replace Q2/T2 and air flow sensor EPROM, U504 (80188) or U403 (8088). 5. Replace interface PCB.

Table 6-4. EST Errors (continued)

Test	Error Code	Error Description	Corrective Action
Test 552: Compares Q2 reading with Q3 reading at steady-state flow of 20 lpm.	5521	Flow rate comparison out of range.	1. Check Q3/T3 electrical and tubing connections. 2. Check air supply for given flow rate. 3. Check for leaks in Q2/T2 couplings. 4. Replace Q2/T2 and air flow sensor EPROM, U504 (80188) or U403 (8088). 5. Adjust or replace REG2. 6. Replace proportional valve group. 7. Replace interface PCB. 8. Continue EST for comparison of Q3/T3 and Q1/T1.
	5528	Air flow reading from Q2 invalid.	1. Check Q2/T2 connection (J6) on interface PCB. 2. Replace Q2/T2 and air flow sensor EPROM, U504 (80188) or U403 (8088). 3. Replace interface PCB.
	5529	Air flow reading from Q3 invalid.	1. Check Q3/T3 electrical and tubing connections with exhalation compartment. 2. Check Q3/T3 connection (J1) on interface PCB. 3. Replace Q3/T3. 4. Replace interface PCB.
	552B	PSOL2 drive current out of range.	1. Verify air source pressure. 2. Check high-pressure hose diameter. 3. Adjust or replace REG2. 4. Check for leaks in Q2/T2 couplings. 5. Replace proportional valve group. 6. Replace Q2/T2 and air flow sensor EPROM, U504 (80188) or U403 (8088). 7. Replace interface PCB. 8. Check for restriction in air inlet filter, air hose, or source gas supply.

Table 6-4. EST Errors (continued)

Test	Error Code	Error Description	Corrective Action
Test 553: Compares Q2 reading with Q3 reading at steady-state flow of 50 lpm.	5531	Flow rate comparison out of range.	1. See error 5521.
	5538	Air flow reading from Q2 invalid.	1. See error 5528.
	5539	Air flow reading from Q3 invalid.	1. See error 5529.
	553B	PSOL2 drive current out of range.	1. See error 552B.
Test 554: Compares Q2 reading with Q3 reading at steady-state flow of 100 lpm.	5541	Flow rate comparison out of range.	1. See error 5521.
	5548	Air flow reading from Q2 invalid.	1. See error 5528.
	5549	Air flow reading from Q3 invalid.	1. See error 5529.
	554B	PSOL2 drive current out of range.	1. See error 552B.
Test 555: Compares Q2 reading with Q3 reading at steady-state flow of 120 lpm.	5551	Flow rate comparison out of range.	1. See error 5521.
	5558	Air flow reading from Q2 invalid.	1. See error 5528.
	5559	Air flow reading from Q3 invalid.	1. See error 5529.
	555B	PSOL2 drive current out of range.	1. See error 552B.
Test 556: Compares Q2 reading with Q3 reading at steady-state flow of 180 lpm (wall air) or 120 lpm (compressor). If wall air flow rate of 180 lpm cannot be established, a Q2/Q3 comparison is made at whatever flow rate the wall supply can deliver.	5561	Flow rate comparison out of range.	1. See error 5521.
	5568	Air flow reading from Q2 invalid.	1. See error 5528.
	5569	Air flow reading from Q3 invalid.	1. See error 5529.
	556B	PSOL2 drive current out of range.	1. See error 552B.

Table 6-4. EST Errors (continued)

Test	Error Code	Error Description	Corrective Action
Test 557: Autozeroes PSOL1 and PSOL2 with flow rate of 1 lpm and stores current required to establish flow in battery-backed RAM. If current used is outside of range 25-380 mA, the test does not fail, but a default current value of 130 mA is used in the calculations.	5571	Unable to autozero PSOL1 and PSOL2 with flow rate of 1 lpm.	1. Check Q1/T1 and Q2/T2 connections (J5 and J6) on interface PCB. 2. If current value displayed in PEAK FLOW window is outside of range 25-380 mA, replace Q1/T1 and oxygen flow sensor EPROM, U403 (80188) or U302 (8088). If value in TIDAL VOL window is outside of same range. replace Q2/T2 and air flow sensor U504 (80188) or U403 (8088). 3. Check proper adjustment of REG1 (if Q1/T1 value is outside of range) or REG2 (if Q2/T2 value is out of range). 4. Replace proportional valve group. 5. Replace REG1 or REG2, as appropriate. 6. Replace interface PCB. 7. Replace compressor.
	5577	Oxygen flow reading from Q1 invalid.	1. Check Q1/T1 connection (J5) on interface PCB. 2. Replace Q1/T1 and oxygen flow sensor EPROM, U406 (80188) or U302 (8088). 3. Replace interface PCB.
	5578	Air flow reading from Q2 invalid.	1. Check Q2/T2 connection (J6) on interface PCB. 2. Check connection of air flow sensor EPROM, U504 (80188) or U403 (8088). 3. Replace interface PCB.
	557A	PSOL1 drive current out of range.	1. Check for leaks in Q1/T1 couplings. 2. Adjust or replace REG1. 3. Replace proportional valve group. 4. Replace Q1/T1 and oxygen flow sensor EPROM, U406 (80188) or U302 (8088). 5. Replace interface PCB.
	557B	PSOL2 drive current out of range.	1. Check for leaks in Q2/T2 couplings. 2. Adjust or replace REG2. 3. Replace proportional valve group. 4. Replace Q2/T2 and air flow sensor EPROM, U504 (80188) or U403 (8088). 5. Replace interface PCB.

Table 6-4. EST Errors (continued)

Test	Error Code	Error Description	Corrective Action
Test 558: Flow-by offsets calibration. Compares Q2 reading with Q3 reading at steady-state flow of 10 lpm. Stores air and exhaled flows in battery-backed RAM.	5581	Flow rate comparison out of range or air controller unable to establish flow within 15 seconds).	1. Check Q3/T3 electrical and tubing connections. 2. Replace Q3/T3. 3. Replace Q2/T2. 4. Adjust or replace REG2. 5. Replace interface PCB
	5588	Q2 reading out of range.	1. Check Q2/T2 electrical and tubing connections. 2. Replace Q2/T2. 3. Check air regulator pressure. 4. Replace air regulator. 5. Replace interface PCB.
	5589	Q3 reading out of range.	1. Check Q3/T3 electrical and tubing connections. 2. Replace Q3/T3. 3. Replace interface PCB.
	558B	PSOL2 drive current out of range.	1. Check for leaks in Q2/T2 couplings. 2. Adjust or replace REG2. 3. Replace proportional valve group. 4. Replace Q2/T2 and air flow sensor EPROM, U504 (80188) or U403 (8088). 5. Replace interface PCB.
Test 559: Flow-by offsets calibration. Compares Q2 reading with Q3 reading at flow of 20 lpm. Stores air and exhaled flows in battery-backed RAM.	5591	Flow rate comparison out of range or air controller unable to establish flow within 15 seconds.	1. See error 5581.
	5598	Q2 reading out of tolerance.	1. See error 5588.
	5599	Q3 reading out of range.	1. See error 5589.
	559B	PSOL2 drive current out of range.	1. See error 558B.

Table 6-4. EST Errors (continued)

Test	Error Code	Error Description	Corrective Action
Test 561: Compares Q1 reading with Q3 reading at steady-state flow of 10 lpm.	5611	Flow rate comparison out of range. Oxygen flow controller unable to establish desired flow rate after 15 seconds	1. Check oxygen supply for given flow rate. 2. Check for leaks in Q1/T1 couplings. 3. Replace Q1/T1 and oxygen flow sensor EPROM, U406 (80188) or U302 (8088). 4. PSOL1 leaks at zero flow. Replace proportional valve group. 5. Replace interface PCB. 6. Check for leaks in CV6.
	5617	Oxygen flow reading from Q1 invalid.	1. Check Q1/T1 connection (J6) on interface PCB. 2. Replace Q1/T1 and oxygen flow sensor EPROM, U406 (80188) or U302 (8088). 3. Replace interface PCB.
	5619	Oxygen flow reading from Q3 invalid.	1. Check Q3/T3 electrical and tubing connections. 2. Check Q3/T3 connection (J1) on interface PCB. 3. Replace Q3/T3. 4. Replace interface PCB.
	561A	PSOL1 drive current out of range.	1. Check for leaks in Q1/T1 couplings. 2. Adjust or replace REG1. 3. Replace proportional valve group. 4. Replace Q1/T1 and oxygen flow sensor EPROM, U406 (80188) or U302 (8088). 5. Replace interface PCB. 6. Check oxygen source pressure. 7. Check high-pressure hose diameter. 8. Check for a restriction in the oxygen inlet filter, oxygen hose, or oxygen supply.
Test 562: Compares Q1 reading with Q3 reading at steady-state flow of 20 lpm.	5621	Flow rate comparison out of range. Oxygen flow controller unable to establish desired flow rate after 15 seconds	1. See error 5611.
	5627	Oxygen flow reading from Q1 invalid.	1. See error 5617.
	5629	Oxygen flow reading from Q3 invalid.	1. See error 5619.
	562A	PSOL1 drive current out of range.	1. See error 561A.

Table 6-4. EST Errors (continued)

Test	Error Code	Error Description	Corrective Action
Test 563: Compares Q1 reading with Q3 reading at steady-state flow of 50 lpm.	5631	Flow rate comparison out of range.	1. See error 5611.
	5637	Oxygen flow reading from Q1 invalid.	1. See error 5617.
	5639	Oxygen flow reading from Q3 invalid.	1. See error 5619.
	563A	PSOL1 drive current out of range.	1. See error 561A.
Test 564: Compares Q1 reading with Q3 reading at steady-state flow of 100 lpm.	5641	Flow rate comparison out of range.	1. See error 5611.
	5647	Oxygen flow reading from Q1 invalid.	1. See error 5617.
	5649	Oxygen flow reading from Q3 invalid.	1. See error 5619.
	564A	PSOL1 drive current out of range.	1. See error 561A.
Test 565: Compares Q1 reading with Q3 reading at steady-state flow of 120 lpm.	5651	Flow rate comparison out of range.	1. See error 5611.
	5657	Oxygen flow reading from Q1 invalid.	1. See error 5617.
	5659	Oxygen flow reading from Q3 invalid.	1. See error 5619.
	565A	PSOL1 drive current out of range.	1. See error 561A.
Test 566: Compares Q1 reading with Q3 reading at steady-state flow of 180 lpm. If flow rate of 180 lpm cannot be established, Q1/Q3 comparison is made at whatever flow rate wall supply can deliver.	5661	Flow rate comparison out of range.	1. See error 5611.
	5667	Oxygen flow reading from Q1 invalid.	1. See error 5617.
	5669	Oxygen flow reading from Q3 invalid.	1. See error 5619.
	566A	PSOL1 drive current out of range.	1. See error 561A.

Table 6-4. EST Errors (continued)

Test	Error Code	Error Description	Corrective Action
Test 567: Flow-by offsets calibration. Compares Q1 to Q3 at flow of 0 lpm.	5671	Q1 vs. Q3 comparison out of range or oxygen controller unable to establish flow.	1. Check Q3/T3 electrical and tubing connections. 2. Replace Q3/T3. 3. Replace Q1/T1 and oxygen flow sensor EPROM, U406 (80188) or U302 (8088). 4. Replace oxygen regulator assembly. 5. Replace interface PCB.
	5677	Oxygen flow reading from Q1 invalid.	1. Check Q1/T1 connection (J6) on interface PCB. 2. Replace Q1/T1 and oxygen flow sensor EPROM, U406 (80188) or U302 (8088). 3. Replace interface PCB.
	5679	Oxygen flow reading from Q3 invalid.	1. Check Q3/T3 electrical and tubing connections within exhalation compartment. 2. Check Q3/T3 connection (J1) on interface PCB. 3. Replace Q3/T3. 4. Replace interface PCB.
	567A	PSOL1 drive current out of range.	1. Check for leaks in Q1/T1 couplings. 2. Adjust or replace REG1. 3. Replace proportional valve group. 4. Replace Q1/T1 and oxygen flow sensor EPROM, U406 (80188) or U302 (8088). 5. Replace Q3/T3. 6. Replace interface PCB.
Test 568: Flow-by offsets calibration. Compares Q1 to Q3 at flow of 10 lpm. Stores oxygen and exhaled flows in battery-backed RAM.	5681	Q1 and Q3 comparison out of range or oxygen controller unable to establish flow within 15 seconds.	1. See error 5671.
	5687	Oxygen flow reading from Q1 invalid.	1. See error 5677.
	5689	Oxygen flow reading from Q3 invalid.	1. See error 5679.
	568A	PSOL1 drive current out of range.	1. See error 567A.

Table 6-4. EST Errors (continued)

Test	Error Code	Error Description	Corrective Action
Test 569: Flow-by offsets calibration. Compares Q1 to Q3 at flow of 20 lpm. Stores oxygen and exhaled flows in battery-backed RAM.	5691	Q1 and Q3 comparison out of range or oxygen controller unable to establish flow within 15 seconds.	1. See error 5671.
	5697	Oxygen flow reading from Q1 invalid.	1. See error 5677.
	5699	Oxygen flow reading from Q3 invalid.	1. See error 5679.
	569A	PSOL1 drive current out of range.	1. See error 567A.
Test 571: Vents safety valve by de-energizing SOL5 with exhalation valve closed and patient wye blocked. Flow delivered by PSOL2 exits through vented safety valve. A flow rate of 180 lpm should not develop more than 20 cmH_2O pressure as sensed by DP. This test assumes DP and air flow sensor Q2 are functional and that tests 521 through 523 and 531 through 535 were passed.	5711	Safety valve relief pressure test failed. DP reading should be less than 20 cmH_2O.	1. Adjust or replace REG4. 2. Replace safety valve. 3. Replace SOL5. 4. Replace interface PCB.
	5716	DP reading invalid. DP reading should be less than 20 cmH_2O.	1. Check pressure transducer PCB connector J4. 2. Replace pressure transducer PCB. 3. Replace interface PCB.
	5717	Oxygen reading from Q1 invalid.	1. Check Q1/T1 connection (J6) on interface PCB. 2. Replace Q1/T1 and oxygen flow sensor EPROM, U406 (80188) or U302 (8088). 3. Replace interface PCB.

Table 6-4. EST Errors (continued)

Test	Error Code	Error Description	Corrective Action
Test 572: Derives system compliance as a weighted average of three points along volume/pressure curve. A flow rate of 5 lpm is established and delivered volume required to obtain 30, 60, and 85 cmH_2O pressure is used to calculate system compliance. This test assumes tests 561 through 566 were passed. If test fails, ventilator uses a default value of 0.01 ml/cmH_2O.	5721	System compliance reading invalid or unable to establish 5 lpm flow. Unable to pressurize to desired value within 15 seconds.	1. Verify that patient wye is blocked and tests 531 through 535 passed. 2. Check for patient tubing system leaks. Verify that tests 541 through 543 passed. 3. Replace patient tubing system with Puritan-Bennett-approved system.
	5726	Patient system failed to achieve desired pressure.	1. Verify that patient wye is properly blocked, exhalation valve is active, and tubing system does not leak. 2. Check pressure transducer PCB connector J4. 3. Replace pressure transducer PCB. 4. Replace interface PCB.
	5727	Temperature-compensated Q1 flow invalid.	1. Check that external oxygen supply is connected and pressure level is 30 psi (206.95 kPa) or greater. 2. Check Q1/T1 connection (J6) on interface PCB. 3. Replace Q1/T1 and oxygen flow sensor EPROM, U406 (80188) or U302 (8088). 4. Replace interface PCB.
	572A	PSOL1 drive current out of range.	1. See error 561A .

Table 6-4. EST Errors (continued)

Test	Error Code	Error Description	Corrective Action
Test 573: Pressurizes safety valve and tests pressure relief. A flow rate of 2 lpm is used to stabilize system pressure at safety valve cracking pressure. Once the pressure is stable, the flow rate is steadily increased to a maximum of 180 lpm. P2 is verified for a stable reading not to exceed 150 cmH_2O. This test assumes test 572 was passed.	5731	Unable to establish 2 lpm oxygen flow; or cracking pressure outside range 90 to 150 cmH_2O; or at maximum flow, pressure is outside range 80 to 160 cmH_2O.	1. Tubing compliance too great. Use shorter tubing. 2. Check oxygen supply for given flow rate. 3. Adjust or replace REG4. 4. Replace safety valve assembly. 5. Adjust or replace REG1. 6. Check for leaks in Q1/T1 couplings. 7. Replace Q1/T1 and oxygen flow sensor EPROM, U406 (80188) or U302 (8088). 8. Replace interface PCB. 9. Replace proportional valve group. 10. Replace internal exhalation valve.
	5735	P2 reading invalid. P2 pressure action assumes that test 521 was passed.	1. Check pressure transducer PCB connector J4. 2. Replace pressure transducer PCB. 3. Replace interface PCB.
	5737	Oxygen reading from Q1 invalid	1. Check Q1/T1 connection (J6) on interface PCB. 2. Replace Q1/T1 and oxygen flow sensor EPROM, U406 (80188) or U302 (8088). 3. Replace interface PCB.
	573A	PSOL1 drive current out of range.	1. See error 561A.
Test 581: Cross-checks P1 and DP at 0 cmH_2O with system pressure relieved. This test assumes test 572 was passed and no leaks have been found.	5811	P1/DP comparison out of range.	1. Adjust or replace REG5, and replace jet venturi. 2. Check pressure transducer PCB connector J4. 3. Replace pressure transducer PCB. 4. Replace interface PCB. 5. Replace SOL7.
	5814	Invalid P1 reading.	1. Replace REG5. 2. Replace pressure transducer PCB.
	5816	DP reading invalid. DP pressure action assumes that test 521 was passed.	1. Check pressure transducer PCB connector J4. 2. Replace pressure transducer PCB. 3. Replace interface PCB.

Table 6-4. EST Errors (continued)

Test	Error Code	Error Description	Corrective Action
Test 582: Prompts operator to set PEEP to 0 cmH_2O and verifies pressure reading.	5821	PEEP did not achieve value of 0 cmH_20.	1. Operator did not rotate <PEEP/CPAP> control to fully counterclockwise position. Continue Total EST as described in Section 5, making sure PEEP pressure reading is zero during next test pass. 2. Verify that tests 521 through 524 passed.
	5823	Operator response timed out.	1. Operator did not set PEEP pressure within 15 seconds. Continue Total EST as described in Section 5. 2. Replace REG5 and jet venturi.
	5824	P1 reading invalid. PEEP pressure action assumes that test 521 was passed.	1. Check REG5 for leaks. 2. Check pressure transducer PCB connector J4. 3. Check connection of pneumatic cable to motherboard. 4. Replace pressure transducer PCB. 5. Replace interface PCB.
Test 583: Calculates average area ratio [(P1 + DP) / P1]applied to exhalation valve over PEEP range of 0 to 36 cmH_2O. Writes ratio into battery-backed RAM. The operator is prompted to raise PEEP, then to lower it to various values. This test assumes tests 561 through 566 were passed. If test fails, ventilator uses default value of 1.35.	5831	Unable to establish 2 lpm oxygen flow; or area ratio outside range 0.90 through 9.0.	1. Check oxygen supply for given flow rate. 2. Check for leaks in Q1/T1 couplings. 3. Replace Q1/T1 and oxygen flow sensor EPROM, U406 (80188) or U302 (8088). 4. Adjust or replace REG1. 5. Replace proportional valve group. 6. Replace interface PCB. 7. See test 562, error 1. 8. Adjust or replace REG5. 9. Replace exhalation valve.
	5833	Operator response timed out.	1. Operator did not respond to prompt within 1 minute. Continue Total EST as described in Section 5. 2. Check that exhalation valve does not leak. 3. Check oxygen supply connection. 4. Adjust or replace REG5 and jet venturi. 5. Check pressure transducer PCB connector J4. 6. Replace pressure transducer PCB. 7. Replace interface PCB.

Table 6-4. EST Errors (continued)

Test	Error Code	Error Description	Corrective Action
Test 583: (continued)	5834	P1 reading invalid. PEEP pressure action assumes that test 521 was passed.	1. Adjust or replace REG5 and jet venturi. 2. Check pressure transducer PCB connector J4. 3. Replace pressure transducer PCB. 4. Replace interface PCB. 5. Replace exhalation valve.
	5836	DP reading invalid.	1. Check pressure transducer PCB connector J4. 2. Replace pressure transducer PCB. 3. Replace conversion PCB. 4. Replace interface PCB. 5. Replace SOL6.
	5837	Oxygen flow reading from Q1 invalid.	1. Check Q1/T1 connection (J6) on interface PCB. 2. Replace Q1/T1 and oxygen flow sensor EPROM, U406 (80188) or U302 (8088). 3. Replace interface PCB.
	583A	PSOL1 drive current out of range.	1. Check oxygen supply connection and pressure. 2. See error 561A.
Test 591: Checks whether a nebulizer is attached to ventilator by prompting operator.	5913	Operator response to [NEB ATTACHED/] prompt timed out.	1. Operator failed to respond to prompt within 15 seconds. Continue Total EST as described in Section 5.

Table 6-4. EST Errors (continued)

Test	Error Code	Error Description	Corrective Action
Test 592: Directs nebulizer output through oxygen nebulizer solenoid SOL1 and oxygen supply line. This test assumes oxygen supply line and nebulizer are attached correctly and that flow through Q1 is within tolerance of that measured by Q3. This test assumes proper operation of Q1 and Q3, i.e., successful completion of tests 561 through 566.	5921	Nebulizer flow at Q3 or Q1 out of range.	1. Check that <PEEP/CPAP> control is set to off position. 2. Empty liquid from nebulizer vial. 3. Check proper nebulizer connection and clear flow in nebulizer venturi. Verify that Puritan-Bennett approved patient tubing system is being used. 4. Check Q3/T3 electrical and tubing connections. 5. Replace SOL1. 6. See error 5611.
	5927	Oxygen flow reading from Q1 invalid.	1. Check Q1/T1 connection (J5) on interface PCB. 2. Replace Q1/T1 and oxygen flow sensor EPROM, U406 (80188) or U302 (8088). 3. Replace interface PCB.
	5929	Exhaled flow reading from Q3 invalid.	1. Check Q3/T3 electrical and tubing connections. 2. Check Q3/T3 connection (J1) on interface PCB. 3. Replace Q3/T3. 4. Replace interface PCB.
Test 593: Directs nebulizer output through nebulizer air solenoid SOL2 from air supply line. This test assumes that air supply line and nebulizer are attached correctly and that Q2 and Q3 are operating properly, i.e., successful completion of tests 551 through 556.	5931	Nebulizer flow at Q3 or Q2 out of range.	1. Check that <PEEP/CPAP> control is set to off position. 2. Empty liquid from nebulizer vial. 3. Check proper nebulizer connection and clear flow in nebulizer venturi. Verify that Puritan-Bennett approved patient tubing system is being used. 4. Check Q3/T3 electrical and tubing connections within exhalation compartment.
	5938	Air flow reading from Q2 invalid.	1. Check Q2/T2 connection (J6) on interface PCB. 2. Replace Q2/T2 and air flow sensor EPROM, U504 (80188) or U403 (8088). 3. Replace interface PCB.
	5939	Exhaled flow reading invalid.	1. Check proper nebulizer, oxygen supply, and tubing connections within exhalation compartment. 2. Check connections of Q3/T3 and heated bacteria filter. 3. Replace Q3/T3. 4. Replace SOL2.

Table 6-4. EST Errors (continued)

Test	Error Code	Error Description	Corrective Action
Test 601: Prompts operator for compressor configuration and directs operator to remove wall air input. Checks PS2 and PS3 for actuation.	6011	Presence of compressor not detected.	1. Respond to prompt [COMPR ATT/] by pressing <ENTER> if unit has compressor, or <CLEAR> if unit does not have compressor. Continue Total EST as described in Section 5. 2. Check start of compressor operation and proper connection of compressor or proper setting of PS3. 3. Check PS2 actuation. 4. Replace PS2 or PS3. 5. Replace interface PCB. 6. Replace compressor relay. 7. Replace compressor.
	6013	Operator response to [COMPR ATT/] or [DISCONNECT AIR] timed out.	1. Press <ENTER> to resume Total EST operation at next test or <ALARM RESET> to exit Total EST. Press <*> to repeat test.
Test 602: Response to the compressor is verified by the previous test 601. Verifies compressor flow by allowing a 120 lpm flow through PSOL2. This test assumes tests 551 through 556 were passed.	6021	Air flow measured at Q2 failed to achieve 120 lpm.	1. Check that compressor inlet and outlet filters, F5 and F6, are clear of obstruction. 2. Test for leaks between compressor outlet and ventilator base. Check for leaks around Q2/T2 couplings. 3. Verify that no flow is coming out of air inlet port. 4. Adjust or replace REG3. 5. Check pulsation damper connection and condition. 6. Replace compressor. 7. Replace compressor shock mounts.
	6028	Q2 air flow reading invalid.	1. Check Q2/T2 connection (J6) on interface PCB. 2. Replace Q2/T2 and air flow sensor EPROM, U504 (80188) or U403 (8088). 3. Replace interface PCB.
	602B	PSOL2 drive current out of range.	1. Check compressor compartment flow rate. (See Section 4.) 2. Replace proportional valve group. 3. Verify that no flow is coming out of air inlet port.

Table 6-4. EST Errors (continued)

Test	Error Code	Error Description	Corrective Action
Test 611: Invokes BUV and verifies that microprocessor is unable to control safety valve, PSOLs, SOL8, SOL3, and SOL4. This test assumes proper functioning of flow sensors Q1 and Q2 (tests 551 through 561 passed) as well as DP.	6111	BUV rate less than 8 bpm.	1. Adjust BUV volumes. 2. Replace interface PCB. 3. Replace PS4. 4. Replace pressure transducer PCB. 5. Replace conversion PCB.
	6116	DP reading less than or equal to 13 cmH_2O during BUV inspiration and greater than or equal to 5 cmH_2O during BUV exhalation.	1. Replace pressure transducer PCB. 2. Replace interface PCB.
	6117	Q1 oxygen flow reading less than or equal to 5 lpm.	1. Check Q1/T1 connection (J6) on interface PCB. 2. Replace Q1/T1 and oxygen flow sensor EPROM, U406 (80188) or U302 (8088). 3. Replace interface PCB. 4. Replace conversion PCB. 5. Adjust/replace REG1. 6. Replace proportional valve group.
	6119	Q3 exhaled flow reading less than or equal to 5 lpm.	1. Check Q3/T3 electrical connection within exhalation compartment. 2. Check Q3/T3 connection (J1) on interface PCB. 3. Replace Q3/T3. 4. Replace interface PCB. 5. Replace conversion PCB.

Table 6-4. EST Errors (continued)

Test	Error Code	Error Description	Corrective Action
Test 612: Tests operation of crossover solenoid valve SOL3 after prompting operator to disconnect oxygen supply. Establishes 10 lpm air flow. Energizes SOL3, causing oxygen supply to pilot safety valve, and resulting in all flow being vented and pressure rise at patient wye being prevented (less than 2 cmH_2O). De-energizes SOL3, causing air supply to pilot safety valve and increasing patient pressure above 30 cmH_2O. This test assumes tests 541 through 543 and tests 551 through 556 were passed.	6121 6123 6126 6128 612B	SOL3 failed to meet specified pressure limits at patient wye. Air flow controller unable to establish 10 lpm flow after 30 seconds.	1. Check that oxygen supply has been disconnected and back pressure bled from line. Check electrical and pneumatic connections to SOL3. 2. Verify that no flow is coming out of top of SV/CV3. 3. Replace SOL3. 4. Replace pressure transducer PCB. 5. Replace SV/CV3. 6. Replace conversion PCB. 7. Replace interface PCB. 8. Replace motherboard. 9. Check for correct orientation of PS4. 10. Replace CPU PCB. 11. Replace PS4. 12. Clean R1 and R2.
Test 613: Invokes BUV and monitors delivered air volume using Q2. The volume of delivered air is displayed in PEAK FLOW bpm display.	6131	BUV air volume out of range 375 to 625 ml.	1. Adjust BUV volumes. 2. Check air supply for given flow rate. 3. Check for leaks in Q2/T2 couplings. 4. Replace Q2/T2 and air flow sensor EPROM, U504 (80188) or U403 (8088). 5. Adjust or replace REG2. 6. Replace proportional valve group. 7. Replace interface PCB. 8. Replace pressure transducer PCB. 9. Replace conversion PCB. 10. Replace PS4.
	6133	Operator did not respond to prompt [UNBLOCK WYE] within 30 seconds.	1. Refer to Section 5 to continue Total EST.
	6138	Q2 air flow reading invalid.	1. Check Q2/T2 connection (J6) on interface PCB. 2. Replace Q2/T2 and air flow sensor EPROM, U504 (80188) or U403 (8088). 3. Replace interface PCB. 4. Replace conversion PCB.

Table 6-4. EST Errors (continued)

Test	Error Code	Error Description	Corrective Action
Test 614: Invokes BUV and monitors delivered oxygen volume using Q1. The volume of delivered oxygen is displayed in TIDAL VOL liters display.	6141	BUV oxygen volume out of range 375 to 625 ml.	1. Adjust BUV volumes. 2. Check oxygen supply for given flow rate. 3. Check for leaks in Q1/T1 couplings. 4. Replace Q1/T1 and oxygen flow sensor EPROM, U403 (80188) or U302 (8088). 5. Adjust or replace REG1. 6. Replace proportional valve group. 7. Replace interface PCB. 8. Replace pressure transducer PCB. 9. Replace conversion PCB. 10. Replace PS4.
	6143	Operator did not respond to prompt [CONNECT O2] within 30 seconds.	1. Refer to Section 5 to continue Total EST.
	6147	Q1 oxygen flow reading invalid.	1. Check Q1/T1 connection (J6) on interface PCB. 2. Replace Q1/T1 and oxygen flow sensor EPROM, U403 (80188) or U302 (8088). 3. Replace interface PCB. 4. Replace conversion PCB.
Test 621: Keyboard test for <ALARM RESET> key. Operator has two chances to press correct key.	6211	Invalid key read. This error condition could be caused by an operator timeout or a short in keyboard.	1. Incorrect keystroke by operator. Press <ENTER> to restart Total EST at next test or press <ALARM RESET> to abort Total EST. 2. Check connection of keyboard to front panel display PCB. 3. Replace DCI-display controller or display controller PCB. 4. Replace keyboard. 5. Replace front panel display PCB.
Test 622: Keyboard test for <MANUAL INSPIRATION> key.	6221	Invalid key read. Error condition could be caused by operator timeout.	1. See error 6211.
Test 623: Keyboard test for <MANUAL SIGH> key.	6231	Invalid key read. Error condition could be caused by operator timeout.	1. See error 6211.
Test 624: Keyboard test for <CLEAR> key.	6241	Invalid key read. Error condition could be caused by operator timeout.	1. See error 6211.

Table 6-4. EST Errors (continued)

Test	Error Code	Error Description	Corrective Action
Test 625: Keyboard test for <LOW EXHALED TIDAL VOL> key.	6251	Invalid key read. Error condition could be caused by operator timeout.	1. See error 6211.
Test 626: Keyboard test for <O_2%> key.	6261	Invalid key read. Error condition could be caused by operator timeout.	1. See error 6211.
Test 627: Keyboard test for <HIGH PRESSURE LIMIT> key.	6271	Invalid key read. Error condition could be caused by operator timeout.	1. See error 6211.
Test 628: Keyboard test for <0> key.	6281	Invalid key read. Error condition could be caused by operator timeout.	1. See error 6211.
Test 629: Keyboard test for <9> key.	6291	Invalid key read. Error condition could be caused by operator timeout.	1. See error 6211.
Test 631: Communication channel A (host/CliniVision port) test. A pattern of A-Z and 0-9 is sent in loop-back mode to RS-232 channel.	6311	Channel A transmit/ receive error.	1. Check that DCI-display controller PCB (80188) or memory PCB (8088) is properly seated. 2. Replace DCI-display controller PCB or memory PCB.
Test 632: Communication channel B (printer port) test. If a printer is attached, it will output a test pattern.	6321	Channel B transmit/ receive error.	1. See error 6311.
Test 633: Real-time calendar/clock test.	6331	Real-time clock test failed.	1. See error 6311.
Test 634: Channel C (7202) port test.	6341	Channel C transmit/ receive error.	1. Check that DCI-display controller PCB is properly seated. 2. Replace DCI-display controller PCB.
Test 635: Channel D (expansion port) test.	6351	Channel D transmit/ receive error.	1. See error 6341.

Table 6-5. Communications Errors

Test	Error Code	Error Description	Corrective Action
Test 70x: Executes DCI tasks	70xx	Ventilator unable to communicate with external device such as printer, 7202 Display, or other computer equipment.	1. Verify proper operation of external devices (including DIP switch settings and cabling). 2. Verify proper DIP switch settings on DCI-display controller or memory PCB. 3. Check connections of DCI interface, including seating of DCI-display controller PCB or memory PCB. 4. Replace DCI-display controller PCB or memory PCB.
Test 71x: Executes tasks to print report under DCI	71xx	Ventilator unable to print DCI report.	1. Verify proper operation of printer (including DIP switch settings and cabling). 2. Verify proper DIP switch settings on DCI-display controller or memory PCB. 3. Check connections of DCI interface, including seating of DCI-display controller PCB or memory PCB. 4. Replace DCI-display controller PCB or memory PCB.
Test 72x: Executes DCI tasks	72xx	Ventilator unable to communicate with external device such as printer, 7202 Display, or other computer equipment.	1. See error 70xx.
Test 73x: Executes DCI tasks related to 7202 Display	73xx	Ventilator unable to communicate with 7202 Display.	1. Verify proper operation of 7202 Display (including DIP switch settings and cabling). 2. Verify proper DIP switch settings on DCI-display controller or memory PCB. 3. Check connections of DCI interface, including seating of DCI-display controller PCB or memory PCB. 4. Replace DCI-display controller PCB or memory PCB.
Test 74x: Executes tasks related to 7202 Display	74xx	Ventilator unable to communicate with 7202 Display.	1. See error 73xx.
Test 76x: Executes tasks related to Waveforms option	76xx	Ventilator unable to complete Waveforms tasks.	1. See error 73xx. 2. Check connections of DCI interface, including seating of DCI-display controller PCB or memory PCB. 3. Replace DCI-display controller PCB or memory PCB.

Table 6-6. Faults

Test	Error Code	Error Description	Corrective Action
Test 99x: Detects transducer and other hardware faults using a series of logical tests that monitor normal ventilator operations. Operating the ventilator beyond rated specifications or in configurations not expressly supported by the operator's manual may defeat these logical tests and induce artificial faults. Transducer faults detected during normal operations indicate that out of range or inaccurate measurements have been made.	9901	Oxygen flow sensor (Q1) reading out of range.	1. Run Total EST. 2. Check Q1/T1 connection (J5) on interface PCB. 3. Replace Q1/T1 and oxygen flow sensor EPROM, U406 (80188) or U302 (8088). 4. Replace interface PCB.
	9902	Air flow sensor (Q2) reading out of range.	1. Run Total EST. 2. Check Q2/T2 connection (J6) on interface PCB. 3. Replace Q2/T2 and air flow sensor EPROM, U504 (80188) or U403 (8088). 4. Replace interface PCB.
	9903	Exhalation flow sensor (Q3/T3) reading out of range.	1. Run Total EST. 2. Check Q3/T3 electrical and tubing connections within exhalation compartment. 3. Check Q3/T3 connection (J1) on interface PCB. 4. Replace Q3/T3. 5. Replace interface PCB. 6. Replace Q3/T3 harness.
	9904	A/D conversion time out. A/D converter on conversion PCB failed to respond within allotted time period.	1. Replace conversion PCB. 2. Replace CPU PCB. 3. Check cable between CPU PCB and conversion PCB.
	9905	Compensated atmospheric pressure reading out of range.	1. Run Total EST. 2. Remove and replace exhalation bacteria filter. 3. Check pneumatic harness connections. 4. Replace pressure transducer PCB. 5. Replace interface PCB. 6. Replace SOL6.

Table 6-6. Faults (continued)

Test	Error Code	Error Description	Corrective Action
Test 99x: (continued)	9906	PS2 and PS3 remain closed.	1. Verify compressor turns on when wall air is not applied. Verify PS3 connection. 2. Check connections between compressor compartment and utility panel, pins 3 and 4. 3. Replace interface PCB. 4. Replace PS3. 5. Replace PS2. 6. Replace motherboard. 7. Replace conversion PCB.
	9907	Watchdog timeout did not occur under program control.	1. Run Total EST. 2. Replace CPU PCB. 3. Replace DCI-display controller or display controller PCB. 4. Replace CPU PCB. 5. Inspect motherboard Multibus strips.
	9908	BUV is active without a detected POST or system fault.	1. Run Total EST. 2. Remove 7202 Display. 3. Check integrity of + 12 V power supply. 4. Replace interface PCB. 5. Replace conversion PCB. 6. Replace both interconnect cables (P/N 4-019231-00) between conversion and interface PCBs. 7. Replace DCI-display controller or display controller PCB. 8. Replace CPU PCB.
	9909	Watchdog timeout did not occur under program control.	1. See error 9907.

Table 6-6. Faults (continued)

Test	Error Code	Error Description	Corrective Action
Test 99x: (continued)	990B	PSOL1 remained in open position. Flow past Q1 was detected after PSOL1 was closed.	1. Run Total EST. 2. Check oxygen tank or supply. 3. Check for leaks in Q1/T1 couplings. 4. Replace Q1/T1 and oxygen flow sensor EPROM, U406 (80188) or U302 (8088). 5. Check electrical connection of proportional solenoid valves. 6. Replace proportional valve group. 7. Replace conversion PCB. 8. Replace interface PCB. 9. Replace REG1.
	990C	PSOL1 failed to open.	1. See error 990B.
	990D	PSOL2 remained in open position. Flow past Q2 was detected after PSOL2 was closed.	1. Run Total EST. 2. Check for leaks in Q2/T2 couplings. 3. Replace Q2/T2 and air flow sensor EPROM, U504 (80188) or U403 (8088). 4. Check electrical connection of proportional solenoid valves. 5. Replace proportional valve group. 6. Replace interface PCB. 7. Replace conversion PCB. 8. Replace pressure transducer PCB. 9. Replace REG2 if wall air is attached. 10. Check compressor compartment components for proper functioning.
	990E	PSOL2 failed to open.	1. See error 990D.
	9910	P1, P2, and DP have been in fault state for longer than 100 ms.	1. Replace pressure transducer PCB.
	9911	Watchdog timeout did not occur during a brownout condition.	1. See error 9907.
	992x	Hardware/option PAL mismatch.	1. Call Technical Support.

Performance Verification

SECTION 7. PERFORMANCE VERIFICATION

Use these procedures to verify ventilator performance whenever the service actions listed in Table 7-1 are completed.

Table 7-1. Performance Verification Intervals

Service Action Performed	Performance Verification Test Requirements
2,500-hour preventive maintenance	All tests
10,000-hour preventive maintenance	All tests
Replacement of proportional solenoid valve assembly	All tests
Replacement of safety valve	All tests
Replacement of REG1/REG2	Tests 2, 3, 9 (all steps), and 10 (steps 1-12)
Replacement of REG3	Tests 2, 3, 9 (all steps), and 10 (steps 13-26)
Replacement of REG5	Tests 2, 3, and 15
Replacement of more than one flow sensor	All tests
Replacement of pressure transducer PCB	Tests 2, 3, and 12 (all steps)
Replacement of pneumatic chassis assembly	All tests
Replacement of compressor	Tests 1-3 (all steps), 9 (steps 1-7), and test 10 (steps 14-26)
Replacement of power supply assembly	Tests 1-3 and 7 (all steps)
Replacement of any ac components	Tests 1-3 and 7 (all steps)
Replacement of any other components	Tests 2 and 3
Whenever J11 is disconnected	Test 16 (steps 3-5)

7.1 Tools and Test Equipment Required

In addition to the standard set of tools, the equipment and tools listed in Tables 7-2 and 7-3 are required for the performance verification.

Table 7-2. Puritan-Bennett Service Materials Required for Performance Verification

Description	Quantity	Part No.
Test lung with strap	1	4-000612-00
Test lung without strap	1	4-011355-00
Tee, male barb, 3/16 in. (5 mm)	1	4-000630-00
Tee (patient pressure adapter)	1	4-011521-00
Connector, female, ¾ in. barb	1	4-003443-00
Barb fitting and nut for pneumatic calibration analyzer	1	4-008103-00 and 4-003475-00
Patient tubing circuit with nebulizer	1	4-018052-00 or equivalent
Oxygen sensor tee	1	4-020935-00 (used with 7820 Oxygen Monitor or equivalent)
No. 2 stopper	1	4-009523-00 or local supplier
No. 2 stopper with 3/16 in. (4.8 mm) OD barbed connector	1	4-003152-00

Table 7-3. Test Equipment Required for Performance Verification

NOTE

Verify the current calibration status of test equipment before using it.

Description	Manufacturer/Model
Electrical safety tester	BIO-TEK Model 501 PRO or equivalent
Pneumatic calibration analyzer capable of measuring high pressure (psi), low pressure (cmH_2O digital display), flow rate (lpm), volume (liters BTPS)	Timeter Corporation RT-200 **NOTE** **Although an RT-200 is required to test BTPS volume and ATP flow, pressure gauges may be used for other pneumatic testing.**
Oxygen analyzer accurate to ±2%	7820 Oxygen Monitor (4-020930-00) or equivalent
Digital multimeter (DMM) accurate to three decimal places	Local supplier

7.2 Preliminary RT-200 Setup

To set up the RT-200 for use in the performance verification procedures, install the barb (P/N 4-008103-00) and nut (P/N 4-003745-00) on the RT-200 High Pressure Range positive port. The barb and nut should remain connected to the RT-200 whenever you use it, unless you must use the special high-pressure fitting.

NOTE

If your RT-200 offers the choice betwen ATP and BTPS volumes, always be sure the BTPS special function is selected when making volume measurements.

To select ATP or BTPS, select Volume setting, then press 00 and <ENTER>. Use 0 to scroll between STD, ATP, and BTPS. Press <ENTER> to lock selection.

7.3 Preliminary Ventilator Cleaning and Inspection

Clean and inspect the ventilator as follows:

9. Clean ventilator exterior. Alcohol is recommended as a cleaning agent. Use Cavicide to kill bloodborne pathogens, if required. Do not soak front panel, as water may seep behind it.
10. Remove any water from humidifier and dry jar, if applicable.
11. Remove ventilator top and back inner and outer panels (Section 9.1).
12. If ventilator has a compressor pedestal, remove compressor pedestal outer and inner back panels (Section 16.1).
13. Open lefthand panel (Section 9.2).
14. Clean interior of ventilator and compressor pedestal (if applicable) by carefully blowing out any dust with deionized gas or by vacuuming with ESD-safe equipment.
15. Inspect air and oxygen filter/water trap assemblies. Clean or replace as required.
16. Remove and inspect electronics compartment cooling fan filter and compressor compartment cooling fan filter (if applicable). Clean or replace as required.
17. Inspect electronics compartment cooling fan and compressor compartment cooling fan(s) (if applicable). Clean or replace as required.
18. If ventilator has a compressor, inspect compressor inlet filter (F5). Clean or replace as required.
19. Visually inspect ventilator and compressor pedestal exterior and interior for obvious problems, such as broken or missing parts, loose assemblies, or disconnected wires, connectors, or tubing. Perform repairs or adjustments as needed.

7.4 Preliminary Ventilator Setup

Set up the ventilator for the performance verification tests as follows:

1. Install a complete Puritan-Bennett (or equivalent) patient tubing circuit with nebulizer. Make sure all bacteria filters and a humidifier are installed. Make sure humidifier is not filled with water.
2. Connect ventilator to a wall or bottled oxygen source.
3. Connect ventilator to a wall or bottled air source.

7.5 Performance Verification Procedures

In general, the performance verification tests should be completed in the given order. Any repairs and retesting of the unit should be completed before you proceed to the next step. If you need to repeat a test, however, the current control settings are completely defined at the beginning of each individual check.

NOTE

If you are performing the performance verification tests in order, you need only make the ventilator setting changes shown in boldface.

Information necessary to locate the cause of a malfunction is in the Troubleshooting Table at the back of this section. If your ventilator does not pass a test step, use the index letter at the end of the step to determine the appropriate corrective action.

Follow these general guidelines when checking out the ventilator:

- Verify that you correctly entered the data on the keyboard by listening for the keyboard beep and watching the appropriate display.
- Use <ALARM SILENCE> and <ALARM RESET> to restore the ventilator to the test condition. Using these keys may be necessary because of the non-standard set of tubing connections, which may cause an apnea or other alarm condition to occur.
- Except for <ALARM SILENCE> and <ALARM RESET>, do not change the control settings during these procedures unless specifically instructed.
- After changing ranges on the RT-200, always zero the RT-200, making sure flow or pressure conditions do not exist.
- If you note a problem during the performance verification, verify that you followed the procedures correctly before attempting to repair the ventilator.

WARNING

Follow accepted safety procedures for electrical equipment when making connections, adjustments, or repairs.

NOTE

The following procedures do not verify the performance of accessories. Verify the performance of accessories using the appropriate procedures in the applicable operator's or service manuals.

7.5.1 Electrical Safety Test (Test 1)

The electrical safety test verifies that ground resistance, leakage current, and current draw are within safe limits. Perform this test whenever you service the ventilator, per your hospital's requirements.

NOTE

After servicing the ventilator, perform an electrical safety test before putting the unit back into operation.

WARNING

If the ventilator fails an electrical safety test, do not proceed to the next electrical safety test until you correct the problem and retest the unit.

NOTE

Before performing the electrical safety tests ensure that the compressor (if applicable) and all accessories are connected and running.

There are no specific ventilator setting requirements for the electrical safety test.

1. Make sure ventilator power is off.
2. VERIFY ground resistance is $\leq$ 0.1 Ω. **A**
3. If applicable, turn on humidifier. The humidifier temperature should be set to a typical operating value.
4. Turn on ventilator power.
5. If ventilator has a compressor, disconnect wall or bottled air supply from ventilator.
6. Ensure that compressor (if applicable) is running. Failure to do so will produce an inaccurate total leakage current reading.
7. VERIFY that forward- and reverse-current leakage to ground is $\leq$100 µA (100/115 V units) or $\leq$500 µA (220/240 V units). **B**
8. If ventilator has a compressor, ensure that compressor is connected and running. Failure to do so will produce an inaccurate current draw reading.
9. VERIFY that current draw is in accordance with Table 7-4. **C**

Table 7-4. Acceptable Current Draw Values

Voltage	Current Draw without Compressor	Current Draw with Compressor
100 V	<4.9 A	<10 A
115 V	<5.3 A	<10 A
220 V	<2.5 A	<4.8 A
240 V	<2.5A	<4.6 A

10. Turn off humidifier if applicable.
11. VERIFY that compressor and electronics compartment cooling fans are operating properly. **D**
12. Turn off ventilator power.
13. If ventilator has a compressor, connect wall or bottled air to ventilator.

7.5.2 Power-On Self-Test (POST) (Test 2)

The Power-On Self-Test (POST), in conjunction with the Total Extended Self-Test (TEST), verifies overall ventilator performance. POST is initiated automatically whenever power to the ventilator is turned on. For additional information about POST, refer to Section 5.

NOTE

There are no specific ventilator setting requirements for POST.

1. Turn ventilator power on.
2. VERIFY that no POST faults are displayed by either 20-character display or CPU PCB LEDs. **E**

7.5.3 Total Extended Self-Test (EST) (Test 3)

WARNING

Do not use or override a ventilator that fails Total EST without verifying its operational readiness by an independent means and determining that a patient will not be placed at risk.

Puritan-Bennett urges medical departments to review the implications of using a ventilator that fails test step 541 or 542. Puritan-Bennett recommends establishing a medical department protocol that defines the conditions under which ventilator usage is acceptable.

Never initiate EST while a patient is connected to the ventilator. The ventilator does not provide normal ventilatory support during EST. A patient connected to the ventilator can be injured by airway pressures or gas flow controlled by EST.

Total Extended Self-Test (EST), in conjunction with POST, verifies overall ventilator performance. For additional information about Total EST, refer to Section 5.

NOTE

There are no specific ventilator setting requirements for Total EST.

1. Make sure ventilator power is on.
2. Press and hold <EST> button. VERIFY that [START EST - ENTER] is displayed in 20-character display.
3. Press <ENTER>. [PAT TUBING OFF - ENTER] will be displayed.
4. Press <ENTER> after verifying that a patient is not connected to the ventilator. [QUICK EST] will be displayed.
5. Press <++>. [TOTAL EST] will be displayed.
6. Press <0>. Record time, date, and status of last EST, values for patient tubing circuit leakage and compliance, and area ratio of exhalation valve, displayed in 7202 Display or 20-character display.
7. Press <I:E RATIO>. Record software part number, software revision level, and installed ventilator options code, displayed in 20-character display.
8. Press <1>. Record four-digit error code and date and time stamp, displayed in 20-character display.
9. Press <RATE bpm>. If available, record 12-digit error code, displayed in 20-character display. Refer to Section 5.2.4 to interpret 12-digit code.
10. Repeat steps 8 and 9 using keys <2> through <6> on numeric keypad.
11. Remove test lung from patient wye.
12. Press <ENTER>. Proceed with EST.
13. VERIFY that during EST test 573 the cracking pressure is greater than 130 cmH_2O (114 cmH_2O in German TUV units). **F**

    (Determine cracking pressure by watching analog meter while test 573 is running the compliance calculation. The analog meter sweeps to 30 cmH_2O, 60 cmH_2O, then 85 cmH_2O. Just after this, the pressure level rises slowly in the cmH_2O display of the PATIENT DATA section of the keyboard. The pressure level displayed in the cmH_2O display continues to rise slowly to about 135 cmH_2O (114 cmH_2O in German TUV units), then starts to flicker rapidly as flow increases through ventilator valving. The cracking pressure is the last pressure level displayed before the display starts to flicker.)
14. VERIFY that [EST PASS], and then [REVIEW APNEA PARAMS], is displayed in 20-character display. **E**

    NOTE

    Do not turn off unit until it begins normal operation; otherwise, [RUN EST-DO NOT USE] will be displayed and BUV will start when the unit is powered up again.
15. Connect test lung (P/N 4-000612-00) to patient wye.

7.5.4 Battery-Backed RAM Test (Test 4)

This test verifies the performance of the battery-backed RAM circuits.

1. Set up the ventilator as follows:

Control	Setting
Analog meter (basic console only)	**<EXHALED VOLUME liters>**
<PEEP/CPAP> knob	Off
cmH_2O digital display	**<MEAN AIRWAY PRESSURE>**
RATE/I:E digital display	**<RATE bpm>**
liters digital display	**<TIDAL VOLUME>**
<NEBULIZER>	**Off**
Mode	**<CMV>**
Waveform	**Square**
<TIDAL VOLUME>	**0.75 liter**
<RESPIRATORY RATE>	**10 bpm**
<PEAK INSPIRATORY FLOW>	**100 lpm**
<SENSITIVITY>	**20 cmH_2O**
<O_2%>	**21%**
<PLATEAU>	**0 seconds**
<HIGH PRESSURE LIMIT>	**60 cmH_2O**
<LOW INSPIRATION PRESSURE>	**3 cmH_2O**
<LOW PEEP/CPAP PRESSURE>	**0 cmH_2O**
<LOW EXHALED TIDAL VOL>	**0 liters**
<LOW EXHALED MINUTE VOL>	**0 liters**
<HIGH RESPIRATORY RATE>	**0 bpm**
Apnea interval	**60 seconds**
Automatic sigh	**Off**
Power	On
Patient wye	4-000612-00 test lung
Humidifier (if applicable)	**Off**

2. Turn off ventilator, wait 30 seconds, then turn ventilator back on.
3. VERIFY that no POST error codes are displayed by 20-character display or CPU PCB LEDs. **G**
4. VERIFY that there are no changes to the settings in step 1 due to the power interruption. **H**

7.5.5 Lamp Test (Test 5)

The lamp test verifies the performance of the lamps, indicators, displays, audio alarm, and analog meter.

1. Set up the ventilator as follows:

Control	Setting
Analog meter (basic console only)	<EXHALED VOLUME liters>
<PEEP/CPAP> knob	Off
cmH_2O digital display	<MEAN AIRWAY PRESSURE>
RATE/I:E digital display	<RATE bpm>
liters digital display	<TIDAL VOLUME>
<NEBULIZER>	Off
Mode	<CMV>
Waveform	Square
<TIDAL VOLUME>	0.75 liter
<RESPIRATORY RATE>	10 bpm
<PEAK INSPIRATORY FLOW>	100 lpm
<SENSITIVITY>	20 cmH_2O
<O_2%>	21%
<PLATEAU>	0 seconds
<HIGH PRESSURE LIMIT>	60 cmH_2O
<LOW INSPIRATION PRESSURE>	3 cmH_2O
<LOW PEEP/CPAP PRESSURE>	0 cmH_2O
<LOW EXHALED TIDAL VOL>	0 liters
<LOW EXHALED MINUTE VOL>	0 liters
<HIGH RESPIRATORY RATE>	0 bpm
Apnea interval	60 seconds
Automatic sigh	Off
Power	On
Patient wye	4-000612-00 test lung
Humidifier (if applicable)	Off

2. Press <LAMP TEST> and then <ENTER>.

NOTE

If you have a 7200a ventilator with software of revision P or greater, or if you have a 7200ae ventilator, the software revision and option code will be displayed in the 20-character display.

3. VERIFY that all lamps, indicators, displays, the audio alarm, and analog meter are activated in the sequence shown in Figure 7-1 or Figure 7-2.

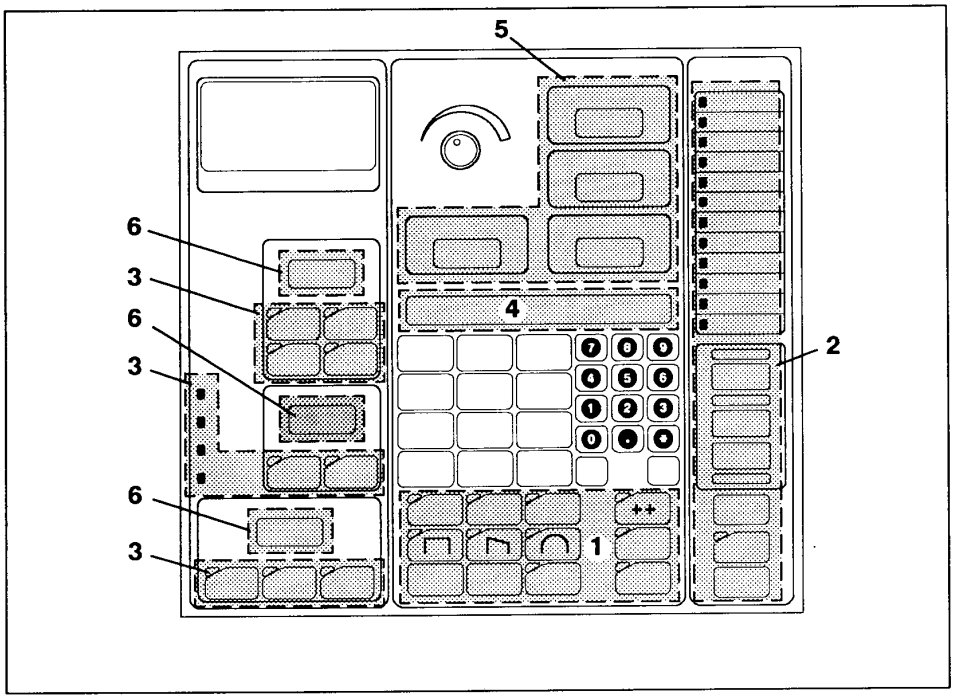


Figure 7-1. Enhanced Keyboard Lamp Test Sequence

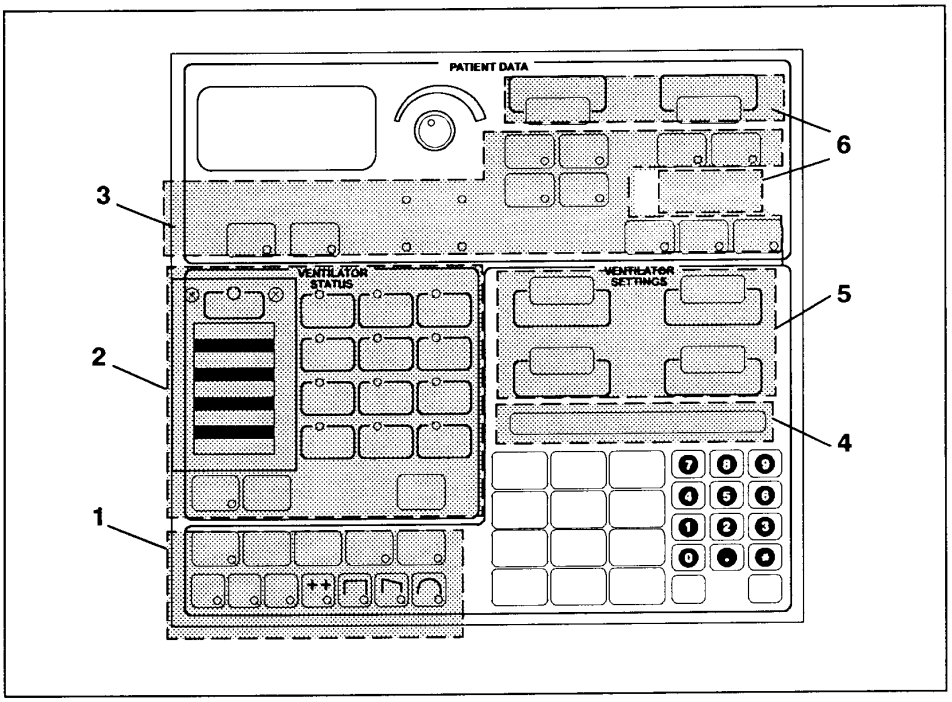


Figure 7-2. Basic Keyboard Lamp Test Sequence

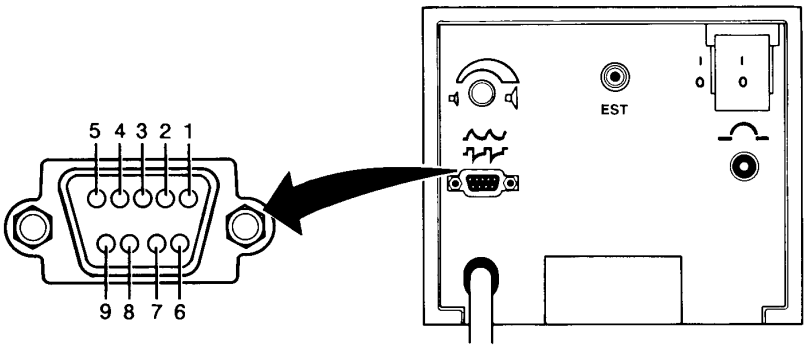
7.5.6 Analog Output Connector Test (Test 6)

The analog output connector test verifies the performance of the pressure level and flow rate level portions of the analog output signal connector, located on the utility panel.

1. Set up the ventilator as follows:

Control	Setting
Analog meter (basic console only)	<EXHALED VOLUME liters>
<PEEP/CPAP> knob	Off
cmH_2O digital display	<MEAN AIRWAY PRESSURE>
RATE/I:E digital display	<RATE bpm>
liters digital display	<TIDAL VOLUME>
<NEBULIZER>	Off
Mode	<CMV>
Waveform	Square
<TIDAL VOLUME>	0.75 liter
<RESPIRATORY RATE>	10 bpm
<PEAK INSPIRATORY FLOW>	100 lpm
<SENSITIVITY>	20 cmH_2O
<O_2%>	21%
<PLATEAU>	0 seconds
<HIGH PRESSURE LIMIT>	60 cmH_2O
<LOW INSPIRATION PRESSURE>	3 cmH_2O
<LOW PEEP/CPAP PRESSURE>	0 cmH_2O
<LOW EXHALED TIDAL VOL>	0 liters
<LOW EXHALED MINUTE VOL>	0 liters
<HIGH RESPIRATORY RATE>	0 bpm
Apnea interval	60 seconds
Automatic sigh	Off
Power	**Off**
Patient wye	4-000612-00 test lung
Humidifier (if applicable)	Off

2. Set DMM to 10 V dc scale.
3. Prepare to measure analog output connector signals by inserting DMM leads into connector (pin 2-positive lead, pin 3-negative lead) or by mating a 9-pin, D-type male test connector to analog output connector so voltages can be measured more easily. See Figure 7-3 for connector pinout.
4. Turn on ventilator power.
5. After POST is completed, press <LAMP TEST> and <ENTER>.
6. VERIFY that DMM displays five different voltage levels: 0, +2.5, +5.0, +7.5, and +10.0 V (all within a tolerance of $\pm$ 0.5 V). **J**
7. Turn off ventilator power.
8. Insert DMM probes into analog output connector (pin 6-positive lead, pin 7-negative lead).
9. Turn on ventilator power.
10. After POST is completed, press <LAMP TEST> and <ENTER>.
11. VERIFY that DMM displays the same five voltage levels as in step 6. **J**
12. Turn off ventilator power.
13. Disconnect DMM and test connector from ventilator.



Pin Number	Description of Signal
Connector shell	Chassis ground: Do not use to connect protective shield to chassis ground. The protective shield must be connected to chassis ground on pin 1.
1	Chassis ground: To be used for protective shield only. The protective shield must also be connected to chassis ground on the peripheral equipment.
2	Pressure signal: 0 to +10 V, corresponding to -20 cmH_2O to +120 cmH_2O. 0 cmH_2O equals approximately +1.4 V. Required impedance matching is 1 KΩ minimum.
3	Pressure signal return
4	—
5	—
6	Flow signal: 0 to +10 V, corresponding to -180 lpm to +180 lpm. 0 lpm equals +5.0 V. Required impedance matching is 1 KΩ minimum.
7	Flow signal return
8	Nurse's call relay: Normally open; closed when activated. Allowable current is 250 mA at +30 V dc (maximum).
9	Nurse's call relay return

Figure 7-3. Analog Output Connector Pinout

7.5.7 Power Supply Test (Test 7)

This test verifies the performance of the power supply.

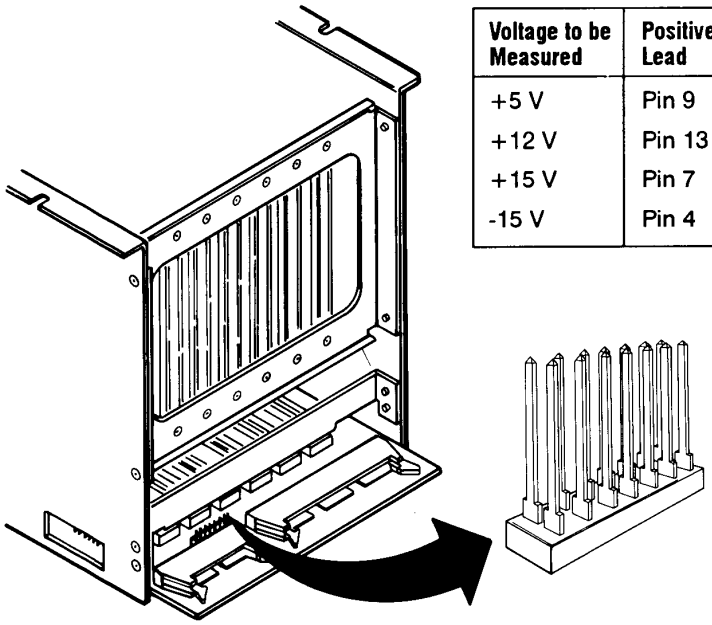
1. Set up the ventilator as follows:

Control	Setting
Analog meter (basic console only)	<EXHALED VOLUME liters>
<PEEP/CPAP> knob	Off
cmH_2O digital display	<MEAN AIRWAY PRESSURE>
RATE/I:E digital display	<RATE bpm>
liters digital display	<TIDAL VOLUME>
<NEBULIZER>	**On**
Mode	<CMV>
Waveform	Square
<TIDAL VOLUME>	0.75 liter
<RESPIRATORY RATE>	10 bpm
<PEAK INSPIRATORY FLOW>	100 lpm
<SENSITIVITY>	20 cmH_2O
<O_2%>	21%
<PLATEAU>	0 seconds
<HIGH PRESSURE LIMIT>	60 cmH_2O
<LOW INSPIRATION PRESSURE>	3 cmH_2O
<LOW PEEP/CPAP PRESSURE>	0 cmH_2O
<LOW EXHALED TIDAL VOL>	0 liters
<LOW EXHALED MINUTE VOL>	0 liters
<HIGH RESPIRATORY RATE>	0 bpm
Apnea interval	60 seconds
Automatic sigh	Off
Power	Off
Patient wye	4-000612-00 test lung
Humidifier (if applicable)	Off

NOTE

Always use insulated test leads to avoid shorting pins.

2. Connect DMM leads to motherboard connector J14 as indicated in Figure 7–4. Turn on ventilator power. VERIFY the voltages while running the lamp test (to load the +5 V and +12 V supplies). **K**
3. Disconnect DMM leads.



Voltage to be Measured	Positive Lead	Negative Lead	Acceptable Range
+5 V	Pin 9	Pin 11	+4.950 to +5.050 V
+12 V	Pin 13	Pin 11	+11.880 to +12.120 V
+15 V	Pin 7	Pin 5	+14.850 to +15.150 V
-15 V	Pin 4	Pin 5	-15.150 to -14.850 V

Figure 7-4. Testing Power Supply Output Voltages

7.5.8 Keyboard Test (Test 8)

This test verifies the performance of the keyboard.

1. Set up the ventilator as follows:

Control	Setting
Analog meter (basic console only)	<EXHALED VOLUME liters>
<PEEP/CPAP> knob	Off
cmH_2O digital display	<MEAN AIRWAY PRESSURE>
RATE/I:E digital display	<RATE bpm>
liters digital display	<TIDAL VOLUME>
<NEBULIZER>	**Off**
Mode	<CMV>
Waveform	Square
<TIDAL VOLUME>	0.75 liter
<RESPIRATORY RATE>	10 bpm
<PEAK INSPIRATORY FLOW>	100 lpm
<SENSITIVITY>	20 cmH_2O
<O_2%>	21%
<PLATEAU>	0 seconds
<HIGH PRESSURE LIMIT>	60 cmH_2O
<LOW INSPIRATION PRESSURE>	3 cmH_2O
<LOW PEEP/CPAP PRESSURE>	0 cmH_2O
<LOW EXHALED TIDAL VOL>	0 liters
<LOW EXHALED MINUTE VOL>	0 liters
<HIGH RESPIRATORY RATE>	0 bpm
Apnea interval	60 seconds
Automatic sigh	Off
Power	On
Patient wye	4-000612-00 test lung
Humidifier (if applicable)	Off

2. One at a time, press each key on keyboard. Do not press <ENTER>. VERIFY that you hear a beep for each key press. To silence a continuous alarm during this step, press <ALARM SILENCE>. L

7.5.9 Gas Supply System Test (Test 9)

This test verifies the performance of the oxygen and air supply system.

NOTE
Do not turn on Peak Hold during this test.

1. Set up the ventilator as follows:

Control	Setting
Analog meter (basic console only)	<EXHALED VOLUME liters>
<PEEP/CPAP> knob	Off
cmH_2O digital display	<MEAN AIRWAY PRESSURE>
RATE/I:E digital display	<RATE bpm>
liters digital display	<TIDAL VOLUME>
<NEBULIZER>	Off
Mode	<CMV>
Waveform	Square
<TIDAL VOLUME>	**2.5 liters**
<RESPIRATORY RATE>	**5 bpm**
<PEAK INSPIRATORY FLOW>	**40 lpm**
<SENSITIVITY>	20 cmH_2O
<O_2%>	21%
<PLATEAU>	0 seconds
<HIGH PRESSURE LIMIT>	60 cmH_2O
<LOW INSPIRATION PRESSURE>	3 cmH_2O
<LOW PEEP/CPAP PRESSURE>	0 cmH_2O
<LOW EXHALED TIDAL VOL>	0 liters
<LOW EXHALED MINUTE VOL>	0 liters
<HIGH RESPIRATORY RATE>	0 bpm
Apnea interval	60 seconds
Automatic sigh	Off
Power	On
Patient wye	**Open**
Humidifier (if applicable)	Off

2. Connect wall air.
3. Select RT-200 setting for 20 psi. Zero RT-200.
4. Disconnect nebulizer tube from nebulizer, and connect it to RT-200 High Pressure Range positive port.
5. Press <NEBULIZER>, then <ENTER> to turn nebulizer on.
6. VERIFY that RT-200 reads between 9.9 and 11.0 psig during inspiration. **M**
7. If ventilator has a compressor, disconnect wall air, and VERIFY that RT-200 reads between 9.9 and 11.0 psig during inspiration. **N**
8. Set <O_2%> to 100.
9. VERIFY that RT-200 reads between 9.9 and 11.0 psig during inspiration. **O**
10. Press <NEBULIZER>, then <ENTER> to turn nebulizer off.
11. Reconnect nebulizer tube to nebulizer.

7.5.10 Peak Inspiratory Flow Test (Test 10)

This test verifies correct peak inspiratory flow.

NOTE

The Low Inspiration Pressure (LIP) and apnea alarms are activated during this test. The LIP alarm prevents the ventilator from going into apnea ventilation.

To prevent apnea ventilation from starting, set <LOW INSPIRATION PRESSURE> to 20 cmH_2O *before* putting ventilator into CPAP mode.

The RT-200 must not be set to BTPS during this test.

1. Set up the ventilator as follows:

Control	**Setting**
Analog meter (basic console only)	<EXHALED VOLUME liters>
<PEEP/CPAP> knob	Off
cmH_2O digital display	<MEAN AIRWAY PRESSURE>
RATE/I:E digital display	<RATE bpm>
liters digital display	<TIDAL VOLUME>
<NEBULIZER>	Off
Mode	**<CPAP>**
Waveform	Square
<TIDAL VOLUME>	2.5 liters
<RESPIRATORY RATE>	5 bpm
<PEAK INSPIRATORY FLOW>	40 lpm
<SENSITIVITY>	**0.5 cmH_2O**
<O_2%>	100%
<PLATEAU>	0 seconds
<HIGH PRESSURE LIMIT>	60 cmH_2O
<LOW INSPIRATION PRESSURE>	**20 cmH_2O**
<LOW PEEP/CPAP PRESSURE>	0 cmH_2O
<LOW EXHALED TIDAL VOL>	0 liters
<LOW EXHALED MINUTE VOL>	0 liters
<HIGH RESPIRATORY RATE>	0 bpm
Apnea interval	60 seconds
Automatic sigh	Off
Power	On
Patient wye	Open
Humidifier (if applicable)	Off

2. Select RT-200 setting for 180 lpm oxygen. Zero RT-200.
3. Set RT-200 Peak/Continuous function off.
4. Connect patient wye to RT-200 High Flow Range port using connector (P/N 4-003443-00).
5. Slowly raise <PEEP/CPAP> knob to maximum.
6. VERIFY that RT-200 reads 162 lpm minimum. **P**
7. Lower <PEEP/CPAP> knob to 0 cmH_2O.
8. Set <O_2%> to 21.
9. Select RT-200 setting for 180 lpm air. Zero RT-200 during exhalation.
10. Slowly raise <PEEP/CPAP> knob to maximum.
11. VERIFY that RT-200 reads greater than 162 lpm. **Q**
12. Lower <PEEP/CPAP> knob to 0 cmH_2O.
13. If ventilator has a compressor, perform steps 14-26. If not, continue with test 11.
14. Disconnect wall or bottled air supply from ventilator.
15. Slowly raise <PEEP/CPAP> knob to maximum.
16. VERIFY that RT-200 reads greater than 110 lpm. **R**
17. Lower <PEEP/CPAP> knob to 0 cmH_2O.

18. Select RT-200 setting for 20 psi. Zero RT-200.
19. Disconnect nebulizer tube from nebulizer, and connect it to RT-200 High Pressure Range positive port.
20. Press <NEBULIZER>, then <ENTER> to turn nebulizer on.
21. Slowly raise <PEEP/CPAP> knob to maximum.
22. VERIFY that RT-200 reads greater than 7.4 psig during inspiration. **S**
23. Lower <PEEP/CPAP> knob to 0 cmH_2O.
24. Press <NEBULIZER>, then <ENTER> to turn nebulizer off.
25. Reonnect nebulizer tube to nebulizer.
26. Reconnect high-pressure air supply to ventilator.

7.5.11 High-Pressure Limit Alarm, Alarm Volume Control, and Nurse's Call Relay Test (Test 11)

This test verifies the performance of the high-pressure limit alarm, alarm volume control, and nurse's call relay.

1. Set up the ventilator as follows:

Control	Setting
Analog meter (basic console only)	**<AIRWAY PRESSURE cmH_2O>**
<PEEP/CPAP> knob	Off
cmH_2O digital display	**<PEAK AIRWAY PRESSURE>**
RATE/I:E digital display	<RATE bpm>
liters digital display	<TIDAL VOLUME>
<NEBULIZER>	Off
Mode	**<CMV>**
Waveform	Square
<TIDAL VOLUME>	**1.5 liters**
<RESPIRATORY RATE>	**1.5 bpm**
<PEAK INSPIRATORY FLOW>	**15 lpm**
<SENSITIVITY>	**20 cmH_2O**
<O_2%>	21%
<PLATEAU>	0 seconds
<HIGH PRESSURE LIMIT>	60 cmH_2O
<LOW INSPIRATION PRESSURE>	20 cmH_2O
<LOW PEEP/CPAP PRESSURE>	0 cmH_2O
<LOW EXHALED TIDAL VOL>	0 liters
<LOW EXHALED MINUTE VOL>	0 liters
<HIGH RESPIRATORY RATE>	0 bpm
Apnea interval	60 seconds
Automatic sigh	Off
Power	**Off**
Patient wye	**Open**
Humidifier (if applicable)	Off

2. Set DMM to read resistance.
3. Insert DMM probes to test NURSE'S CALL signal via analog output connector (pin 8 and pin 9, polarity unimportant). See Figure 7-3 for connector pinout.
4. Turn on ventilator.
5. Press <ALARM RESET>.
6. VERIFY that DMM reads infinite resistance (open circuit). **T**
7. Block patient wye with no. 2 stopper.
8. Press <ALARM RESET>.
9. Press <MANUAL INSPIRATION>.
10. VERIFY that ventilator digital pressure display reads 56 to 63 cmH_2O, and that high pressure limit alarm activates. **U**
11. VERIFY that DMM reads zero resistance (short circuit). **V**
12. Slowly rotate alarm volume control on utility panel from fully counterclockwise position to fully clockwise position.
13. VERIFY that alarm volume steadily increases. **W**
14. Set <HIGH PRESSURE LIMIT> to 120 cmH_2O (all units except German) or 100 cmH_2O (German units).
15. Press <ALARM RESET>.
16. VERIFY that when alarm is off, DMM reads infinite resistance (open circuit). **X**
17. Disconnect DMM.

7.5.12 Gas Volume Accuracy Test (Test 12)

The gas volume accuracy test verifies the accuracy of the volume of gas delivered to the patient.

1. Set up the ventilator as follows:

Control	Setting
Analog meter (basic console only)	<AIRWAY PRESSURE cmH_2O>
<PEEP/CPAP> knob	Off
cmH_2O digital display	<PEAK AIRWAY PRESSURE>
RATE/I:E digital display	<RATE bpm>
liters digital display	<TIDAL VOLUME>
<NEBULIZER>	Off
Mode	<CMV>
Waveform	Square
<TIDAL VOLUME>	**0.25 liter**
<RESPIRATORY RATE>	1.5 bpm
<PEAK INSPIRATORY FLOW>	**20 lpm**
<SENSITIVITY>	20 cmH_2O
<O_2%>	**100%**
<PLATEAU>	0 seconds
<HIGH PRESSURE LIMIT>	120 cmH_2O (all units except German); 100 cmH_2O (German units)
<LOW INSPIRATION PRESSURE>	20 cmH_2O
<LOW PEEP/CPAP PRESSURE>	0 cmH_2O
<LOW EXHALED TIDAL VOL>	0 liters
<LOW EXHALED MINUTE VOL>	0 liters
<HIGH RESPIRATORY RATE>	0 bpm
Apnea interval	60 seconds
Automatic sigh	Off
Power	On
Patient wye	**Open**
Humidifier (if applicable)	Off

2. Select RT-200 setting for volume oxygen and the BTPS function. Zero RT-200 during exhalation.
3. Connect patient wye to RT-200 High Flow Range port with connector (P/N 4-003443-00).
4. Press <MANUAL INSPIRATION>, then pause. Repeat five times.
5. VERIFY that RT-200 reads between 0.22 and 0.30 liter. **Y**
6. Set <TIDAL VOLUME> to 1.5 liters.
7. Press <MANUAL INSPIRATION>, then pause. Repeat three times.
8. VERIFY that RT-200 reads between 1.4 and 1.75 liters. **Y**
9. Set <O_2%> to 21.
10. Select RT-200 setting for volume air. Zero RT-200 during exhalation.
11. Press <MANUAL INSPIRATION>, then pause. Repeat five times.
12. VERIFY that RT-200 reads between 1.44 and 1.82 liters. **Y**
13. Set <TIDAL VOLUME> to 0.25 liter.
14. Press <MANUAL INSPIRATION>, then pause. Repeat three times.
15. VERIFY that RT-200 reads between 0.23 and 0.30 liter. **Y**

7.5.13 Sensitivity Accuracy Test (Test 13)

The sensitivity accuracy test verifies the accuracy of the sensitivity measurement.

1. Set up the ventilator as follows:

Control	Setting
Analog meter (basic console only)	<AIRWAY PRESSURE cmH_2O>
<PEEP/CPAP> knob	Off
cmH_2O digital display	<PEAK AIRWAY PRESSURE>
RATE/I:E digital display	<RATE bpm>
liters digital display	<TIDAL VOLUME>
<NEBULIZER>	Off
Mode	<CMV>
Waveform	Square
<TIDAL VOLUME>	**1 liter**
<RESPIRATORY RATE>	1.5 bpm
<PEAK INSPIRATORY FLOW>	**100 lpm**
<SENSITIVITY>	**10 cmH_2O**
<O_2%>	21%
<PLATEAU>	0 seconds
<HIGH PRESSURE LIMIT>	120 cmH_2O (all units except German); 100 cmH_2O (German units)
<LOW INSPIRATION PRESSURE>	**3 cmH_2O**
<LOW PEEP/CPAP PRESSURE>	0 cmH_2O
<LOW EXHALED TIDAL VOL>	0 liters
<LOW EXHALED MINUTE VOL>	0 liters
<HIGH RESPIRATORY RATE>	0 bpm
Apnea interval	60 seconds
Automatic sigh	Off
Power	On
Patient wye	**4-000612-00 test lung**
Humidifier (if applicable)	Off

2. Disconnect tubes and connectors from RT-200.
3. Squeeze and very slowly release test lung.
4. VERIFY that an assist breath is triggered at -9 to -11 cmH_2O as displayed on analog meter. **Z**
5. Set <SENSITIVITY> to 5 cmH_2O.
6. Squeeze and very slowly release test lung.
7. VERIFY that an assist breath is triggered at -4 to -6 cmH_2O as displayed on analog meter. **Z**
8. Set <SENSITIVITY> to 0.5 cmH_2O.
9. Squeeze and very slowly release test lung.
10. VERIFY that an assist breath is triggered at approximately -0.5 cmH_2O as displayed on analog meter. **Z**

7.5.14 Oxygen Percentage Accuracy Test (Test 14)

This test verifies the accuracy of the percentage of oxygen delivered to the patient.

1. Set up the ventilator as follows:

Control	Setting
Analog meter (basic console only)	<AIRWAY PRESSURE cmH_2O>
<PEEP/CPAP> knob	Off
cmH_2O digital display	<PEAK AIRWAY PRESSURE>
RATE/I:E digital display	<RATE bpm>
liters digital display	<TIDAL VOLUME>
<NEBULIZER>	Off
Mode	<CMV>
Waveform	Square
<TIDAL VOLUME>	**0.25 liter**
<RESPIRATORY RATE>	**10 bpm**
<PEAK INSPIRATORY FLOW>	**20 lpm**
<SENSITIVITY>	**20 cmH_2O**
<O_2%>	**30%**
<PLATEAU>	0 seconds
<HIGH PRESSURE LIMIT>	120 cmH_2O (all units except German); 100 cmH_2O (German units)
<LOW INSPIRATION PRESSURE>	3 cmH_20
<LOW PEEP/CPAP PRESSURE>	0 cmH_2O
<LOW EXHALED TIDAL VOL>	0 liters
<LOW EXHALED MINUTE VOL>	0 liters
<HIGH RESPIRATORY RATE>	0 bpm
Apnea interval	60 seconds
Automatic sigh	Off
Power	On
Patient wye	4-000612-00 test lung
Humidifier (if applicable)	Off

2. Ensure that oxygen monitor is calibrated before testing oxygen percentages.

NOTE

After changing the <O_2%> setting on the ventilator, wait until the oxygen monitor reading stabilizes before taking a reading.

3. Remove silicone rubber connector attached to ventilator outlet. Connect oxygen monitor to ventilator between ventilator outlet and main flow bacteria filter using sensor tee (4-020935-00).
4. VERIFY that oxygen monitor reads between 27 and 33%. **AA**
5. Make these ventilator control settings:

Control	Setting
Waveform	Descending ramp
<PEAK INSPIRATORY FLOW>	100 lpm
<TIDAL VOLUME>	1.5 liters

6. VERIFY that oxygen monitor reads between 27 and 33%. **AA**
7. Make these ventilator settings:

Control	Setting
<PEAK INSPIRATORY FLOW>	60 lpm
<TIDAL VOLUME>	0.25 liters
<O_2%>	60

8. VERIFY that oxygen monitor reads between 57 and 63.9%. **AA**

9. Make these ventilator control settings:

Control	Setting
Waveform	Square
<PEAK INSPIRATORY FLOW>	20 lpm
<TIDAL VOLUME>	1.5 liters
<RESPIRATORY RATE>	5 bpm

10. VERIFY that oxygen monitor reads between 57 and 63%. **AA**
11. Make these ventilator control settings:

Control	Setting
<PEAK INSPIRATORY FLOW>	60 lpm
<O_2%>	80

12. VERIFY that oxygen monitor reads between 76 and 84%. **AA**
13. Make these ventilator control settings:

Control	Setting
Waveform	Sine
<PEAK INSPIRATORY FLOW>	100 lpm
<TIDAL VOLUME>	0.25 liter

14. VERIFY that oxygen monitor reads between 76 and 84%. **AA**
15. Remove oxygen monitor and tee, and reconnect main flow bacteria filter to ventilator outlet port using adapter removed in step 3.

7.5.15 PEEP System Test (Test 15)

This test verifies the performance of the PEEP system.

1. Set up the ventilator as follows:

Control	Setting
Analog meter (basic console only)	<AIRWAY PRESSURE cmH_2O>
<PEEP/CPAP> knob	Off
cmH_2O digital display	**<PEEP/CPAP>**
RATE/I:E digital display	<RATE bpm>
liters digital display	<TIDAL VOLUME>
<NEBULIZER>	Off
Mode	<CMV>
Waveform	**Square**
<TIDAL VOLUME>	**0.5 liter**
<RESPIRATORY RATE>	**1 bpm**
<PEAK INSPIRATORY FLOW>	**20 lpm**
<SENSITIVITY>	20 cmH_2O
<O_2%>	80%
<PLATEAU>	0 seconds
<HIGH PRESSURE LIMIT>	120 cmH_2O (all units except German); 100 cmH_2O (German units)
<LOW INSPIRATION PRESSURE>	3 cmH_2O
<LOW PEEP/CPAP PRESSURE>	0 cmH_2O
<LOW EXHALED TIDAL VOL>	0 liters
<LOW EXHALED MINUTE VOL>	0 liters
<HIGH RESPIRATORY RATE>	0 bpm
Apnea interval	60 seconds
Automatic sigh	Off
Power	On
Patient wye	**4-003152-00 test cork with orifice with 4-011355-00 test lung over it**
Humidifier (if applicable)	Off

2. Select RT-200 setting for 250 cmH_2O. Zero RT-200.

NOTE

If the ventilator has a bottom-loading exhalation compartment, remove the front cover to gain access to the exhalation valve pilot tube.

3. Tee into patient circuit at wye using coupling (4-003443-00), tee (4-011521-00), and one small-bore tube. Connect one end to RT-200 Low Pressure Range positive port.
4. Set digital <PEEP/CPAP> to 10 cmH_2O.
5. Press <MANUAL INSPIRATION>.
6. VERIFY that ventilator analog meter reads between 8 and 12 cmH_2O. **AB**
7. VERIFY that RT-200 reads between 8 and 12 cmH_2O. **AC**
8. Set digital <PEEP/CPAP> to 30 cmH_2O.
9. VERIFY that ventilator analog meter reads between 27 and 33 cmH_2O. **AB**
10. VERIFY that RT-200 reads between 27 and 33 cmH_2O. **AC**
11. Turn <PEEP/CPAP> knob fully clockwise.
12. VERIFY that ventilator analog meter reads above 45 cmH_2O. **AB**
13. VERIFY that RT-200 reads above 45 cmH_2O. AC
14. Set <PEEP/CPAP> to 20 cmH_2O.
15. Remove coupling and tee from patient circuit.
16. Turn ventilator power off.
17. Disconnect exhalation valve pilot tube from valve. Using 4-000630-00 tee and small-bore tube, connect it to RT-200 Low Pressure Range positive port.

18. VERIFY that RT-200 reads an exhalation valve pilot pressure of 0 cmH_2O. **AD**
19. Restore patient tubing circuit to normal configuration.
20. Turn on ventilator power.

7.5.16 Heated Exhalation Bacteria Filter and Power Disconnect Alarm Test (Test 16)

This test verifies the performance of the exhalation bacteria filter heater and the power disconnect alarm.

1. Set up the ventilator as follows:

Control	Setting
Analog meter (basic console only)	<AIRWAY PRESSURE cmH_2O>
<PEEP/CPAP> knob	20 cmH_2O
cmH_2O digital display	<PEEP/CPAP>
RATE/I:E digital display	<RATE bpm>
liters digital display	<TIDAL VOLUME>
<NEBULIZER>	Off
Mode	<CMV>
Waveform	Square
<TIDAL VOLUME>	0.5 liter
<RESPIRATORY RATE>	1 bpm
<PEAK INSPIRATORY FLOW>	20 lpm
<SENSITIVITY>	20 cmH_2O
<O_2%>	80%
<PLATEAU>	0 seconds
<HIGH PRESSURE LIMIT>	120 cmH_2O (all units except German); 100 cmH_2O (German units)
<LOW INSPIRATION PRESSURE>	3 cmH_2O
<LOW PEEP/CPAP PRESSURE>	0 cmH_2O
<LOW EXHALED TIDAL VOL>	0 liters
<LOW EXHALED MINUTE VOL>	0 liters
<HIGH RESPIRATORY RATE>	0 bpm
Apnea interval	60 seconds
Automatic sigh	Off
Power	On
Patient wye	**4-000612-00 test lung**
Humidifier (if applicable)	Off

NOTE

If power to the ventilator has been turned off for an extended period of time, it will be necessary to allow the exhalation bacteria filter heater to warm up for 10 minutes before checking the temperature of the exhalation bacteria filter heater.

2. VERIFY that exhalation bacteria filter heater is warm to the touch. **AE**
3. Unplug ventilator, leaving power switch on.
4. VERIFY that audio alarm sounds. **AF**
5. Turn off ventilator power.
6. Plug ventilator back in.
7. Turn ventilator back on.

7.6 Returning Ventilator to Patient Use

Restore the ventilator to a fully operational state as follows:

1. If any repairs were performed, ensure that all connectors, circuit boards, hardware, and cable straps are in place.
2. Rerun electrical safety test if any repairs were made.
3. Reinstall top and back ventilator panels and compressor panels.
4. Notify appropriate hospital personnel that normal ventilator operating parameters must be restored before ventilator can be used on a patient.
5. After reassembling ventilator, run Total EST.

7.7 Troubleshooting

Use this troubleshooting information in conjunction with this performance verification.

A Ground line resistance $\geq$0.1 Ω

1. Check for short circuits across or visible damage to power cord. Verify secure connections of ground wires and wires at terminal block in utility panel.
2. Try another ac outlet.

B Leakage current out of specification

1. If compressor is connected, disconnect it and remeasure.
2. Check for damage to power cord.
3. Replace power supply.
4. Replace compressor shock mounts.
5. Replace compressor.
6. Replace surge suppressor.

C Current draw out of specification

1. Turn off humidifier, and disconnect it from electrical source. Recheck current draw. If current draw is now within specification, service humidifier.
2. If ventilator has a compressor, connect ventilator to wall air to turn compressor off. Recheck current draw. If current draw is now within specification, service compressor.
3. Service power supply.

D Compressor and ventilator cooling fans not operating properly

1. Verify ac voltage to fan.
2. Replace fan.

E POST and Total EST not passed

1. Refer to error code section (Section 6).

F REG4 cracking pressure too low.

1. Adjust REG4.

G POST error codes following power interruption

1. Check battery voltage. If low, check battery charger voltage.
2. Check for defective diode CR1 on motherboard. If diode is defective, replace motherboard.
3. If 1401 or 1501 error code persists, troubleshoot per Section 6.

H Ventilator settings changed due to power interruption

1. Check battery voltage. If low, check battery charger voltage.
2. Replace 80188 CPU PCB or memory PCB.
3. Replace motherboard.

I Lamps, Indicators, displays, audio alarm, or analog meter not active during lamp test

1. If audio alarm is not active, check diode CR2 on motherboard.
2. Replace front panel display PCB.
3. Replace DCI-display controller or display controller PCB.
4. Replace conversion PCB or interface PCB.
5. Replace analog meter.

J Voltage levels out of specification at analog output connector

1. Check for open or short circuits in utility panel harness (4-019239-00) between analog output connector and motherboard.
2. Reseat interface and conversion PCBs.
3. Replace interface PCB.
4. Replace conversion PCB.

K Power supply voltages out of specification

1. Adjust power supply output voltages per Section 11.
2. Replace power supply or appropriate power supply module.

L Keyboard test failed

1. Verify proper operation of audio alarm.
2. Replace keyboard.
3. Replace front panel display PCB.
4. Replace DCI-display controller or display controller PCB.

M Regulated air pressure out of range 9.9 to 11.0 psig (68.26 to 75.85 kPa)

1. Check for obstruction in air inlet filters F3 and F4.
2. Verify source pressure.
3. Check screen filter F11.
4. Check Q2/T2 coupling connections.
5. Adjust REG2.
6. Replace REG2.
7. Check for leaky compressor check valve CV4.

N Regulated compressor pressure out of range 9.9 to 11.0 psig (68.26 to 75.85 kPa)

1. Check for occluded compressor inlet and outlet filters.
2. Check for leaks in pulsation damper or plastic tees.
3. Check Q2/T2 coupling connections.
4. Adjust/replace REG3.
5. Replace compressor.
6. Replace Q2/T2.
7. Check for leaky CV2.
8. Make sure SOL9 is closed after compressor startup. If it is not, replace SOL9 or PS3.

O Regulated oxygen pressure out of range 9.9 to 11.0 psig (68.26 to 75.85 kPa)

1. Check for obstruction in oxygen inlet filters F1 and F2.
2. Verify source pressure.
3. Check screen filter F10.
4. Check Q1/T1 coupling connections.

5. Adjust REG1.
6. Replace REG1.

P Oxygen flow less than 162 lpm with maximum PEEP

1. Verify source pressure.
2. Check for tubing obstructions or leaks.
3. Check diameter of high-pressure oxygen hose.
4. Replace Q1/T1.
5. Replace interface PCB.
6. Replace proportional solenoid valves.

Q Air flow less than 162 lpm with maximum PEEP

7. Verify source pressure.
8. Check for tubing obstructions or leaks.
9. Check diameter or high-pressure air hose.
10. Replace Q2/T2.
11. Replace interface PCB.
12. Replace proportional solenoid valves.

R Compressor air flow less than 110 lpm with maximum PEEP

1. Verify that there is no obstruction in tubing to compressor or in compressor inlet or outlet filter.
2. Verify that there is no flow coming out of air inlet port.
3. Adjust REG3
4. Replace compressor.

S Compressor pressure less than 7.4 psig at high flow

1. Verify that there is no flow coming out of air inlet port.
2. Adjust REG3.
3. Check for leaks in pulsation damper and plastic tees.
4. Verify that there is no obstruction in tubing to compressor or filters.
5. Check SOL9 for leaks.
6. Replace compressor.

T Resistance across nurse's call relay out of range

1. Check for a short circuit in utility panel harness (P/N 4-019239-00) between analog output connector and motherboard.
2. Replace interface PCB.

U Analog meter or patient pressure display does not read proper value or high pressure limit alarm does not activate when patient wye blocked

1. Check for tubing leak.
2. Verify that analog meter reads 0 cmH_2O during exhalation. Readjust meter, if it does not.
3. Replace pressure transducer PCB.
4. Replace analog meter.

V Too much resistance across nurse's call relay during alarm condition

1. Verify wiring of 9-pin test connector, checking for open or short circuits.
2. Replace interface PCB.

W Audio alarm does not operate properly

1. Replace alarm potentiometer.
2. Replace audio alarm.

3. Replace power switch.
4. Check for blown diode CR2 on motherboard. Replace motherboard if necessary.
5. Replace interface PCB.
6. Replace DCI-display controller or display controller PCB.
7. Replace front panel display PCB.
8. Replace utility panel harness.

X Resistance across nurse's call relay not infinite when alarm is off

1. Check for a short circuit in wiring to NURSE'S CALL circuitry.
2. Replace interface PCB.

Y Delivered gas volumes out of range

1. Verify that RT-200 is in BTPS mode and is zeroed.
2. Check for tubing leak or obstruction.
3. Replace oxygen or air flow sensors Q1/T1 or Q2/T2 depending upon step failed.

Z Sensitivity problems

1. Verify that analog meter reads 0 cmH_2O during exhalation (at PEEP of 0). If it does not, readjust.
2. Check patient pressure connections in exhalation compartment and pneumatic chassis.
3. Replace analog meter.
4. Replace pressure transducer PCB.
5. Replace exhalation valve.
6. Check for improperly functioning check valve CV5.

AA Oxygen percentages out of range

1. Make sure oxygen analyzer is properly calibrated.
2. Replace gel and membrane cap on oxygen analyzer.
3. Replace oxygen sensor.
4. Try another oxygen analyzer.
5. Replace proportional solenoid valves.
6. Replace conversion PCB.
7. Replace interface PCB.

AB Analog meter PEEP reading out of range

1. Check for tubing leak or obstruction.
2. Check exhalation valve area ratio linearity in EST. If ratio is nonlinear, replace exhalation valve.
3. Replace pressure transducer PCB.
4. Replace interface PCB.
5. Replace conversion PCB.
6. Install new exhalation valve.

AC RT-200 PEEP reading out of range

1. Check for tubing leak or obstruction.
2. Zero RT-200.
3. Try another pressure gauge.

AD RT-200 does not read 0 cmH_2O PEEP

1. Check for leaking REG5.
2. Replace pressure transducer PCB.

AE Exhalation bacteria filter not warm

1. Verify power to heater using DMM.
2. Replace heater assembly.

AF Power disconnect alarm test failed

1. Verify battery voltages.
2. Verify battery charging circuit voltage.
3. Check for blown CR2 diode on motherboard. Replace motherboard if necessary.
4. Check audio alarm harness (part of alarm assembly) for open or short circuits.
5. Check display cable assembly (P/N 4-019234-00) for open or short circuits.
6. Check conversion PCB interconnection cable assembly (P/N 4-019231-00) for open or short circuits.
7. Verify continuity of ventilator power switch (zero resistance when up, infinite resistance when down). Replace switch if necessary.
8. Replace audio alarm assembly.
9. Replace DCI-display controller or display controller PCB, front panel display PCB, and interface PCB, as necessary.
10. Replace conversion PCB.

10,000 Hour Service Kit Installation

MALLINCKRODT

Installation Instructions

7200® Series Ventilator 10,000–Hour Preventive Maintenance Kit

Introduction

These are the instructions for installing the *7200* Series Ventilator 10K preventive maintenance kit for 115 V and 220/240 V ventilators.

Significant statements

Statements preceded by the following words and graphics are of special significance.

Warning

Means that there is a possibility of injury to yourself or others.

Caution

Means there is a possibility of damage to the equipment or other property.

Note

Indicates points of particular interest or special emphasis that make for more efficient and convenient operation of the equipment.

Kit contents

Before starting the installation, verify the kit contents and inspect for any signs of damage that may have occurred during transit. If there are any problems, or you have any questions, contact a Mallinckrodt Service Representative at 1-800-635-5267.

10K PM kits for 115 V and 220/240 V *7200* ventilators:

- 115 V (P/N 4-020790-00)
- 220/240 V (P/N 4-020804-00)

The 2.5K PM kit (provided in a separate package) is included with the 10K PM kit. Table 1 lists the contents of the 2.5K PM kit for both 115 V and 220/240 V ventilators.

Table 2 lists the additional 10K PM parts.

Table 1. 2.5K PM kit (115 V and 220/240 V)

Quantity	Part Description	Part Number
2	Filter element for water trap and filter assembly with metal head and stopcock-type drain valve, inlet oxygen/air (F1/F3)	4-018055-00
2	Filter element for water trap and filter assembly with plastic head and spring-loaded, push-type drain valve, inlet oxygen/air (F1/F3)	4-020282-00
2	Screw, flat, black oxide (bezel mounting) (basic keyboard only)	4-019351-00
2	Lamp, alarm, 12 V (basic keyboard only)	4-030198-00
2	Filter O-ring seal replacement set (for water traps)	4-020285-00
2	O-ring, intermediate version (for water traps)	4-016176-00
2	O-ring, later version (for water traps)	4-008467-00
2	O-ring, latest version (for water traps)	4-016177-00
1	Installation Instructions	4-022295-00
1	Label, 2.5K PM record	4-023481-00

Table 2. 115 V and 200/240 V 10K PM kits

115 V or 220/240 V or Both	Quantity	Part Description	Part Number
Both	1	O_2 Regulator Assembly (REG1)	4-020276-00
	1	• Screen filter (F11)	4-020719-00
	1	• Copper right-angle tube with nuts and ferrules	part of REG1 assembly
	1	• Nut and spacer	4-019587-00
	1	• Grab-ring	4-019588-00
	1	• O-ring	4-019589-00

Table 2. 115 V and 200/240 V 10K PM kits (Continued)

115 V or 220/240 V or Both	Quantity	Part Description	Part Number
Both	1	Air Regulator Assembly (REG2)	4-020277-00
	1	• Screen filter (F10)	4-020719-00
	1	• Copper right-angle tube with nuts and ferrules	part of REG2 assembly
	1	• Nut and spacer	4-019587-00
	1	• Grab-ring	4-019588-00
	1	• O-ring	4-019589-00
	1	Tubing, 3/16" ID, 11.5" (29.2 cm)	4-008575-00 part of REG2 assembly
115 V 60 Hz	1	Fan, electronics compartment cooling	4-019135-00
200/240 V 50/60 Hz	1	Fan, electronics compartment cooling	4-021216-00
Both	1 pkg	Battery 2-pack with return mailer	4-021526-00
	1	Power switch	4-012411-00
	2	Bacteria filter assembly (F7) (F8)	4-011905-00
	1	Tubing assembly (R4)	4-000314-00
	1	Tubing assembly (air capacitor)	4-011413-00
	2	Filter, brass (F2) oxygen, (F4) air (for water traps)	4-000034-00
	1	Solenoid valve assembly (SOL4)	4-019344-00
	1	*7200* 10K PM label	4-023486-00
	1	Installation Instructions 10K kit	4-020792-00

Tools and equipment required

Tables 3 and 4 list the test equipment and service tools, or their equivalent, required to perform the 10K preventive maintenance installation.

Table 3. Test equipment required

Description	Manufacturer Model (or equivalent)
Electrical safety tester	BIO-TEK Model 501 PRO
Pneumatic calibration analyzer capable of measuring high pressure (psi), low pressure (cmH_2O digital display), flow rate (Lpm) volume (liters BTPS)	Performance Test System *PTS 2000* (P/N 4-076185-00)
Oxygen analyzer accurate to ±2%	MiniOx® 3000 (P/N 4-023698-00) (or equivalent)
Digital multimeter (DMM), accurate to three decimal places	Local supplier

Table 4. Puritan-Bennett service materials

Service Materials	Quantity	Part Number
Standard tool kit	1	NA
Static-dissipative service kit	1	4-018149-00
Test lung with strap	1	4-000612-00
Test lung without strap	1	4-011355-00
Tee, male barb, 3/16 inch (5 mm)	1	4-000630-00
Tee (patient pressure adapter)	1	4-011521-00
Coupling, female, for barbed cuff fittings	1	4-003443-00
Patient tubing circuit with nebulizer (simplified)	1	4-018052-00 (or equivalent)
Oxygen sensor tee	1	4-020935-00 used with MiniOx 3000 (P/N 4-023698-00) (or equivalent)
Tube, small-bore, 3/16-inch ID	2	Various parts. See hospital accessories catalog.
No. 2 stopper	1	4-009523-00 (or equivalent)
No. 2 stopper with 3/16-inch (5 mm) OD barbed connector	1	4-003152-00

Table 4. Puritan-Bennett service materials

Service Materials	Quantity	Part Number
Leak detectoriniOx® 3000 (P/N 4-023698-00) (Any leak detector meeting Mil L 25567 D may be substituted.)	1	4-004489-00 (or equivalent))
Tube, oxygen regulator	1	4-019113-00
Tube, air regulator	1	4-019112-00
Grease, Krytox	1	4-732130-00
R5 restrictor (replace if missing)	1	4-019407-00
7200 Series Ventilatory Service Manual	1	4-031052-00
7250 Metabolic Monitor Operator's Manual (if monitor is installed on ventilator)	1	4-022395-00

Preinstallation notes

Be sure to read *all* instructions completely before starting any work.

- The 10K preventive maintenance kit includes a separate package containing the 2.5K PM kit contents (Table 1). *Remove and save the label* attached to the installation instructions for the 2.5K PM kit. Discard the *2.5K Installation Instructions*, as the information is included in these (10K) instructions.
- Discard the original parts after installing new parts *except* for the batteries. Return the batteries, for recycling, in the mailer supplied.
- When installing (10K PM kit), clean and inspect the ventilator as described in Section 7.3 of the service manual.

Caution

- To ensure proper reassembly, note or label wire and tube positions before disconnecting parts.
- Take precautions to prevent dirt and other particles from entering the ventilator interior.
- To prevent shredding, pull gently when disconnecting the silicone tubes from the barbed fittings.

Preinstallation tests

The following tests should be performed on the ventilator **before** and **after** installing the 10K PM kit. Successful results before installation helps to troubleshoot the ventilator if the tests fail after the installation.

1. Run an electrical safety test as described in Section 7.6.1 of the service manual.
2. Run a Total EST (Figure 1) as described in Section 7.6.3 of the service manual.

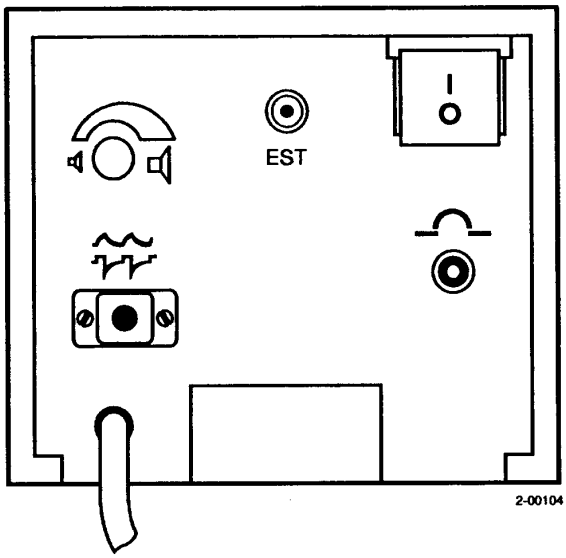


Figure 1. Location of total EST button

Remove ventilator accessories

Warning

To prevent electrical shock hazard, disconnect electrical power sources from the ventilator before servicing. To prevent injury, disconnect external pneumatic sources from the ventilator.

Note

Reference Figure 2 when performing this procedure.

1. Unplug the ventilator from the facility power source.
2. Remove the following accessories (see Section 3 in the service manual).
   - 7202 display
   - printer
   - MiniOx 3000 oxygen monitor
   - flex arm and patient tubing
   - *7250®* metabolic monitor (see Figure 3)
3. Disconnect the wall air and O_2 sources from the ventilator inlet ports.
4. Remove the hoses from the air and O_2 water trap assemblies.
5. Lock the 2 brakes on the ventilator cart casters.

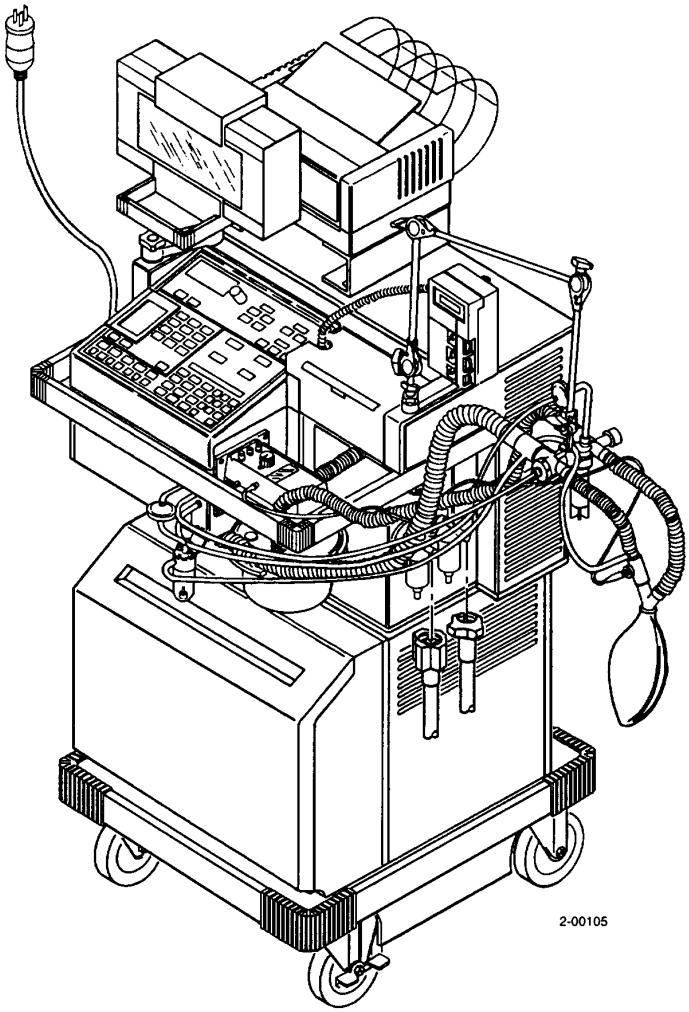


Figure 2. Ventilator accessories

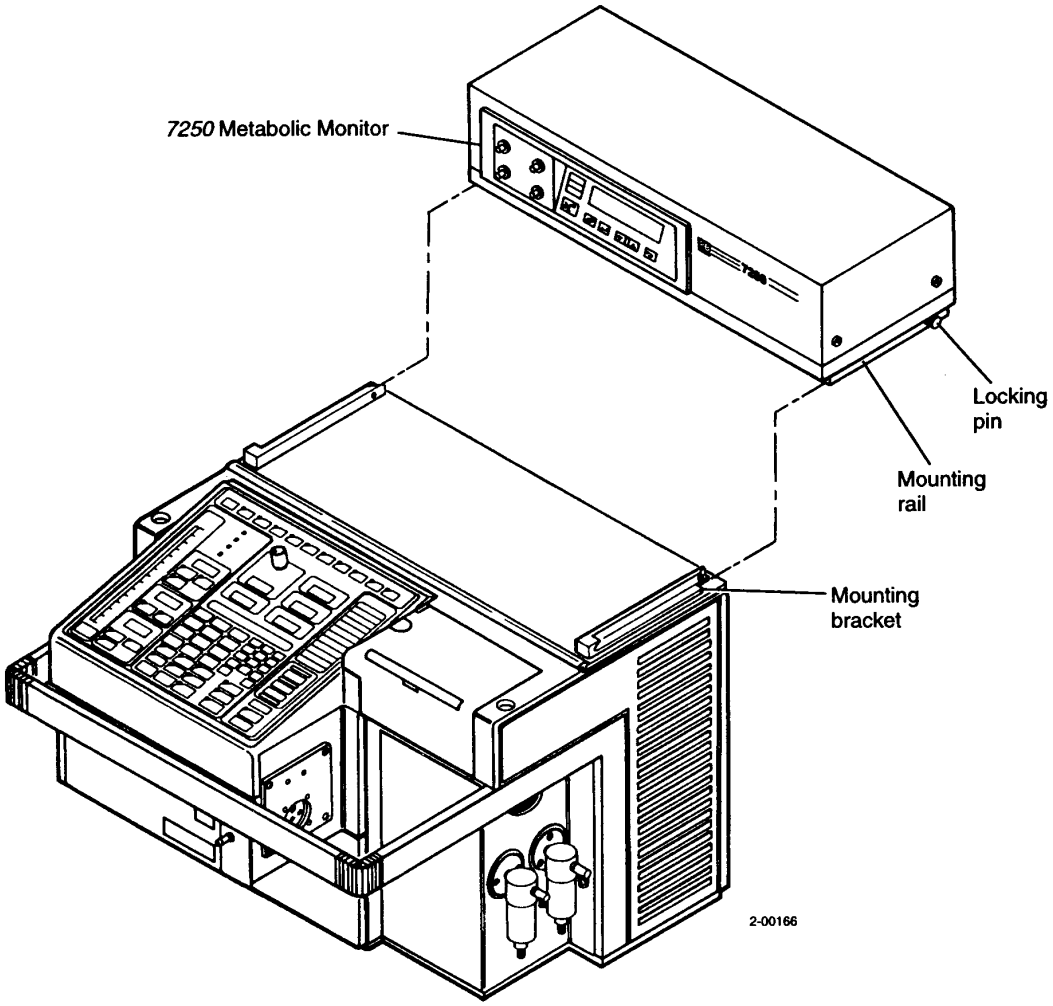


Figure 3. Remove metabolic monitor

Installation procedures

These instructions are written in a logical step-by-step sequence; however, the sequence is not rigid and can be modified to fit your maintenance style.

Replace incandescent lamps (basic keyboard)

Caution

To prevent a potential malfunction of the audible alarm during backup ventilation, inspect the replacement lamps to ensure any 14 V lamps are replaced with 12 V lamps. Refer to Figure 4 to identify 14 V lamps.

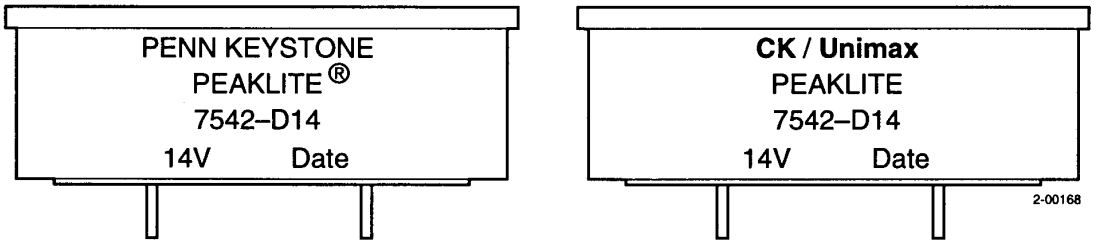


Figure 4. 14 V lamp identification

Note

Reference Figure 5 when performing this procedure.

Replace the incandescent lamps (12 V or 14 V) that light the NORMAL and CAUTION indicators.

1. Remove the 2 black flathead screws that secure the bezel to the keyboard. Set the bezel aside and discard the screws.
2. Remove the 2 lamps and discard.
3. Install the 2 replacement lamps (P/N 4-030198-00).
4. Replace the original bezel and secure with the 2 black oxide replacement screws (P/N 4-019351-00).

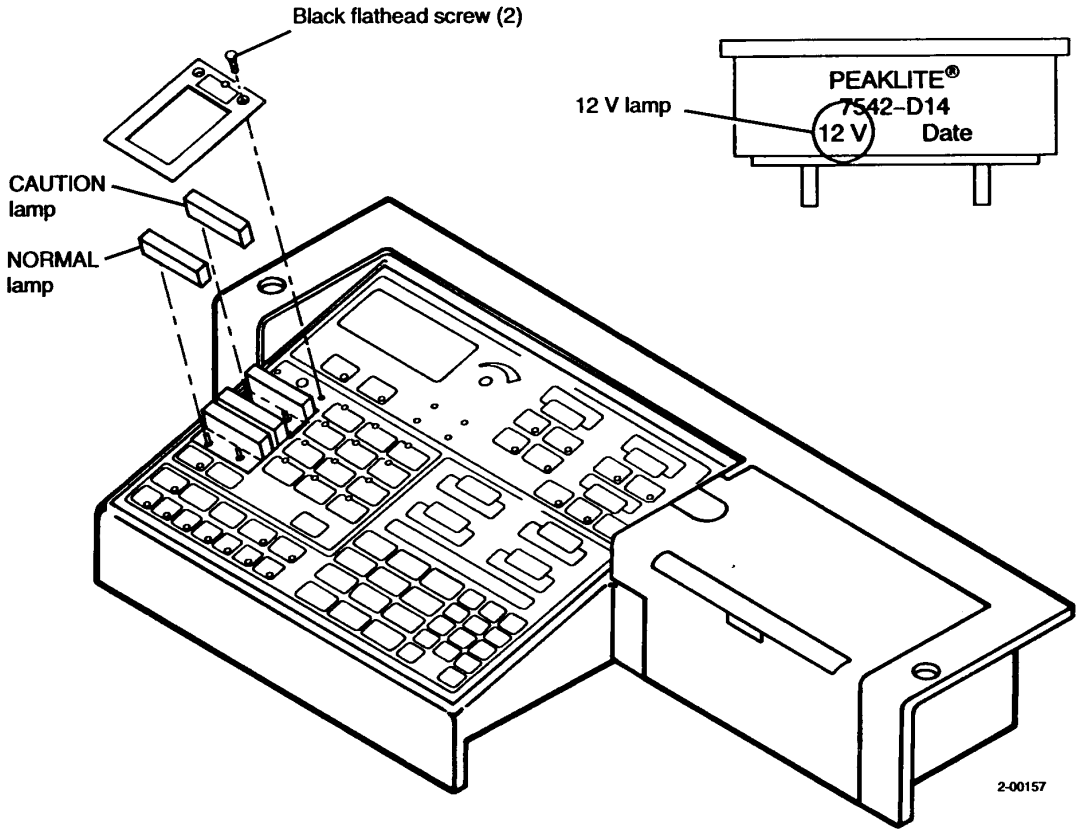


Figure 5. Lamp replacement

Rebuild water trap assemblies

Caution

To avoid damage to the threads of the intermediate- or latest-version bowls, do not interchange the bowls. These two versions of the water trap/filter assemblies look very similar, but the bowls have different threadings.

Note

Reference Figure 6 when performing this procedure.

1. Remove the air and O_2 water trap assemblies:
   a. Remove the **2 screws** that secure the O_2 water trap assembly to the mounting plate. Set water trap and hardware aside.
   b. Remove the **3 screws** that secure the air water trap assembly to the mounting plate. Set water trap and hardware aside.

c. Remove the bowls by turning counterclockwise. Empty the bowls to prevent residual moisture, at the bottom of the bowl, from entering the ventilator.

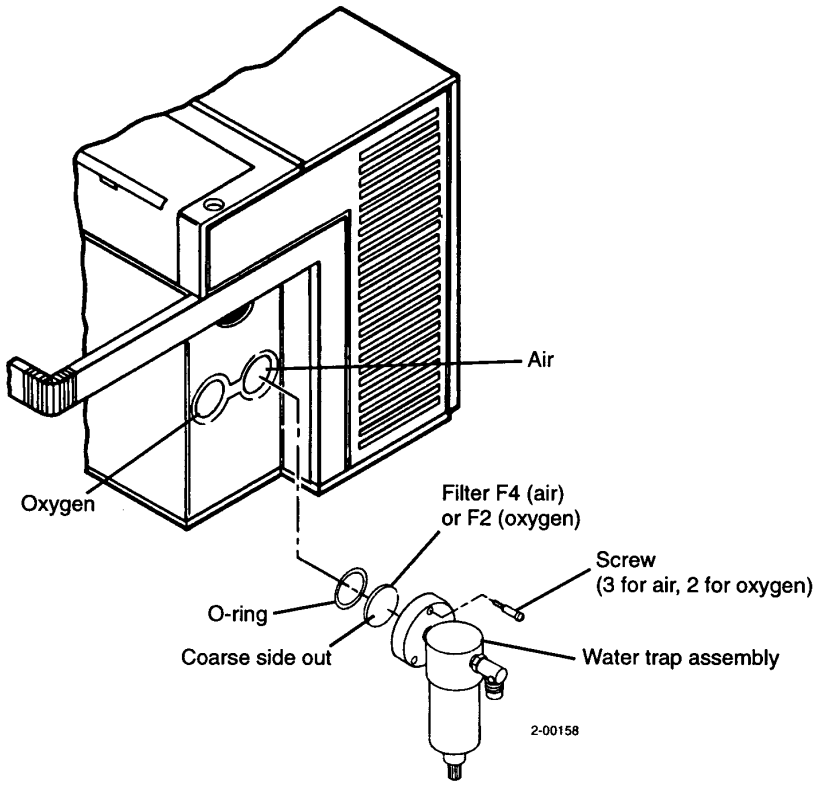


Figure 6. Replace water traps

Note

There are four versions of water trap assemblies (Figure 7). The 10K PM kit contains parts for all four versions. Discard any parts that do not apply to your ventilator.

2. Identify the type of water trap from Figure 7:
   - **Early version:** (blue head) push-pin drain valve.
   - **Later version:** (gray head) push-pin drain valve.
   - **Intermediate version:** (blue head) gold thumbscrew drain valve.
   - **Latest version:** (black head) black thumbscrew drain valve.
3. Disassemble the water traps and inspect the brass filter.

   If necessary, clean the brass filter with a solution of detergent and warm water. Rinse thoroughly in running water and dry with clean, dry compressed air

   or

   replace the brass filter with P/N 4-000034-00 (not provided in 10K PM kit).

4. Replace the filter elements and O-ring sets with the appropriate parts:
   - **Early version** use filter element (P/N 4-020282-00) and O-ring set (P/N 4-020285-00).
   - **Later version** use filter element (P/N 4-020282-00) and O-ring (P/N 4-008467-00).
   - **Intermediate version** If the existing water trap has an older filter with a shaft, discard both the filter and shaft and replace with the new filter element (P/N 4-018055-00). Replace the flat O-ring (P/N 4-016176-00).
   - **Latest version** use filter element (P/N 4-018055-00) and the round O-ring (P/N 4-016177-00).
5. Discard the old parts.
6. Rebuild the water trap making sure all O-rings, gaskets, and filter elements are properly seated.
7. Set the rebuilt water traps aside; do not reinstall at this time.

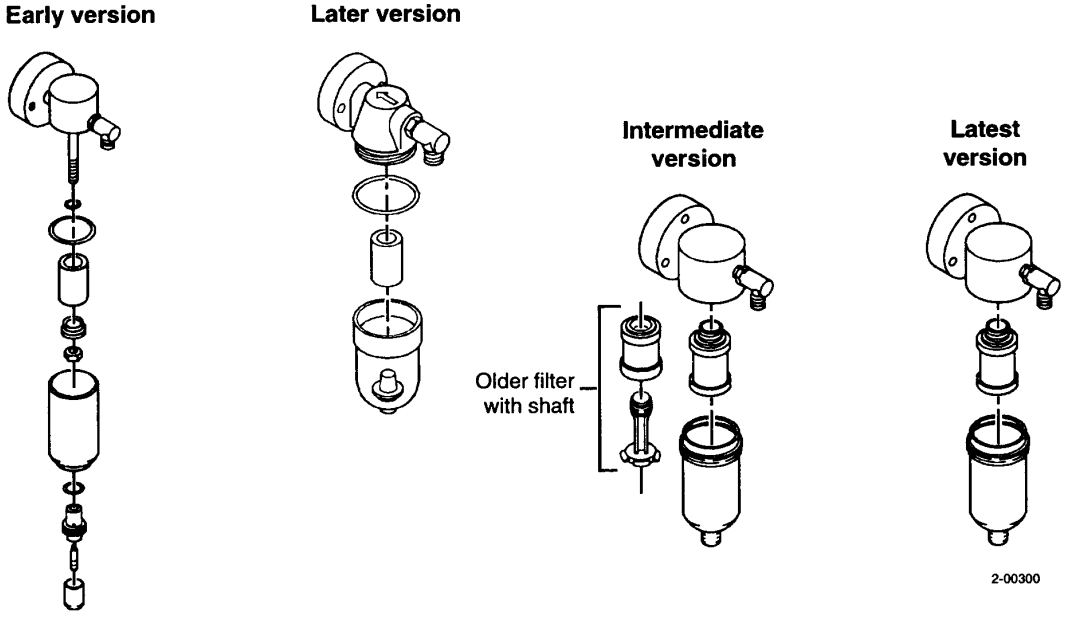


Figure 7. Water trap types

Remove panels

Note

Reference Figure 8 when performing this procedure.

1. Your ventilator has one of two top panel types: pop-on or screw-on.
   a. To remove the pop-on type, simply pop the top panel off the inner panel and set it aside.
   b. To remove the screw-on type, remove the 4 screws and washers and set the top panel and hardware aside.
2. If your ventilator's side door is held in place with 2 thumbscrews, located on the back panel, continue with this step; otherwise, go to step 3.
   a. Remove the 2 thumbscrews and set aside.
   b. If the side door has a stop bracket kit installed, remove the kit's 2 screws and washers; then swing the side door open.
      or
      If the side door does not have a stop bracket kit installed, simply open the side door.
   c. Remove the 2 screws and washers that secure the back panel to the ventilator. Set the back panel and hardware aside. Go to step 4.
3. Remove the 2 screws and washers that secure the back panel to the ventilator. Set the back panel and hardware aside.
4. If your ventilator is a 220/240 V unit perform the steps below; otherwise, go to step 5.

   Remove the 14 screws and washers that secure the inner back panel to the ventilator. Set the panel and hardware aside.
5. For side doors without the 2 thumbscrews, remove the 2 screws and washers that secure the door and set the hardware aside. Swing the door open.
6. The inner top panel does not have to be removed; however, if you wish to remove it, loosen the 4 screws on the back lip and remove the 4 screws on the top that secure it to the cabinet and lift the inner panel off. Set the inner panel aside.
7. If your ventilator has a pneumatic brace, remove the 4 screws and washers that secure the brace. Set the brace and hardware aside.

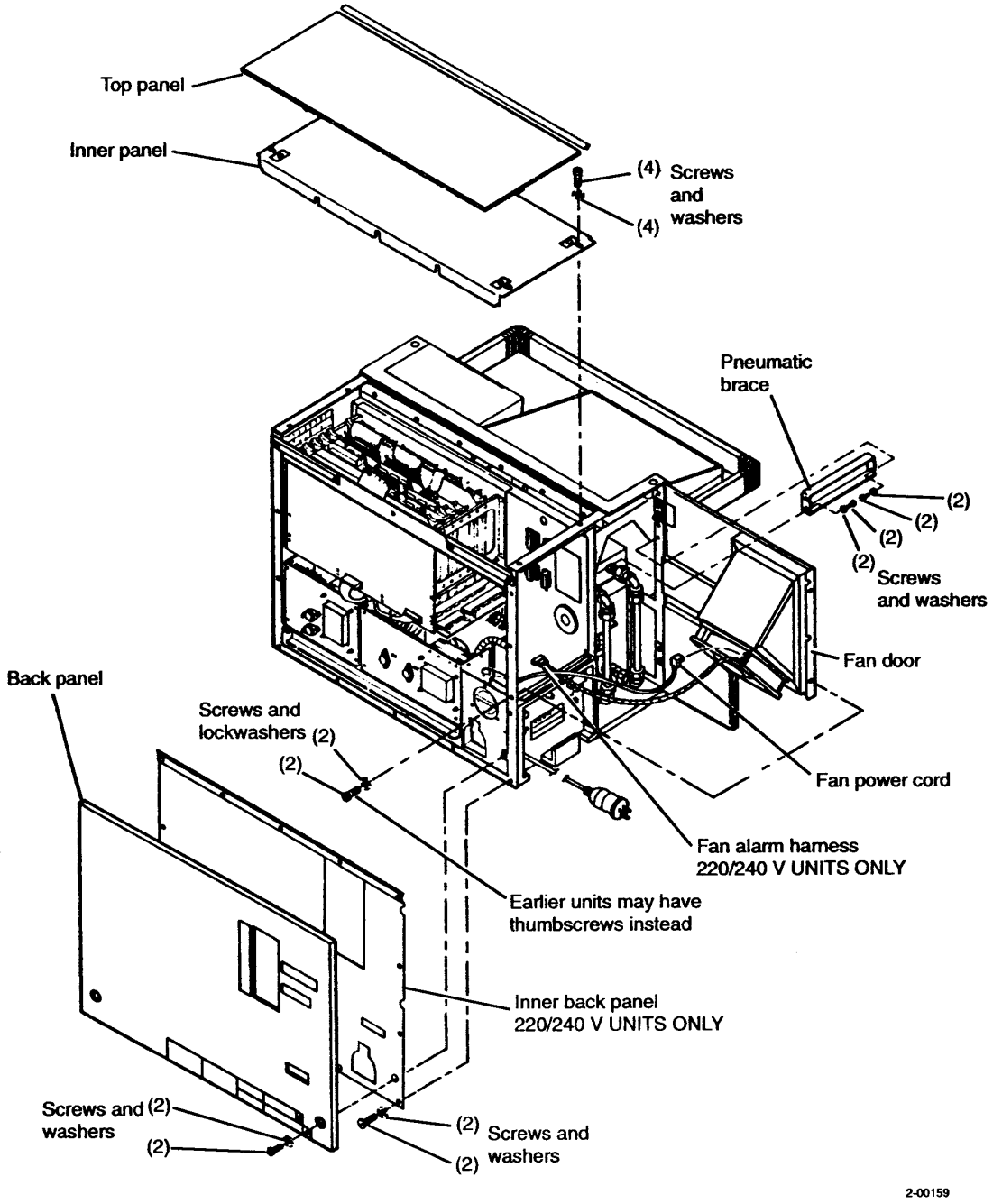


Figure 8. Remove panels

Raise console

Note

Reference Figure 9 when performing this procedure.

1. If your ventilator has a bottom-loading exhalation compartment, remove the 2 screws and washers that secure the front panel to the ventilator cabinet. Set the panel and hardware aside;

   or

   if your ventilator has a front-loading exhalation compartment, unlock the latch and open the panel.
2. Remove the 2 console retaining screws.
3. Open the main flow bacteria filter compartment door and remove the console retaining screw that attaches the upper-right corner of the console assembly to the ventilator cabinet. Set screw aside.
4. Raise and prop open the console assembly.
5. Detach the safety valve flex tube from the connector on the console assembly.
6. Detach the 2 tubes attached to REG5.

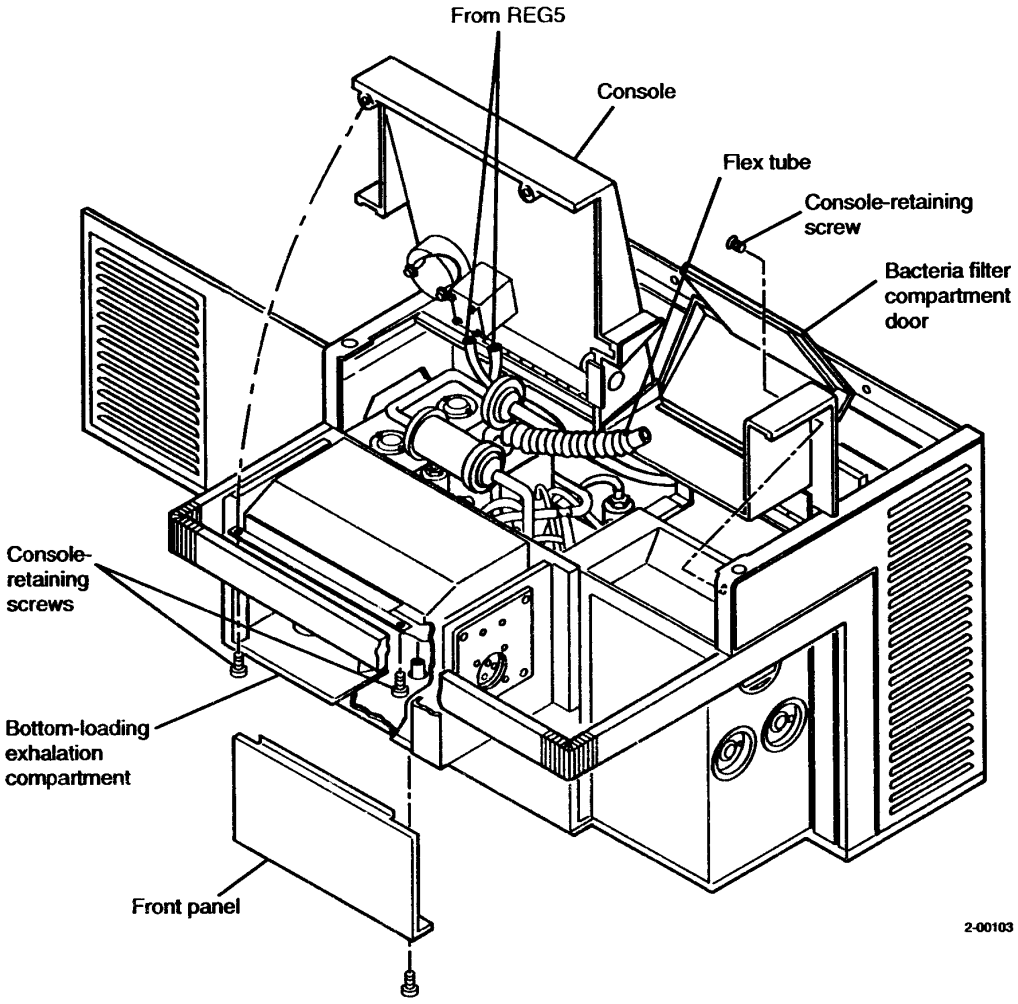


Figure 9. Raise console

Clip alarm wires on new fan

Caution

- Do not perform this procedure on 115 V or German 220/240 V ventilators.
- This procedure is performed on the **new** fan supplied with the kit P/N 4-021216-00 (for 220/240 V non-German ventilator).

Note

Reference Figure 10 when performing this procedure.

1. Using your fingernail, or a blunt-tip instrument, press the clip to release the harness connector, then pull the harness out.

Caution

Be careful not to damage the coated harness next to the red, white, and black wires.

2. Pull out the fan wires (shown in the diagram below) as far as they will go.
3. Cut the red, white, and black wires as close to the fan body as possible.
4. Making sure not to pinch the coated fan harness, reassemble the connector to the fan.

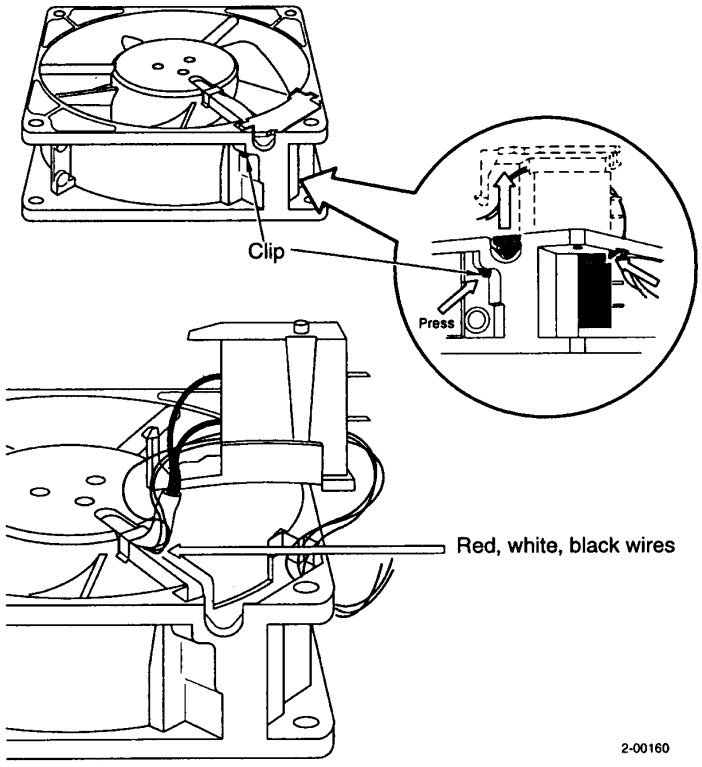


Figure 10. Clip alarm wires on new fan (non-German 220/240 V)

Clean fan filter and replace fan

Note

Reference Figure 11 when performing this procedure.

Caution

To prevent overheating ventilator components, be sure the flow arrow on the fan points toward the inside of the ventilator.

Fan access door with removable louver panel

1. Remove the louver panel by popping the bottom of the panel out of the fan access door. Set panel aside.
2. Remove the filter by grasping the tab at the bottom of the filter and pulling it out.
3. Clean the filter by vacuuming or washing with a mild detergent, then rinsing and drying thoroughly. Set filter aside.
4. Disconnect the fan power cord.

   For German 220/240 V ventilators, disconnect the fan harness from the utility panel.

Caution

Be sure to follow the procedure below; otherwise, the four fan screws will break.

5. Detach the door's outer finger guard by removing the 4 nuts, lockwashers, and washers. Set finger guard and hardware aside.
6. Detach the door's inner finger guard and fan by removing 4 screws, lockwashers, and washers. Set finger guard and hardware aside. Discard the fan.
7. Install the replacement fan (P/N 4-019135-00 for the 115 V ventilator or P/N 4-021216-00 for the 220/240 V ventilator) and filter by reversing this procedure.

Fan access door with nonremovable panel

1. The filter sits between the outside panel and the fan. Remove the filter by sliding it up and out of the fan access door.
2. Clean the filter by vacuuming or washing with a mild detergent, then rinsing and drying thoroughly.
3. Disconnect the fan power cord.

   For German 220/240 V ventilators, you must also disconnect the fan harness from the utility panel.

Note

Some earlier version ventilators have two sets of screws and washers that attach the fan and finger guard; one set securing the fan to the access door and one set securing the finger guard to the fan. If this is the case, replace the 2 sets of screws with the longer type screw (P/N 4-002568-00) as shown in Figure 11.

4. Detach the fan and finger guard by removing the 4 screws, lockwashers, and flat washers that secure the fan to the inside of the fan access door. Set finger guard and hardware aside. Discard the fan.
5. Install the replacement fan (P/N 4-019135-00 for the 115 V ventilator or P/N 4-021216-00 for the 220/240 V ventilator) and filter by reversing this procedure.

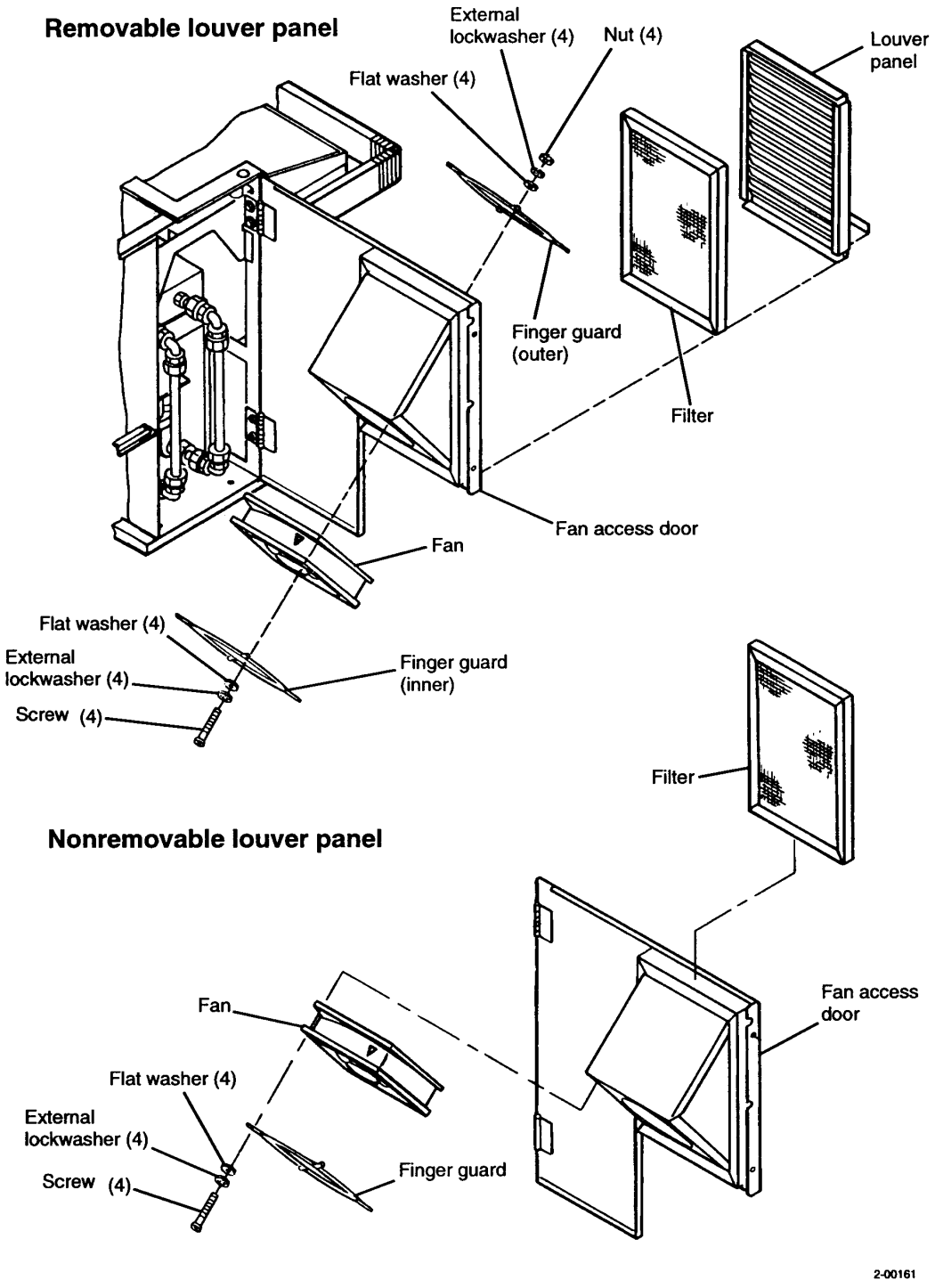


Figure 11. Replace fan and clean filter

Replace batteries and power switch

Note

Reference Figure 12 when performing these procedures.

Battery replacement

1. Disconnect the utility harness from the motherboard at the J11 connector.
2. Slide the 2 batteries and battery liner out from the utility panel and disconnect the batteries from the battery connector. Set the batteries aside; do not discard.
3. Clean the battery terminals if oxidized.
4. Place the new batteries (P/N 4-021526-00) in the liner and connect the terminals to the battery connector. Slide the batteries (in liner) into the utility panel.
5. Reconnect the utility harness to the motherboard at J11.

Warning

To avoid an accidental shorting and to prevent a fire hazard, do not discard the batteries. Dispose of them appropriately as described below.

6. Repackage the old batteries in the same way the new batteries were packaged (positive terminals taped, terminals in foam).
7. Recycle the old batteries by returning them in the return mailer or dispose of them as instructed on the mailer.

Power switch replacement

1. Disconnect the white and brown connectors from the power switch.
2. Remove the power switch by pressing the top and bottom of the switch while pushing out. Discard the power switch.
3. If the new switch does not fit into the switch opening, remove the utility panel and use a metal file to lightly file the right or left sides (not top and bottom) of the aluminum plate opening. Smooth out the rough edges with a piece of sandpaper.

Caution

Metal filings can seriously damage ventilator electronics.

4. Carefully vacuum any filings from the utility panel.
5. Install the new switch (P/N 4-012411-00) and reconnect the white and brown connectors.
6. Test the new switch:
   a. Reconnect electrical power to the ventilator.
   b. Turn the ventilator power switch ON then OFF to ensure it actuates freely.
   c. Disconnect electrical power.

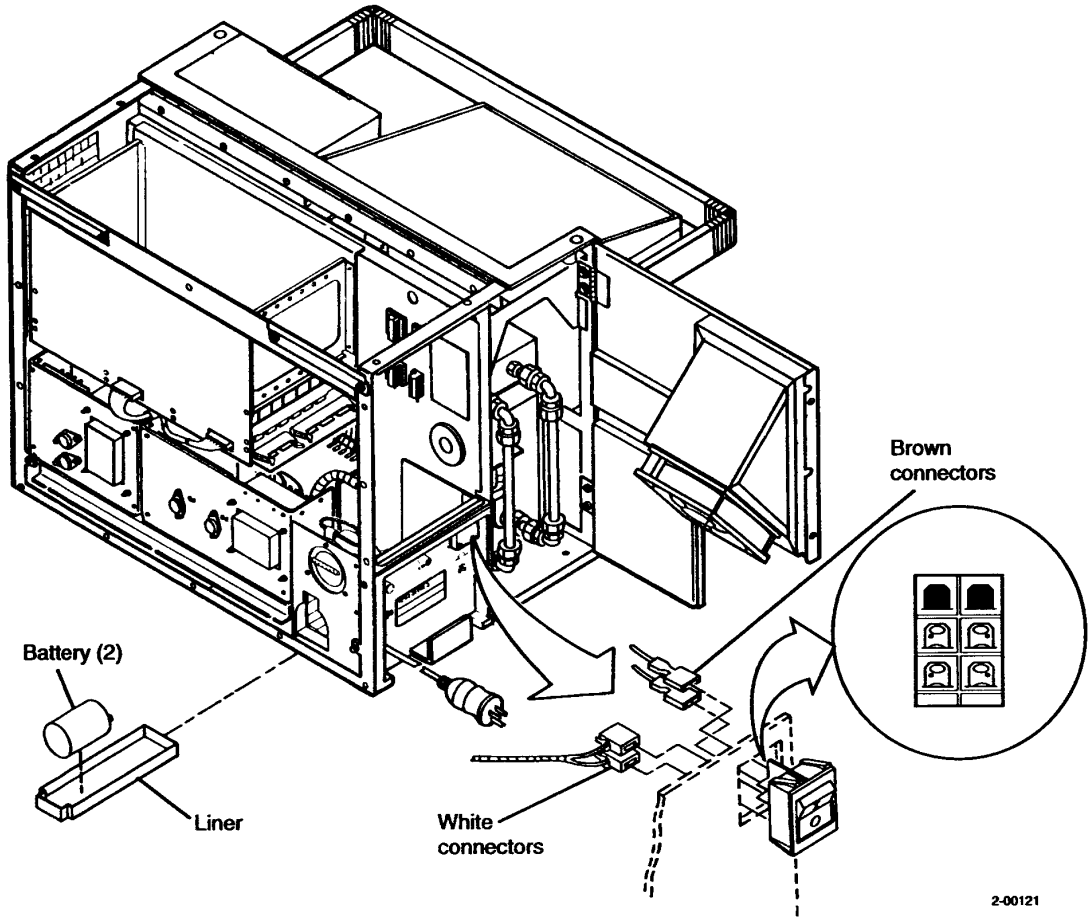
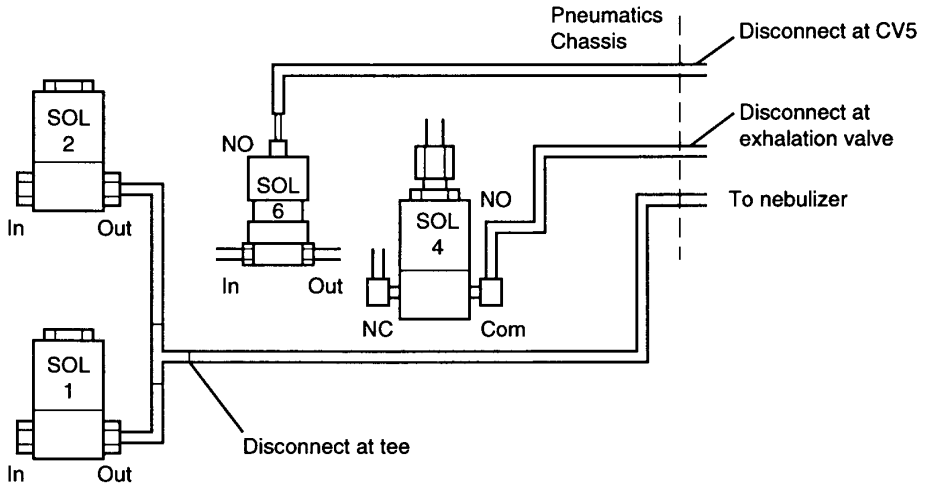


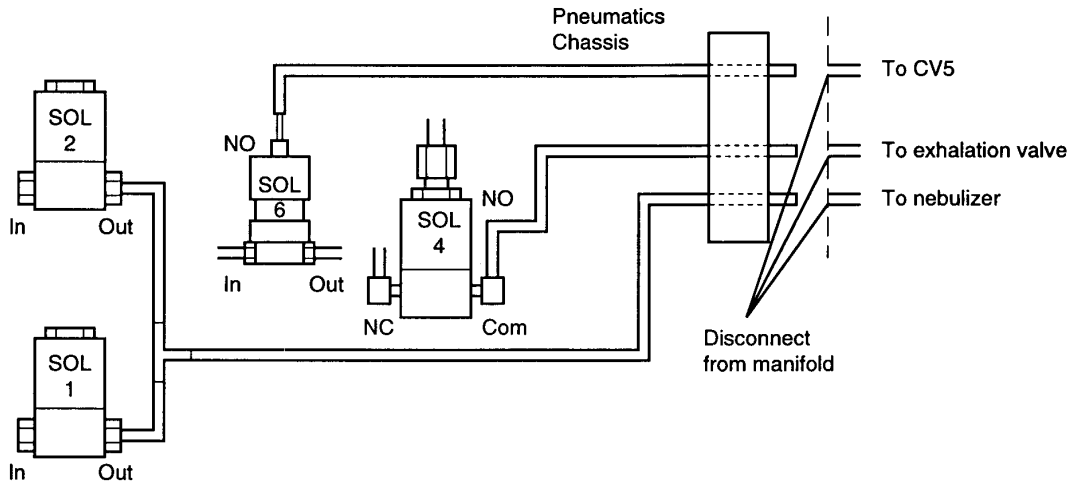
Figure 12. Replace batteries and power switch

Disconnect tubing

Disconnect the tubing between the pneumatic chassis and the exhalation compartment (Figure 13).



Later Version



Earlier Version

Figure 13. Disconnect tubing between pneumatic chassis and exhalation compartment

Remove pneumatic chassis

Caution

- To prevent possible electrostatic damage to the pressure transducer PCB, use a static-dissipative service kit when handling the pneumatic chassis.
- Flow sensors are very fragile and must be protected from debris of any kind. Debris contacting a sensing element will destroy the sensor.
- When loosening the nuts to remove the sensors, be sure not to lose any O-rings. If O-rings are not reinstalled, leakage may occur.

Note

Reference Figure 14 when performing this procedure.

1. Swing open the fan access door.
2. Remove pneumatic chassis foam insulation inserts.
3. Leaving the harness connected and elbows on, remove the oxygen and air sensor assemblies (Q1/T1 and Q2/T2) from the pneumatic chassis assembly by unscrewing the upper-most and bottom-most plastic nuts. Gently pull the sensor/elbow assembly toward you to disconnect. Lay the sensor assemblies on top of the exhalation compartment.
4. If the ventilator does not have a compressor, go to step 5
   or
   if the ventilator has a compressor, remove the compressor vent silencer (located between the sensors) and disconnect the compressor flow tube from the barbed plastic elbow connector.
5. Remove the 2 screws and washers that secure the pneumatic chassis to the ventilator cabinet. Set hardware aside.
6. Disconnect the pneumatic chassis harness from the motherboard at the J10 connector.
7. Slide the pneumatic chassis out through the side of the cabinet.

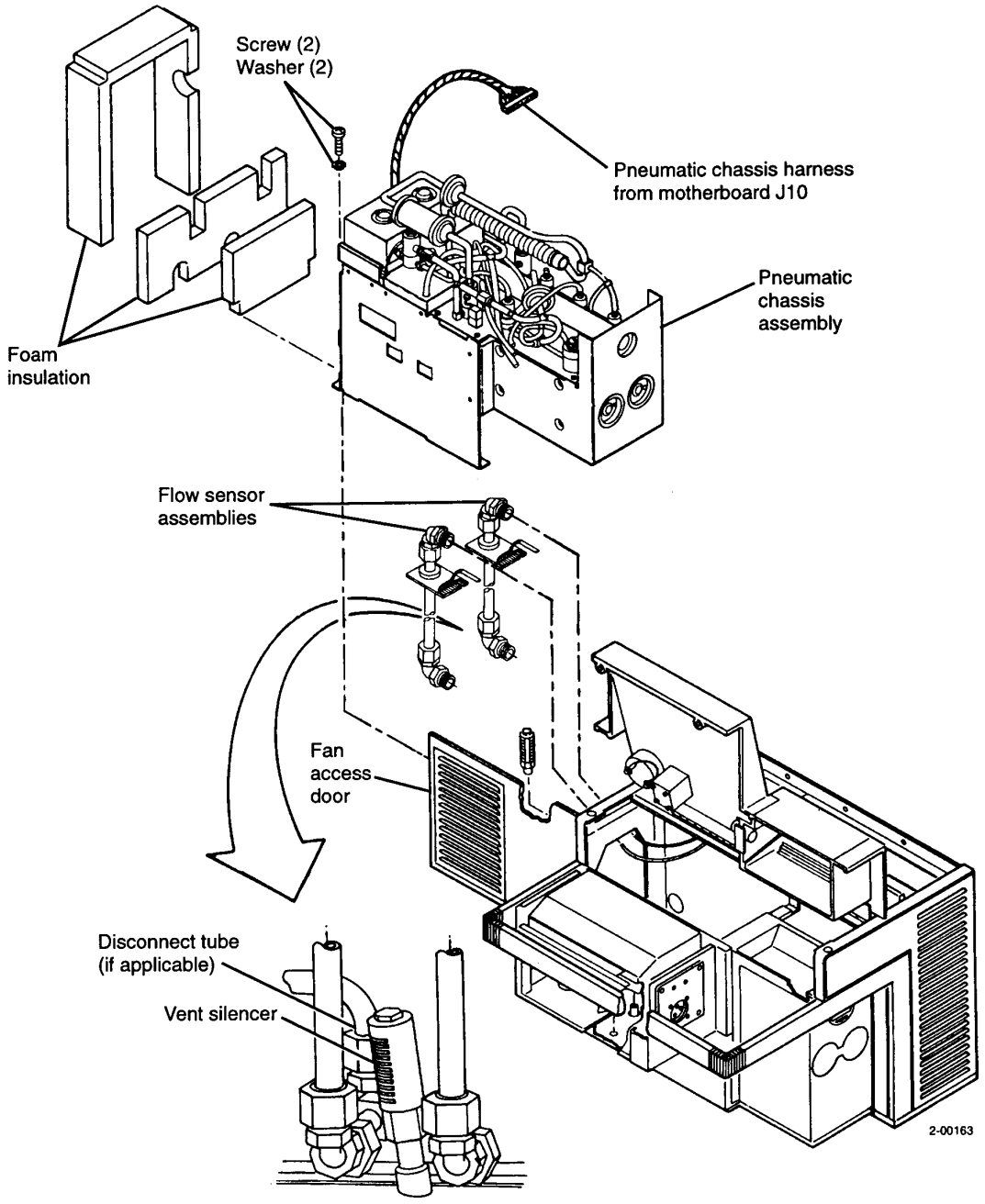


Figure 14. Remove pneumatic chassis

Remove REG1 and REG2

Note

- Do **not** install the new REG1 and REG2 assemblies at this point.
- Reference Figure 15 when performing this procedure.

This procedure describes how to remove REG1 first, followed by the removal of REG2.

1. Lay the pneumatic chassis on its side with the pressure transducer PCB on the bottom.
2. Remove REG1 (oxygen) assembly first then remove REG 2 (air) assembly.
   a. Remove the copper tubing (with nuts and ferrules) by disconnecting it from the brass nipple at the PS1 (PS2) tee. Discard tubing and hardware.

Note

The horizontal part of the REG1 copper tube is longer than the horizontal part of the REG2 copper tube.

   b. Remove the 2 bolts (with 7/16" hex head) and lockwashers that secure REG1 (REG2) to the pneumatic chassis plate. Remove regulator and set hardware aside.
   c. Label, then disconnect, the leads from PS1 (PS2).
   d. Disconnect the tubing between REG1 and the manifold vent. Discard the tubing.
   e. Disconnect the tubing, at the REG1 (REG2) pressure port, that runs to SOL3.
   f. Remove REG1 (REG2) and discard.
   g. If your ventilator does not have a compressor, continue to the procedure entitled "Replace SOL2, air capacitor, R4, F7, and F8."
   or
   If your ventilator has a compressor, remove the plug from the top of the new REG2 (P/N 4-020277-00) and replace it with the elbow from the old REG 2.

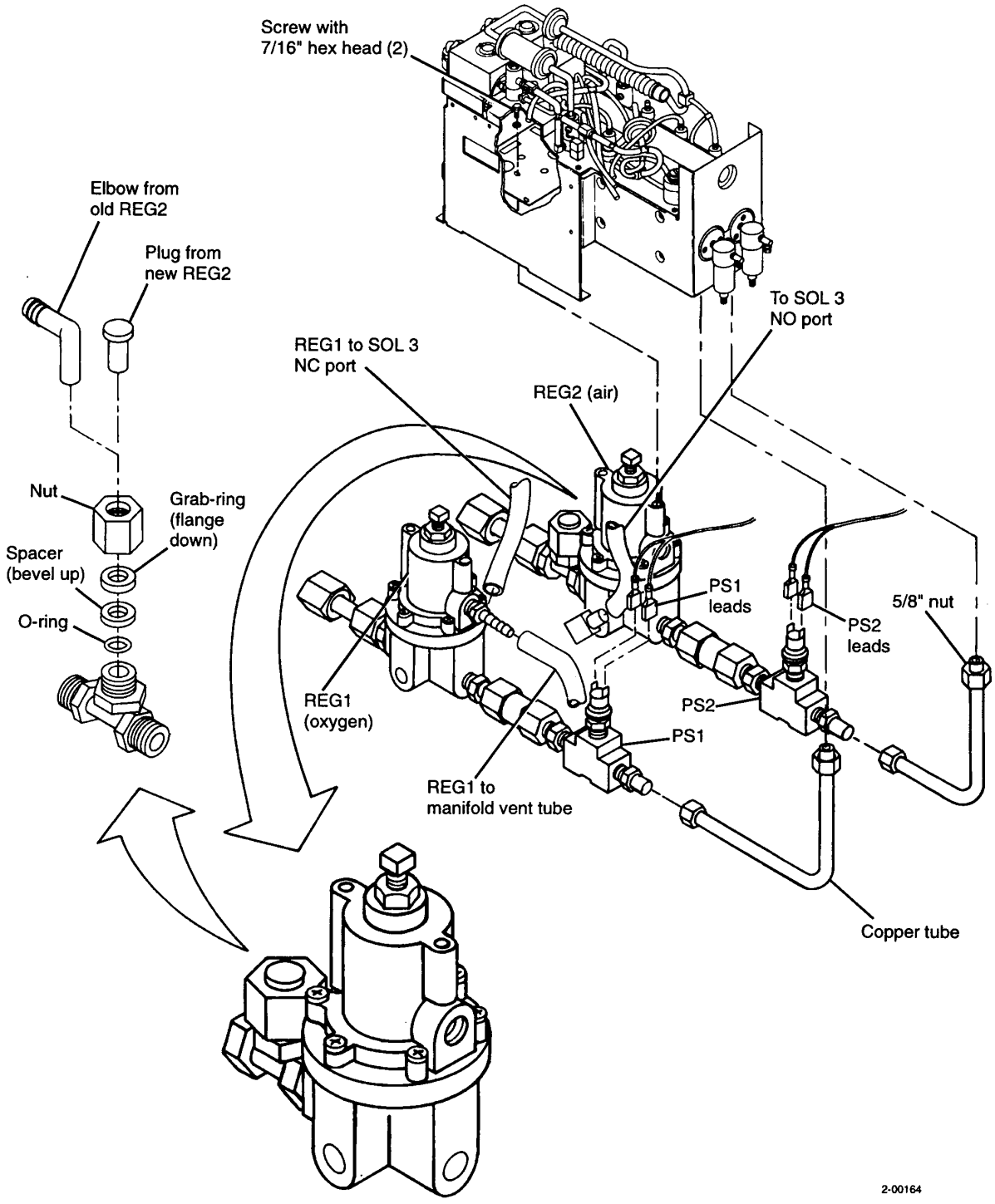


Figure 15. Remove REG1 and REG2

Replace SOL4, air capacitor, R4, F7 and F8

Note

Reference Figure 16 when performing this procedure.

1. Disconnect the electrical connector from SOL4.
2. Label, then disconnect, the tubes connected to SOL4.
3. Remove the 2 mounting screws and lockwashers that secure SOL4 to the mounting plate. Discard SOL4 and set hardware aside.
4. Replace SOL4 (P/N 4-019344-00) by securing to the mounting plate using the 2 screws and lockwashers.
5. Disconnect the air capacitor, R4 tubing assembly, and bacteria filter (F8) and discard.
6. Replace the air capacitor (P/N 4-011413-00), R4 tubing assembly (P/N 4-000314-00), and the bacteria filter assembly (P/N 4-011905-00).
7. Replace the (F7) pilot pressure outlet filter (P/N 4-011905-00).
8. Check to verify that R5 is installed; if missing, install (P/N 4-019407-00).

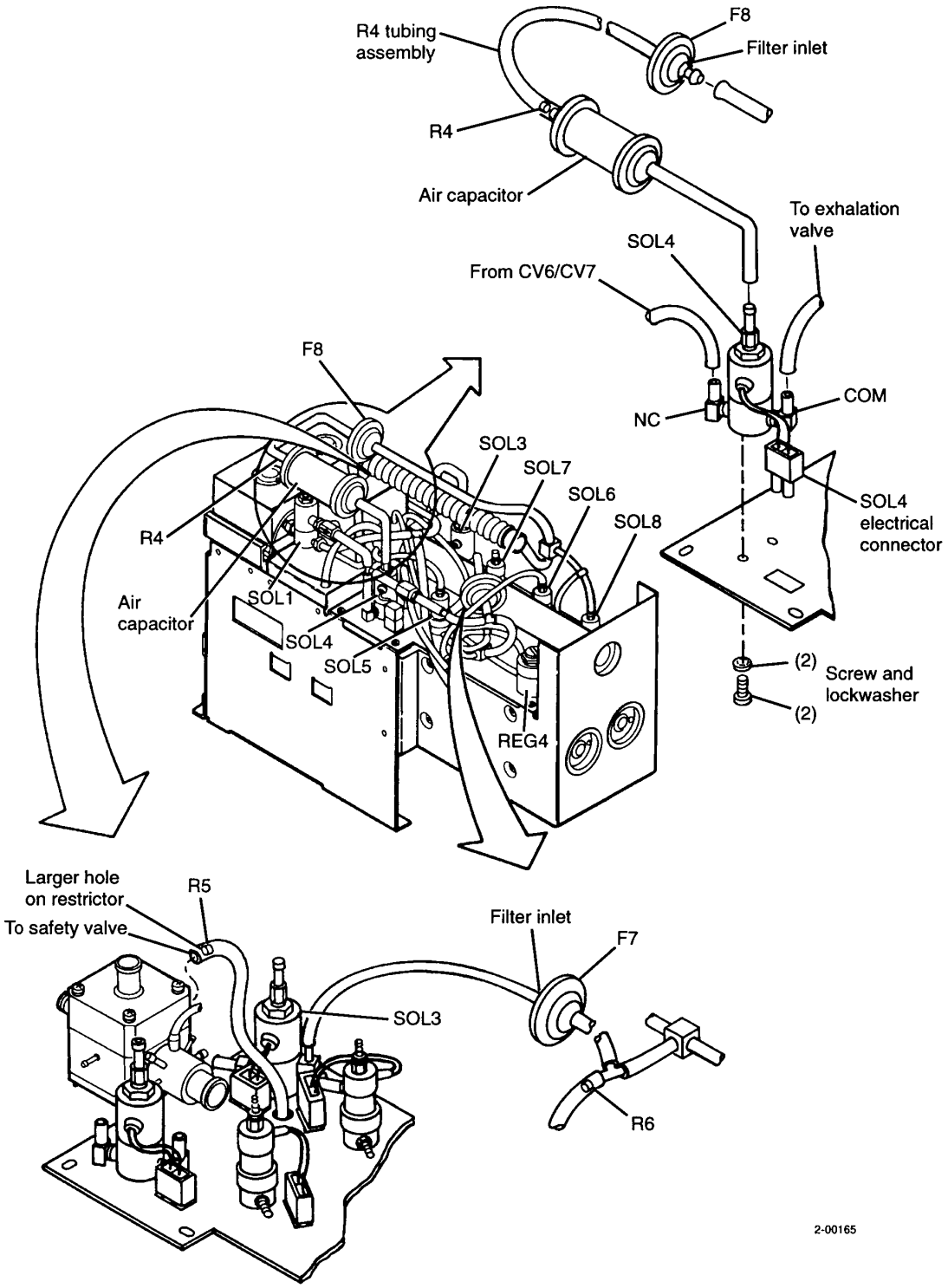


Figure 16. Replace air capacitor, R4 tubing assembly, and filters

Install REG1 and REG2

Caution

The copper tube (with nut and ferrule) can be fitted easily to the regulator if it is connected to the regulator *before* the regulator is mounted in place. Any binding of the parts will prevent you from feeling the increased resistance when the nut engages the ferrule. The nuts should be tightened until the resistance increases, and then, by a 1/4 turn more. Over tightening *does not* improve the integrity of the connection and may require the tube, nut, and ferrule to be replaced.

Note

When installing REG1 and REG2, apply a small amount of Krytox grease (P/N 4-732130-00) to each ferrule before tightening the nuts.

1. Install the REG1 (O_2 regulator assembly) (P/N 4-020276-00), including the nut and spacer (4-019587-00), grab-ring (P/N 4-019588-00), and the O-ring (P/N 4-019589-00) by reversing the "Removing REG1 and REG2" procedure.
2. Install the REG2 (air regulator assembly) (P/N 4-020277-00), including the nut and spacer (4-019587-00), grab-ring (P/N 4-019588-00), and the O-ring (P/N 4-019589-00) by reversing the "Remove REG1 and REG2" procedure.
3. With the pneumatic chassis removed, connect the inlet water trap assemblies to the pneumatic chassis.

Purge the system

1. Connect the high-pressure air and high-pressure oxygen source to the air and O_2 inlet valves.
2. Allow gas to purge the pneumatics for 5 seconds.

Test REG1 and REG2

After the air and O_2 regulators are purged, the high-pressure side of the pneumatics should be checked for leaks.

1. Attach the flow sensors to the pneumatic chassis.
2. Connect the respective high-pressure gas to the gas inlets (nominal 50 psig pressure is required).

Note

- Applying leak detector (P/N 4-004489-00 or equivalent) to metal parts will not cause corrision. Any leak detector meeting Mil L 25567 D may be substituted.
- Leak-detector fluid may be transferred, for use, into a smaller container. The container should be of similar material (as the original container) and labeled with the identical part number, lot code, and expiration date.

3. Using a leak-test fluid, apply (with small brush) to all metal fittings, connections, and adapters located between the water trap outlet and regulator inlet port.

4. Check for bubbles at all fittings and connections. If bubbles form, a leak is present and must be repaired. Loosen or tighten the fitting where the leak is present. If this does not eliminate the leak, the part causing the leak must be replaced.
5. Use a clean cloth to remove the leak detector.
6. Remove the air and oxygen water trap assemblies and flow sensors.

Reinstall pneumatic chassis and water trap assemblies

Caution

When reinstalling the pneumatic chassis, **do not** install the flow sensors or insulation at this time.

1. Reinstall the pneumatic chassis by reversing the procedures "Remove pneumatic chassis" followed by "Disconnect tubing."
2. Reinstall the water trap assemblies by reversing step 1 in the procedure entitled "Rebuild water trap assemblies."

Reinstall flow sensors and insulation

1. Reinstall the oxygen and air sensor assemblies (Q1/T1 and Q2/T2) to the pneumatic chassis by screwing the upper-most and bottom-most plastic nuts to the pneumatic chassis (Figure 14).
2. Reinstall the foam insulation inserts (Figure 14).

Finish ventilator reassembly and test

1. Reconnect the fan's alarm harness and power cord.
2. Lower the console and reconnect the flex tube between the safety valve and the white console connector.
3. Reinstall the accessories required to run the performance verification.
4. Run the ventilator performance verification as described in Section 7 of the service manual.
5. Replace the 3 console retaining screws: one in the upper-right corner of the console and the two in the exhalation compartment.
6. Replace the exhalation compartment front panel, or close the panel and lock in place, whichever is applicable (Figure 9).
7. Replace the ventilator cabinet panels by reversing the procedure entitled "Remove panels."
8. Replace the *7250* metabolic monitor if applicable (Figure 3).
9. If a *7250* metabolic monitor is installed, perform a volume calibration (as described in the *7250 Metabolic Monitor Operator's Manual*) to restore calibration constants to the ventilator BBR.

Record 10K PM installation

Note

- Two Preventive Maintenance Record labels are supplied. Place the 2,500-hour label under the clear cover of the 10,000-hour PM label.
- Reference Figure 17 for label placement.

1. Fill out the 5-year warranty maintenance record
   or
   fill out and attach the Preventive Maintenance Record label.
2. Apply the label to a clean dry surface and rub in place to secure.

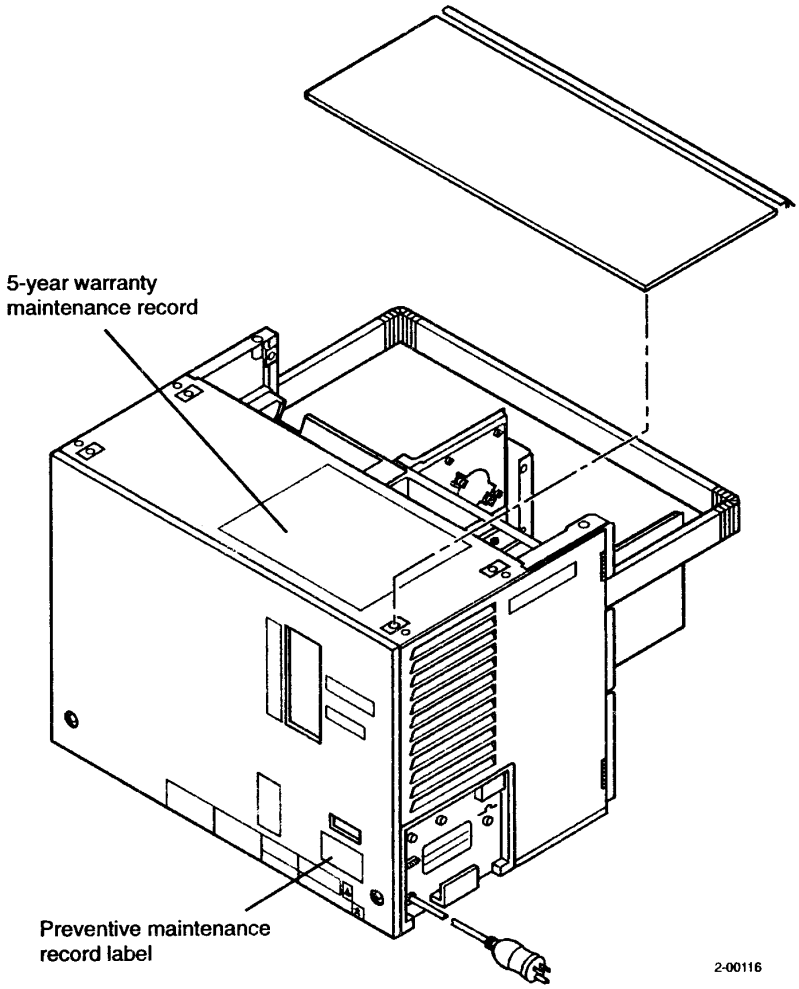


Figure 17. Record the 10K PM

Performance Verification Record Proforma

MALLINCKRODT

SERVICE DIVISION

PERFORMANCE VERIFICATION RECORD

7200 SERIES VENTILATOR

Serial Number: _____
Asset ID Number: _____
Customer: _____ Service Recap Number: _____

Model Number: ☐A ☐SP ☐SPI ☐E ☐SPE ☐AE	Last Vent. 10K PM Hours
Software Revision/Option Code	Last Comp 10K PM Hours
Ventilator Hours	Compressor Hours
7202 Display ☐ N/A S/N _____	☐ Verified

Memory Codes				EST Codes			
Code	Date	Time	Address	Code	Date	Time	Address
1.				1.			
2.				2.			
3.				3.			
4.				4.			
5.				5.			
6.				6.			

Calibrated Test Equipment	Manufacturer	Model	Serial Number	Cal Due
Electrical Safety Analyzer	Dynatech	234D or 235		
	Bio-Tek	601 PRO		
	Dale	600		
Pneumatic Analyzer				
Oxygen Analyzer				
Digital Multimeter	Fluke	87		

Performance Verification Tests Chapter 7.6 of the *7200 Series* Service Manual				
7.6.1	Electrical Safety Tests	Target	Actual	Adjusted
	Ground Resistance	<0.1 OHM	Ω	Ω
	Forward Current Leakage	➢ ≤100µA @ 100/115Vac ➢ ≤500µA @ 220/240Vac	uA	uA
	Reverse Current Leakage	➢ ≤100µA @ 100/115Vac ➢ ≤500µA @ 220/240Vac	uA	uA
	Current Draw w/ Compressor	<10A @ 100/115Vac <4.8A @ 220Vac <4.6A @ 240Vac	A	A
	Current Draw w/o Compressor	<4.9A @ 110Vac <5.3A @ 115Vac <2.5 @ 220/240Vac	A	A
	Cooling Fan Operation	Ventilator: ☐ Verified	Compressor: ☐ Verified ☐ N/A	
7.6.2	Power-On Self Test	☐ Verified		
7.6.3	Total EST	☐ Verified		
7.6.4	Battery-Backed Ram Test	☐ Verified		
7.6.5	Lamp Test	☐ Verified		
7.6.16	Heated Exhalation Bacteria Filter	☐ Verified		
	Power Disconnect Alarm	☐ Verified		
7.7	OK to Return to Patient Use	☐ Yes ☐ No		

Parts Used:
☐ None

Support Engineer: _____ Date: _____

Section 6 of Manual.
+ Cable

Service Recap Number: _____

7.6.6 Analog Output Connector Test		Target	Actual (2 & 3) Adjusted		Actual (6 & 7) Adjusted	
0 Vdc		-0.5 to +0.5 Vdc	Vdc	Vdc	Vdc	Vdc
+2.5 Vdc		+2.00 to 3.00 Vdc	Vdc	Vdc	Vdc	Vdc
+5.0 Vdc		+4.50 to 5.50 Vdc	Vdc	Vdc	Vdc	Vdc
+7.5 Vdc		+7.00 to 8.00 Vdc	Vdc	Vdc	Vdc	Vdc
+10.0 Vdc		+9.50 to 10.50 Vdc	Vdc	Vdc	Vdc	Vdc
7.6.7 Power Supply Test			Actual		Adjusted	
+5 Vdc	Pin 9+ & Pin 11-	+4.95 to +5.05 Vdc	Vdc		Vdc	
+12 Vdc	Pin 13+ & Pin 11-	+11.88 to +12.12 Vdc	Vdc		Vdc	
+15 Vdc	Pin 7+ & Pin 5-	+14.85 to +15.15 Vdc	Vdc		Vdc	
-15 Vdc	Pin 4+ & Pin 5-	-15.15 to -14.85 Vdc	Vdc		Vdc	
7.6.8 Keyboard Test		☐ Verified				
7.6.9 Gas Supply System Test			Actual		Adjusted	
Wall Air Regulator		9.9 - 11.0 PSIG	PSIG		PSIG	
Compressor		9.9 - 11.0 PSIG	PSIG		PSIG	
Oxygen Regulator		9.9 - 11.0 PSIG	PSIG		PSIG	
7.6.10 Peak Inspiratory Flow Test			Actual		Adjusted	
Oxygen Maximum Flow		≥162 LPM	LPM		LPM	
Wall Air Maximum Flow		>162 LPM	LPM		LPM	
Compressor Maximum Flow		>110 LPM	LPM		LPM	
Compressor Minimum Pressure, Max Flow		>7.4 PSIG	PSIG		PSIG	
7.6.11 High Pressure Alarm, Alarm Volume, Nurses Call		☐ Verified				
7.6.12 Gas Volume Accuracy Test			Actual		Adjusted	
Oxygen - .25 L		0.22 - 0.30 L	L		L	
Oxygen - 1.5 L		1.40 - 1.75 L	L		L	
Air - 1.5 L		1.44 - 1.82 L	L		L	
Air - .25 L		0.23 - 0.30 L	L		L	
7.6.13 Sensitivity Accuracy Test			Actual		Adjusted	
10 cmH_2O		-9 to -11 cmH_2O	cmH_2O		cmH_2O	
5 cmH_2O		-4 to -6 cmH_2O	cmH_2O		cmH_2O	
0.5 cmH_2O		≅ -0.5 cmH_2O	cmH_2O		cmH_2O	
7.6.14 Oxygen Percentage Accuracy			Actual			
30% O_2 w/Square Wave		27 - 33%	%		%	
30% O_2 w/Ramp Wave		27 - 33%	%		%	
60% O_2 w/Ramp Wave		57 - 63.9%	%		%	
60% O_2 w/ Square Wave		57 - 63%	%		%	
80% O_2 w/ Square Wave		76 - 84%	%		%	
80% O_2 w/Sine Wave		76 - 84%	%		%	
7.6.15 Peep System Test			Actual		Adjusted	
10 cmH_2O		8 - 12 cmH_2O	cmH_2O		cmH_2O	
30 cmH_2O		27 - 33 cmH_2O	cmH_2O		cmH_2O	
Maximum		>45 cmH_2O	cmH_2O		cmH_2O	
Exhalation Pilot Pressure, 0 cmH_2O		☐ Verified				

Support Engineer: _____ Date: _____