840 Service Manual

Ventilator System

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Copyright information

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Definitions

This manual uses three special indicators to convey information of a specific nature. They include:

Warning

Indicates a condition that can endanger the patient or the ventilator operator.

Caution

Indicates a condition that can damage the equipment.

NOTE:

Indicates points of particular interest that make operation of the ventilator more efficient or convenient.

Warnings, cautions, and notes

Please take the time to familiarize yourself with the following caveats as they cover safety considerations, special handling requirements, and regulations that govern the use of the *840* Ventilator System.

- To ensure proper servicing and avoid the possibility of physical injury, only qualified personnel should attempt to service or make authorized modifications to the ventilator.

  The user of this product shall have sole responsibility for any ventilator malfunction due to operation or maintenance performed by anyone not trained by Puritan Bennett staff.
- To avoid an electrical shock hazard while servicing the ventilator, be sure to remove all power to the ventilator by disconnecting the power source and turning off all ventilator power switches.
- To avoid a fire hazard, keep matches, lighted cigarettes, and all other sources of ignition (e.g., flammable anesthetics and/or heaters) away from the *840* Ventilator System and oxygen hoses.

  Do not use oxygen hoses that are worn, frayed, or contaminated by combustible materials such as grease or oils. (Textiles, oils, and other combustibles are easily ignited and burn with great intensity in air enriched with oxygen.)

  In case of fire or a burning smell, immediately disconnect the ventilator from the oxygen supply, facility power, and BPS.
- When handling any part of the *840* Ventilator System, always follow your hospital infection control guidelines for handling infectious material.

  Puritan Bennett recognizes that cleaning, sterilization, sanitation, and disinfection practices vary widely among healthcare institutions. It is not possible for Puritan Bennett to specify or require specific practices that will meet all needs, or to be responsible for the effectiveness of cleaning, sterilization, and other practices carried out in the patient care setting.

Puritan Bennett does recommend that users of its products that require cleaning and sterilization/disinfection consider the *National Standards and Recommended Practices for Sterilization* published by the Association for the Advancement of Medical Instrumentation (AAMI), as well as the following Center for Disease Control (CDC) publications: *Guidelines for Maintenance of In-use Respiratory Therapy Equipment* and *Guidelines for Prevention of Nosocomial Pneumonia*.

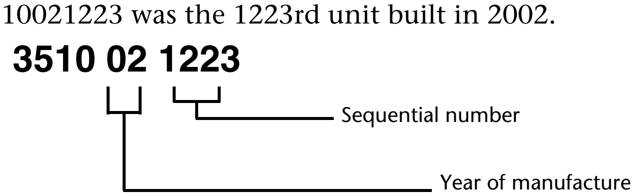
- Patients on life-support equipment should be appropriately monitored by competent medical personnel and suitable monitoring devices.
- The *840* Ventilator System is not intended to be a comprehensive monitoring device and does not activate alarms for all types of dangerous conditions for patients on life-support equipment.
- For a thorough understanding of ventilator operations, be sure to thoroughly read the *840 Ventilator System Operator's and Technical Reference Manual* before attempting to use the system.
- Before activating any part of the ventilator, be sure to check the equipment for proper operation and, if appropriate, run SST (Short Self Test).
- Do not use sharp objects to make selections on the graphical user interface (GUI) display or keyboard.
- Federal law (U.S.) restricts the sale of this device to, or by the order of, any physician.
- Check the ventilator periodically as outlined in this manual; do not use if defective. Immediately replace parts that are broken, missing, obviously worn, distorted, or contaminated.
- An alternative source of ventilation should always be available when using the *840* Ventilator System.
- The *840* Ventilator System is a member of the *800 Series*™ family of products. Any accessory whose model number is 80x (for example, the 802 Backup Power Source or 806 Compressor Unit) operates with all *800 Series* ventilators. An accessory whose model number is 84x operates only with a model *840* Ventilator System.

Year of manufacture

The year of manufacture for ventilators whose serial numbers begin with 4200 is indicated on the rear panel of the BDU as shown here. The two digit number following the year indicates the month of manufacture.

2003 – 10

For ventilators whose serial numbers begin with 3510, the year of manufacture is indicated by the serial number’s 5th and 6th digits. In the example below, a ventilator with serial number 3510021223 was the 1223rd unit built in 2002.



Electromagnetic susceptibility

The *840* Ventilator System complies with the requirements of IEC 601-1-2 (EMC Collateral Standard), including the E-field susceptibility requirements at a level of 10 volts per meter, at frequencies from 26 MHz to 1 GHz, *and the ESD requirements of this standard*. However, even at this level of device immunity, certain transmitting devices (cellular phones, walkie-talkies, cordless phones, paging transmitters, etc.) emit radio frequencies that could interrupt ventilator operation if located in a range too close to the ventilator. It is difficult to determine when the field strength of these devices becomes excessive. Practitioners should be aware that radio frequency emissions are additive, and that the ventilator must be located a sufficient distance from transmitting devices to avoid interruption. Do not operate the ventilator in a magnetic resonance imaging (MRI) environment. Section 7 describes possible ventilator alarms and what to do if they occur. Consult with your institution's biomedical engineering department in case of interrupted ventilator operation and before relocating any life support equipment.

Customer assistance

For further assistance contact Puritan-Bennett Corporation at 1.800.255.6774 or your local Puritan Bennett representative.

About this manual

This manual provides information needed to service the Puritan Bennett *840* Ventilator System. This manual is intended for use by certified biomedical engineering technicians or personnel with equivalent experience and training in servicing this type of equipment. It is recommended that the user complete the Puritan Bennett training class geared specifically to the *840* Ventilator System.

While this manual covers the ventilator configurations currently supported by Puritan Bennett, it may not be all-inclusive and may not be applicable to your ventilator. Within the USA, contact Puritan Bennett at 1.800.255.6774 for questions regarding the applicability of the information.

CONTENTS

1 General information

2 Theory of operation

Contents

Contents

Contents

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FIGURES

Figures

Figures

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Tables

Tables

SECTION 1

General information

This section provides introductory information on the Puritan Bennett *840* Ventilator System. Included are a description of the ventilator, including specifications, required tools and test equipment, schedule of maintenance, and controls and indicators.

1.1 How to use this manual

This manual describes how to service the *840* Ventilator System. Puritan Bennett recommends that you become familiar with this manual and accompanying labels before attempting to operate or maintain the ventilator.

The *840 Ventilator System Service Manual* is intended to be used in conjunction with the *840 Ventilator System Operator's and Technical Reference Manual*. Both manuals are needed for field repair of the ventilator.

In several cases, however, similar information is contained in both manuals:

- Refer to the "Maintenance and service" section of the *840 Ventilator System Operator's and Technical Reference Manual* for operator maintenance of filters and the patient system. Refer to Section 8 of this manual for complete ventilator maintenance information.
- Refer to the "Part numbers" appendix of the *840 Ventilator System Operator's and Technical Reference Manual* for patient system part numbers. Refer to Section 9 of this manual for complete part ordering information.

1.2 General product description

The Puritan Bennett *840* Ventilator System is a critical care ventilator intended for acute and subacute care of infant, pediatric, and adult patients.

Electronically controlled and pneumatically powered, the *840* Ventilator System contains a breath delivery unit (BDU), graphical user interface (GUI), and backup power source (BPS). An optional compressor unit and cart are also available.

The BDU is the core of the ventilator. It contains the pneumatics that deliver gas and electronic and electrical systems that control pneumatics, monitor alarms, and distribute power. The ventilator includes two independent central processing units (CPUs): one for the BDU that controls ventilation, and one for the GUI that monitors ventilator and patient data. The GUI CPU verifies that the BD CPU is functioning properly and prevents a single fault from causing a simultaneous failure of controlling and monitoring operations.

The GUI provides a communications path between the ventilator and the operator. By using the touch screen, keys, and knob on the GUI the practitioner gives initial instructions and data to the ventilator. The GUI CPU processes this information and stores it in the ventilator's memory. The BD CPU uses this stored information to control and monitor the flow of gas to and from the patient.

The *840* Ventilator System supplies mandatory or spontaneous breaths with a preset oxygen concentration. A mandatory breath can be pressure- or volume-controlled. A spontaneous breath allows the patient peak inspiratory flows up to 200 L/min with or without pressure support.

The BPS (Backup Power Supply) provides dc power to the BDU in the event that ac power is lost. A new, fully charged BPS allows the ventilator to function (without compressor or humidifier) for at least 30 minutes; thus, the BPS can power the ventilator for transport purposes within the respiratory care facility. The BPS should always be connected to the ventilator during operation.

The optional compressor unit provides compressed air to the BDU, and can be used in place of wall or bottled air for normal operation. The compressor unit is powered by and communicates with the BDU.

NOTE:

An external air source is required when performing service mode calibrations and performance verification testing.

1.3 Configuration information

The *840* Ventilator System is available in a variety of versions, intended to meet differing needs and regulations throughout the world. The major differences in configuration among ventilators are listed below:

Electrical requirements: Available in 100 V, 50/60 Hz; 120 V, 60 Hz; 220 – 240 V, 50 Hz; 220 – 240 V, 60 Hz.

Languages: Keyboard, labels, software, and operator's manual available in a variety of languages.

Compressor: With or without compressor unit.

Mounting: Cart- or shelf-mount available.

Power cord: A variety of plug ends are available. Refer to the parts list in Section 9 of this manual or the *840 Ventilator System Operator's and Technical Reference Manual* for specific part numbers.

Oxygen and air fittings: Ventilator available with diameter index safety standard (DISS) male, DISS female, noninterchangeable screw thread (NIST) male, Air Liquide, and sleeve index system (SIS) male fittings.

Oxygen and air hoses: Versions available to connect to DISS male, Air Liquide, SIS male, British Oxygen Company (BOC) female, NIST male, and Dräger female supply fittings. DISS female x DISS female versions available in different colors to satisfy different countries' requirements.

Accessories: Ventilators may be equipped with accessories listed in Section 1.4.

1.4 Accessories

The following accessories are either required or can be used with the ventilator.

Patient circuit: A variety of reusable Puritan Bennett patient circuits, adult and pediatric, with and without water traps, and with and without heated wire, is available. Consult the "Part numbers" appendix of the *840 Ventilator System Operator's and Technical Reference Manual* for patient circuit ordering information.

Humidification device: The *840* Ventilator System supports the use of an optional humidification device, including a heated humidifier, heat and moisture exchanger (HME), or heated wire. A mounting bracket is available for the Fisher & Paykel M480/M730 Humidifier. An ac socket for the humidifier is available on 100 and 120 V ventilators.

Remote nurse call unit: An analog output connector permits connection to a remote nurse call unit. (Puritan Bennett does not supply nurse's call units or cables.) Refer to the *840 Ventilator System Operator's and Technical Reference Manual* for nurse call specifications.

1.5 Specifications

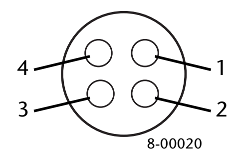
Table 1-1: Ventilator specifications

Physical characteristics	
Weight	Breath delivery unit (BDU): 18.2 kg (40.1 lb) Graphic user interface (GUI): 5.7 kg (12.6 lb) Backup power source (BPS): 6.6 kg (14.6 lb) Cart: 15.5 kg (34.2 lb) 804 Compressor unit: 31.6 kg (69.7 lb) 806 Compressor unit (100 V, 120 V): 23.6 kg (52 lb) 806 Compressor unit (220 V): 24.5 kg (54 lb)
Dimensions	BDU: 330 mm high x 457 mm wide x 254 mm deep (13 in. high x 18 in. wide x 10 in. deep) GUI: 460 mm high x 394 mm wide x 170 mm deep (18.1 in. high x 15.5 in. wide x 6.7 in. deep) BPS: 83 mm high x 244 mm wide x 254 mm deep (3.25 in. high x 9.6 in. wide x 10 in. deep) Cart: 998 mm high x 582 mm wide x 602 mm deep (39.3 in. high x 22.9 in. wide x 23.7 in. deep) 804 Compressor: 417 mm high x 458 mm wide x 362 mm deep (16.4 in. high x 18 in. wide x 14.25 in. deep) 806 Compressor: 425 mm high x 458 mm wide x 362 mm deep (17 in. high x 18 in. wide x 14.25 in. deep)
Connectors	Inspiratory limb connector: ISO 22-mm conical male Expiratory limb connector (on expiratory filter): ISO 22-mm conical male Air and oxygen inlets: DISS male, DISS female, NIST, Air Liquide, or SIS fitting (depending on country and configuration)
Environmental requirements	
Temperature	Operating: 10 to 40 °C (50 to 104 °F) at 10 to 95% relative humidity, noncondensing Storage: -20 to 50 °C (-4 to 122 °F) at 10 to 95% relative humidity, noncondensing
Atmospheric pressure	Operating: 700 to 1060 hPa (10.2 to 15.4 psi) Storage: 500 to 1060 hPa (7.3 to 15.4 psi)
Altitude	Operating: -443 to 3280 m (-1350 to 10,000 ft) Storage: Up to 6560 m (20,000 ft)
Pneumatic specifications	
Oxygen and air inlet supplies	Pressure: 241 to 690 kPa (35 to 100 psi) **Warning** Due to excessive restriction of the Air Liquide, SIS, and Dräger hose assemblies, reduced ventilator performance levels may result when oxygen or air supply pressures < 50 psi (345 kPa) are employed. Flow: Maximum of 200 L/min
Oxygen sensor life	The oxygen sensor should be replaced two years after date of manufacture, or as often as necessary. Actual sensor life depends on operating environment; operation at higher temperature or O_2% levels will shorten sensor life.

Table 1-1: Ventilator specifications (continued)

Gas mixing system	Range of flow from the mixing system: Can be set to 150 L/min standard temperature and pressure, dry (STPD). Additional flow is available (up to 80 L/min for pediatric patients whose IBW ≤ 24 kg, and up to 200 L/min for adults whose IBW > 24 kg) for compliance compensation. Leakage from one gas system to another: Meets standard EN 60601-2-12. Operating pressure range: 35 to 100 psi (241 to 690 kPa) Air/oxygen regulator bleed: Up to 3 L/min
Electrical specifications	
Input power	Ventilator operation without compressor: 100 V~, 50/60 Hz; 5.1 A; 510 VA 120 V~, 60 Hz; 4.5 A; 540 VA 220 – 240 V~, 50 Hz; 1.5 A; 330 - 360 VA 220 – 240 V~, 60 Hz; 1.5 A; 330 - 360 VA Ventilator operation with compressor: 100 V~, 50/60 Hz; 10.7 A; 1070 VA 120 V~, 60 Hz; 10.1 A; 1212 VA 220 – 240 V~, 50 Hz; 4.1 A; 902 - 984 VA 220 – 230 V~, 60 Hz; 4.1 A; 902 - 943 VA Mains overcurrent release: Ventilator: 5 A, 100 – 120 V~; 5 A, 220 – 240 V~ Auxiliary mains: 10 A, 100 – 120 V~; 5 A, 220 – 240 V~ Ventilator operation without humidifier or compressor: Approximately 1126 BTU Ventilator operation with 806 compressor and without humidifier: Approximately 3078 BTU
NOTE: Above values obtained using the following ventilator settings at 22 °C ambient temperature: mode, A/C; mandatory type, PC; IBW, 85 kg; f_{TOT}, 20/min; P_{SUPP}, 30 cmH_2O; T_I, 1 s; Rise Time Percent (was Flow Acceleration), 50%; O_2%, 50%; P_{MEAN}, 50 cmH_2O; P_{SENS}, 3 cmH_2O. Input power specifications are for ventilators with Fisher & Paykel MR730 humidifiers. (Humidifier connection only available on 100 – 120 V ventilators.)	
Leakage current	Earth leakage current: At 100 – 120 V~ operation: 300 µA At 220 – 240 V~ operation: 500 µA Enclosure/patient leakage current: 100 – 120 V~ operation: 100 µA maximum 220 – 240 V~ operation: 100 µA maximum Humidifier leakage current: 50 µA maximum Patient auxiliary leakage current: Not applicable **Warning** In the event of a defective earth conductor, connecting equipment to the auxiliary mains socket outlet(s) (that is, the humidifier or compressor connections) may increase patient leakage current to values that exceed the allowable limits.
Alarm volume	45 dB(A) to 85 dB(A)

Table 1-1: Ventilator specifications (continued)

<table>
<tr><td>802 Backup Power Source (BPS)</td><td>
24 V dc, 6.5 Ah
Operating time (for a new, fully charged battery): at least 30 minutes. Actual duration depends on ventilator settings, battery age, and level of battery charge.
Recharge time: Automatically recharges within 8 hours maximum while ventilator is connected to ac power.
Shelf life: 24 months from date of manufacture.
Recharge requirements: Recharge every 6 months when storage temperature is -20 to 29 °C (-5 to 84 °F); every 3 months when storage temperature is 30 to 40 °C (86 to 104 °F); every 2 months when storage temperature is 41 to 50 °C (105 to 122 °F).
Storage conditions: Store at -20 to 50 °C (-4 to 122 °F), 25 to 85% relative humidity; avoid direct sunlight.
NOTE:
BPS battery life specifications are approximate. To ensure maximum battery life, maintain full charge and minimize the number of complete discharges.
</td></tr>
<tr><td>Communications capabilities</td><td>
Remote alarm (nurse’s call) port (Figure 1-1). Allows medium- and high-urgency alarm conditions to be annunciated at locations away from the ventilator (for example, when the ventilator is in an isolation room). The ventilator signals an alarm using a normally open or a normally closed signal. The ventilator asserts a remote alarm when there is an active medium- or high-urgency alarm condition, unless the alarm silence function is active. The remote alarm port is a 4-pin female connector. Allowable current is 500 mA at 30 V dc (maximum).


<table>
<tr><th>Pin</th><th>Signal</th></tr>
<tr><td>1</td><td>Normally closed (NC)</td></tr>
<tr><td>2</td><td>Relay common</td></tr>
<tr><td>3</td><td>Normally open (NO)</td></tr>
<tr><td>4</td><td>Not connected</td></tr>
</table>
Figure 1-1. Remote alarm (nurse’s call) port pinout
</td></tr>
</table>

Table 1-1: Ventilator specifications (continued)

<table>
<tr><td>Communication capabilities (cont)</td><td>

RS-232 (serial) port (Figure 1-2). A 9-pin male connector configured as data terminal equipment (DTE). Allowable current is 0.2 A at 10 V dc (maximum).

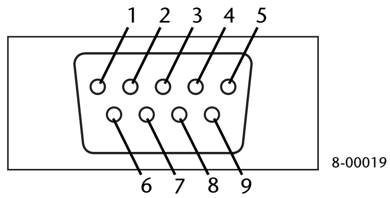
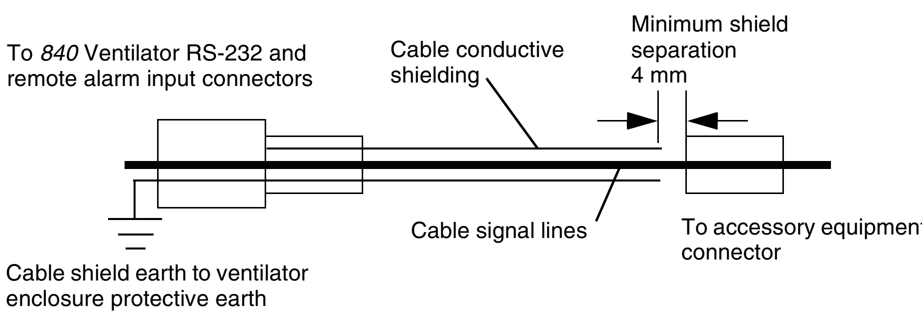


Figure 1-2. *840* Ventilator System RS-232 serial port pinout

Pin	Signal
1	Not connected
2	Receive data (RxD)
3	Transmit data (TxD
4	Data terminal ready (DTR), terminated high
5	Ground (GND)
6	Not connected
7	Request to send (RTS)
8	Clear to send (CTS)
9	Not connected

</td></tr>
<tr><td></td><td>

NOTE:
The connection of accessories or equipment to the ventilator's RS-232 and remote alarm ports requires electrical separation of conductive earth (ground) connections between different items of equipment of a system. The system cable assembly shielding can interconnect the ventilator and other equipment, increasing the risk of excessive enclosure leakage current from external equipment. For safe connection and prevent a double earth ground, the shield conductor must have separation of 4 mm between the equipment and ventilator conductors, as shown below:



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</table>

1.6 Compliance and approvals

The *840* Ventilator System was developed in accordance with pertinent FDA guidances and North American and EN 46001/ISO 13485 international standards (Table 1-2). The manufacturing facility for this product is EN 46001 certified.

The ventilator's IEC 60601-1/EN 60601-1 classification is Protection class I, Type B, internally powered, IPX1 drip-proof equipment, continuous operation.

Table 1-2: Compliance with standards

Standards/certifications	Configurations	Certification agency
North America		
Authorized to bear the CSA certification mark, signifying the product has been evaluated to the applicable ANSI/Underwriters Laboratories Inc. (UL) and CSA standards for use in the US and Canada. CSA C22.2 No. 601.1 CSA C22.2 No. 601.1 Supplement 1 IEC No. 60601-2-12 UL No. 2601-1	120 V, 60 Hz 220 – 240 V, 50 Hz 220 – 240 V, 60 Hz	Canadian Standards Association (CSA)
Worldwide		
CB scheme certification: IEC 60601-1 IEC 60601-1-1 IEC 60601-1-2 IEC 60601-2-12	100 V, 50/60 Hz 120 V, 60 Hz 220 – 240 V, 50 Hz 220 – 240 V, 60 Hz	Canadian Standards Association (CSA)
IEC 60601-1-4 ISO 10651-1	220 – 240 V, 50 Hz 220 – 240 V, 60 Hz	--
European		
Approved to the type test requirements of Annex III of the Medical Device Directive. EN 60601-1 EN 60601-1-1 EN 60601-1-2 EN 794-1	220 – 240 V, 50 Hz 220 – 240 V, 60 Hz	TÜV Product Service
EN 60601-1-4		--

1.7 Technical information

Refer to Table 1-3 for *840* Ventilator System miscellaneous technical information.

NOTE:
When pressure units are set to hPa, pressure delivery and spirometry are subject to an additional 2% error.

Table 1-3: Technical information

Maximum limited pressure	127.5 cmH_2O (130 hPa)
Maximum working pressure	100 cmH_2O (102 hPa), ensured by high pressure limit 90 cmH_2O (pressure-based ventilation)
Measuring and display devices	Pressure measurements: Type: Silicon solid-state differential pressure transducer Sensing position: Inspiratory and expiratory limbs (used to algorithmically approximate circuit wye pressure) Measurements: Mean circuit pressure (range: -20 to 120 cmH_2O, -20.4 to 122 hPa); peak circuit pressure (range: -20 to 130 cmH_2O, -20.4 to 133 hPa)
	Volume measurements: Type: Hot film anemometer. Sensing position: Exhalation compartment Measurements: Exhaled tidal volume (range: 0 to 6,000 mL); total minute volume (range: 0 to 99.9 L)
Measuring and display devices (cont)	Oxygen measurement: Type: Galvanic cell Sensing position: Inspiratory manifold Measurement: Delivered% O_2 (range: 0 to 103%)
	Display of settings, alarms, and monitored data: Type: Two liquid crystal display (LCD) touch screens
Minute volume ($\dot{V}_{E\ TOT}$) capability	25 to 75 L/min
Results of ventilator patient circuit testing (using circuits identified for use with *840* Ventilator)	Inspiratory pressure drop from inlet of open safety valve to outlet port without inspiratory filter: At 5 standard liters per minute (SL/min): 0.06 cmH_2O At 30 SL/min: 0.28 cmH_2O At 60 SL/min: 0.95 cmH_2O Inspiratory pressure drop across inspiratory filter: At 5 SL/min: 0.17 cmH_2O At 30 SL/min: 0.56 cmH_2O At 60 SL/min: 1.37 cmH_2O
	Inspiratory pressure drop from inlet of open safety valve with inspiratory filter: At 5 SL/min: 0.17 cmH_2O At 30 SL/min: 0.84 cmH_2O At 60 SL/min: 2.32 cmH_2O
	Pressure drop across 1.68 m (5.5 ft) inspiratory or expiratory limb with water trap, to patient wye: Neonatal patient circuit N/A (no water trap) Pediatric patient circuit at 30 SL/min: 0.73 cmH_2O Adult patient circuit at 60 SL/min: 1.05 cmH_2O

Table 1-3: Technical information (continued)

Results of ventilator patient circuit testing (using circuits identified for use with *840* Ventilator) (continued)	Pressure drop across 1.22 m (4 ft) inspiratory or expiratory limb without water trap, to patient wye: Neonatal patient circuit at 5 SL/min: 0.45 cmH_2O (inspiratory limb) Neonatal patient circuit at 5 SL/min: 0.40 cmH_2O (expiratory limb) Pediatric patient circuit at 30 SL/min: 0.56 cmH_2O Adult patient circuit at 60 SL/min: 0.70 cmH_2O
	Pressure drop across Fisher & Paykel humidifier and lead-in tube: Neonatal patient circuit at 5 SL/min: 0.14 cmH_2O Pediatric patient circuit at 30 SL/min: 0.28 cmH_2O Adult patient circuit at 60 SL/min: 0.93 cmH_2O
	Expiratory pressure drop across exhalation compartment: At 5 SL/min: 0.21 cmH_2O (with neonatal filter and vial) At 30 SL/min: 1.5 cmH_2O At 60 SL/min: 3.40 cmH_2O Total inspiratory pressure drop: Neonatal patient circuit with neonatal filter/vial at 5 SL/min: 0.76 cmH_2O Pediatric patient circuit with water traps at 30 SL/min: 1.85 cmH_2O Pediatric patient circuit without water traps at 30 SL/min: 1.68 cmH_2O Adult patient circuit with water traps at 60 SL/min: 4.30 cmH_2O Adult patient circuit without water traps at 60 SL/min: 3.95 cmH_2O
	Total expiratory pressure drop: Neonatal patient circuit with neonatal filter and vial at 5 SL/min: 0.61 cmH_2O Pediatric patient circuit with water traps at 30 SL/min: 2.23 cmH_2O Pediatric patient circuit without water traps at 30 SL/min: 2.06 cmH_2O Adult patient circuit with water traps at 60 SL/min: 4.45 cmH_2O Adult patient circuit without water traps at 60 SL/min: 4.10 cmH_2O
	Internal volume: Inspiratory pneumatics: 50 mL ±5 mL Expiratory pneumatics: 1000 mL ±25 mL (including expiratory filter and collector vial) The *840* Ventilator automatically adjusts for volume losses due to gas compressibility (that is, automatic compliance compensation), subject to a maximum delivered volume of 2500 mL.
NOTE: • Patient circuit testing specifications are with the ventilator powered off, and are based on the recommended configurations shown in the *840 Ventilator System Operator's and Technical Reference Manual*. • To ensure that compliance compensation functions correctly, the user must run SST with the circuit configured as intended for use on the patient.	
Bacteria filter efficiency	99.97% for nominal particle size of 0.3 µm (micron) at 100 L/min

1.8 Range, resolution, accuracy, and new patient/default settings

Ranges, resolutions, accuracies, and new patient defaults for ventilator settings, alarm settings, and patient data are listed in Table 1-4.

Table 1-4: Ventilator range, resolution, accuracy, new patient/defaults

Setting	Range, resolution, accuracy, new patient/default
Ventilator settings	
Apnea ventilation	
Apnea expiratory time (T_E)	Range: $T_E \geq 0.2$ s Resolution: 0.01 s Accuracy: ± 0.01 s New patient: Apnea T_{TOT} - Apnea T_I
Apnea flow pattern	Range: Square or descending ramp Resolution: Not applicable Accuracy: Not applicable New patient: Descending ramp with NEONATAL patient circuit Square with PEDIATRIC or ADULT patient circuit
Apnea I:E ratio	Range: ≤ 1.00:1 Resolution: 0.01 Accuracy: ± 0.01 s of the inspiratory time determined by the I:E ratio and respiratory rate settings New patient: 1: Apnea T_E/T_I
Apnea inspiratory pressure (P_I)	Range: 5 to 90 cmH_2O: P_I + PEEP < 90 cmH_2O Resolution: 1.0 cmH_2O Accuracy: ± (3.0 + 2.5% of setting) cmH_2O, measured at the patient wye, 1 second after the beginning of inspiration when the Rise Time Percent (formerly Flow Acceleration) is 100% New patient: 15 cmH_2O
Apnea inspiratory time (T_I)	Range: T_I 0.2 s to 8.00 s T_{high} 0.2 s to 30 s in Bi-Level mode Resolution: 0.01 s Accuracy: ± 0.01 s New patient: Based on V_T , Peak Flow, Plateau time, and Waveform shape in VC
Apnea interval (T_A)	Range: 10 to 60 s Resolution: 1 s Accuracy: ± 0.01 s
Apnea mandatory type	Range: VC or PC Resolution: N/A Accuracy: N/A New patient: PC with NEONATAL patient circuit VC with PEDIATRIC or ADULT patient circuit

Table 1-4: Ventilator range, resolution, accuracy, new patient/defaults (continued)

Setting	Range, resolution, accuracy, new patient/default
Apnea O_2%	Range: 21 to 100% Resolution: 1% Accuracy: ± 3% by volume over the entire breath, achieved at the ventilator's inspiratory port in steady state when at least 8 breaths and a total volume of 1 liter has been delivered, and 15 seconds have passed following a settings change affecting the delivered flow trajectories. New patient: 40% with NEONATAL patient circuit 100% with PEDIATRIC or ADULT patient circuit
Apnea peak inspiratory flow ($\dot{V}_{MAX}$)	Range: 1.0 to 30 L/min when patient circuit is neonate 3.0 to 60 L/min when patient circuit is pediatric 3.0 to 150 L/min when patient circuit is adult Resolution: 0.1 L/min for peak flows from 3 to 20 L/min 1 L/min for peak flows above 20 L/min Accuracy: ± (0.5 + 10% of setting) L/min of the flow command input to the flow controller, at the end of each control interval, after the first 100 milliseconds of inspiration. New patient: Maximum of 1.0 or (0.87 x IBW) L/min with NEONATAL patient circuit Maximum of 3.0 or (0.572 x IBW) L/min with PEDIATRIC patient circuit Maximum of 3.0 or (0.435 x IBW) L/min with ADULT patient circuit
Apnea respiratory rate (f)	Range: 2.0 to 40/min Resolution: 0.1/min for 2.0 to 9.9/min; 1/min for 10 to 40/min Accuracy: ± (0.1 + 0.6% of setting)/min averaged over 60 s or 5 breaths, whichever occurs later New patient: 20/min with NEONATAL patient circuit 14/min with PEDIATRIC patient circuit 10/min with ADULT patient circuit
Apnea tidal volume rate (V_T)	Range: ≥ 5 mL with NEONATAL patient circuit ≥ 25 mL with PEDIATRIC or ADULT patient circuit ≤ 2500 mL with ADULT patient circuit IBW base range: 1.16 x IBW minimum, 45.7 x IBW maximum Resolution: 1.0 mL for 25 to 100 mL 5 mL for 100 to 400 mL 10 mL for 400 to 2,500 mL (full scale) Accuracy: For T_I < 600ms, ± (10+10% x 600ms/$T_I$ms of setting), mL otherwise ± (10+10% of setting), mL with PEDIATRIC or ADULT patient circuit; ± (4+10% of setting), mL with NEONATAL patient circuit Applicable during steady state when 3 consecutive breaths are within 1% of each other, and only when the flow limit and compliance compensation limits are not reached. New patient: Maximum of 5 mL or (7.25 x IBW); with NEONATAL patient circuit (7.25 x IBW); with PEDIATRIC or ADULT patient circuit
Normal (non-apnea) ventilation	
Constant during rate change	Range: Inspiratory time, I:E ratio, or expiratory time Resolution: Not applicable Accuracy: Not applicable New patient: Inspiratory time

Table 1-4: Ventilator range, resolution, accuracy, new patient/defaults (continued)

Setting	Range, resolution, accuracy, new patient/default
Disconnect sensitivity (D_{SENS})	Range: 20 to 95% Resolution: 1% Accuracy: Not applicable New patient: 75%
Expiratory sensitivity (E_{SENS})	Range: 1 to 80% Resolution: 1% Accuracy: Not applicable New patient: 25%
Expiratory time (T_E)	Range: $T_E \geq 0.2$ s Resolution: 0.01 s Accuracy: ±0.01 s New patient: 60/f(new patient) - T_I (new patient), s
Rise Time Percent (formerly Flow Acceleration)	Range: 1 to 100% Resolution: 1% Accuracy: Not applicable New patient: 50%
Flow pattern	Range: Square or descending ramp Resolution: Not applicable Accuracy: Not applicable New patient: Descending ramp with NEONATAL patient circuit Square with PEDIATRIC or ADULT patient circuit
Flow sensitivity ($\dot{V}_{SENS}$)	Range: 0.1 to 10.0 L/min with NEONATAL patient circuit 0.2 to 20.0 L/min with PEDIATRIC or ADULT patient circuit Resolution: 0.1 L/min Accuracy: Not applicable New patient: 1.0 L/min with NEONATAL patient circuit 2.0 L/min with PEDIATRIC patient circuit 3.0 L/min with ADULT patient circuit
Humidification type	Range: HME, non-heated expiratory tube, or heated expiratory tube Resolution: Not applicable Accuracy: Not applicable Default: non-heated expiratory tube
Ideal body weight (IBW)	Range: 0.5 kg (1.1 lb) to 7 kg (15.4 lb) with NEONATAL patient circuit 3.5 kg (7.7 lb) to 35 kg (77 lb) with PEDIATRIC patient circuit 7.0 kg (15.4 lb) to 150 kg (330 lb) with ADULT patient circuit Resolution: 0.1 kg for 0.5 kg to 3.5 kg 0.5 kg for 4.0 to 9.5 kg 1 kg for 10 to 50 kg 5 kg for 50 to 100 kg 10 for 100 to 150 kg Accuracy: Not applicable New patient: 3.0 kg with NEONATAL patient circuit 15 kg with PEDIATRIC patient circuit 50 kg with ADULT patient circuit

Table 1-4: Ventilator range, resolution, accuracy, new patient/defaults (continued)

Setting	Range, resolution, accuracy, new patient/default
I:E ratio	Range: ≤ 4.00:1 Resolution: 0.01 for 4.00:1 to 1:9.99 0.1 for 1:10.0 to 1:99.9 1 for 1:100 to 1:299 Accuracy: ±0.01 s of the inspiratory time determined by the I:E ratio and respiratory rate settings New patient: 1: T_E /T_I
Inspiratory pressure (P_I)	Range: 5 to 90 cmH_2O: P_I + PEEP ≤ 90 cmH_2O Resolution: 1.0 cmH_2O Accuracy: ± (3.0 + 2.5% of setting) cmH_2O, measured at patient wye (end inspiratory pressure after 1 s when Rise Time Percent (was Flow Acceleration) is 100%) New patient: 15 cmH_2O
Inspiratory time (T_I)	Range: T_I 0.2 to 8.00 s T_{high} 0.2 to 30 s in Bi-Level mode Resolution: 0.01 s Accuracy: ± 0.01 s New patient: Based on Vt, Peak Flow, Plateau time, and Waveform shape in VC
Mandatory type	Range: VC or PC Resolution: Not applicable Accuracy: Not applicable New patient: PC with NEONATAL patient circuit VC with PEDIATRIC or ADULT patient circuit
Mode	Range: A/C, SIMV, SPONT, or Bi-Level Resolution: Not applicable Accuracy: Not applicable New patient: SIMV with NEONATAL patient circuit A/C with PEDIATRIC or ADULT patient circuit
O_2%	Range: 21 to 100% Resolution: 1% O_2 Accuracy: ± 3% by volume over the entire breath, achieved at the ventilator's inspiratory port in steady state when at least 8 breaths and a total volume of 1 liter has been delivered, and 15 seconds have passed following a settings change affecting the delivered flow trajectories.
Patient circuit type	Range: Neonatal (if Neo-mode option is active), Pediatric, or Adult Resolution: Not applicable Accuracy: Not applicable
Peak inspiratory flow ($\dot{V}_{MAX}$)	Range: 1.0 to 30 L/min with NEONATAL patient circuit 3.0 to 60 L/min with PEDIATRIC patient circuit 3 to 150 L/min with ADULT patient circuit Resolution: 0.1 L/min for flows of 3 to 20 L/min; 1 L/min for flows above 20 L/min Accuracy: ± (0.5 + 10% of setting) L/min of the flow command input to the flow controller, at the end of each control interval, after the first 100 milliseconds of inspiration.

Table 1-4: Ventilator range, resolution, accuracy, new patient/defaults (continued)

Setting	Range, resolution, accuracy, new patient/default
PEEP	Range: 0 to 45 cmH_2O Resolution: 0.5 cmH_2O for 0 to 19.5 cmH_2O; 1 cm for 20 to 45 cmH_2O Accuracy: ± (2.0 + 4% of setting) cmH_2O measured at patient wye. PEEP measured with returned flow < 5 L/min. New patient: 3 cm H_2O
Plateau time (T_{PL})	Range: 0.0 to 2.0 s Resolution: 0.1 s Accuracy: ± 0.01 s New patient: 0.0 s
Pressure sensitivity (P_{SENS})	Range: 0.1 to 20 cmH_2O below PEEP Resolution: 0.1 cmH_2O Accuracy: Not applicable New patient: 2 cm H_2O
Pressure support (P_{SUPP})	Range: 0 to 70 cmH_2O: P_{SUPP} + PEEP ≤ 90 cm H_2O Resolution: 1 cmH_2O Accuracy: ± (3.0 +2.5% of setting) cmH_2O measured at the patient wye 1 second after the beginning of inspiration when the Rise Time Percent (was Flow Acceleration) is 100%, provided that inspiration is not terminated prematurely.
Respiratory rate (f)	Range: 1 to 100/min ≤ 150 /min with NEONATAL patient circuit ≤ 100 /min with PEDIATRIC or ADULT patient circuit Resolution: 0.1/min for 1.0 to 9.9/min; 1/min for 10 to 100/min Accuracy: ± (0.1 + 0.6% of setting)/min averaged over 60 seconds or 5 breaths, whichever occurs last New patient: 20/min with NEONATAL patient circuit 14/min with PEDIATRIC patient circuit 10/min with ADULT patient circuit
Safety ventilation	Settings are identical to new patient values, except: mode = A/C, mandatory type = PC, respiratory rate = 16/min, inspiratory time = 1 s, inspiratory pressure = 10 cmH_2O, PEEP = 3 cmH_2O, trigger type = pressure, O_2% = 100% (21% if O_2 not available), patient circuit type = last set value or ADULT if none available, humidification type = last set value or NON-HEATED EXP TUBE if none available, humidifier volume = last set value or 480 mL if none available. Alarm settings in safety ventilation: high circuit pressure = 20 cmH_2O, high exhaled minute volume = OFF, high exhaled tidal volume = OFF, high respiratory rate = OFF, low exhaled mandatory tidal volume = OFF, low exhaled minute volume = 0.05 L, low exhaled spontaneous tidal volume = OFF
Support type	Range: PS, TC, or NONE Resolution: Not applicable Accuracy: Not applicable New patient: PS

Table 1-4: Ventilator range, resolution, accuracy, new patient/defaults (continued)

Setting	Range, resolution, accuracy, new patient/default
Tidal volume (V_T)	Range: ≥ 5 mL with NEONATAL patient circuit ≥ 25 mL with PEDIATRIC or ADULT patient circuit ≤ 2500 mL with ADULT patient circuit IBW based range: 1.16 x IBW minimum, 45.7 x IBW maximum Resolution: 1.0 mL for 25 to 100 mL 5 mL for 100 to 400 mL 10 mL for 400 to 2,500 mL (full scale) Accuracy: For T_I < 600ms, ± (10+10% x 600ms/$T_I$ms of setting), mL otherwise ± (4+10% of setting), mL with NEONATAL patient circuit ± (10+10% of setting), mL with PEDIATRIC or ADULT patient circuit Applicable during steady state when 3 consecutive breaths are within 1% of each other, and only when the flow limit and compliance compensation limits are not reached. New patient: Maximum of 5 mL or (7.25 x IBW) with NEONATAL patient circuit (7.25 x IBW) with PEDIATRIC or ADULT patient circuit
Trigger type	Range: Flow with NEONATAL patient circuit Pressure or Flow with PEDIATRIC or ADULT patient circuit Resolution: Not applicable Accuracy: Not applicable New patient: Flow
Setting limits for volume control (VC) mandatory breaths	Tidal volume: 25 mL ≤ V_T ≤ 2500 mL; 1.16 mL/kg ≤ V_T ≤ 45.7 mL/kg (default 7.25 mL/kg) Inspiratory time: 0.2 s ≤ T_I ≤ 8 s Expiratory time: 0.2 s ≤ T_E ≤ 59.8 s I:E ratio: 1:299 ≤ I:E ≤ 1:4.00 Flow (at 1/min ≤ f ≤ 100/min): 3 L/min ≤ $\dot{V}$ ≤ 60 L/min for IBW ≤ 24 kg 150 L/min ≤ $\dot{V}$ for IBW > 24 kg Minute volume (using square flow pattern, I:E = 1:1, and f ≥ 30/min): 30 L/min ≤ $\dot{V}_E$ for IBW < 24 kg 30 L/min < $\dot{V}_E$ < 75 L/min for IBW 24 to 54 kg Maximum $\dot{V}_E$ = 75 L/min for IBW 55 to 150 kg T_I is a function of V_T, flow pattern, T_{PL}, and $\dot{V}_{MAX}$ T_E is a function of V_T, flow pattern, T_{PL}, and f I:E is the result of T_I and T_E Any combination of settings for V_T, $\dot{V}_{MAX}$, T_{PL}, f, and flow pattern that violates these boundaries is rejected. Refer to the Technical Reference section of the *840 Ventilator System Operator's and Technical Reference Manual* for more details.

Table 1-4: Ventilator range, resolution, accuracy, new patient/defaults (continued)

Setting	Range, resolution, accuracy, new patient/default
Setting limits for pressure control (PC) mandatory breaths	Inspiratory pressure: P_I = 5 to 90 cmH_2O; P_I + PEEP ≤ 90 cmH_2O; P_I + PEEP + 2 cmH_2O ≤ $\uparrow P_{MEAN}$ Inspiratory time: 0.2 s ≤ T_I ≤ 8 s Expiratory time: 0.2 s ≤ T_E ≤ 59.8 s I:E ratio: 1:299 ≤ I:E ≤ 1:4.00 Respiratory rate: 1/min ≤ f ≤ 100/min High circuit pressure limit: 7 cmH_2O ≤ $\uparrow P_{MEAN}$ ≤ 100 cmH_2O T_I is a function of f (for I:E or T_E constant during rate change) and T_E. T_E is a function of f (for I:E or T_I constant during rate change) and T_I. I:E is a function of f (for T_I or T_E constant during rate change), T_I, and T_E. Any combination of settings for P_I, PEEP, $\uparrow P_{MEAN}$, f, T_I, I:E, or T_E that violates these boundaries is rejected. Refer to the Technical Reference section of the *840 Ventilator System Operator's and Technical Reference Manual* for more details.
Setting limits when selected support type is pressure support (PS)	Support pressure: P_{SUPP} = 0 to 70 cmH_2O; P_{SUPP} + PEEP ≤ 90 cmH_2O PEEP: PEEP = 0 to 45 cmH_2O; PEEP + 7 cmH_2O ≤ $\uparrow P_{MEAN}$ High circuit pressure limit: P_{SUPP} + PEEP + 2 cmH_2O ≤ $\uparrow P_{MEAN}$ Any combination of settings for P_{SUPP}, PEEP, or $\uparrow P_{MEAN}$ that violates the above boundaries is rejected. Refer to the Technical Reference section of part of the *840 Ventilator System Operator's and Technical Reference Manual* for more details.
Alarm settings	
Apnea interval (T_A)	Range: 10 to 60 s Resolution: 1 s
High circuit pressure limit ($\uparrow P_{PEAK}$)	Range: 7 to 100 cmH_2O Resolution: 1 cmH_2O New patient: 30 cmH_2O with NEONATAL patient circuit 40 cmH_2O with PEDIATRIC or ADULT patient circuit NOTE: New symbol for peak circuit pressure (monitored) (was $P_{CIRC\ MAX}$)
High exhaled minute volume limit ($\bar{\uparrow}\dot{V}_{E\ TOT}$)	Range: 0.1 to 100 L or OFF Resolution: 0.005 L for 0.05 to 0.5 L; 0.05 L for 0.5 to 5 L; 0.5 for 5 to 99.5 L New patient: ((20 x 7.25 x IBW x 1.30/1000) + 0.05) with NEONATAL patient circuit ((14 x 7.25 x IBW x 1.30/1000) + 0.05) with PEDIATRIC patient circuit ((10 x 7.25 x IBW x 1.30/1000) + 0.05) with ADULT patient circuit
High exhaled tidal volume limit ($\bar{\uparrow}V_{TE}$)	Range: 5 to 3000 mL or OFF 5 to 500 mL with NEONATAL patient circuit 25 to 1500 mL with PEDIATRIC patient circuit 25 to 3000 mL with ADULT patient circuit Resolution: 1 mL for 5 to 99 mL; 5 mL for 100 to 399 mL; 10 mL for 400 to 2500 mL New patient: maximum of 5 mL or (7.25 x IBW x 1.30)
High respiratory rate limit ($\bar{\uparrow}f_{TOT}$)	Range: 10 to 170/min or OFF ≤ 170/min with NEONATAL patient circuit ≤ 110/min with PEDIATRIC or ADULT patient circuit Resolution: 1/min New patient: OFF

Table 1-4: Ventilator range, resolution, accuracy, new patient/defaults (continued)

Setting	Range, resolution, accuracy, new patient/default
Low exhaled mandatory tidal volume limit (⤓$_{TE\ MAND}$)	Range: 1 to 2500 mL or OFF < High Exhaled Tidal Volume Limit ≤ 300 mL with NEONATAL patient circuit ≤ 1000 mL with PEDIATRIC patient circuit ≤ 2500 mL with ADULT patient circuit Resolution: 1 mL for 25 to 99 mL; 5 mL for 100 to 399 mL; 10 mL for 400 to 2500 mL New patient: 7.25 x IBW x 0.70
Low exhaled minute volume limit (⤓$\dot{V}_{E\ TOT}$)	Range: < high exhaled minute volume limit OFF (immediately following the soft limit of 0.01 L/min) to 10 L/min with NEONATAL patient circuit 0.05 L/min ≤ ⤓$\dot{V}_{E\ TOT}$ ≤ 30 L/min with PEDIATRIC patient circuit 0.05 L/min ≤ ⤓$\dot{V}_{E\ TOT}$ ≤ 60 L/min with ADULT patient circuit Resolution: 0.005 L for 0.01 to 0.50 L; 0.05 L for 0.50 to 5.0 L; 0.50 L for 5.0 to 60.0 L New patient: maximum of 0.01 or ((20 x 7.25 x IBW x 0.70/1000) - 0.05) with NEONATAL patient circuit ((14 x 7.25 x IBW x 0.70/1000) - 0.05) with PEDIATRIC patient circuit ((10 x 7.25 x IBW x 0.70/1000) - 0.05) with ADULT patient circuit
Low exhaled spontaneous tidal volume limit (⤓$V_{TE\ SPONT}$)	Range: 1 to 2500 mL or OFF < high exhaled tidal volume limit ≤ 300 mL with NEONATAL patient circuit ≤ 1000 mL with PEDIATRIC patient circuit ≤ 2500 mL with ADULT patient circuit Resolution: 1 mL for 1 to 100 mL; 5 mL for 100 to 400 mL; 10 mL for 400 to 2500 mL New patient: 7.25 x IBW x 0.70
Monitored data	
Breath type	Range: Type: Control, assist, or spontaneous Phase: Inspiration or exhalation Resolution: Not applicable Accuracy: Not applicable
Delivered O_2% (O_2%)	Range: 0 to 103% Resolution: 1% O_2 Accuracy: ±3% O_2 of full scale
End expiratory pressure (PEEP)	New symbol for end expiratory pressure (monitored) (was $P_{E\ END}$) Range: -20.0 to 130 cmH_2O Resolution: 0.1 cmH_2O for -20.0 to 9.9 cmH_2O; 1.0 cmH_2O for 10 to 130 cmH_2O Accuracy: ± (2 + 4% of reading) cmH_2O (relative to pressure measured at the exhalation side of the patient wye when the end-expiratory flow is less than 60 lpm)
End inspiratory pressure ($P_{I\ END}$)	Range: -20.0 to 130 cmH_2O Resolution: 0.1 cmH_2O for -20.0 to 9.9 cmH_2O; 1.0 cmH_2O for 10 to 130 cmH_2O Accuracy: ± (2 + 4% of reading) cmH_2O (relative to the patient wye for pressure control breaths with inspiratory times of 1 s or longer)

Table 1-4: Ventilator range, resolution, accuracy, new patient/defaults (continued)

Setting	Range, resolution, accuracy, new patient/default
Exhaled minute volume ($\dot{V}_{E\ TOT}$)	Range: 0.00 to 99.9 L Resolution: 0.01 L for 0.00 to 9.99 L; 0.1 L for 10.0 to 99.9 L Accuracy: For T_E < 600 ms: ± ((10 x respiratory rate) +10% x (600 ms/T_E) of reading) mL ± ((4 x respiratory rate) + 10% of reading) mL with NEONATAL patient circuit ± ((10 x respiratory rate)+10% of reading) mL with PEDIATRIC or ADULT patient circuit T_E = time to exhale 90% of exhaled volume
Exhaled tidal volume (V_{TE})	Range: 0 to 6000 mL Resolution: 0.1 mL for 0 to 9.9 mL; 1 mL for 10 to 6000 mL Accuracy: For T_I < 600 ms: ±10 (+10% (600 ms/T_E) of setting) mL ± (4 + 10% of reading) mL with NEONATAL patient circuit ± (10 + 10% of reading) mL with PEDIATRIC or ADULT patient circuit Compliance- and BTPS-compensated T_E = time to exhale 90% of exhaled volume
I:E ratio	Range: 1:599 to 149:1 Resolution: 0.1 for 9.9:1 to 1:9.9; 1.0 for 149:1 to 10:1 and 1:10 to 1:599 Accuracy: ± 1%
Mean airway pressure (P_{MEAN})	New symbol for mean airway pressure (was $\overline{P}_{CIRC}$). Range: -20.0 to 120 cmH_2O Resolution: 0.1 cmH_2O for -20.0 to 9.9 cmH_2O; 1 cmH_2O for 10 to 120 cmH_2O Accuracy: ± (3 + 4% of reading) cmH_2O relative to pressure measured at the exhalation side of the patient wye.
Peak circuit pressure (P_{PEAK})	Range: -20.0 to 130 cmH_2O Resolution: 0.1 cmH_2O for -20.0 to 9.9 cmH_2O; 1.0 cmH_2O for 10 to 130 cmH_2O Accuracy: N/A NOTE: New symbol for peak circuit pressure (monitored) (was $P_{CIRC\ MAX}$)
Spontaneous minute volume (V_{ESPONT})	Range: 0.00 to 99.9 L Resolution: 0.01 L for 0.00 to 9.99 L; 0.1 L for 10.0 to 99.9 L Accuracy: For T_E < 600 ms: ± ((10 x respiratory rate) + 10% (600 ms/T_E) of reading) mL For $T_E \geq$ 600 ms: ± ((10 x respiratory rate) + 10% of reading) mL
Total respiratory rate (f_{TOT})	Range: 0 to 200/min Resolution: 0.1/min for 0.0 to 9.9/min; 1/min for 10 to 200/min Accuracy: ± 0.8/min

1.9 Tools, equipment, and service materials

The tools, equipment, and service materials listed in Table 1-5 are used to service the *840* Ventilator System. Refer to Section 5 for a list of required tools, equipment, and service materials specific to performance verification.

Table 1-5: Tools, equipment, and service materials

Description	Manufacturer/model or Puritan Bennett part number	Where used
Adapter, patient pressure ("T" connector)	4-011521-00	Performance verification
Barometer	See under “Pneumatic calibration analyzer”	Atmospheric pressure transducer calibration
Cable, trigger	4-075360-00	Performance verification
Cable, null modem	4-075361-00	Performance verification
Pentium 166 Mhz computer, equipped, at a minimum, with the following: • 32 MB RAM (64 MB for NT systems) • 800x600 screen display resolution with 256 colors • Two available serial ports • Windows® 95, 98, 2000, XP or NT 4.0 operating system • Mouse or equivalent pointer device • 2x or higher CD-ROM drive • 1 Gigabyte available hard disk space • One available TCP/IP network port with BNC connector (if software download desired)	Local supplier	Performance verification
Connector, barb	4-000845-00	Performance verification
Cotton swabs	Local supplier	General cleaning
Coupling, barb connector	4-003443-00	Performance verification
Digital multimeter (DMM) accurate to 3 decimal places, with test leads	Fluke Model 87 or equivalent	Performance verification, general troubleshooting

Table 1-5: Tools, equipment, and service materials (continued)

Description	Manufacturer/model or Puritan Bennett part number	Where used
Disinfectant/cleaner	The following solutions are acceptable for disinfecting/cleaning the 840 ventilator: Mild dishwashing detergent Isopropyl alcohol (70% solution) Bleach (10% solution) Window cleaning solution (with isopropyl alcohol and ammonia) Ammonia (15% solution) Hydrogen peroxide (3% solution) Formula 409® cleaner (Clorox Company) Amphyl disinfectant (National Laboratories, Reckitt & Colman Inc.) Cavicide® surface disinfectant (Metrex Research Corporation) Control III germicide (Meril Products Inc.) Glutaraldehyde (3.4% solution)	General cleaning
Electrical safety analyzer capable of measuring ground resistance and leakage current	Dale Model 600, Dale Technology Inc., P.O. Box 196, 401 Claremont Ave., Thornwood, NY 10594 USA, 800.544.3253 http://www.daletech.com or equivalent	Performance verification
Electrostatic shielding bags: 8 x 5 in. (20.3 x 12.7 cm) 11 x14 in. (27.9 x 35.6 cm) 18 x 14 in. (45.7 x 35.6 cm) 26 x 4 in. (66.0 x 10.2 cm)	 4-009803-00 4-009800-00 4-009801-00 4-009804-00	 Backlight inverter, vent head LED, GUI LED, and exhalation PCB storage Card cage PCBs, GUI LCD panels, inspiratory PCB, motherboard PCB, compressor PCB storage GUI CPU PCB storage Keyboard PCB storage
Filter, inspiratory, *Re/Flex*™ (for use on *PTS 2000*™ tester port)	4-074600-00	Performance verification
Finger cots or gloves	Local supplier	Removing window from GUI, performance verification
Flex tube, 21.0 in. (53.4 cm) (gold standard tube) (2 required)	4-018506-00	EST, performance verification
Grease, Krytox	4-732130-00	Lubricating O-rings
Hose, regulator calibration	4-079050-00 (quick disconnect) 4-079051-00 (female)	Performance verification
Isopropyl alcohol	Local supplier	General cleaning
Leak detector fluid	4-004489-00	Leak-testing
Exhalation port test hose assembly	4-076704-00	Performance verification

Table 1-5: Tools, equipment, and service materials (continued)

Description	Manufacturer/model or Puritan Bennett part number	Where used
Patient circuit, adult (reusable, without water traps or heated wire) (2 required)	N-4401008	SST, performance verification
Patient circuit, pediatric (reusable, without water traps or heated wire)	G-061223-00	SST, performance verification
Pneumatic calibration analyzer or equivalent devices capable of measuring oxygen percent, flow, BTPS volume, pressure, and barometric pressure. Oxygen analyzer connector tee. Required accuracies: • Flow: 2.75% of reading ±0.05 slpm • Volume: 2% of reading or ±1 digit • Low pressure (-150 to +150 cmH_2O): 0.75% of reading ±0.04 cmH_2O • High pressure (0 to 150 psig): 1.0% of reading ±0.1 psi • Oxygen percentage: ±2% oxygen • Barometric pressure: Range: 10 to 16 psia; resolution: 0.0 to 1 psia; operating temperature: 10 to 40 °C; measurement accuracy: ±0.75 of reading; response: ≤ 100 ms.	Puritan Bennett *PTS 2000* Performance Test System (4-074686-00) (includes accessory kit with serial cable) **NOTE:** If you use a device other than the *PTS 2000* Performance Test System, refer to the "Manual ventilator check" in Section 5 of this manual.	Performance verification, regulator adjustment. Barometer used for atmospheric pressure transducer calibration.
Software download device	4-075497-00	BDU and GUI software updates
Static-dissipative field service kit (includes wrist strap, static dissipative mat, and earth (ground) cord)	4-018149-00	Various service procedures
Stoppers, no. 1, 5, and 5.5 (with center bore and luer fitting: 4-071856-00)	Local supplier	SST, EST, performance verification
Stopper, no. 5.5 with center bore and Fitting, luer, bulkhead	4-076467-00 4-012470-00	Performance verification
Test lung, 0.5 L	4-000612-00	EST, performance verification
Test lung, 3 L	N-3800006	Performance verification
Test lung, 4 L	4-075578-00	Performance verification
Tie wraps	4-000003-00 (small) 4-000004-00 (large)	Various places

Table 1-5: Tools, equipment, and service materials (continued)

Description	Manufacturer/model or Puritan Bennett part number	Where used
Tool kit, including the following: • Diagonal cutters • Needlenose pliers • Nutdriver, 3/16-in. • Nutdriver, 5/16-in. • Nutdriver, 11/32-in. • Screwdriver, #0 Phillips • Screwdriver, #1 Phillips • Screwdriver, #2 Phillips • Screwdriver, 1/8-in. flat-blade • Screwdriver, 1/4-in. flat-blade • Wrench, 5/16-in. open-end • Wrench, 7/16-in. open-end • Wrench, 9/16-in. open-end • Wrench, adjustable	Local supplier	 General repair General repair General repair General repair General repair General repair General repair General repair General repair General repair General repair General repair Replacing pressure switch Removing oxygen filter
Tubing, silicone, 3/16 in. ID x 5/16 in. OD, 36 in. (91.4 cm)	4-008577-00	Performance verification
Tubing, silicone, 1/8 in. ID x 1/4 in. OD, 4.75 in. (12.1 cm)	4-008578-00	Performance verification
Vacuum cleaner, ESD-safe, with 0.2 µm filter (rated for photocopiers and laser printers)	Local supplier	General cleaning
Wrench, caster	N-4800168	Replacing casters
Wye	4-000338-00	SST, performance verification

1.10 Periodic maintenance

Caution

- To prevent component damage due to excessive wear, perform preventive maintenance and replace components at recommended intervals, as indicated in Table 1-6. You may find it convenient to note anticipated replacement dates for all components based on typical usage rates or recommended intervals.
- Puritan Bennett has determined the *840* Ventilator's preventive maintenance schedule based on the life expectancies of ventilator parts. Be aware that these parts, listed below, could also require unscheduled corrective maintenance and that other parts, not listed, could also require corrective maintenance during your ventilator's lifetime.

Table 1-6 lists the periodic maintenance activities required for the 840 Ventilator System. See the Ventilator Information screen for total hours of operation for the ventilator and compressor. For details on patient system maintenance, refer to the *840 Ventilator System Operator's and Technical Reference Manual*.

Table 1-6: Schedule of periodic maintenance

Frequency	Part	Maintenance
Several times a day or as required by your institution's policy	Patient circuit: inspiratory and expiratory limbs	Check for water build-up, empty, and clean as necessary.
	Inspiratory and expiratory bacteria filters	Inspect and check resistance across inspiratory and expiratory filters before every use, after 15 days of continuous use in expiratory limb, or if you suspect excess resistance. SST checks the resistance of the expiratory filter.
	Collector vial, water traps, and drain bag	Check and empty as needed.
Daily or as necessary	Oxygen sensor	Calibrate oxygen sensor by pressing 100% O_2/CAL 2 min key.
	Air inlet filter bowl	If cracked, replace bowl. If any sign of moisture is visible, remove ventilator from use and inspect.
Every 250 hours (or more often, if required)	Compressor inlet filter	Either vacuum filter or wash filter in a warm detergent solution, rinse, and dry well. Replace filter when it shows signs of wear.
Every 6 months	Entire ventilator	Run EST.
Every year	Atmospheric pressure transducer, expiratory valve, flow sensors, and vent inop test	Perform calibration/test.
	Entire ventilator	Perform electrical safety tests, and inspect ventilator for mechanical damage and for label illegibility.
Varies: Every year or 100 autoclave cycles. Consult product Directions for Use.	Reusable expiratory or expiratory bacteria filters	Replace. Sterilize between patients and circuit changes, or according to your institution's policy. Sterilize before nondestructive disposal.
2 years or as necessary	Oxygen sensor BPS battery pack	Replace. Actual sensor life depends on operating environment; operation at higher temperature or O_2% levels will result in shorter sensor life. Actual BPS life depends on the history of use and ambient conditions.
Every 10,000 hours Every 15,000 hours	Various parts	Use appropriate preventive maintenance kit (see Table 1-7). **NOTE:** If any part found in a preventive maintenance kit requires replacement before the recommended interval elapses, consider installing the entire kit anyway.

1.11 Service kits

Table 1-7 lists the *840* Ventilator System service kits. Section 9 lists the mounting kits available for the ventilator.

Table 1-7: Service kits

Interval	Description	Part no.	Kit contents
10,000 hours	GUI and BDU	4-079056-00	Filter, air inlet (F2) with O-ring Filter, oxygen (F1) Filter, oxygen inlet (F3) with O-ring Installation instructions Label, preventive maintenance Lamps, fluorescent backlight (for 9.4"color LCD displays) Spring
	Oxygen sensor	4-072214-00	Oxygen sensor
	BPS (6 month shelf life)	4-070523-SP	Battery pack
15,000 hours (806 only)	Compressor, 100 V ~, 50/60 Hz	4-076806-00	15 K PM label Compressor assembly for appropriate voltage configuration Fans (qty. 2) Filter element for water trap assembly Main inlet filter Outlet filter for solenoid assembly Tie wrap, large, for air dryer assembly Tie wraps, small for fan harnesses (qty. 2) Tinnerman clips (qty. 6)
	Compressor, 120 V ~, 60 Hz	4-076805-00	
	Compressor, 220 – 240 V ~, 50/60 Hz	4-076807-00	

1.12 Controls and indicators

Refer to Figure 1-3 through Figure 1-10 and Table 1-8 through Table 1-15 for ventilator controls and indicators.

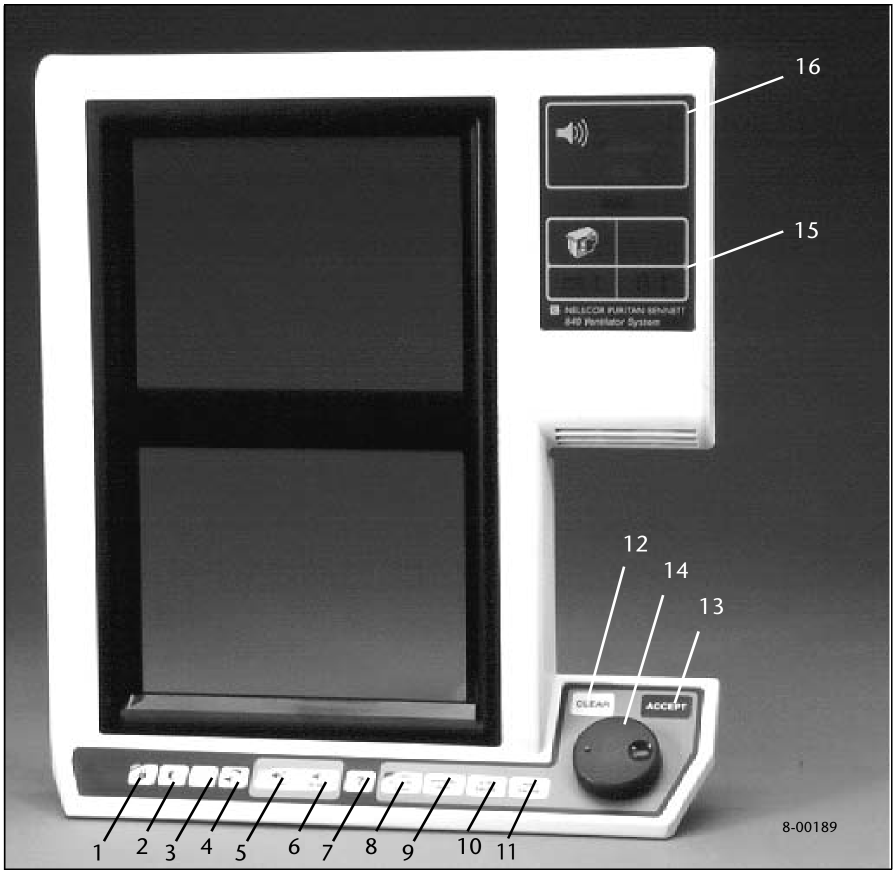


Figure 1-3. Monochrome GUI front view (showing all keys)

Table 1-8: GUI front view

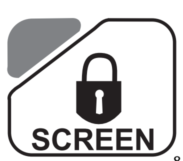
Index (Figure 1-3)	Labeling	Function
1	 8-00435 *or*  8-10001 (US version only)	Screen lock key. When the yellow light on the screen lock key is lit, touching the screen or off-screen controls (including the knob and ACCEPT key) has no effect until you press the screen lock key again. New alarms (or when an alarm's urgency level escalates) automatically unlock the screen and controls. The screen lock allows you to clean the touch screen and prevents inadvertent changes to settings and displays.

Table 1-8: GUI front view (continued)

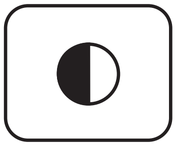
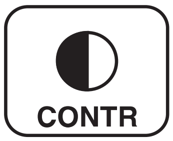
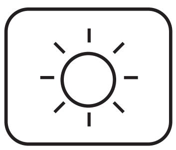
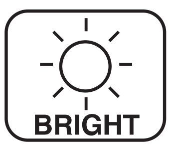
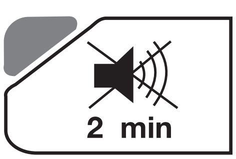
Index (Figure 1-3)	Labeling	Function
2	 8-00429 *or*  8-10002 (US version only)	**Color GUI (10.4-inch screen):** No key **Color GUI (9.4-inch screen):** Key inactive **Monochrome GUI:** Display contrast key. Allows you to adjust screen contrast when you hold down this key while turning the knob.
3	 8-00444 *or*  8-10003 (US version only)	**Color GUI (10.4-inch screen):** No key **Color GUI (9.4 inch screen):** Key present but inactive **Monochrome GUI:** Display brightness key. Allows you to adjust screen brightness when you hold down this key while turning the knob.
4	 8-00407 *or*  8-10004 (US version only)	Alarm volume key. Allows you to adjust the alarm volume when you hold down this key while turning the knob. You cannot turn off alarm volume.
5	 8-00402	Alarm silence key. Turns off alarm sound for 2 minutes. The yellow light on the alarm silence key lights during the silence period, and turns off if you press the alarm reset key or the 2-minute interval times out. A new, high-urgency alarm cancels the silence. Alarms that can be silenced (lockable) include all Patient-Data Alarms and Circuit Disconnect (see Table 7-2 for details). Each time you press the alarm silence key, the silence period resets to 2 minutes. Each time you press the alarm silence key (whether or not there is an active alarm), the keypress is recorded in the alarm log.

Table 1-8: GUI front view (continued)

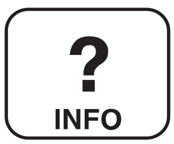
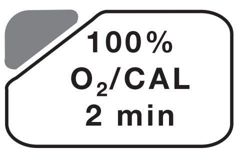
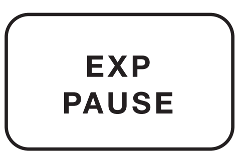
Index (Figure 1-3)	Labeling	Function
6	 8-00441	Alarm reset key. Clears active alarms or autoreset high-urgency alarms, cancels an active alarm silence, and is recorded in the alarm log. (Pressing the alarm reset key is not recorded in the alarm log if no alarm is active.) You cannot reset a DEVICE ALERT alarm.
7	 8-00411 *or*  8-10005 US version only	Displays basic operating information about the ventilator.
8	 8-00401	Delivers 100% oxygen (if available) for 2 minutes and calibrates the oxygen sensor. The green light on this key lights to indicate that 100% O_2 delivery is active. Pressing this key again restarts the 2-minute delivery interval. You may cancel the 2-minute interval by touching the CANCEL button on the GUI touch screen. Oxygen sensor calibration can be tested using a procedure in the *840 Ventilator System Operator's and Technical Reference Manual*.
9	 8-00436	Delivers one manual breath to the patient according to the current mandatory settings. To avoid breath stacking, a manual inspiration is not delivered during inspiration or the restricted phase of exhalation. You can use the MANUAL INSP key to supplement minute volume or to help measure a patient data parameter, such as peak inspiratory pressure.
10	 8-00419	Allows you to measure auto-PEEP. Hold this key down until the maneuver begins (at the next ventilator-initiated inspiration), and release when the measurement is stable, up to 20 s. The measured values for intrinsic and total PEEP are displayed at the end of the expiratory pause. Displays and freezes the most recently selected graphics, allowing you to see when expiratory pressure stabilizes. EXP PAUSE is not functional in SPONT. It has no effect during the inspiratory phase of a breath. The pause is canceled and inspiration begins if you release the EXP PAUSE key, the patient triggers an inspiration, an alarm occurs, or the maximum 20-s pause interval elapses. If flow triggering is active, backup pressure sensitivity is used to detect patient effort. Only one expiratory pause is allowed during a breath. Expiratory pause requests are ignored in apnea ventilation, safety ventilation, occlusion status cycling (OSC), and idle mode. During an expiratory pause, occlusion alarm detection is suspended. During expiratory pause, the apnea interval is extended by the amount of time the pause is active. In SIMV, the cycle during which the pause becomes active (and the next scheduled VIM will occur) is extended by the amount of time the pause is active. For purposes of I:E ratio calculation, expiratory pause is considered part of the exhalation phase.

Table 1-8: GUI front view (continued)

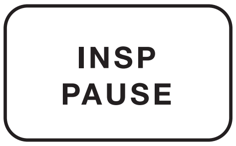
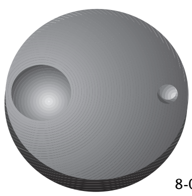
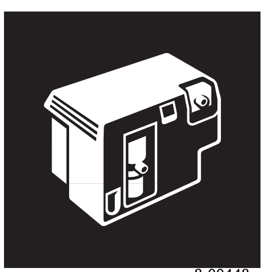
Index (Figure 1-3)	Labeling	Function
11	 8-00431	Extends the inspiratory phase of the current or next mandatory breath (depending upon when pressed) for the purpose of measuring plateau pressure, compliance, and, if possible, resistance. Pressing and releasing this key initiates an *automatic inspiratory pause* lasting between 0.5 and 2 seconds. Pressing and holding this key initiates a *manual inspiratory pause* extending inspiration up to 7 seconds.
12	 8-00415	Cancels a proposed setting.
13	 8-00406	Applies new settings.
14	 8-00433	Adjusts the value of a setting. A button that is highlighted means that the knob is linked to that setting. Where applicable, turning the knob clockwise increases the value, and turning the knob counterclockwise decreases the value.
15	System operation indicators  8-00448 non-US version *or*  8-10007 US version	Gray normal ventilator operation indicator. Indicator appears unilluminated when no ventilator inoperative condition exists. US version text is not visible when no ventilator inoperative condition exists.

Table 1-8: GUI front view (continued)

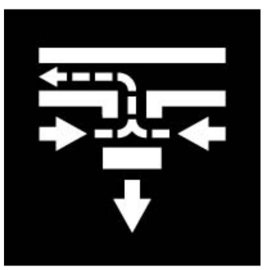
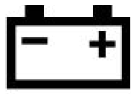
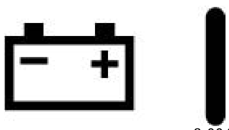
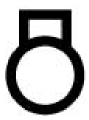
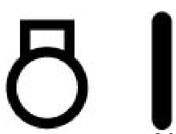
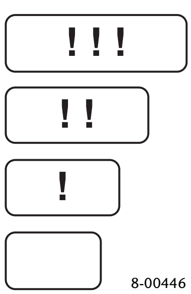
Index (Figure 1-3)	Labeling	Function
15 (cont)	 8-00447 non-US version *or*  8-10007 US version	Red ventilator inoperative indicator. Illuminates when the ventilator cannot support ventilation and requires service. The ventilator enters the safe state and discontinues detection of new patient data or alarm conditions. A qualified service technician must repair the ventilator to correct the problem and must execute EST successfully before normal ventilation is allowed. This indicator is accompanied by an audio signal and cannot be reset.
15 (cont)	 8-00459 non-US version *or*  8-10008 US version	Red safety valve open (SVO) indicator. Illuminates when the ventilator has entered its safe state and opened its safety valve to allow the patient to breathe unassisted from room air.

Table 1-8: GUI front view (continued)

Index (Figure 1-3)	Labeling	Function
	 8-00460 *or* **BATTERY READY** US version only	Green BPS ready indicator. The ventilator senses that the BPS is installed, operational, and has at least 2 minutes of estimated run time.
	 8-00457 *or* **BATTERY ON** US version only	On BPS power indicator. When yellow bar to the right of a lit BPS ready indicator (battery symbol) is lit, ventilator is operating on BPS, and ac power is insufficient to support ventilator operation. During BPS operation, power to the compressor unit and the humidifier outlet (if available) is off.
	 8-00461 *or* **COMPRESSOR READY** US version only	Green compressor ready indicator. The compressor logic cable and air supply hose are connected to the ventilator. The compressor is up to operating pressure but not supplying gas to the ventilator. The compressor motor turns on intermittently to keep the compressor chamber pressurized.
15 (cont)	 8-00458 *or* **COMPRESSOR ON** US version only	Green compressor operating indicator. When symbol to the right of a lit compressor unit ready indicator is lit, compressor is supplying air to the ventilator. This indicator does not light unless the compressor is actually supplying air to the ventilator.
16	 8-00446	Red high-urgency alarm indicator (! ! !) blinks rapidly if active; it is steadily lit if autoreset. Yellow medium-urgency alarm indicator (! !) blinks slowly if active; it turns off if autoreset. Yellow low-urgency alarm indicator (!) is steadily lit if active; it turns off if autoreset. Green normal ventilator operation indicator steadily lit. This indicator is off if the ventilator is not in a ventilation mode, for example, during service mode or short self test (SST).

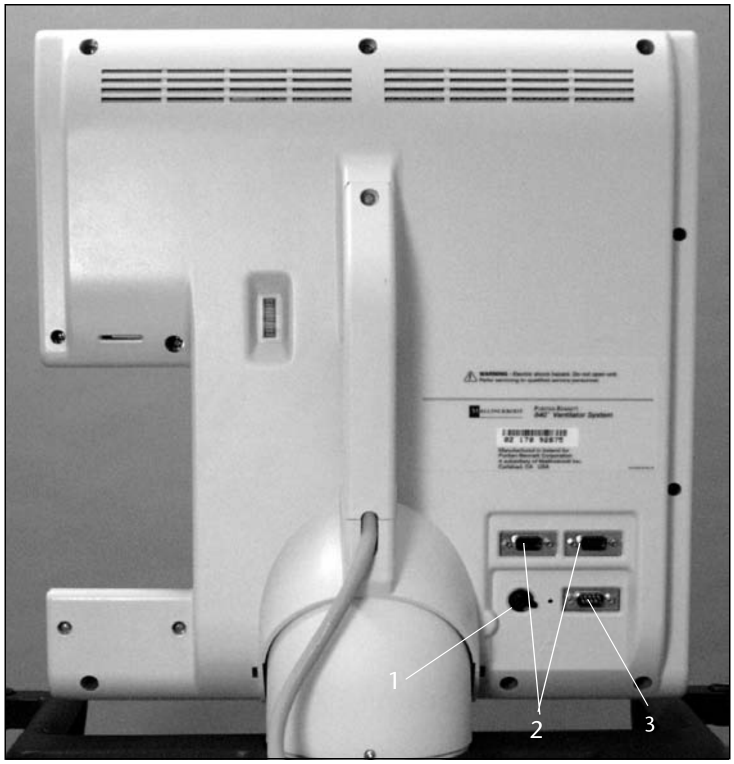


Figure 1-4. 10.4-inch GUI rear view

Table 1-9: GUI rear view

Index (Figure 1-4)	Labeling	Function
1	**Remote alarm**	Remote alarm (nurse's call) port
2	**RS-232**	10.4-inch GUI only: Two serial ports with 9-pin male connector configured as data terminal equipment (DTE). **NOTE:** Allowable current is 0.2 A at 10 V dc (maximum).
3	**RS-232 NULL**	Null modem port (9.4-inch and 10.4-inch GUI)

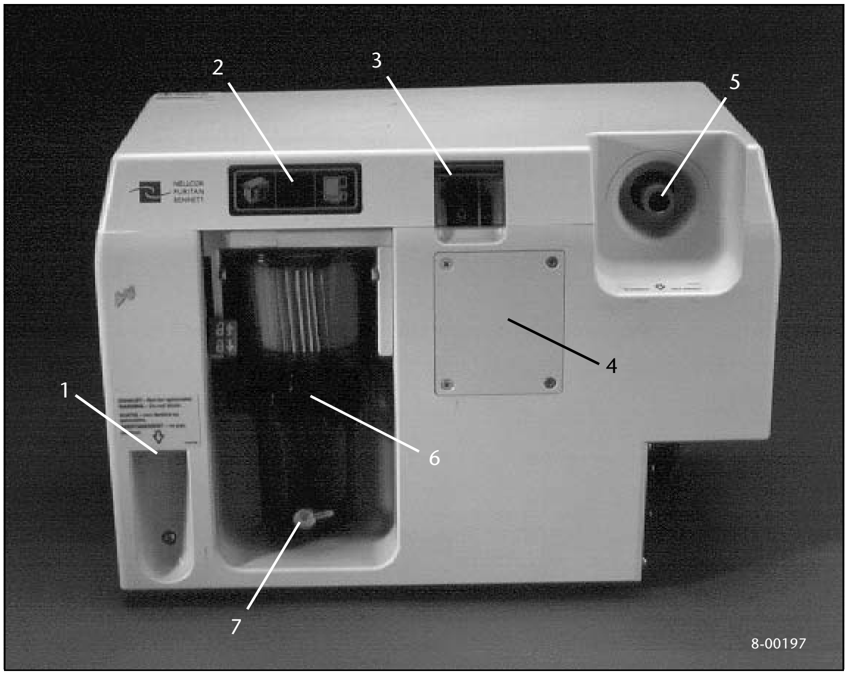


Figure 1-5. BDU front view

Table 1-10: BDU front view

Index (Figure 1-5)	Labeling	Function
1	EXHAUST port	BDU exhaust port. Gas is vented to atmosphere.
2	Ventilator operation indicators  8-00447 non-US version *or*  8-10007 US version	Red ventilator inoperative indicator. (See Table 1-8, item 15.)

Table 1-10: BDU front view (continued)

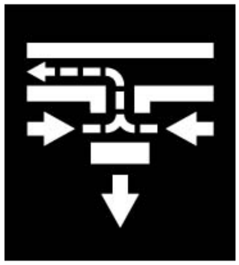
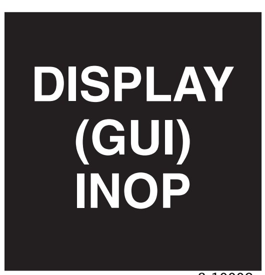
Index (Figure 1-5)	Labeling	Function
2 (cont)	 8-00459 non-US version *or*  8-10008 US version	Red safety valve open (SVO) indicator. (See Table 1-8, item 15.)
	 8-00454 non-US version  8-10009 US version	Gray normal GUI indicator. Indicator appears unilluminated when no loss of GUI condition exists. US version text is not visible when no loss of GUI condition exists.

Table 1-10: BDU front view (continued)

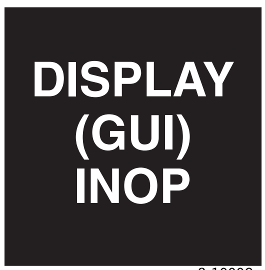
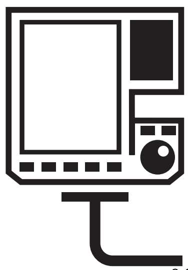
Index (Figure 1-5)	Labeling	Function
2 (cont)	 8-00455 non-US version *or*  8-10009 US version	Red loss of GUI indicator. The ventilator has detected a malfunction that prevents the GUI from reliably displaying or receiving information.
3	 8-00439 non-US version *or*	Power switch. **I** or **ON** represents on position;  represents off position for only a part of the equipment. This switch turns off power to the BDU and GUI, but still allows the BPS to be charged if ac power is present. The ac indicator LED is lit when ac power is available to the ventilator.
	 8-10006 US version	
4	(Humidifier outlet, shown covered)	North-American style electrical receptacle for humidifier. Receptacle available in 100 – 120 V ventilators only. Ventilator supports a humidifier rated for up to 2.3 A (270 VA) with a maximum leakage current of 50 µA.
5	*To patient* port	Ventilator outlet
6	*From patient* port	Expiratory limb connector on exhalation filter
7	(Collector vial drain port)	Collector vial drain port. Use to attach drainage bag.

Figure 1-6. BDU I/O panel

Table 1-11: BDU I/O panel

Index (Figure 1-6)	Labeling	Function
1	**TEST**	TEST (service) button. Enables service mode. When you turn on the ventilator and press this button after the first beep from the BDU, the ventilator is placed into service mode (for example, to run EST).
2	**PTS 2000**	Puritan Bennett *PTS 2000* Performance Test System connection.
3	 8-00418 *or* **Data Key** US version	Data key connection **Caution** Do not remove the data key. The data key cover can only be removed with a screwdriver. The data key enables software options, and stores ventilator operational hours and the serial numbers for the BDU and GUI. The data key is for use by a qualified service technician only.

Table 1-11: BDU I/O panel (continued)

Index (Figure 1-6)	Labeling	Function
4	 8-00461 *or* **Compressor** US version	Compressor data cable connection
5	 8-00427 *or* **Display (GUI)** US version	GUI cable connection

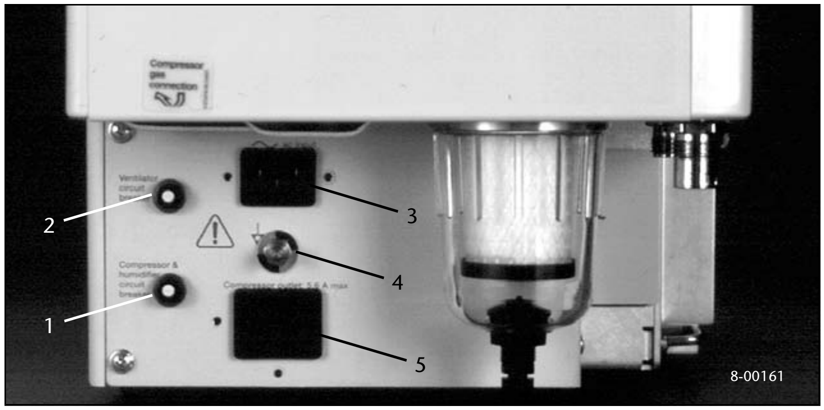


Figure 1-7. BDU right-side panel

Table 1-12: BDU right-side panel

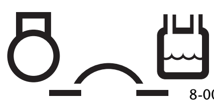
Index (Figure 1-7)	Labeling	Function
1	 8-00430 *or* **Compressor & humidifier circuit breaker** US version	Ventilator circuit breaker for compressor and humidifier **NOTE:** A humidifier connection is only available on 100 – 120 V ventilators.
2	 8-00416 *or* **Ventilator circuit breaker** US version	Circuit breaker for ventilator power supply
3	 8-00405 *or*  **ac input** 8-00405 US version	Alternating current (at ac inlet and ac power indicator)

Table 1-12: BDU right-side panel (continued)

Index (Figure 1-7)	Labeling	Function
4	 8-00426	Potential equalization point (ground). Provides a means of connection between equipment (such as electrical safety analyzer) and the potential equalization busbar of the electrical connection. A common grounding point for the entire ventilator.
5	 **5.6 A Max** 8-00437 *or* **Compressor outlet: 5.6 A max** US version	Maximum allowed output to auxiliary mains socket (compressor electrical connection)

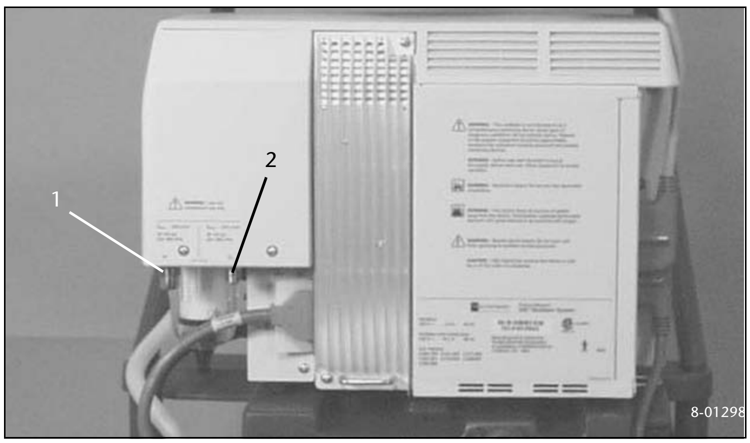


Figure 1-8. BDU rear view

Table 1-13: BDU rear view

Index (Figure 1-8)	Labeling	Function
1	(High-pressure air fitting)	DISS male, DISS female, NIST, Air Liquide, or SIS fitting
2	(High-pressure oxygen fitting)	DISS male, DISS female, NIST, Air Liquide, or SIS fitting

Figure 1-9. GUI rear view

Table 1-14: GUI rear view

Index (Figure 1-8)	Labeling	Function
1	(Warning label)	Warns user of hazards associated with the operation of the 840 ventilator and GUI
2	(Serial number label)	Unique assigned number. Must be the same as the GUI serial number stored on the data key.

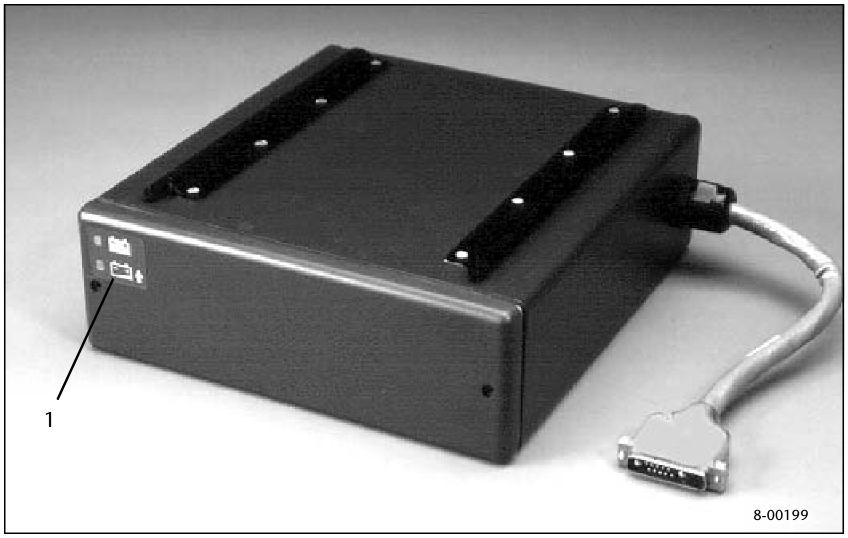
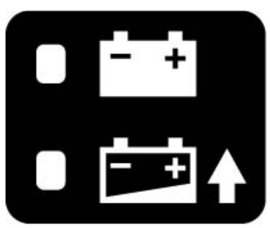
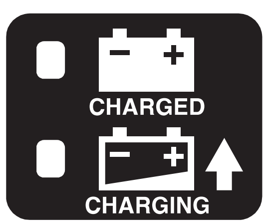


Figure 1-10. BPS controls and indicators

Table 1-15: BPS controls and indicators

Index (Figure 1-10)	Labeling	Function
1	 8-00456 *or*  8-00462 US version	BPS charging indicator. When the ventilator is operating on mains power, the top symbol (green indicator next to gray battery icon) indicates that the BPS is charged, and the bottom symbol (yellow indicator next to gray battery icon) indicates that the BPS is charging.

1.13 Onscreen symbols and abbreviations

Consult the *840 Ventilator System Operator's and Technical Reference Manual* to interpret these.

1.14 Ventilator serial numbers and software version

The *840* Ventilator System serial numbers and software versions can be displayed on the GUI upper subscreen. On the GUI upper screen, select the VENT CONFIG button. The ventilator configuration subscreen displays the current software revisions for the BDU, GUI, compressor, and audible alarm subsystem.

1.15 Service philosophy

Field service of the ventilator is limited to the service activities described in this manual. For field service, technical support, or information on technical training, call 1.800.225.6774 (within the USA) or contact your Puritan Bennett representative (outside the USA).

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SECTION 2

Theory of operation

This section details the operational theory of the *840* Ventilator System and contains the following information:

- description of major ventilator assemblies
- overview of ventilator operation
- description of the pneumatic system
- description of the electrical system, including printed circuit boards (PCBs)
- detailed description of the interactions among all ventilator components during breath delivery and under certain other conditions
- other hardware operations
- emergency modes of operation

2.1 Major ventilator subassemblies

The *840* Ventilator System is an electronically controlled, pneumatically powered ventilator consisting of a breath delivery unit (BDU), graphic user interface (GUI), the 802 Backup Power Source (BPS), and patient system. Optional components include the 806 Compressor Unit and a ventilator cart. Figure 2-1 shows the *840* Ventilator System with the optional compressor unit and cart.

Figure 2-1. *840* Ventilator System

2.1.1 Breath delivery unit (BDU)

The BDU, shown in Figure 2-2, is the core of the *840* Ventilator System. Its pneumatic system, under control of the breath delivery (BD) central processing unit (CPU), mixes oxygen and air and controls gas flow to the patient. Breath delivery proceeds according to operator-selected parameters entered through the GUI. The patient's exhaled gas is routed through an opened exhalation valve. Oxygen is provided by an external supply, and air is provided by either an external supply or the optional compressor unit.

In addition to the BD CPU and other electronics that control ventilation, the BDU also houses the ac mains components and power supply.

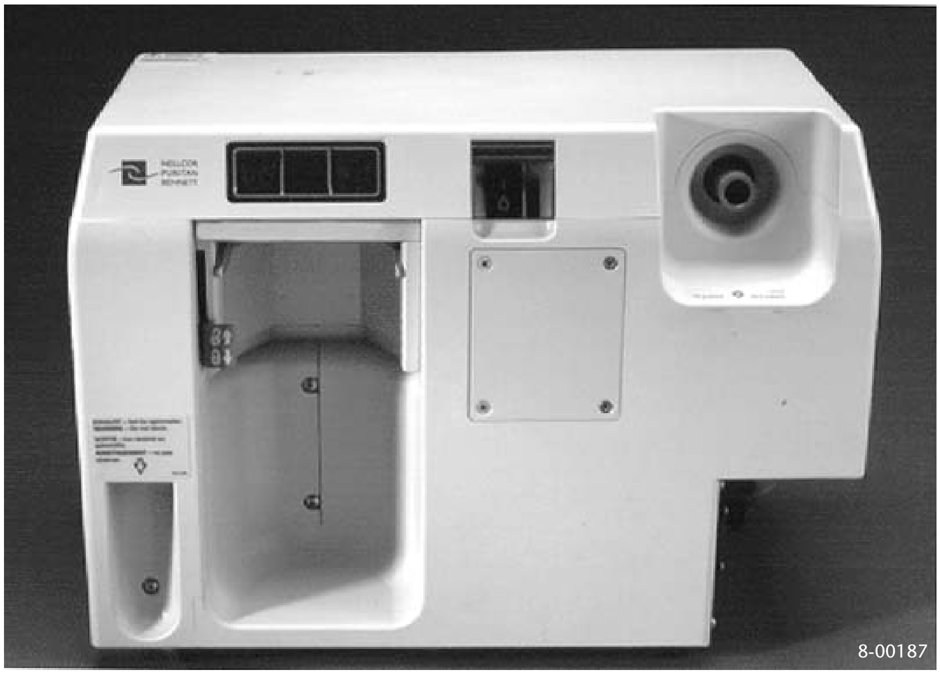


Figure 2-2. BDU

2.1.2 Graphic user interface (GUI)

The GUI (Figure 2-3) provides the operator interface to and from the ventilator. Ventilation mode, parameters, and alarm settings are entered by the operator via the GUI. The GUI CPU monitors BDU communications. In turn, the GUI displays patient and ventilator performance information.

Figure 2-3. 10.4-inch GUI

2.1.3 806 Compressor Unit

The optional 806 Compressor Unit (Figure 2-4) provides compressed room air (200 L/min peak flow, 2.5 L BTPS breath volume) when ac power is available, provided external compressed air is unavailable. The compressor charges an accumulator at start-up and maintains the charge (stand-by operation) for immediate use when external compressed air is used. The compressor unit receives electrical power from and communicates with the BDU.

Figure 2-4. Compressor unit

2.1.4 802 Backup Power Source (BPS)

The BPS (Figure 2-5) supplies power to the BDU power supply when facility ac power is lost or when a 30 volt drop in ac is detected. The BPS automatically charges while the ventilator is connected to ac power and will operate the system up to 30 minutes with new, fully charged batteries. The BPS does not supply the compressor unit or the humidifier with electrical power. The ventilator automatically switches back to ac power when facility power returns within the required limits.

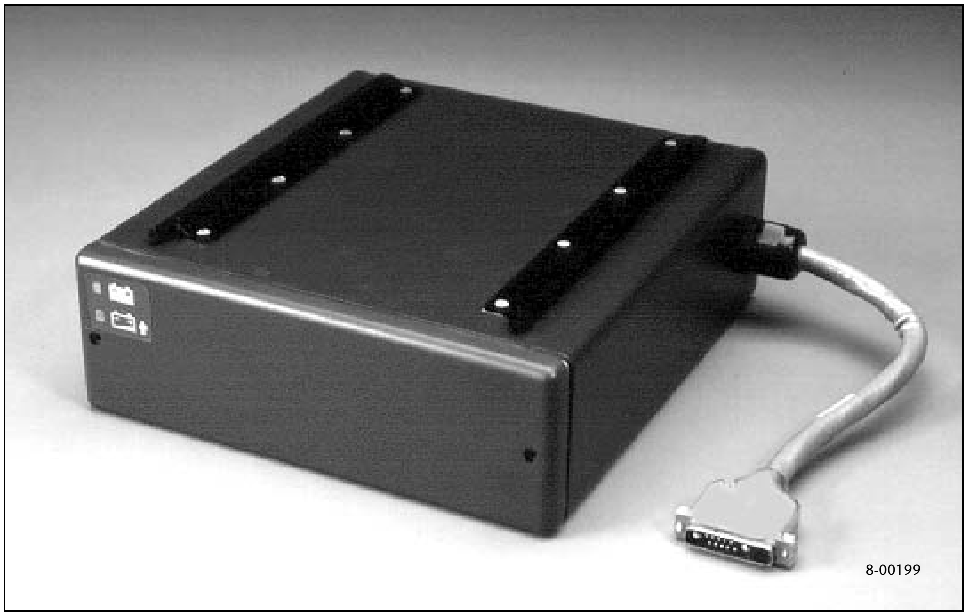


Figure 2-5. BPS

2.1.5 Cart

The optional cart, shown in Figure 2-6, mounts system components and accessories, including the compressor unit. It also provides mobility for the ventilator. Brakes on the front casters prevent the cart from rolling and turning.

Figure 2-6. Cart

2.1.6 Patient system

The patient system (adult, reusable version shown in Figure 2-7) includes reusable or single-patient use tubing plus an inspiratory filter that prevents gas-borne particles from exiting the ventilator. A humidifier or heat and moisture exchanger (HME), water traps, and other accessories can be added.

Figure 2-7. Patient system

NeoMode, a software option, requires the use of the neonatal patient system. In addition to the patient tubing and inspiratory filter, the neonatal patient system includes a disposable expiratory filter, a collector vial , and a special mounting plate, as shown in Figure 2-8.

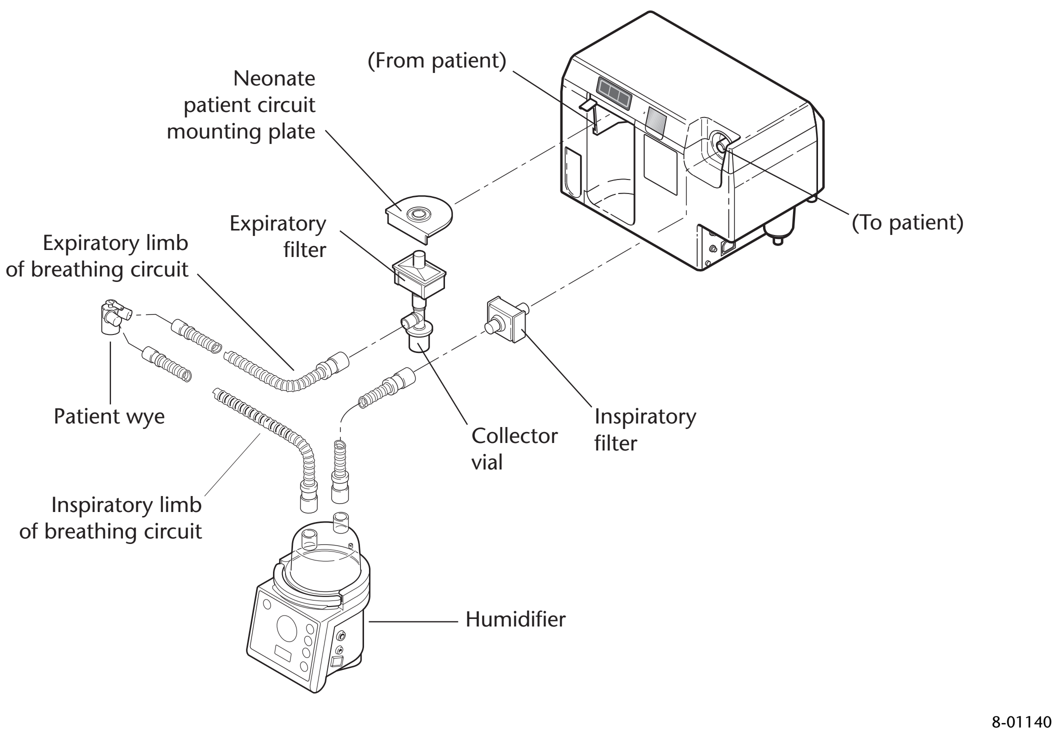


Figure 2-8. NeoMode patient system

2.2 Operational overview

By using the touch screen, keys, and knob on the GUI, the operator gives instructions and data to the ventilator (see Figure 2-9). The GUI CPU processes this information and stores it in the ventilator's memory. The BDU CPU uses this stored information to control and monitor the flow of gas to and from the patient. Any new settings information is transferred and verified using a four-way transaction between the BDU and GUI CPUs. Each CPU then performs continuous background verification of settings integrity.

To allow the GUI to monitor BDU function, the BDU samples and records the following raw signal data, then transmits it to the GUI: inspiratory pressure, expiratory pressure, exhalation valve current, and the air and oxygen inspiratory valves. The BDU also sends the following setting and breath information to the GUI: high circuit pressure limit, breath phase, breath mode, autozero offsets, inspiratory time, apnea interval, target pressure for pressure controlled breaths, breath phase start, and time stamp.

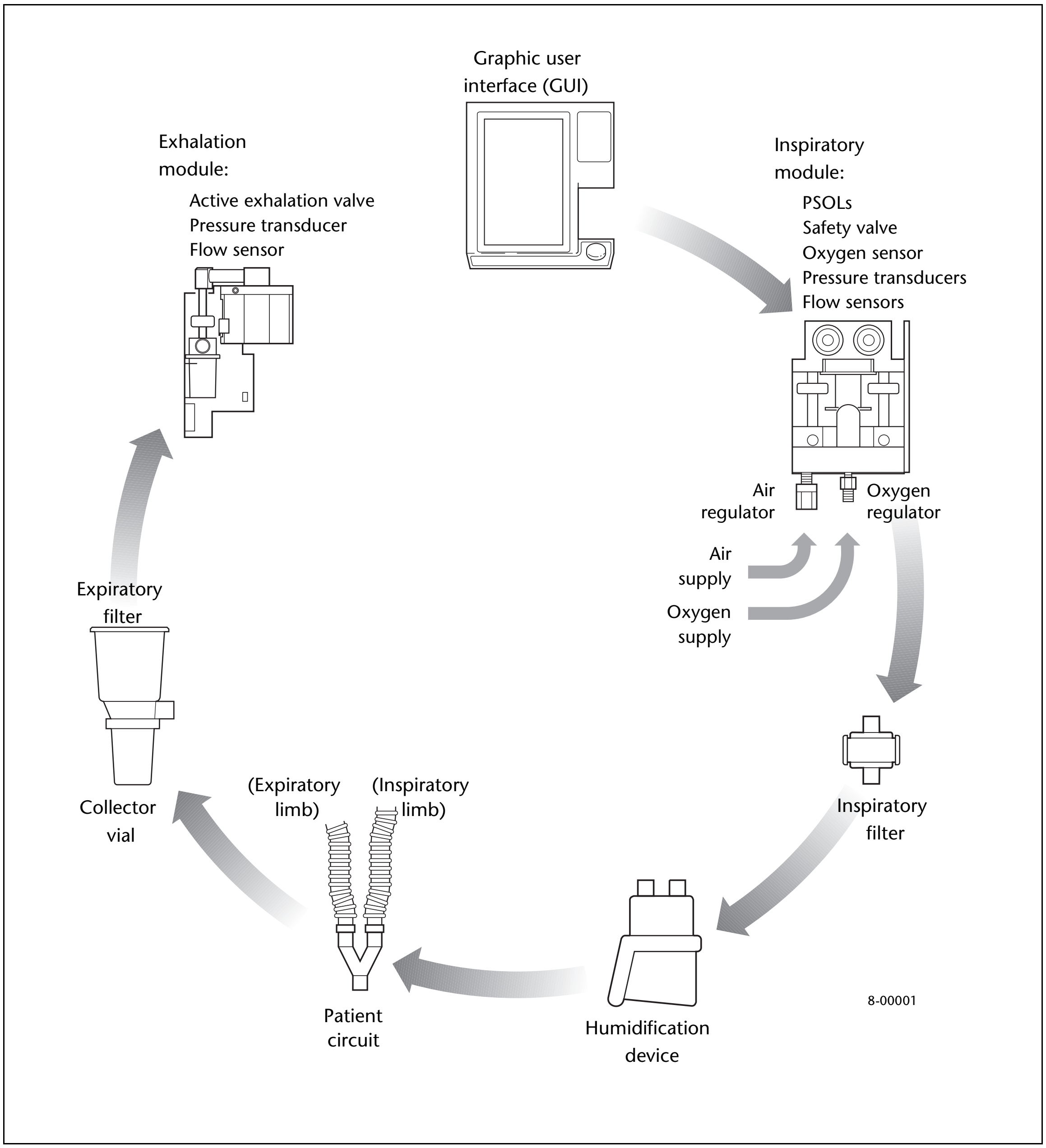


Figure 2-9. *840* Ventilator System block diagram

The GUI logs an event in the diagnostic log and declares a ventilator inoperative condition if:

- Any raw signal data from three BDU transmissions within 24 hours is corrupted.
- The GUI does not receive data from the BDU within the time required.
- The GUI determines that raw data is valid, but settings or alarm limits are not being handled properly.

The ventilator uses flow or pressure triggering to recognize patient effort. When *pressure triggering* (P-TRIG) is selected, the ventilator monitors pressure in the patient circuit. As the patient draws gas from the circuit and the airway pressure drops by at least the value selected for pressure sensitivity ($\dot{V}_{SENS}$), the ventilator triggers a breath.

When *flow triggering* ($\dot{V}$-TRIG) is selected, the BDU maintains a constant flow of gas through the patient circuit (called *base flow*) during the later part of exhalation. The ventilator indirectly measures patient flow (assuming minimal leaks) by monitoring the difference between the inspiratory and expiratory flow sensor measurements. If the patient is not inspiring, any difference between the delivered and the exhaled flow is due to sensor inaccuracy or leaks in the patient system. To compensate for leaks in the patient system, the operator can increase the flow sensitivity, which ideally equals desired flow sensitivity + leak flow.

As the patient inspires from the base flow, the ventilator measures less exhaled flow while delivered flow remains constant. As the patient continues to inspire, the difference between the two flows, measured by the inspiratory and expiratory transducers, increases.

The ventilator declares an inspiration when the flow inspired by the patient (that is, the difference between the measured flows) is equal to or greater than the operator-selected value for flow sensitivity ($\dot{V}_{SENS}$).

As a backup method of triggering inspiration, a pressure sensitivity of 1 cmH_2O is also in effect. This setting is the most sensitive setting that is still large enough to avoid autocycling, yet will trigger with acceptable patient effort.

Air and oxygen from cylinders, wall supplies, or compressor (air only) enter the ventilator through hoses and fittings (the fittings are available in several versions). Once inside the ventilator, air and oxygen are regulated to pressures appropriate for the ventilator, then mixed according to the operator-selected O_2%.

The ventilator delivers the mixed air and oxygen through the *inspiratory module*, and out to the patient. The oxygen concentration of the delivered gas is monitored here, using a galvanic oxygen sensor. The galvanic sensor generates a voltage proportional to the oxygen concentration. The ventilator alarms if the monitored oxygen concentration is more than seven percent above or below the O_2% setting, or below 18%. A safety valve relieves patient pressure if necessary (for example, if the patient circuit is kinked or occluded). The operator selects the humidification type, which the ventilator uses to correct for gas temperature and humidity.

Ventilator inspiratory pneumatics consist of two parallel circuits: one for oxygen and one for air. The primary elements of the inspiratory pneumatics are two proportional solenoid valves (PSOLs), which control the flow of gas delivered to the patient. Air and oxygen flow sensors, along with pressure signals from the inspiratory and exhalation modules, provide feedback that is used by the BDU CPU to control the PSOLs. As a result, the ventilator supplies mixed breathing gas to the patient according to operator-set variables. The mixed air and oxygen passes through the patient circuit external to the ventilator.

The *patient circuit* includes the components external to the ventilator that route gas between the ventilator and the patient. These components include the *inspiratory filter* (which protects against contamination between the patient and ventilator), a humidification device, the inspiratory and expiratory limbs of the patient circuit (the tubing through which the gas travels), a *collector vial* (which protects the expiratory system from bulk moisture in the exhaled gas), and an *expiratory filter* (which limits the bacteria in the patient's exhaled gas from escaping to room air or contaminating the ventilator).

The ventilator actively controls the exhalation valve, which is accurately positioned by software throughout inspiration and exhalation, and allows the ventilator to deliver aggressive breaths while minimizing pressure overshoots, controlling PEEP, and relieving excess pressures. The exhalation system monitors the gas leaving the patient circuit for spirometry.

Throughout the respiratory cycle, pressure transducers monitor inspiratory, expiratory, and atmospheric pressures. The temperature of the exhaled gas is heated to a temperature above its dew point to prevent condensation in the exhalation compartment.

Power to operate the ventilator comes from ac mains (wall) power or the BPS. The integral power supply is designed to protect against excessive voltages, temperatures, or current draws. A power cord retainer prevents accidental disconnection. A power switch cover protects against spills and accidental ac power-off.

The ventilator includes the BPS that supplies dc power to the ventilator if ac power is lost. A fully charged BPS operating under nominal ambient conditions can power the ventilator for at least 30 minutes. The BPS recharges during operation from ac power. The GUI and BPS indicate when the ventilator is operating on the BPS. The BPS does not power the compressor unit or the humidifier power outlet.

In some situations, the ventilator declares a *ventilator inoperative* condition. A hardware failure or critical software error that could compromise safe ventilation triggers this condition. When this occurs, the ventilator inoperative indicator lights and the ventilator enters the *safety valve open (SVO)* state. To correct a ventilator inoperative condition, the ventilator must be turned off, then powered on again; at power on, a qualified service technician must run extended self test (EST). The ventilator must pass EST before normal ventilation can resume.

In the safety valve open (SVO) state, the safety valve allows the patient to breathe room air unassisted. The ventilator remains in the SVO state until the condition that caused the SVO state is corrected or, if the ventilator declared a ventilator inoperative condition, the power on self test (POST) verifies that power levels to the ventilator are acceptable and that the major electronics systems are functioning correctly.

If the ventilator enters the SVO state, the safety valve open indicator lights and a high-urgency alarm sounds. The ventilator enters the SVO state if a hardware or software failure occurs that could compromise safe ventilation, both air and oxygen supplies are lost, or an occlusion is detected. In case of a malfunction that prevents software from opening the safety valve, there is also an analog circuit that opens the safety valve if system pressure exceeds 100 to 120 cmH_2O.

2.3 Pneumatic system

This subsection describes the *840* Ventilator pneumatics, as follows:

- Inspiratory module: Contains the following pneumatic subsystems:
  - Gas supply conditioning subsystem
  - Flow control subsystem
  - Safety valve/inspiration monitoring subsystem
- Patient system
- Exhalation module
- Compressor unit (optional)

Figure 2-10 and Figure 2-11 are diagrams of the pneumatic system. Table 2-1 lists the components within the pneumatic system.

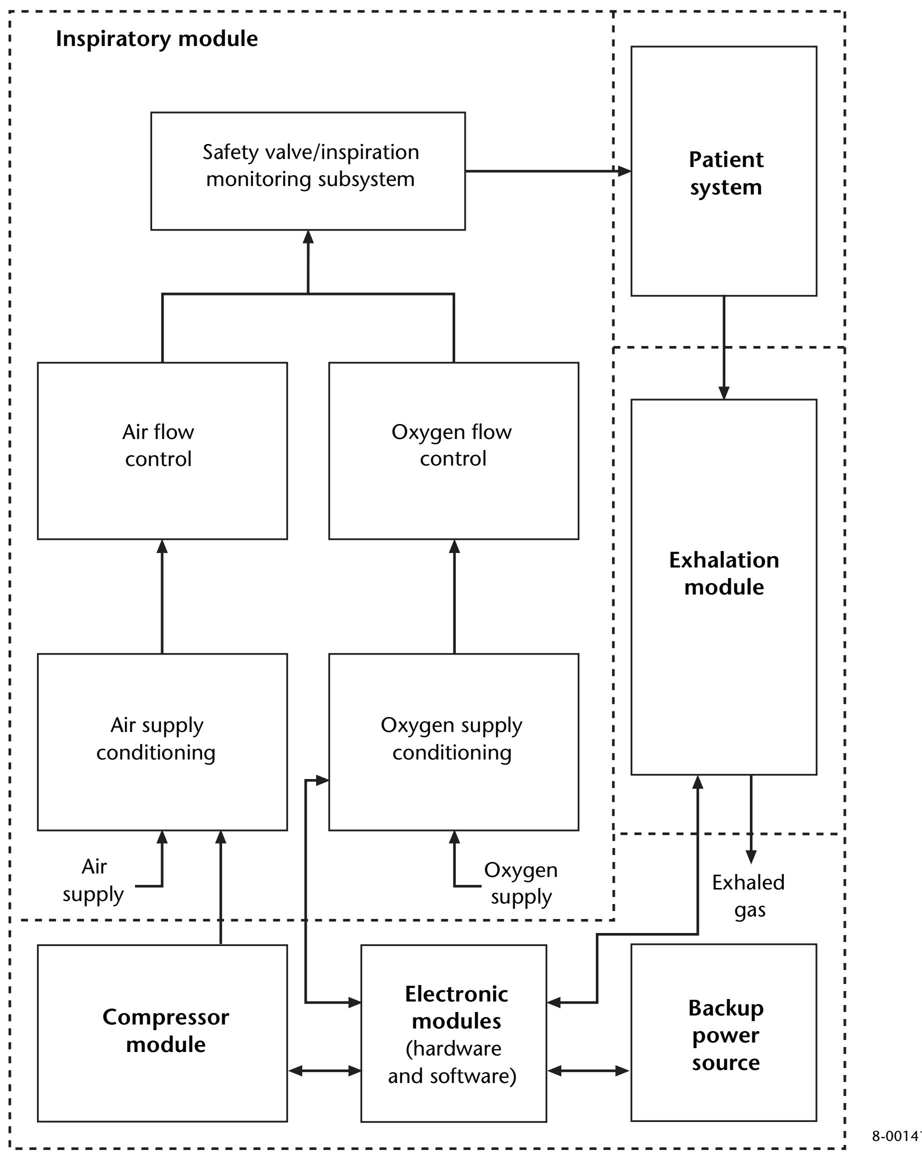


Figure 2-10. Pneumatic system block diagram

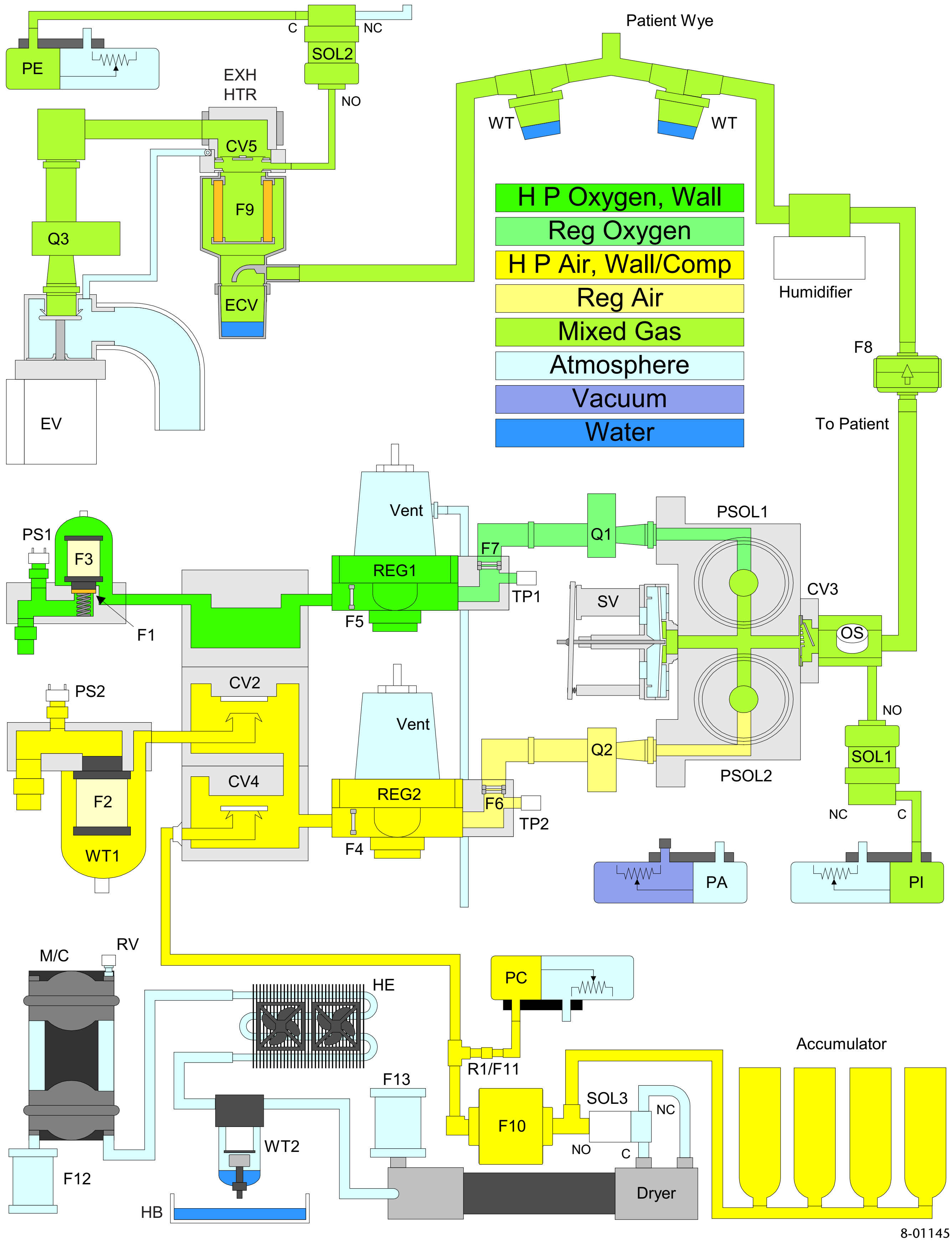


Figure 2-11. Pneumatic system diagram

Table 2-1: Pneumatic component descriptions

Reference designator	Component	Description
Inspiratory module		
--	Fitting, inlet	Connects external oxygen and air sources to ventilator via hoses. Fittings include diameter index system standard (DISS) (male or female), noninterchangeable screw thread (NIST), Air Liquide, and Sleeved Index System (SIS).
	Manifold, flow sensor	Holds bases of flow sensors Q1 and Q2, and houses pressure valves TP1 and TP2 and pneumatic noise filters F6 and F7.
--	Manifold, PSOL/SV	Houses proportional solenoid valves (PSOL1 AND PSOL2) and safety valve (SV).
--	Orifice, inspiratory pressure relief	Bypasses inspiratory check valve to relieve pressure when an occlusion is present in exhalation circuit while safety valve is open. Minimizes rebreathing of exhaled gas during SVO.
CV2 **CV4**	Check valve, air/compressor	CV2 opens to admit external compressed air and CV4 closes to isolate compressor unit. When CV4 opens to allow compressor-supplied compressed air, CV2 closes to prevent compressed air (compressor source) from venting out the air (external source) inlet fitting.
CV3	Check valve, inspiratory	Opens to supply inspiratory gas and restricts exhalation flow in reverse direction.
F1	Filter, oxygen impact	Traps particles larger than 65 to 110 µm (microns).
F3 **F2**	Filter, inlet, oxygen/air	Filters matter greater than 0.3 µm (micron).
F5 **F4**	Filter, screen, oxygen/air impact	Filters large debris from REG1 and REG2. These filters are part of the regulator assemblies (one in each regulator).
F7 **F6**	Filter, pneumatic noise, oxygen/air	Conditions gas flow by eliminating swirling of gas induced by elbows and restrictions. These filters are part of the flow sensor manifold (two in each manifold).
OS	Sensor, oxygen (percentage)	Measures partial pressure of oxygen in inspired gas. Range is 21 to 100% O_2.
PA	Pressure transducer, absolute	Measures atmospheric pressure (psia). Located on inspiratory electronics PCB.
PI	Pressure transducer, inspiratory	Measures pressure (psig) at outlet manifold. Located on inspiratory electronics PCB.
PS1 **PS2**	Pressure switch, oxygen/air	Opens when pressure is less than 20.0 psig nominal. Closes when pressure is greater than 31.5 psig nominal.
PSOL1 **PSOL2**	Proportional solenoid valve, oxygen/air	0 to 200 L/min BTPS output (intermittent) or 0 to 180 L/min BTPS output (steady state).
Q1 **Q2**	Sensor, flow, oxygen/air	Measures oxygen or air flow before PSOL.
REG1 **REG2**	Regulator, oxygen/air	Reduces input supply pressure (35 to 100 psig, flow up to 200 L/min BTPS) to output pressure (9 psig minimum to 12 psig maximum).

Table 2-1: Pneumatic component descriptions (continued)

Reference designator	Component	Description
SOL1	Solenoid, autozero, inspiratory pressure transducer	+6 V, three-way solenoid. Energized (common to normally closed) when transducer is autozeroed. De-energized (common to normally open) all other times.
SV	Safety valve	+12 V actuator. Commanded open (de-energized) at 100 cmH_2O, during power on self test (POST), loss of both source gases, or due to ventilator inoperative condition. Energized (closed) all other times.
TP1 **TP2**	Pressure valve, oxygen/air	Allows measurement of REG1 and REG2 output.
WT1	Water trap, air	Houses air inlet filter (F2) and includes a manual drain.
Patient system		
--	Humidification device (optional)	Humidifies inspired gas.
--	Wye	Connects inspiration and expiration tubing forming a closed circuit.
ECV	Collector vial, exhalation	Collects water (up to 250 mL with the full line at 200 mL) resulting from condensation in patient circuit. Neonatal collector vial collects up to 25 mL water (with the full line at 15 mL) .
F8	Filter, inspiratory (main flow)	Filters matter greater than 0.3 µm (micron) (nominal) at 100 L/min flow.
F9	Filter, expiratory	Filters matter greater than 0.3 µm (micron) (nominal) at 100 L/min flow.
WT	Trap, water	Collects excessive water. Present only on certain patient circuits.
--	Mounting plate (neonatal only)	Allows neonatal expiratory filter to be installed in place of adult filter.
Exhalation module		
CV5	Check valve, exhalation	Opens during exhalation to let exhaled gas into exhalation system. Prevents rebreathing when safety valve is open.
EV	Exhalation valve	Electronically controlled, electrically operated valve that opens during exhalation (as required to maintain positive end expiratory pressure (PEEP)/continuous positive airway pressure (CPAP). Closed during inspiration.
EXH HTR	Heater, exhalation	16 W heater that maintains gas temperature above condensation level.
PE	Pressure transducer, expiratory	Measures pressure (psig) at a port on exhalation transducer PCB.
Q3	Sensor, exhalation flow	Measures exhalation flow.
SOL2	Solenoid, autozero, expiratory pressure transducer	+6 V, three-way solenoid valve. Energized (common to normally closed) when transducer is autozeroed. De-energized (common to normally open) all other times.

Table 2-1: Pneumatic component descriptions (continued)

Reference designator	Component	Description
806 Compressor Unit (optional)		
Accumulator	Accumulator	Four 1-L cylinders store compressed air generated by the compressor.
Dryer	Air dryer	Removes water vapor from the compressed air to lower the dew point below ambient temperature.
F10	Filter	0.3 micron filter that filters gas going to the ventilator.
F11	Filter	Filters air to the pressure transducer on the PCBA.
F12	Filter, intake silencer	Filters and silences the compressor intake.
F13	Silencer	Reduces noise from the air dryer.
HB	Housing base	Collects water emptied from the water trap where it evaporates using heat from the compressor motor and air flow from the fans.
HE	Heat exchanger	Cools the compressed air allowing water vapor to condense.
M/C	Motor/compressor assembly	Supplies compressed air to the ventilator. Includes starting capacitor, shock mounts, inlet filter, and relief valve.
PC	Compressor pressure transducer	Differential pressure transducer that measures accumulator pressure.
R1	Restrictor	Reduces pressure pulsations to the pressure transducer on the PCBA.
RV	Relief valve	Prevents over-pressurization of the compressor system. Opens when pressure reaches 36 psig.
SOL 3	Unloading solenoid	Opens to atmosphere upon compressor start-up to reduce start-up load on the compressor. During continuous use, vents excess accumulator pressure to the air dryer to assist in drying compressed air.
WT2	Water trap	Collects condensate as the compressed air cools in the heat exchanger. Automatically drains collected water to the housing base where it evaporates.

2.3.1 Inspiratory module

The inspiratory module, which is part of the BDU, is shown in Figure 2-12 and Figure 2-13. It includes the gas supply conditioning, flow control, and safety valve/inspiration monitoring subsystems. Figure 2-14 is a diagram of the inspiratory module gas flow.

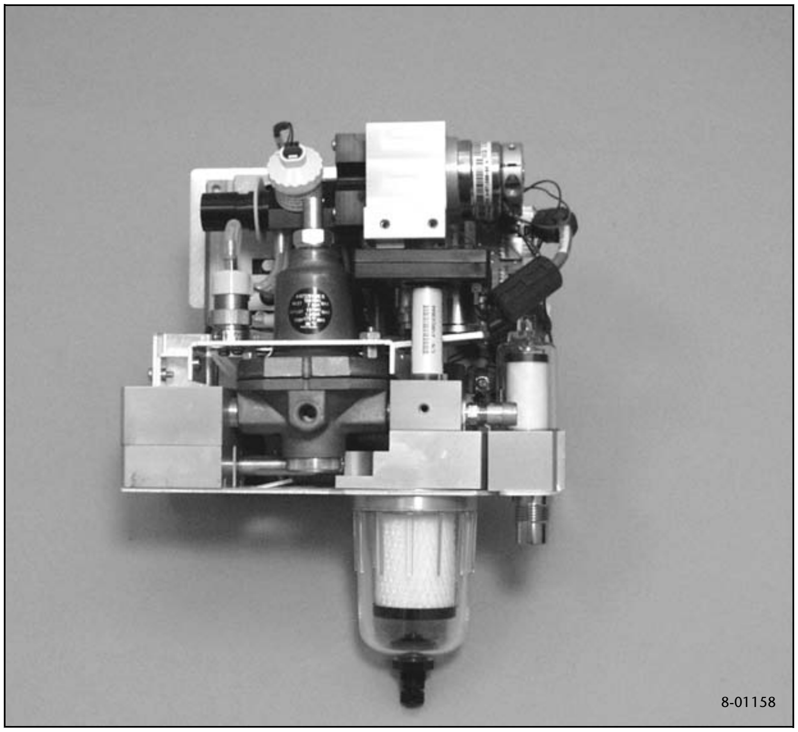


Figure 2-12. Inspiratory module

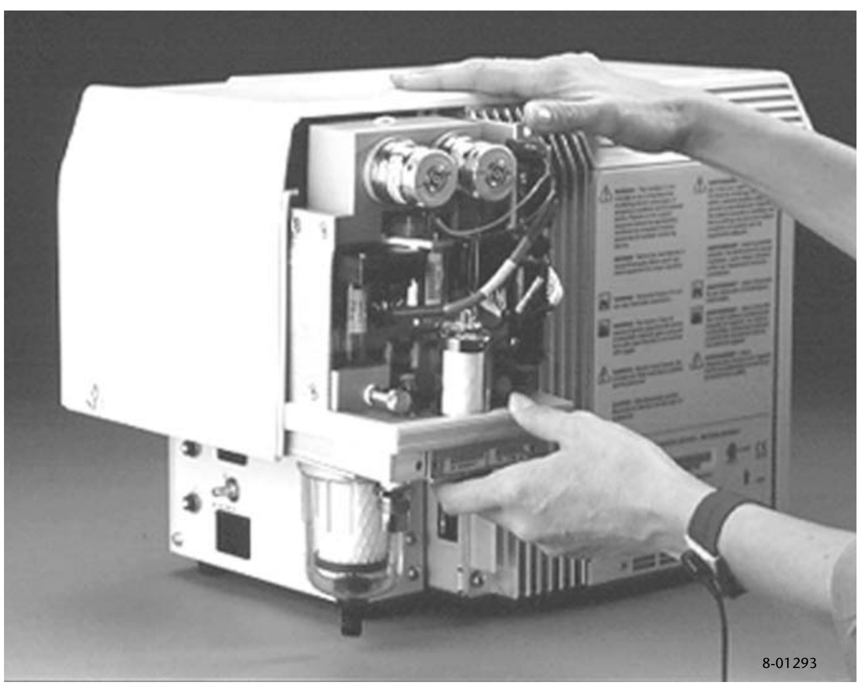


Figure 2-13. Inspiratory module in ventilator

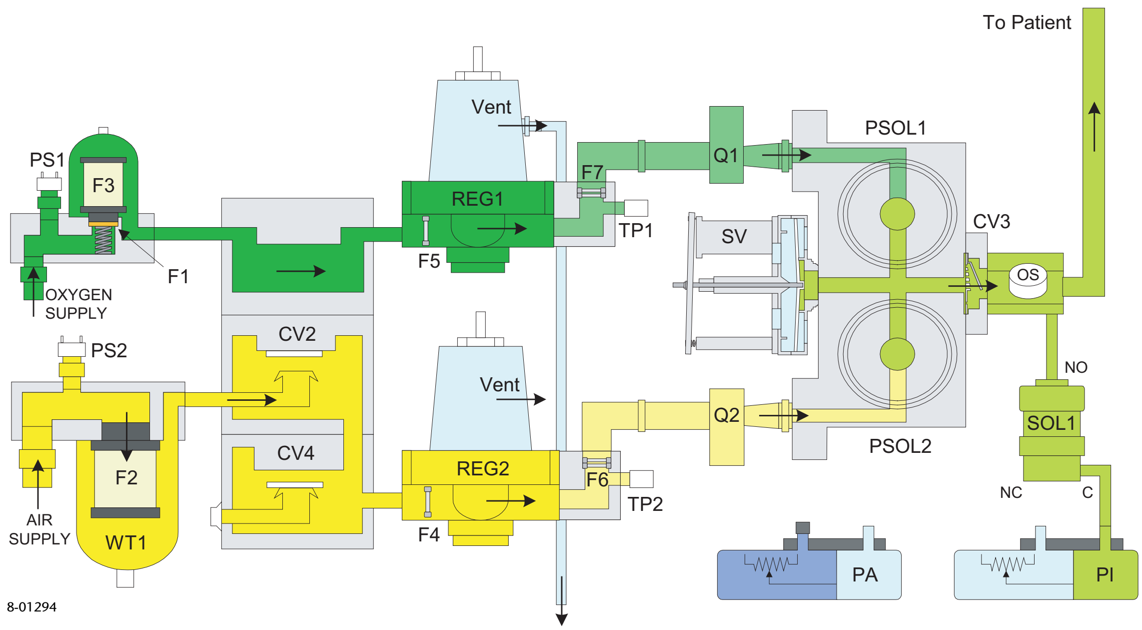


Figure 2-14. Inspiratory module gas flow diagram

2.3.1.1 Gas supply conditioning subsystem

The gas supply conditioning subsystem (Figure 2-15) receives air and oxygen from external supplies and regulates the gases to usable pressures. This subsystem has two parallel, but not identical, pneumatic circuits for oxygen and air. The gas supply conditioning subsystem supplies the patient with the alternate gas when one gas source is lost. It does this by sending signals to the electronics when a gas source falls below a minimum pressure. Figure 2-16 illustrates the gas flow through gas supply conditioning subsytem.

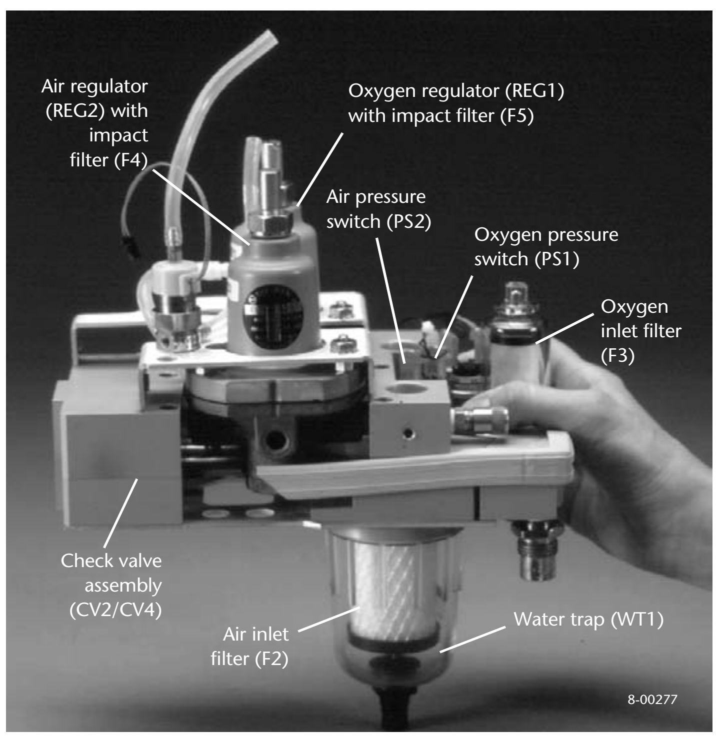


Figure 2-15. Gas supply conditioning subsystem

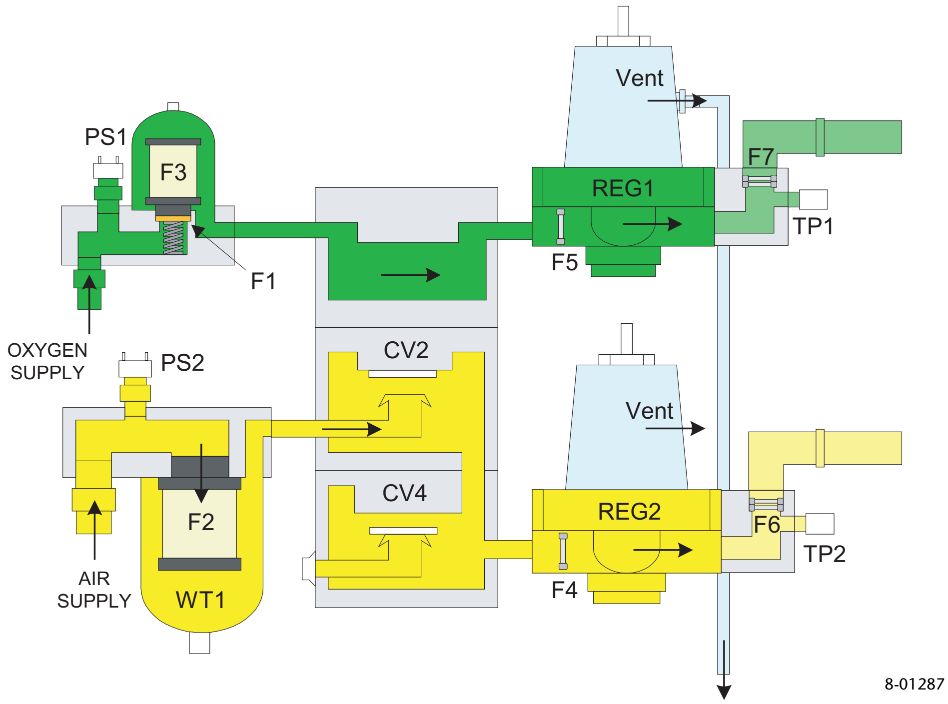


Figure 2-16. Gas supply conditioning subsystem gas flow diagram

2.3.1.1.1 Gas supply conditioning subsystem components

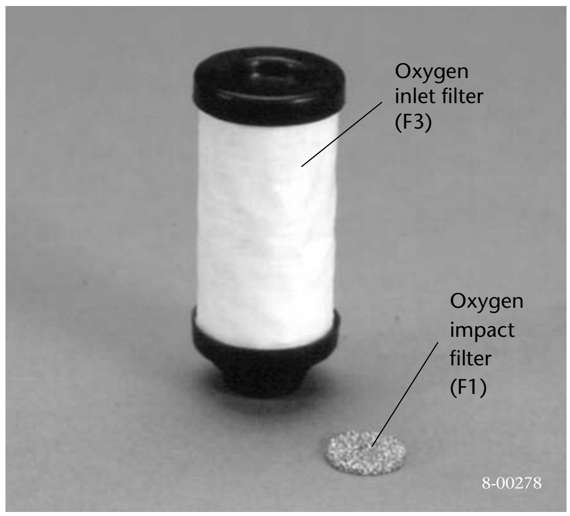
The oxygen side of the gas supply conditioning subsystem includes the following components:

- The ***oxygen hose and inlet fitting*** connect an external oxygen source to the ventilator. Inlet fittings are available in DISS male, DISS female, NIST male, Air Liquide, and SIS male.
- The ***oxygen pressure switch (PS1)*** senses a loss of supply pressure. This 12V, normally open switch closes when gas pressure reaches 31.5 psig nominal and opens when gas pressure reaches 20.0 psig nominal.
- The ***oxygen impact filter (F1)*** filters matter larger than 65 to 110 µm (microns).
- The ***oxygen inlet filter (F3)*** protects the pneumatic systems from debris by trapping particles down to 0.3 µm (micron). The bowl and O-ring must be properly installed to prevent oxygen leakage into the inspiratory module.
- The ***oxygen regulator (REG1)*** is a spring-loaded, venting line regulator that maintains 9 to 12 psig output throughout a 35 to 100 psig supply range, from less than 1 L/min to 200 L/min. Its nominal output is 10.5 psig at 2 L/min. REG1 vents outside the BDU. The REG1 FRU includes the ***oxygen impact screen filter (F5)***, which removes debris entering REG1.
- The ***oxygen pressure valve (TP1)*** checks the oxygen regulator setting (REG1).
- The ***oxygen pneumatic noise filter (F7)***, housed in the flow sensor manifold, conditions gas flow by eliminating swirling of gas induced by elbows and restrictions.

The air side of the gas supply conditioning subsystem includes the following components:

- The ***air hose and inlet fitting*** connect an external high-pressure air source to the ventilator. Inlet fittings are available in DISS male, DISS female, NIST male, Air Liquide, and SIS male fittings.
- The ***air pressure switch (PS2)*** senses a loss of supply pressure. This 12 V, normally open switch closes when gas pressure reaches 31.5 psig nominal and opens when gas pressure reaches 20.0 psig nominal.
- The ***air inlet filter (F2)*** protects the pneumatic systems from debris by trapping particles down to 0.3 μm (micron).
- The coalescing ***air water trap (WT1)*** removes condensation from the high-pressure air. This condensation can be caused by pressure drops between the wall outlet and water trap. WT1 also houses F2. It has a screw-type drain valve.
- The ***air and compressor check valves (CV2 and CV4)***, housed in the check valve manifold, are high-pressure unidirectional valves that prevent ventilator backflow into the air system. CV2 opens and CV4 closes when wall air pressure exceeds compressor air pressure (or no compressor is installed). CV4 opens and CV2 closes when compressor air exceeds wall air pressure (or wall air is not connected). When wall air pressure is equal to compressor air pressure, both check valves are open.
- The ***air regulator (REG2)*** is a spring-loaded, venting line regulator that maintains 9 to 12 psig output throughout a 35 to 100 psig supply range, from less than 1 L/min to 200 L/min. Its nominal output is 10.5 psig at 2 L/min. REG2 vents inside the BDU. The ***air impact screen filter (F4)***, housed in REG2, removes debris entering REG2.
- The ***air pressure valve*** (TP2) checks the oxygen regulator setting (REG2).
- The ***air pneumatic noise filter (F6)***, housed in the flow sensor manifold, conditions gas flow by eliminating swirling of gas induced by elbows and restrictions.

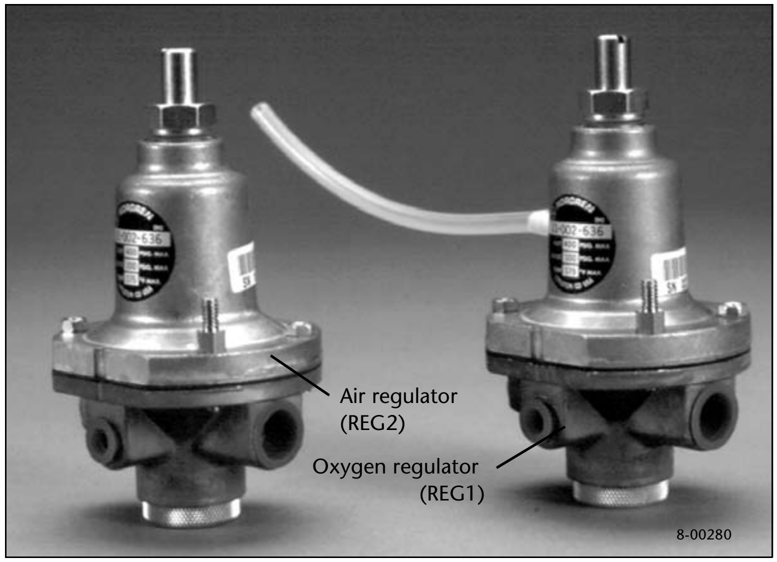
Oxygen/air pressure switches (PS1/PS2)



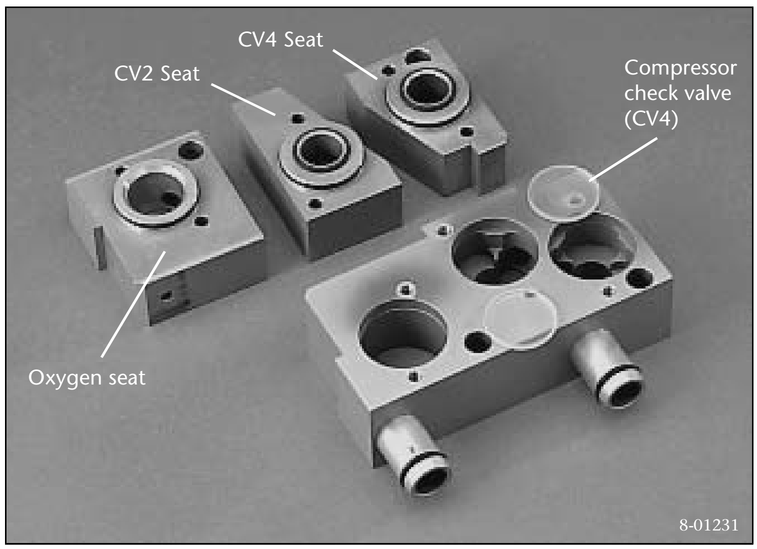
Oxygen Filters (F1 and F3)

Air inlet filter (F2)

Figure 2-17. Gas supply conditioning subsystem components



Oxygen and air regulators (REG1 and REG2)



Air and compressor check valves (CV2 and CV4)

Figure 2-17. Gas supply conditioning subsytem components (continued)

2.3.1.1.2 Gas supply conditioning subsystem operation

High-pressure oxygen and air enter the ventilator. Normally-open pressure switches, PS1 and PS2, monitor oxygen and air supply pressures. When gas pressure reaches 31.5 psig nominal, the respective pressure switch closes, signaling the inspiratory electronics PCB that the supply is adequate. When the oxygen or air pressure drops to 20.0 psig nominal, the corresponding pressure switch opens, causing a NO AIR SUPPLY or NO O2 SUPPLY alarm. (See Section 7 for alarm handling.) The patient is ventilated with the remaining gas source. If both gas sources are lost, the ventilator alarms and opens the safety valve, and the patient breathes air from the room, unassisted by the ventilator.

On the air side, the air inlet filter (F2) protects the pneumatic system from debris and WT1 protects the pneumatic system from water condensation. The air transfer tube directs the air to the check valve manifold, which contains the air check valve (CV2) and the compressor check valve (CV4). These check valves direct air from the highest pressure to the next part of the system.

NOTE:
Use an external (optional) water trap if there is condensation in the piping system.

On the oxygen side, two filters protect the pneumatic system from debris. The first filter, the oxygen impact filter (F1), traps particles down to 65 µm (microns) and the subsequent filter, the oxygen inlet filter (F3), traps particles down to 0.3 µm (micron). The oxygen transfer tube directs oxygen to the check valve manifold. There is no check valve for oxygen.

On both the oxygen and air sides, filtered gas passes through screen filters F5 and F4, which are part of regulators REG1 and REG2. The regulators maintain a stable nominal output of 10.5 psig. Pneumatic noise filters F7 and F6, part of the flow sensor manifold, condition gas flow by eliminating swirling of gas induced by elbows and restrictions.

Pressure valves TP1 and TP2 let you check the regulator settings. This is done as part of the performance verification (see Section 5).

2.3.1.2 Flow control subsystem

The flow control subsystem, shown in Figure 2-19 and Figure 2-18, controls the mixture and flow of oxygen and air to the patient. It is mounted on the gas supply conditioning subsystem.

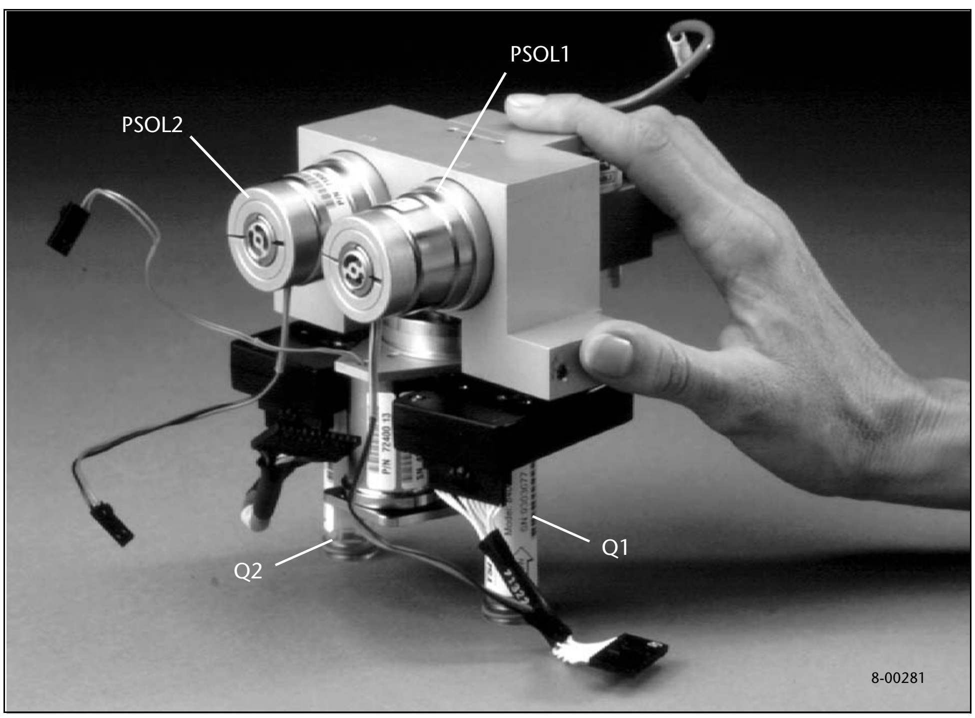


Figure 2-18. Flow control subsystem

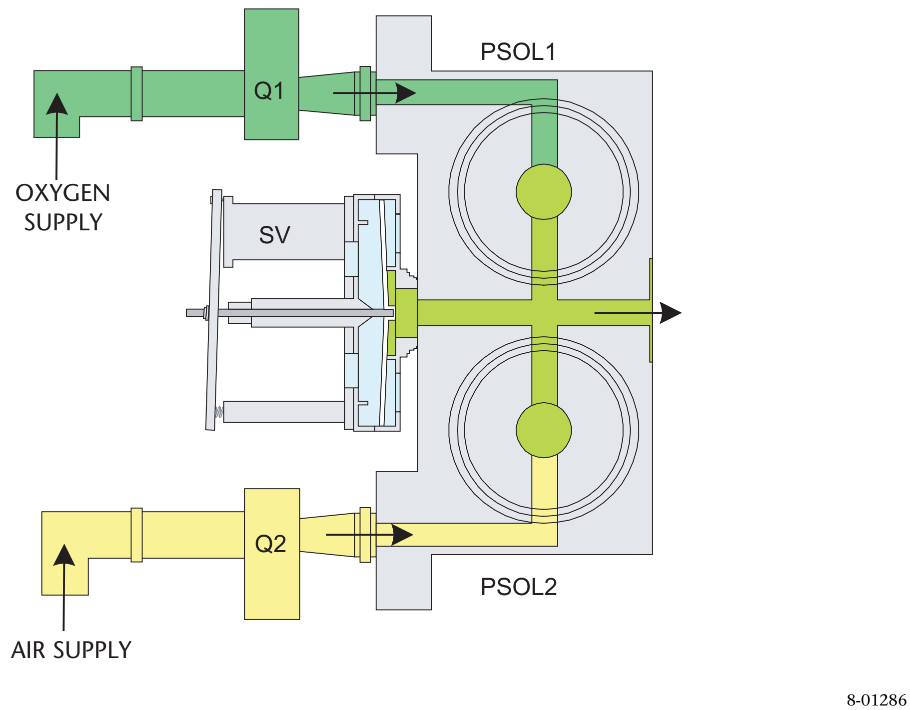


Figure 2-19. Flow control subsystem gas flow diagram

2.3.1.2.1 Flow control subsystem components

The flow control subsystem includes two parallel pneumatic circuits for oxygen and air; the components on either side are interchangeable. The following components, shown in Figure 2-21, comprise this subsystem:

- The ***oxygen and air flow sensors (Q1 and Q2)*** measure gas flow in the oxygen and air circuits. The same flow sensor works on either the oxygen or air side. The flow sensors use unique harnesses which determine the identity of each flow sensor. The flow sensors have an onboard EPROM preprogrammed with the sensor's serial number. Any time you install a new sensor or swap existing sensors, you must run the flow sensor calibration function (part of the service mode). At power-on, the BDU verifies the serial number, sensor position (air or oxygen), and calibration data from both flow sensors.
- Q1 and Q2 use a hot film (Figure 2-20) within each sensor to measure gas velocity (flow). The hot film constitutes one leg of a bridge circuit. The bridge is supplied by a constant current. With no flow, all legs of the bridge circuit have equal resistance. As flow increases (velocity increases), hot film temperature (and resistance) decreases. Current through the hot film leg increases, and the bridge circuit becomes unbalanced. Output voltage V_{OUT} increases proportionally to gas flow.
- The ***oxygen and air proportional solenoid valves (PSOL1 and PSOL2)*** are software-driven and individually controlled to deliver the prescribed air/oxygen mixture to the patient. Each proportional solenoid valve includes a linear motor that controls a poppet valve. The poppet valves open in proportion to the applied current.

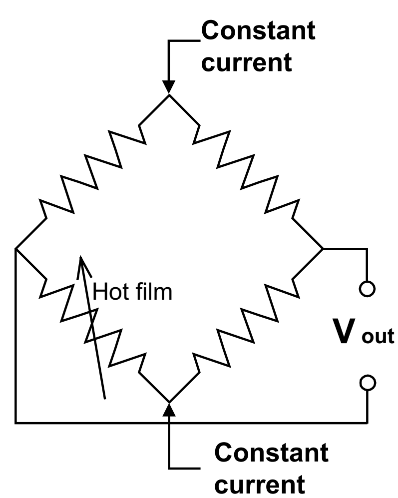
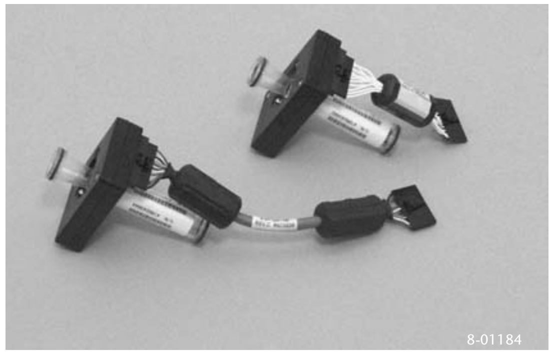
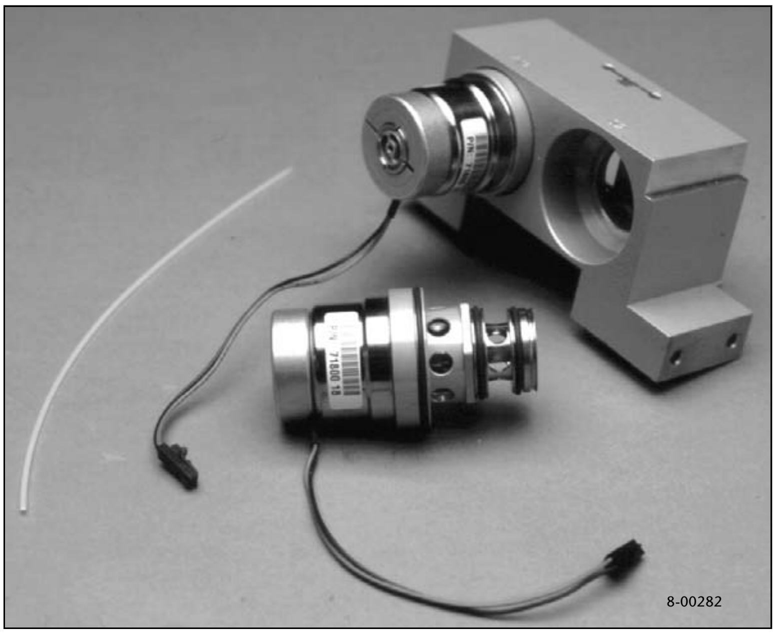


Figure 2-20. Hot film



Oxygen and air flow sensors (Q1 and Q2) with ferrites installed



Oxygen and air proportional solenoid valves (PSOL1 and PSOL2)

Figure 2-21. Flow control subsystem components

2.3.1.2.2 Flow control subsystem operation

The flow control subsystem controls the following ventilation parameters:

- Peak flow (up to 200 L/min for spontaneous breaths)
- Square and descending waveforms
- Tidal volume (25 to 2500 mL)
- Oxygen percentage (21 to 100%)
- Breath rate (1 to 100/min)

The PSOL control loop operates in two modes: PSOLs closed and PSOLs opened.

While the ventilator is in the PSOLs closed mode, the following are true:

- The flow requirement is determined by BDU software (lookup table or calculate). Required current is then calculated and is added to lift-off current.
- Current is sent to the PSOL. A reasonableness check is performed on this current.
- Flow is checked at flow sensors Q1 and Q2.
- Target flow and flow at the sensor are compared (error determined). The current needed to reposition the PSOL is calculated and sent to the applicable PSOL.
- The PSOL current is checked for reasonableness.

While the ventilator is in the PSOLs opened mode, the following are true:

- Flow is checked at flow sensors Q1 and Q2.
- Target flow and flow at the sensor is compared (error determined). Current needed to reposition the PSOL is calculated and sent to the applicable PSOL.
- The PSOL current is checked for reasonableness.

Target gas flow is derived differently for each breath type (volume-limited mandatory, pressure-limited mandatory, spontaneous, and spontaneous with pressure support). The flow control algorithm compensates for aging components. It also prevents overshoot.

2.3.1.3 Safety valve and inspiration monitoring subsystem

The safety valve and inspiration monitoring subsystem, shown in Figure 2-22 and Figure 2-23, is mounted on the gas supply conditioning subsystem. This subsystem includes:

- A safety valve section that, under certain circumstances, vents excessive ventilator pressure and lets the patient breathe room air.
- An inspiration monitoring section that monitors the pressure and oxygen concentration of the inspiratory gas.

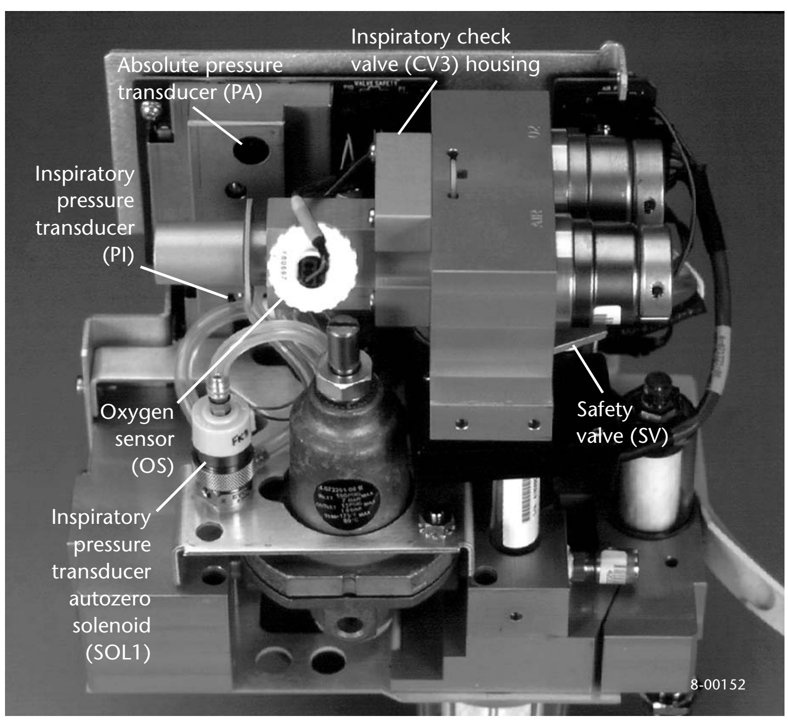


Figure 2-22. Safety valve and inspiration monitoring subsystem

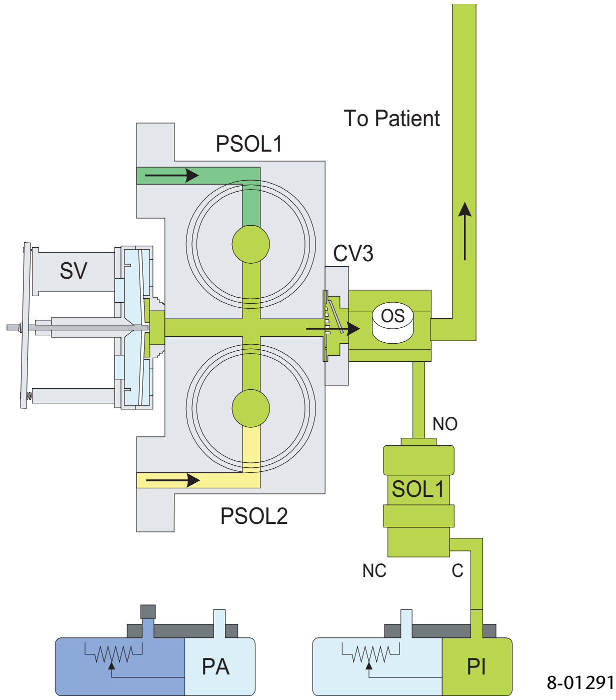


Figure 2-23. Inspiration monitoring subsystem gas flow diagram

2.3.1.3.1 Safety valve and inspiration monitoring subsystem components

The safety valve section includes the following components, shown in Figure 2-23:

- The ***safety valve*** (***SV***) consists of a +12 V solenoid actuator that is normally energized (closed) while the ventilator operates. The closed valve prevents gas from escaping to the room and thus allows the ventilator to deliver gas through the outlet manifold to the patient.

  SV has two important safety functions. First, if outlet pressure exceeds the maximum operating pressure or if pressure measured at the expiratory pressure transducer (PE) reaches 100 cmH_2O, the valve passively relieves the excess pressure. The actual SV relief pressure may vary depending on the patient flow rate. Second, if the control system detects a catastrophic failure, the valve is opened and the patient can freely breathe room air.

  Under some circumstances, including when a ventilator inoperative condition is declared, SV is de-energized, opening the patient circuit to atmosphere and venting pressure. Typically, if patient pressure exceeds 100 cmH_2O (measured at PE), the BD CPU commands SV to de-energize. If pressure at SV exceeds 115 cmH_2O nominal, SV is mechanically forced open.

- The ***outlet manifold*** houses the oxygen sensor (OS), the inspiratory check valve (CV3), and the pressure relief orifice. (See Figure 2-24.)

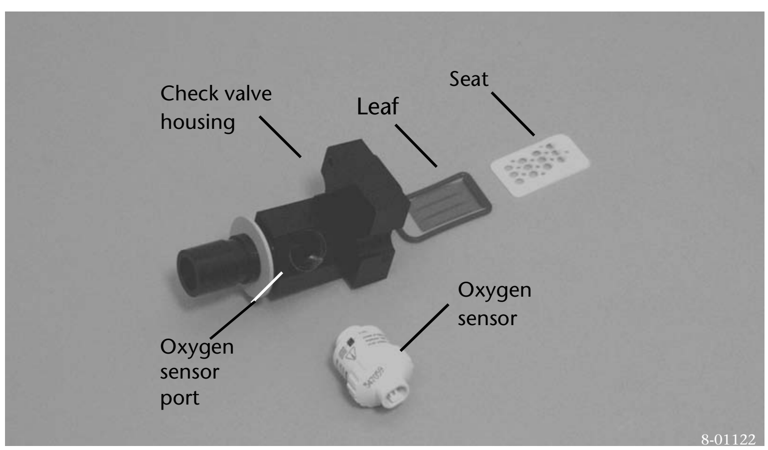
- The ***inspiratory check valve*** (***CV3***) opens to supply inspiratory gas. It also restricts exhalation flow in the reverse direction when SV is open.

The inspiration monitoring section includes the following components:

- The ***oxygen sensor*** (***OS***) monitors the oxygen concentration of delivered gas. This galvanic sensor generates a voltage proportional to the oxygen concentration. The ventilator alarms if the monitored oxygen concentration is not within ±7% of the oxygen percentage setting.

- Two solid-state differential pressure transducers monitor the pressure of the inspiratory and exhaled gases. The ***inspiratory pressure transducer*** (***PI***), located on the inspiratory electronics PCB at the inspiratory limb, monitors the pressure of the inspiratory gas. The ***expiratory pressure transducer*** (***PE***), located in the exhalation compartment, monitors the pressure of the exhaled gas.
- The ***inspiratory pressure transducer autozero solenoid*** (***SOL1***) is a +6 V, three-way solenoid. It is energized periodically to set a zero reference or offset voltage for the inspiratory pressure transducer (PI). During the autozero procedure, SOL1 connects PI to atmosphere.
- The ***absolute pressure transducer*** (***PA***), located on the inspiratory electronics PCB, measures atmospheric pressure (psia). One port is opened to the atmosphere and one port is connected to a sealed vacuum chamber.

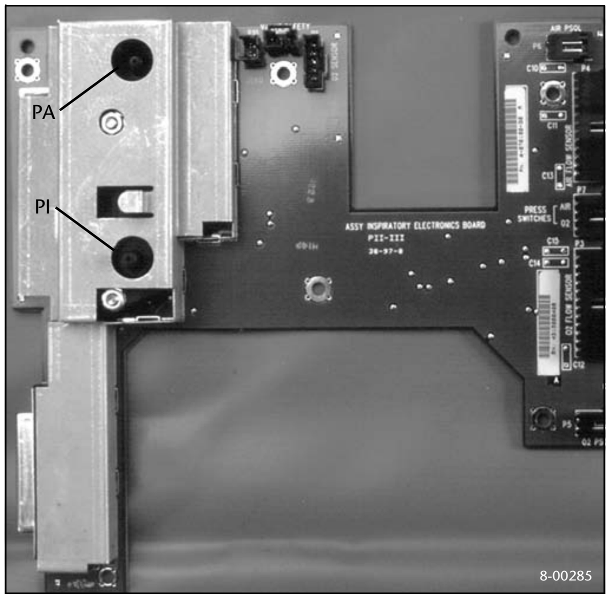
Safety valve (SV)



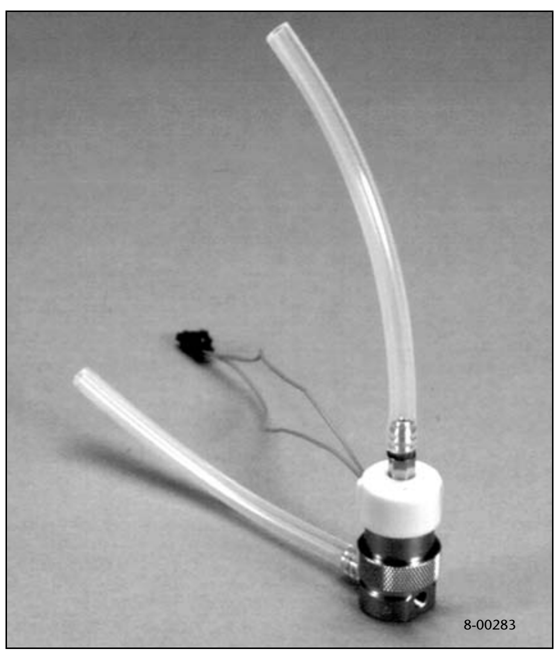
Inspiratory outlet manifold

Figure 2-24. Safety valve and inspiration monitoring subsystem components

Oxygen sensor (OS)



Absolute and inspiratory pressure transducers (PA and PI) on inspiratory electronics PCB



Inspiratory pressure transducer autozero solenoid (SOL1)

Figure 2-24: Safety valve and inspiration monitoring subsystem components (continued)

2.3.1.3.2 Safety valve section operation

During normal operation, the safety valve is energized closed so that gas is delivered to the patient.

Should the operating pressure of the patient system exceed 100 cmH_2O (measured at PE), components in the safety valve subsystem work together to relieve excess pressure.

If pressure at the safety valve reaches nominal 115 cmH_2O, the valve is forced open.

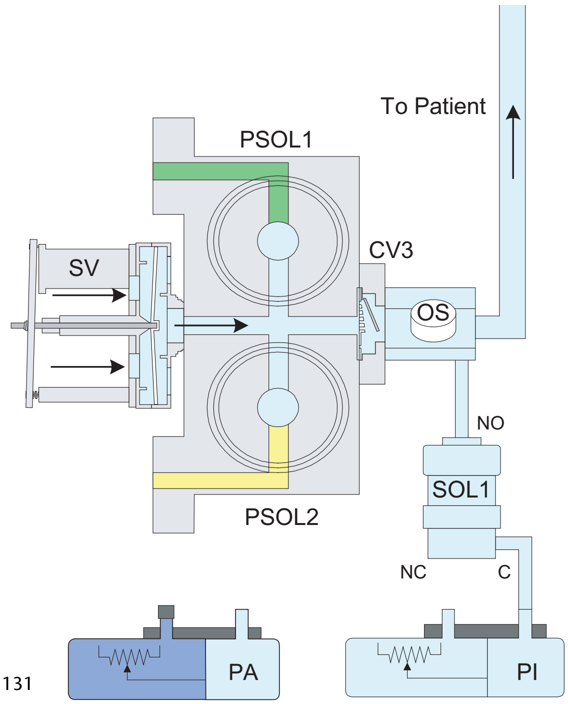


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Figure 2-25. Safety valve open gas flow diagram

In case of a catastrophic failure, such as a power failure, SV is de-energized. This action permits the patient to breathe room air. CV3, which is built into the outlet manifold, prevents rebreathing from room air by ensuring that exhalation occurs only through the exhalation valve.

2.3.1.3.3 Inspiration monitoring section operation

Pressure transducers PI, PE, and PA monitor inspiratory, expiratory, and atmospheric pressures throughout the respiratory cycle.

A patient-triggered inspiration is initiated when the patient pressure measured by the expiratory pressure transducer drops below the baseline (PEEP) by an amount equal to or greater than the pressure sensitivity setting.

Although exhalation can be triggered by time, pressure, or flow, expiratory pressure is monitored throughout the inspiratory phase. Exhalation is initiated when the system determines the expiratory pressure equals or exceeds PEEP plus the effective working pressure for spontaneous, pressure-supported breaths.

Ongoing diagnostics monitor ventilator pressures and check for severe occlusions and circuit disconnects by comparing pressure at PE and PI.

2.3.1.4 Inspiratory module operation

The following subsections describe the interaction between the pneumatic subsystems comprising the inspiratory module.

2.3.1.4.1 Air flow summary

The air flow throughout the inspiratory module and the related components are show in Figure 2-26 below.

1 Inlet fitting
2 Air pressure switch (PS2)
3 Air inlet filter (F2)
4 Air water trap (WT1)
5 Transfer tube
6 Check valve manifold
7 Air check valve (CV2)
8 Compressor check valve (CV4)
9 Air impact screen filter (F4)
10 Air regulator (REG2)
11 Flow sensor manifold
12 Air pressure valve (TP2)
13 Air pneumatic noise filter (F6)
14 Air flow sensor (Q2)
15 PSOL/SV manifold
16 Air proportional solenoid valve (PSOL2)
17 Safety valve (SV)
18 Outlet manifold
19 Inspiratory check valve (CV3)
20 Pressure relief orifice
21 Oxygen sensor (OS)
22 Inspiratory outlet
23 Inspiratory pressure transducer (PI)
24 Absolute pressure transducer (PA)
25 Inspiratory pressure transducer autozero solenoid (SOL1)
26 Inspiratory electronics PCB

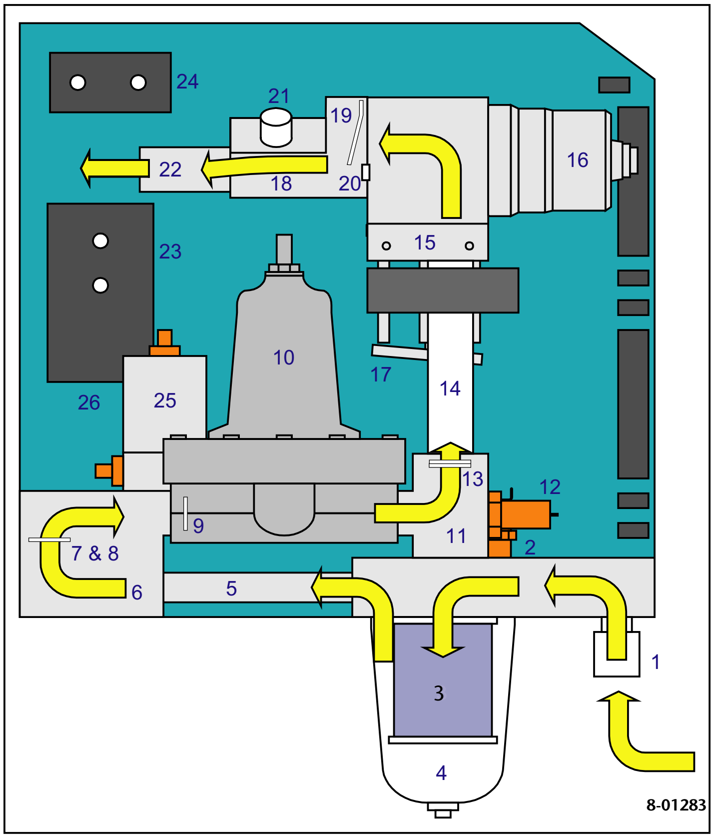


Figure 2-26. Air flow diagram

Gas in. Wall air enters the ventilator at the air inlet fitting. The ventilator requires wall air pressure maintained between 35 and 100 psig with intermittent flow up to 200 L/min. If wall air falls below compressor pressure, an optional compressor unit supplies air to the ventilator at the check valve manifold.

Pressure monitoring. Wall air is monitored by PS2 (normally open). As air pressure increases above 31.5 psig nominal, PS2 closes, indicating sufficient wall air pressure to operate the ventilator.

Filtration. The air inlet filter (F2) traps particles down to 0.3 µm (micron), protecting the pneumatic system from debris. Coalescing-type water trap WT1 collects condensation.

Wall or compressor air. Externally supplied air continues through a transfer tube to the check valve manifold, which contains the air check valve (CV2) and the compressor check valve (CV4). Depending on wall air pressure, either wall air or compressor output is supplied. If wall air pressure falls below 26 psig, compressor air is supplied to REG2.

Regulation. From the check valve manifold, air enters REG2 via the air impact screen filter (F4). F4 traps particles. REG2 reduces air pressure from 35 – 100 psig to 9 – 12 psig (10.5 psig nominal). It vents 2 L/min inside the BDU.

Turbulence smoothing. Low-pressure air enters the flow sensor manifold, which houses the air pressure valve (TP2) and the air pneumatic noise filter (F6). TP2 is used to check REG2 settings. F6 conditions gas flow by eliminating swirling of gas induced by elbows and restrictions.

Air and oxygen mixing. Air continues on to the air flow sensor (Q2), where air flow is measured. Software calculates air flow at Q2 and target flow. Software-controlled current is applied to PSOL2, opening it to allow a predetermined air flow through PSOL2. The PSOL/SV manifold houses proportional solenoid valves PSOL1 and PSOL2, and the safety valve (SV). Mixed gas is delivered to the patient circuit through the inspiratory outlet.

Safety valve. Should the operating pressure of the patient circuit exceed 100 cmH_2O (measured at PE), the safety valve opens. The outlet manifold houses the oxygen sensor (OS), the inspiratory check valve (CV3), and the pressure relief orifice. CV3 prevents rebreathing from the room by ensuring that exhalation occurs only through the exhalation valve.

Inspiration monitoring. The oxygen concentration of the delivered gas is measured by the oxygen sensor (OS). The ventilator alarms if the monitored oxygen concentration is not within ±7% of the oxygen percentage setting. Pressure measurements are made by two differential pressure transducers.

The inspiratory pressure transducer autozero solenoid (SOL1) is energized periodically to set a zero reference or offset voltage for the inspiration pressure transducer.

2.3.1.4.2 Oxygen flow summary

The following paragraphs describe oxygen flow throughout the inspiratory module (Figure 2-27).

1 Oxygen inlet fitting
2 Oxygen pressure switch (PS1)
3 Oxygen impact filter (F1)
4 Oxygen inlet filter (F3)
5 Transfer tube
6 Check valve manifold
7 Oxygen impact screen filter (F5)
8 Oxygen regulator (REG1)
9 Regulator vent
10 Flow sensor manifold
11 Oxygen pressure valve (TP1)
12 Oxygen pneumatic noise filter (F7)
13 Oxygen flow sensor (Q1)
14 PSOL/SV manifold
15 Oxygen proportional solenoid (PSOL1)
16 Inspiratory check valve (CV3)
17 Pressure release orifice
18 Outlet manifold
19 Oxygen sensor (OS)
20 Inspiratory outlet

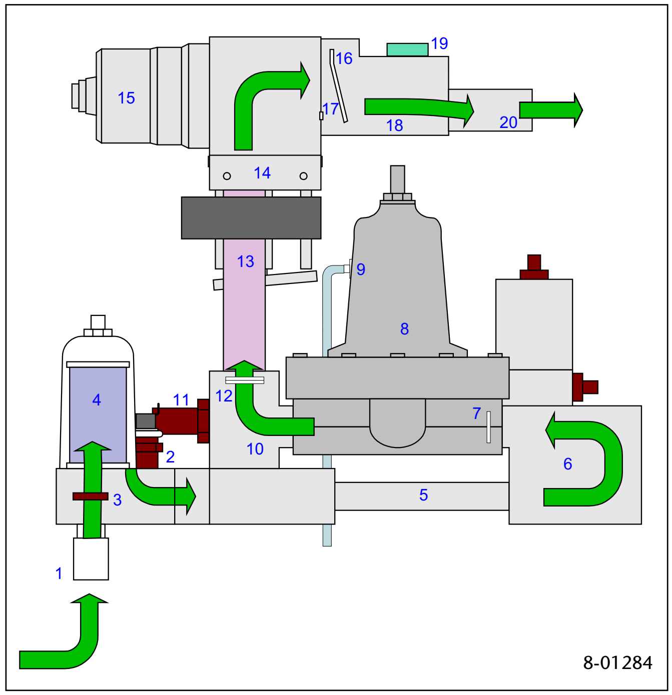


Figure 2-27. Oxygen flow diagram

Gas in. Oxygen enters the ventilator at the oxygen inlet fitting. The ventilator requires oxygen pressure maintained between 35 and 100 psig with intermittent flow up to 200 L/min.

Pressure monitoring. Oxygen is monitored by PS1 (normally open). As oxygen pressure increases above 31.5 psig nominal, PS1 closes, indicating sufficient oxygen pressure to operate the ventilator.

Filtration. The oxygen impact filter (F1) traps particles down to 65 µm (microns). The oxygen inlet filter (F3) traps particles down to 0.3 µm. These filters act together, protecting the pneumatic system from debris. Oxygen continues through a transfer tube, the check valve manifold, and on to REG1. PSOL1 provides primary, and REG1, secondary, cross-contamination protection. Thus, no oxygen check valve is required in the check valve manifold.

Regulation. Oxygen enters REG1 through the oxygen impact screen filter (F5). This filter traps large particles to prevent acceleration and to reduce particle temperature. REG1 reduces oxygen pressure from 35 – 100 psig to 9 – 12 psig (10.5 psig nominal). It vents at a maximum of 2 L/min (outside the BDU to prevent oxygen buildup).

Turbulence smoothing. Low-pressure oxygen enters the flow sensor manifold, which houses the oxygen pressure valve (TP1) and the oxygen pneumatic noise filter (F7). TP1 checks REG1 settings. F7 conditions gas flow by eliminating swirling of gas induced by elbows and restrictions.

Oxygen and air mixing. Oxygen continues on to the oxygen flow sensor (Q1), where oxygen flow is measured. Software calculates oxygen flow at Q1 and target flow. Software-controlled current is applied to PSOL1, opening it and allowing a predetermined oxygen flow through PSOL1. The PSOL/SV manifold houses proportional solenoid valves PSOL1 and PSOL2 and safety valve SV. Mixed gas is delivered to the patient circuit through the inspiratory outlet.

Safety valve. If the operating pressure of the patient circuit exceeds 100 cmH_2O (measured at PE), SV opens. The outlet manifold houses the galvanic oxygen sensor (OS), the inspiratory check valve (CV3), and the pressure relief orifice. CV3 prevents rebreathing from the room by directing exhaled gas to the exhalation valve.

Inspiration monitoring. The oxygen concentration of the delivered gas is measured by OS. The ventilator alarms if the monitored oxygen concentration is not within 7 percentage points of the O_2 percentage setting. Pressure measurements are made by two solid-state differential pressure transducers.

SOL1 is energized periodically to set a zero reference or offset voltage for the inspiration pressure transducer.

2.3.2 Patient System

The patient system, shown in Figure 2-28 and Figure 2-29, includes external components that deliver gas from the ventilator to the patient, control certain aspects (heat, humidity) of patient ventilation, and isolate the ventilator from the patient using bacteria filters. The patient circuit can heat and humidify delivered gas when a humidification device is installed. A variety of optional accessories can be used in the patient circuit. Figure 2-28 shows a typical patient system configuration.

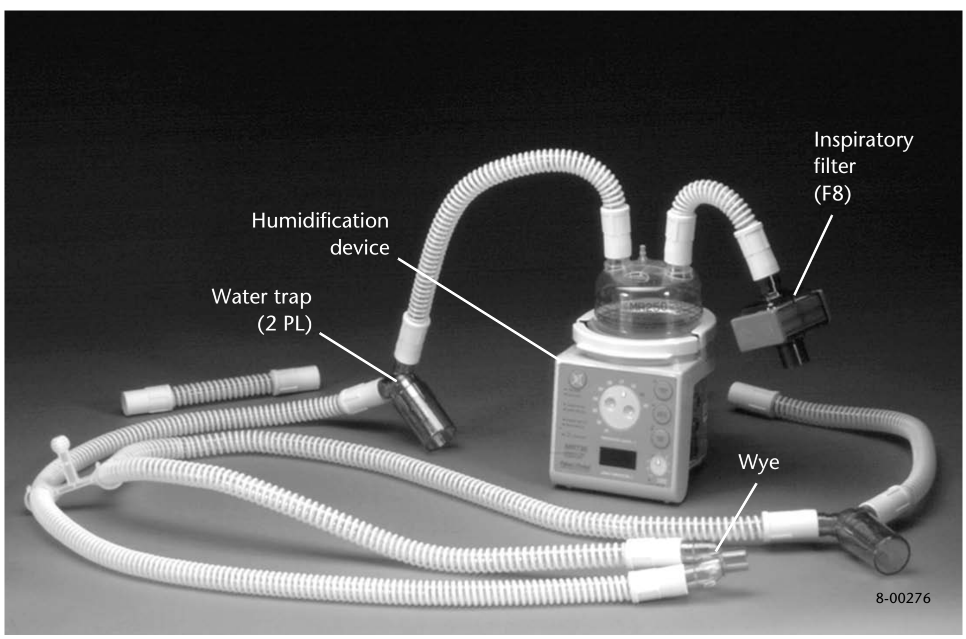


Figure 2-28. Patient system (minus exhalation collector vial and expiratory filter)

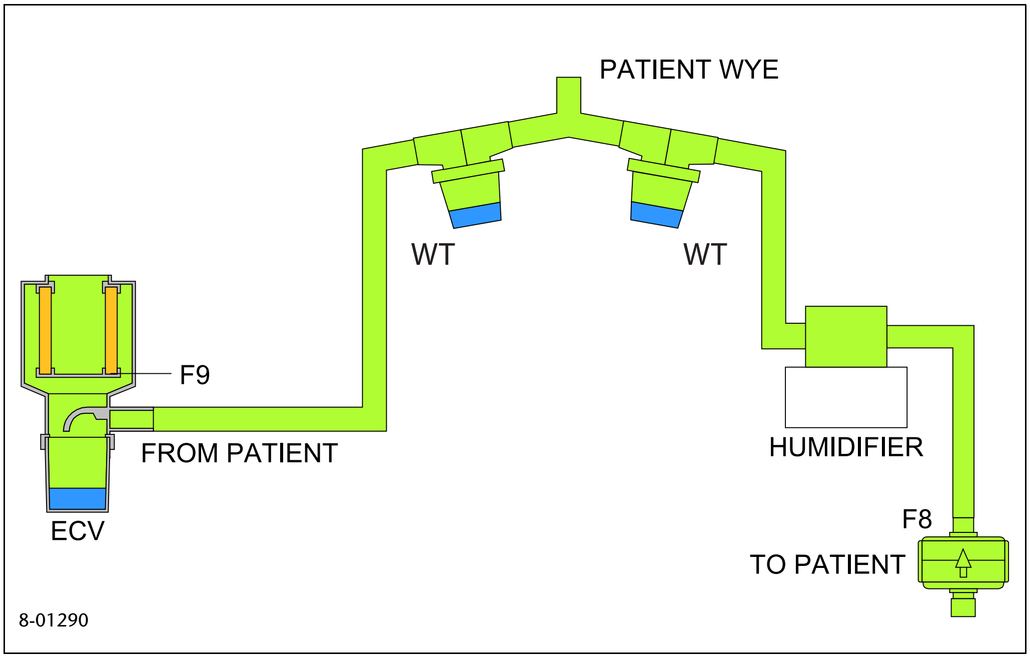


Figure 2-29. Patient system flow diagram

2.3.2.1 Patient system components

The patient system includes the following components:

- The ***inspiratory (main flow) filter*** (***F8***) (the Puritan Bennett *D/Flex*™ or *Re/Flex* Filter) helps protect the patient from contamination by supplied gas. It also helps protect the ventilator from contamination by the patient circuit. F8 captures particles of 27 nanometers nominal at a flow of 30 L/min with 99.99% efficiency. It has 22-mm ISO conical connections.
- ***Water traps (WT)*** in the inspiratory and exhalation sides of the patient circuit collect excessive water that may condense on the inside walls of the tubing. (Not present on all patient circuit models.)
- An optional ***humidification device*** warms and humidifies gas delivered to the patient.
- A ***wye*** connects inspiration and exhalation tubing, forming a closed circuit.
- The ***exhalation collection vial (ECV)*** collects up to 250 mL of fluid from the exhaled gas.
- The ***expiratory filter*** (***F9***) (Puritan Bennett *D/X800*™ single-patient use filter or *Re/X800*™ reusable filter) helps prevent bacteria in exhaled gas from being vented to room air and reduces cross-contamination of the ventilator. The filter captures particles of 27 nanometers nominal at a flow of 30 L/min with 99.99% efficiency. It has 22-mm ISO conical connections.
  The NeoMode DAR (PN 351919005) disposable expiratory filter and the Puritan Bennett Neo Re/x800 reusable expiratory filter are designed specifically for use with the NeoMode option.
- The ***mounting plate***, used only with neonatal patient systems, allows the ventilator to accommodate the neonatal expiratory filter.

Caution

To protect the exhalation assembly, always use a Puritan Bennett expiratory filter or a recommended DAR expiratory filter.

2.3.2.2 Patient system operation

A predetermined oxygen/air gas mixture flows from the ventilator, through F8, and the optional humidification device. WT collects excessive moisture (due to condensation), and inspiration gas is delivered to the patient through the wye. Exhaled gas flows through the wye, to the ECV, and through F9.

2.3.3 Exhalation module

The exhalation module, shown in Figure 2-31 and Figure 2-30, conditions exhaled patient gas by heating gas/water vapor mixture to prevent condensation within the exhalation module. The exhalation valve opens and closes for exhalation and inspiration. During exhalation, the exhalation valve controls the PEEP/CPAP (baseline) pressure. A flow sensor monitors flow and a pressure transducer monitors pressure.

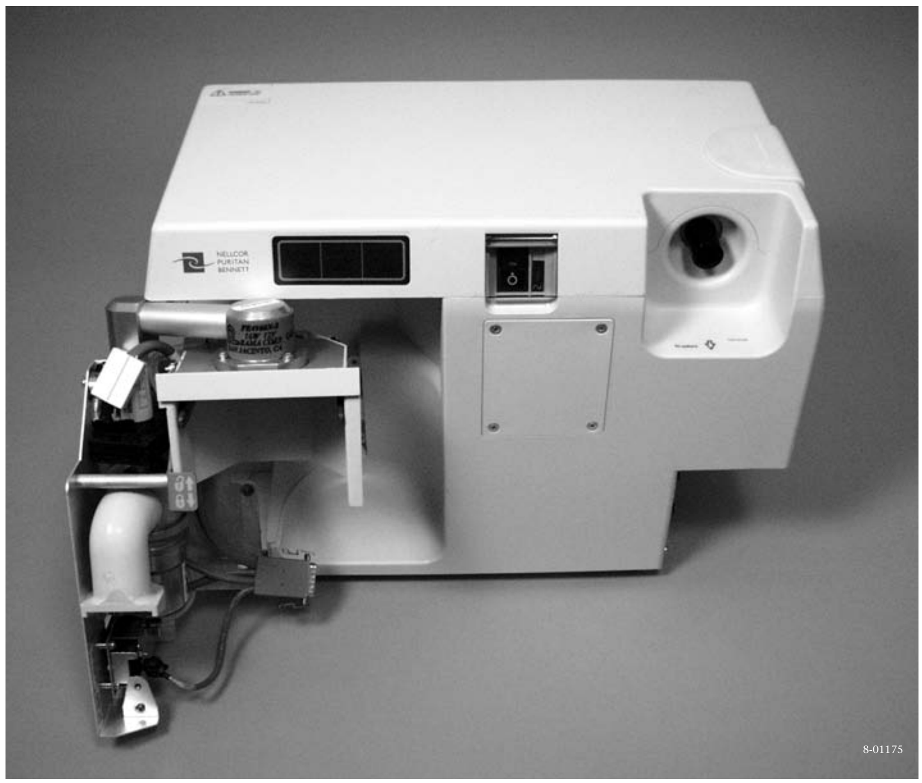


Figure 2-30. Exhalation module (removed from BDU)

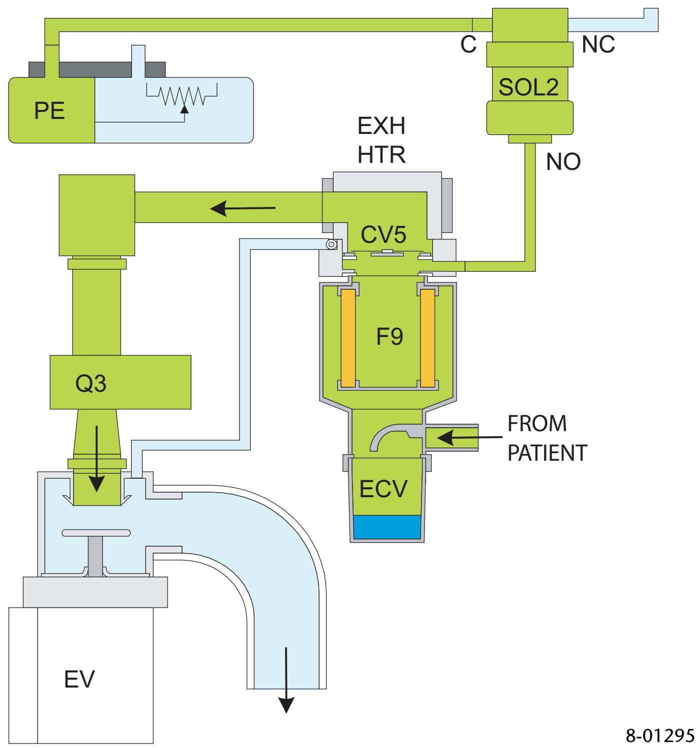
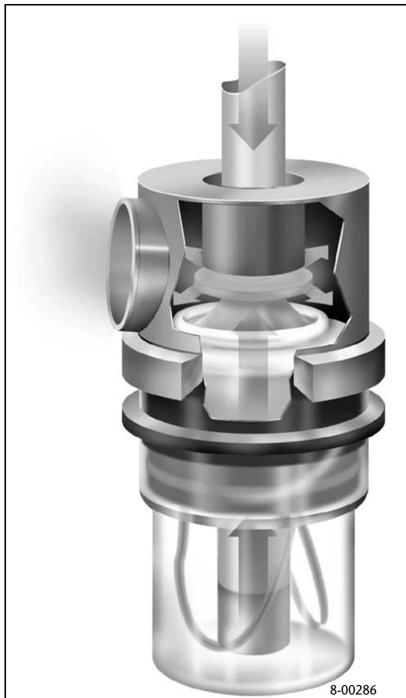


Figure 2-31. Exhalation module flow diagram

2.3.3.1 Exhalation module components

The exhalation module includes the following components, shown in Figure 2-32:

- The ***exhalation check valve*** (***CV5***) is a one-way device that prevents room air from entering the exhalation system. The pressure of the exhaled gas opens the valve, resulting in exhaled gas flowing into the exhalation system. When the patient stops exhaling, the valve closes.
- The 16 W ***exhalation heater*** (***EXH HTR***) heats the gas as it reaches the exhalation system. The heater maintains gas temperature above condensation levels to prevent condensation in the exhalation module.
- The ***exhalation flow sensor*** (***Q3***) provides flow information on exhaled gas. Flow sensor measurements are used to determine net gas flow to the patient and spirometry.



Exhalation valve

- The ***exhalation valve*** (***EV***) closes during inspiration to prevent delivered gas from venting to the atmosphere. It opens during exhalation to maintain the operator-selected PEEP/CPAP. This *active exhalation valve* is actively controlled at all times electronically. The exhalation valve is actively coordinated with the PSOLs to allow very fast rise time and to minimize pressure spikes that would otherwise occur.

  Using an active exhalation valve also minimizes pressure rises during inspiration when a patient coughs; the valve is opened and excess pressure vented.

- The ***expiratory pressure transducer autozero solenoid*** (***SOL2***) is a +12 V, three-way solenoid that is opened periodically to set a zero reference or offset voltage for the expiratory pressure transducer (PE). Both the inspiration and expiratory pressure transducers are zeroed together. During the autozero procedure, both solenoids are energized so that ambient pressure is supplied to both ports of both transducers. An average offset pressure voltage for each pressure transducer is calculated and tested, and stored in data memory.

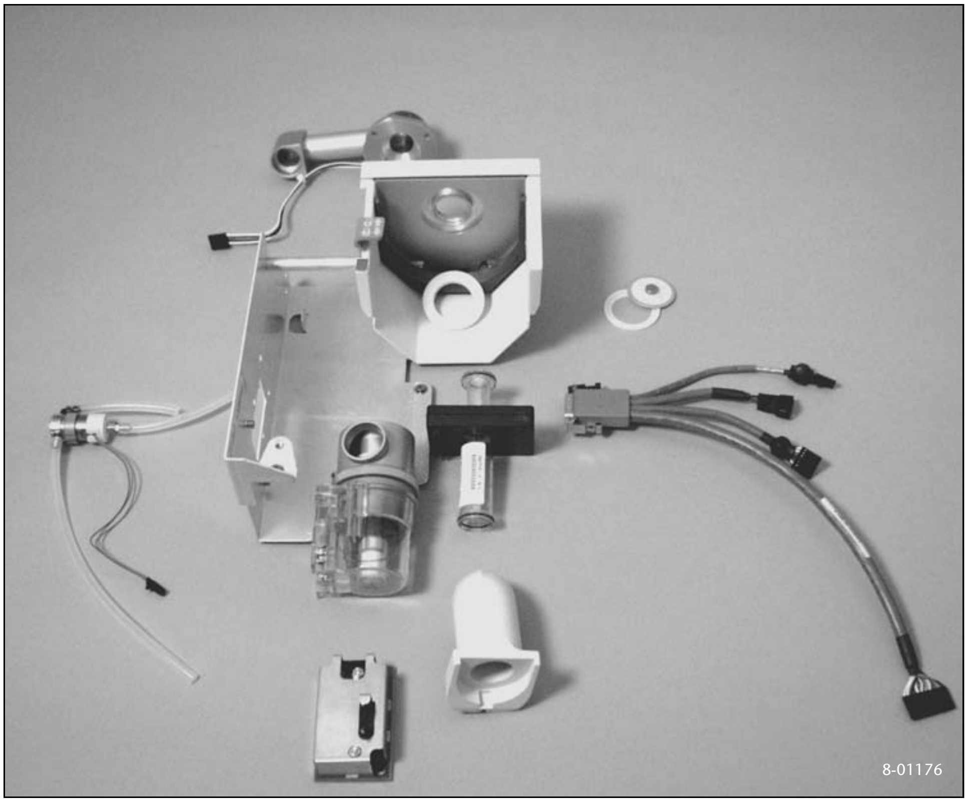
- The ***expiratory pressure transducer*** (***PE***) (on the exhalation transducer PCB) measures the exhalation system pressure. The ventilator uses exhalation pressure readings in breath delivery calculations. The transducer is autozeroed via SOL2.

- A ***pressure port*** allows pressure measurements in the exhalation module.

2.3.3.2 Exhalation module operation

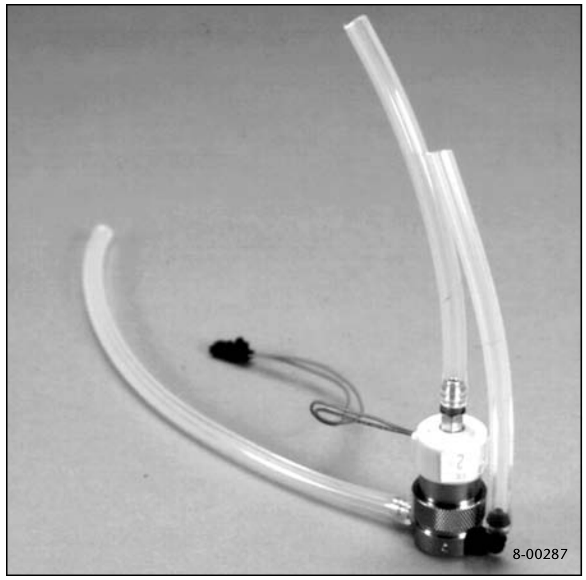
During exhalation, patient gas enters the exhalation system from the patient circuit. The ventilator actively controls the exhalation valve (EV), opening and closing it in precise increments throughout inspiration and exhalation. Such precise control of the valve allows the ventilator to deliver aggressive breaths while minimizing pressure overshoots, controlling PEEP, and relieving excess pressures. The exhalation module also performs spirometry of the exhaled gas and monitors flow sensitivity.

The exhalation heater (EXH HTR) heats the exhaled gas to minimize moisture in the exhalation module, while thermistors provide the ventilator with temperature feedback. The expiratory pressure transducer (PE), on the exhalation transducer PCB, and the exhalation flow sensor (Q3) provide readings used in breath delivery calculations.

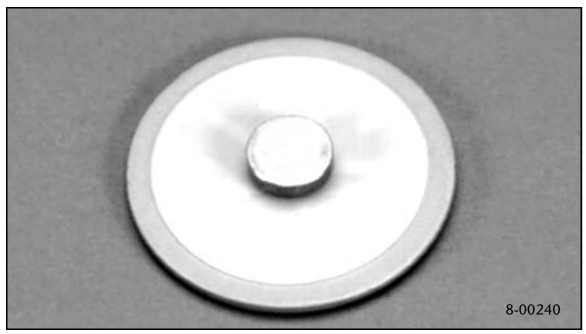


Exhalation flow sensor (Q3)

Figure 2-32. Exhalation module components



Expiratory pressure transducer autozero solenoid (SOL2)



Exhalation check valve (CV5)

Exhalation heater (EXH HTR)

Figure 2-32: Exhalation module components (continued)

2.3.4 806 Compressor Unit

The optional, cart-mounted 806 compressor unit, shown in Figure 2-34, is the latest style compressor system available for use with the 840 ventilator. When ac power is present, the compressor system supplies air to the ventilator in the event that a hospital air source is unavailable or the source pressure drops below 26 psig.

Figure 2-33. 806 compressor on cart

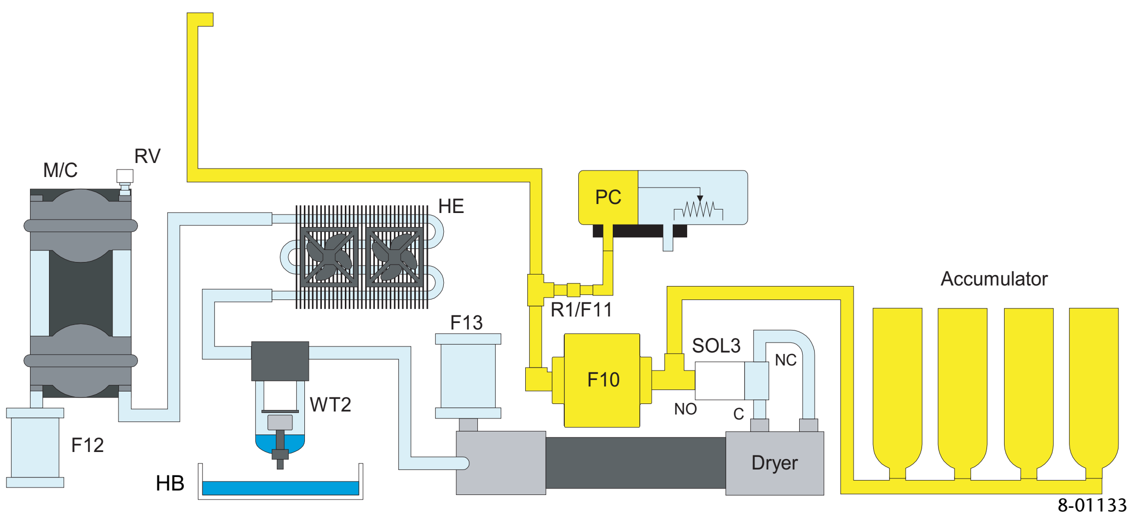


Figure 2-34. 806 Compressor Pneumatic diagram

2.3.4.1 806 Compressor unit components

The 806 compressor includes the following components, shown in Figures 2-35 – 2-40:

- The ***intake filter/silencer (F12)*** filters the compressor intake air and reduces compressor sound.
- The ***motor/compressor (M/C)*** is a dual-piston compressor that pressurizes room air to supply the ventilator.

- An emergency ***relief valve (RV)*** protects the compressor system against overpressurization by opening at 36 psig.
- Cooling ***fans*** blow air across a ***heat exchanger (HE)*** which removes heat from the compressed air. The air flow from the fans also helps to cool the motor/compressor.
- A ***water trap (WT2)*** collects the condensation formed as the compressed air travels through the heat exchanger. The water trap automatically dispenses its contents into the ***housing base (HB)*** where it evaporates.
- A membrane ***air dryer*** lowers the dew point below ambient temperature by removing residual water vapor from the compressed air prior to being stored in the accumulator. An attached ***silencer (F13)*** reduces noise from the air drying process.
- The compressor ***unloading solenoid (SOL3)*** opens at compressor start-up to reduce the load on the compressor. As a secondary function, excess flow is vented through SOL3 to the air dryer during periods of low demand to assist in removing water vapor from the air dryer.
- Compressed air, sufficient to meet the ventilator's full flow requirements, is stored in the ***accumulator***.
- The 0.3 micron ***filter (F10)*** screens particles from compressed air flowing to the ventilator.
- The ***compressor pressure transducer (PC)*** measures pressure in the accumulator and the pressure signal is used to control the operation of the solenoid, compressor motor, and fans. Air going to the pressure transducer passes through a ***restrictor (R1)*** to reduce pressure pulsations and a ***filter (F11)*** to prevent contaminants from entering the transducer.

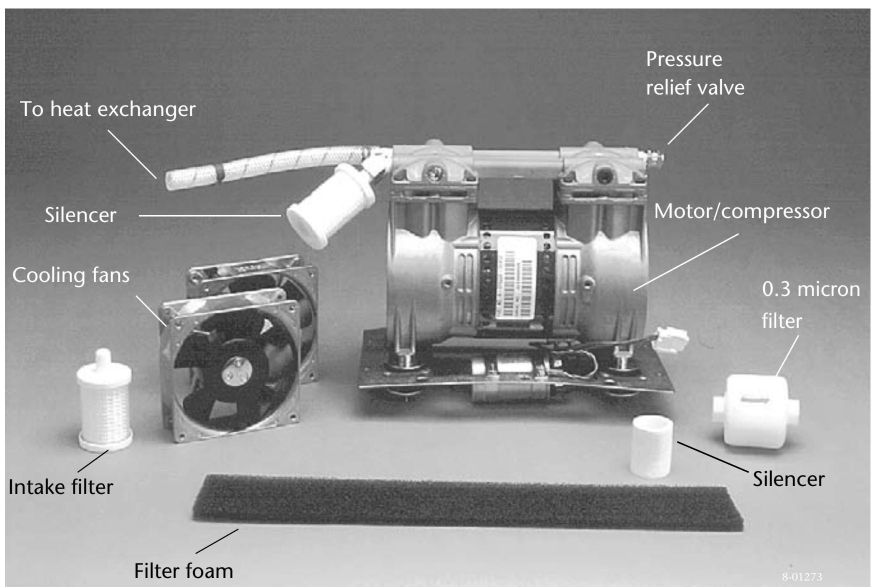


Figure 2-35. 806 components

Figure 2-36. Heat exchanger

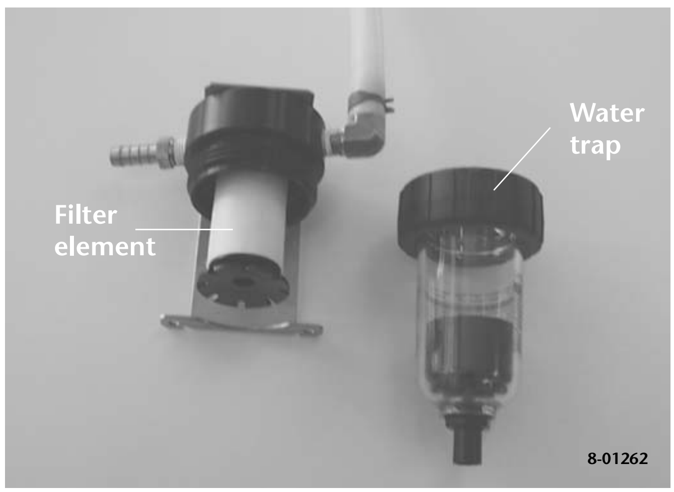


Figure 2-37. 806 water trap assembly

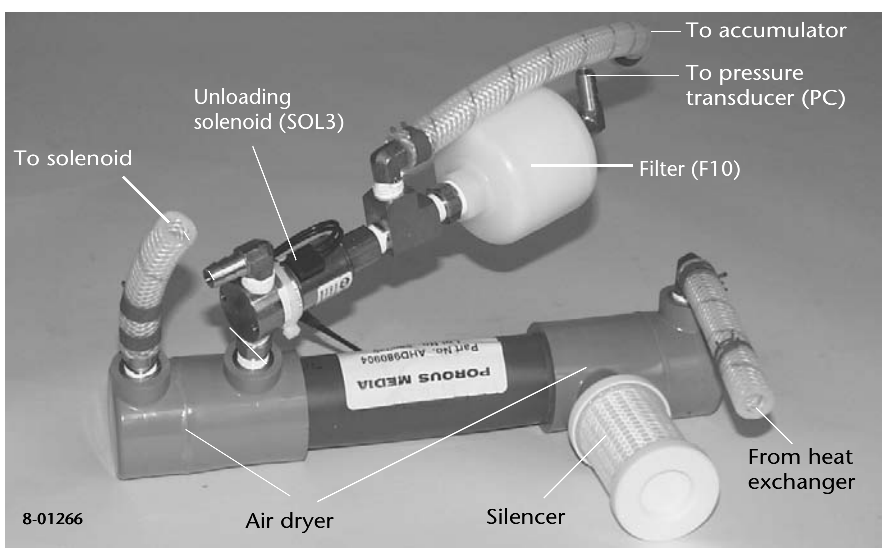


Figure 2-38. Air dryer assembly

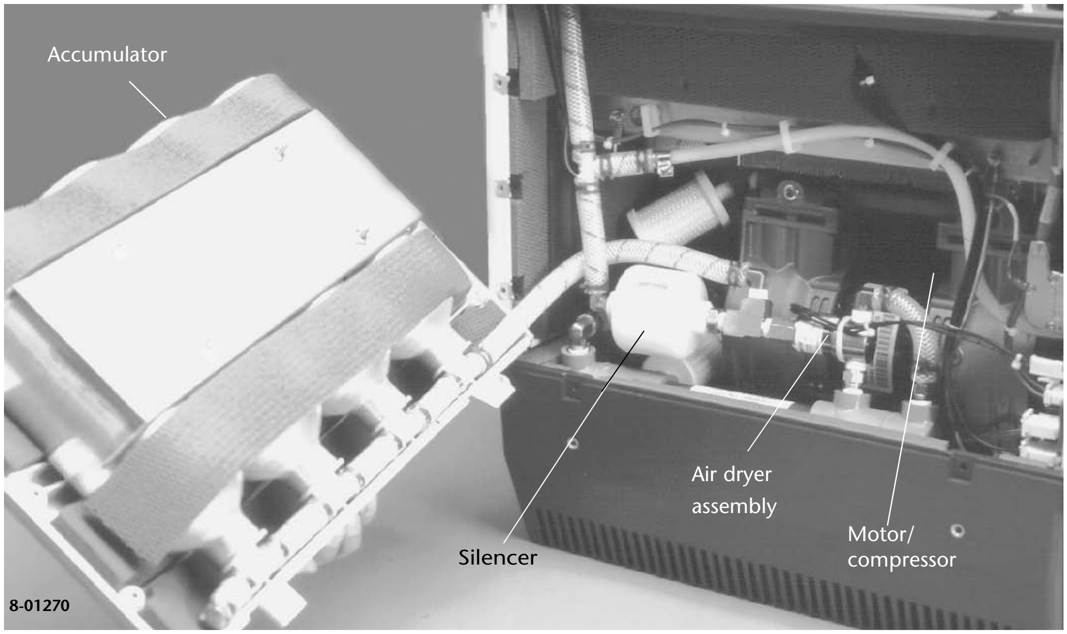


Figure 2-39. 806 back panel

2.3.4.2 806 Compressor unit operation

The 806 compressor is powered by and communicates with the 840 BDU. The BDU sends a signal to the compressor after completing POST, and the compressor enters either stand-by mode or run mode depending upon the state of the air-side pressure switch, PS2. If PS2 is closed, indicating sufficient wall air pressure, the compressor charges the accumulator to 27 psig and enters stand-by mode, ready to supply air to the ventilator in the event of a loss of wall air pressure. If PS2 is open, the compressor enters run mode, and acts as the ventilator's air source.

When the compressor is operating, two cooling fans (Figure 2-40) blow air downward over a heat exchanger used to condense water vapor from the compressed air. After passing through the heat exchanger, the compressed air flows through a water trap and membrane air dryer which remove excess water vapor prior to being stored in the accumulator. The air dryer also lowers the dew point to a temperature below ambient, preventing condensation from entering the ventilator.

Figure 2-40. 806 cooling fans

During the start-up sequence, a solenoid valve (SOL3) opens 1 second prior to the time the compressor motor starts, and remains open for 0.5 seconds afterwards, reducing the load on the compressor. A transducer on the PCBA measures the accumulator pressure, and the signal is used to control the compressor operation. If pressure in the accumulator drops below 13 psig, the compressor shuts down and the ventilator delivers 100% O_2 to the patient.

In stand-by mode, the compressor shuts off when the pressure reaches 27 psig in the accumulator, and turns on when the pressure drops to 22.5 psig. (This pressure drop can occur because of small leaks in the compressor system or because of cooling of compressed air in the accumulator.)

The compressor PCBA contains an hour meter that records the elapsed run time of the compressor. This information is stored in the EEPROM on the PCBA, as is the compressor's serial number. If a replacement PCBA is required, the EEPROM from the existing PCBA can be removed and installed on the new board, preserving the compressor elapsed time and serial number.

For more information regarding the 806 compressor operation, see Section 2.4.12 and Figure 2-76.

2.4 Electrical system

2.4.1 Summary of electrical components

The *840* Ventilator electrical system, shown in Figure 2-41, includes the following:

- ac distribution components, including power cord, ac panel (circuit breakers, ac filter PCB, power relay, and other components), and power switch
- Power supply
- Rechargeable BPS, which supplies power to operate the ventilator if ac power is interrupted
- Optional compressor unit including compressor, compressor PCB, and other components
- Card cage, including motherboard PCB, BD CPU PCB, and AI PCB
- GUI, including the GUI CPU PCB, keyboard, GUI LED PCB, backlight inverter PCB, knob, two VGA liquid crystal display (LCD) panels, a touch frame PCB, and alarm speaker

NOTE:

The 10.4-inch GUI features color LCD panels, updated GUI CPU, touch frame, and backlight inverter PCBs, and three serial communications ports. There is a single serial communications port on the older 9.4-inch monochrome GUI (no longer available) and the 9.4-inch color GUI color LCD panels, and one serial communications port.

- BDU LED PCB
- BD (continuous-tone) alarm
- Inspiratory electronics PCB
- Exhalation transducer PCB
- Data key subsystem

For a discussion of electropneumatic parts, or electrical parts used in close conjunction with pneumatic parts, see Section 2.3. For wiring details, see Figure 2-41, Figure 2-43, Figure 2-46, Figure 2-51, Figure 2-61, Figure 2-70, Figure 2-72, and Figure 2-78. Table 2-2 describes the electronic parts.

Table 2-2: Electronic Component Descriptions

Reference Designator	Component	Description
--	Power cord	Connects facility ac power to the ventilator.
AC Panel (Figure 2-43)		
CB1	Main circuit breaker	Provides over-current protection to the power supply.
CB2	Auxiliary circuit breaker	Provides over-current protection to the humidifier and compressor.
--	ac filter PCB	Filters electrical noise to and from the ventilator.
J1	ac receptacle	Receives facility ac power via the power cord.
J2	Potential equalization connector	Provides attachment point to equalize electrical potential between the ventilator and other equipment (such as electrical safety analyzer).
J3	Humidifier receptacle	Located at the front of the ventilator, receives ac power from power relay K1 and provides ac power to the humidifier.
J4	Compressor receptacle	Receives ac power from power relay K1 and provides ac power to the compressor via the compressor ac power cord.
K1	Power relay	Switches power to the humidifier and compressor receptacles when ac power is present and ventilator power switch is ON.
Power System (Figure 2-46)		
--	Power supply	Converts ac and dc (from BPS) inputs to supply dc power to ventilator electronics. Outputs include GUI +5V, GUI +12V, VH +5V, VH +12V, VH +15V, VH -15V, BPS +36V, and relay +12V.
--	Back-up power source (BPS)	With new, fully charged batteries, provides at least 30 minutes of back-up power in the event of an ac line failure or temporary disconnect. Output signals from the BPS PCB include charging*, charged*, BPS model, IBATT, VBATT, and E-BP. **NOTE:** When the ventilator is running on battery power, the compressor and humidifier are non-operational. * indicates signal is active low

Table 2-2: Electronic Component Descriptions (continued)

Reference Designator	Component	Description
Card Cage (Figure 2-51 & Figure 2-54)		
--	Motherboard PCB	Provides the main electrical interconnect between the breath delivery CPU PCB, analog interface PCB, breath delivery LED PCB, exhalation module, inspiratory module, power supply, power switch, and BD alarm.
--	Breath delivery (BD) CPU PCB	Contains the electronics and software that control all breath delivery functions in the 840 ventilator. Communicates with the GUI CPU to respond to operator inputs and display ventilation parameters.
--	Analog interface (AI) PCB	Provides the interface for all analog signals in the ventilator. The AI and BD CPU PCBs together provide the main intelligence and drive for the mechanical devices and electronic sensors used in ventilation.
Breath Delivery Unit (Figure 2-46)		
--	BD LED PCB	Contains visual alarm indicators and LED drivers to annunciate safety valve open, loss of GUI, and ventilator inoperative conditions. All indicators are powered by +12V.
S1	Power switch	Switches power to the power relay (K1), and power supply, enabling its secondary outputs used by ventilator electronics.
--	BD audio alarm	A continuous-tone alarm sounds if one or more of the following events occurs: a ventilator inoperative condition, loss of communication between the BD and GUI CPU PCBs, detection of a GUI alarm fault, power switch failure, or low voltage condition detected by the +5V sentry on the AI PCB.
--	Data key	Required for proper ventilator operation, the data key stores BDU and GUI serial numbers, hours of ventilator operation, and enables ventilator software options.
Exhalation Module (Figure 2-72)		
--	Exhalation transducer PCB	Produces a voltage signal proportional to pressure in the patient circuit exhalation limb using the exhalation pressure transducer (PE). The PCB uses a +10V reference.
PE	Exhalation transducer	Measures the pressure difference in the patient circuit exhalation limb relative to atmospheric air pressure.
EXH HTR	Exhalation heater	Heats the patient's exhaled gas, preventing condensation in the exhalation module. The 16 W exhalation heater uses +12V.
Q3	Exhalation flow sensor	Measures exhalation flow for use in determining net flow to the patient and for spirometry. Flow sensor drivers use +12V and +5V. Thermistor supply voltage is +12V.
EV	Exhalation valve	Closes on inspiration, preventing delivered gas from venting to atmosphere. Opens upon exhalation, maintaining operator-selected PEEP/CPAP level. Electronically controlled throughout the breath cycle, the exhalation valve uses a maximum of 6V.
SOL2	Exhalation pressure transducer autozero solenoid	This +12V, 3-way solenoid periodically exposes the exhalation pressure transducer to atmospheric pressure for setting a zero-reference offset voltage.

Table 2-2: Electronic Component Descriptions (continued)

Reference Designator	Component	Description
Inspiratory Module (Figure 2-70)		
--	Inspiratory electronics PCB	Produces voltage signals proportional to the pressure in the patient circuit inspiratory limb and atmospheric pressure using the inspiratory pressure transducer (PI) and absolute pressure transducer (PA), respectively. Also provides an interface for the oxygen sensor. The PCB uses a +10V reference.
PA	Absolute pressure transducer	Measures atmospheric pressure for use in volume delivery calculations.
PI	Inspiratory pressure transducer	Measures pressure in the patient circuit inspiratory limb relative to atmospheric pressure.
SV	Safety valve	This +12V valve opens when de-energized (during POST, at pressures > 100 cm H_2O, during ventilator inoperative conditions, or when both source gases are lost). Energized closed all other times.
PSOL2	Air PSOL	A +12V proportional solenoid valve. Regulates the flow of air in the inspiratory circuit by adjusting flow proportionally to the supplied current which is under feed-back control from the Q2 flow sensor signal and the inspiratory pressure transducers.
PSOL1	Oxygen PSOL	A +12V proportional solenoid valve. Regulates the flow of oxygen in the inspiratory circuit by adjusting flow proportionally to the supplied current which is under feed-back control from the Q1 flow sensor signal and the inspiratory pressure transducers.
SOL1	Inspiratory pressure transducer autozero solenoid	This +12V, 3-way solenoid periodically exposes the inspiratory pressure transducer to atmospheric pressure for setting a zero-reference offset voltage.
Q1	Oxygen flow sensor	Measures inspiratory oxygen flow. Measurements are used to control PSOL1. Flow sensor drivers use +12V and +5V. Thermistor supply voltage is +12V.
Q2	Air flow sensor	Measures inspiratory air flow. Measurements are used to control PSOL2. Flow sensor drivers use +12V and +5V. Thermistor supply voltage is +12V.
PS1	Oxygen pressure switch	Senses inlet oxygen pressure and opens if pressure drops below 20.0 psig nominal. Closes when pressure is greater than 31.5 psig nominal.
PS2	Air pressure switch	Senses inlet air pressure and opens if pressure drops below 20.0 psig nominal. Closes when pressure is greater than 31.5 psig nominal.
--	Oxygen sensor	Senses inlet oxygen pressure and opens if pressure drops below 20.0 psig nominal. Closes when pressure is greater than 31.5 psig nominal.

Table 2-2: Electronic Component Descriptions (continued)

Reference Designator	Component	Description
GUI (Figure 2-60 & Figure 2-61)		
--	Graphical user interface (GUI) CPU PCB	Provides microprocessor control and monitoring of the display and user interface system. Communicates with the BD CPU PCB via an Ethernet connection.
	Backlight inverter PCB	Converts +12V input into high-voltage ac that powers the fluorescent lamps that backlight the LCD display panels. Pulse width modulation from the GUI CPU board determines the magnitude of the ac voltage which determines the brightness of the displays. Two backlight inverter PCBs individually control the upper and lower LCD panels on the 10.4-inch GUI. On the 9.4-inch GUI, one PCB performs the backlight functions for both displays.
	Touch frame PCB	Contains the electronics and firmware to detect inputs to the GUI touchscreen by means of locating the logical X/Y coordinate position of an operator's touch.
	LCD displays	Two variable voltage, 9.4-inch (older version) or 10.4-inch (current version) color LCD flat panels display ventilator settings and patient information.
	GUI LED PCB	Contains LED drivers and light bars that illuminate visual alarm and status indicators on the GUI LED panel.
	Keyboard/knob PCB	A membrane keyboard assembly containing the multiposition rotary encoder knob is used to change selected ventilator settings, accept or clear settings changes, provide alarm silence, reset, and volume adjust functions, actuate screen lock and information functions, and deliver manual inspiration, inspiratory and expiratory pause, and 100% O_2.
	RS-232 connectors	Three (10.4-inch GUI) or one (9.4-inch GUI) RS-232 connectors provide for serial communications with external devices such as printers or ventilator monitors.
	Remote alarm connector	Enables/disables an external alarm device (such as a nurse's call). Relay contacts are closed during normal ventilation, and open during an alarm condition or when unit is off.
	VGA controllers	Plug-in modules (on some versions of the GUI CPU board) that provide a video interface between the GUI CPU PCB and the LCD flat panels. The VGA controllers are integrated into the current version of the GUI CPU PCB.
	GUI alarm assembly	The ventilator's primary alarm, emits multiple frequency alarm sounds under control of the GUI CPU PCB.
806 Compressor (optional; Figure 2-78)		
--	Compressor PCB	Controls the functions of the compressor motor, cooling fans, and unloading solenoid.
SOL3	Unloading solenoid	A +12V, 3-way solenoid controlled by logic signals that reduces back pressure on the compressor during start-up and periods of low demand. Also vents excess accumulator pressure to assist in transporting water vapor from the air dryer.
M/C	Motor compressor	ac powered and logic-controlled, supplies compressed air to the ventilator when adequate wall air pressure is unavailable. Contains internal over-temperature protection device.

Table 2-2: Electronic Component Descriptions (continued)

Reference Designator	Component	Description
--	Fans	ac powered and logic-controlled, provides cooling air to the compressor motor and heat exchanger. Fans run only when the compressor motor is running.
--	Starting capacitor	Provides added voltage to overcome mechanical friction upon compressor motor start-up.
TH1	Thermostat	Located on the compressor PCB, provides over-temperature protection to the compressor system. Activates before compressor motor internal protection device.
PC	Compressor pressure transducer	Located on the compressor PCB, measures accumulator pressure and outputs are used by compressor control logic.
--	Relay	Operated by compressor control logic, switches power to the compressor motor and fan connectors on the PCB.

2.4.2 Overview of electrical system operation

The *840* Ventilator System uses a dual-microprocessor architecture with an Ethernet network as the primary channel of communication between the two 68040 microprocessors. The BDU microprocessor handles the breath delivery control and monitoring functions; the GUI microprocessor reads and interprets information from/to the operator via the keyboard, knob, and displays. The BDU continues to operate independently of the GUI during a temporary loss of communication. For safety, the GUI's CPU monitors the BDU's CPU activities. The BD CPU is located on the BD CPU PCB, while the GUI CPU is located on the GUI CPU PCB.

To start ventilation, the operator enters data through the GUI. The GUI CPU processes this data, then stores it in memory. The BD CPU, in conjunction with the analog interface (AI) PCB, uses this data to communicate with ventilator internal and external devices including the GUI, compressor unit, and BPS, and to control and monitor the flow of gas to and from the patient. All analog signals to and from the system sensors and actuators are controlled by software running within the BD CPU.

The BD CPU and AI PCBs plug into the motherboard PCB. The motherboard PCB interfaces input/output (I/O), industry pack (IP) bus, Ethernet signals, and power.

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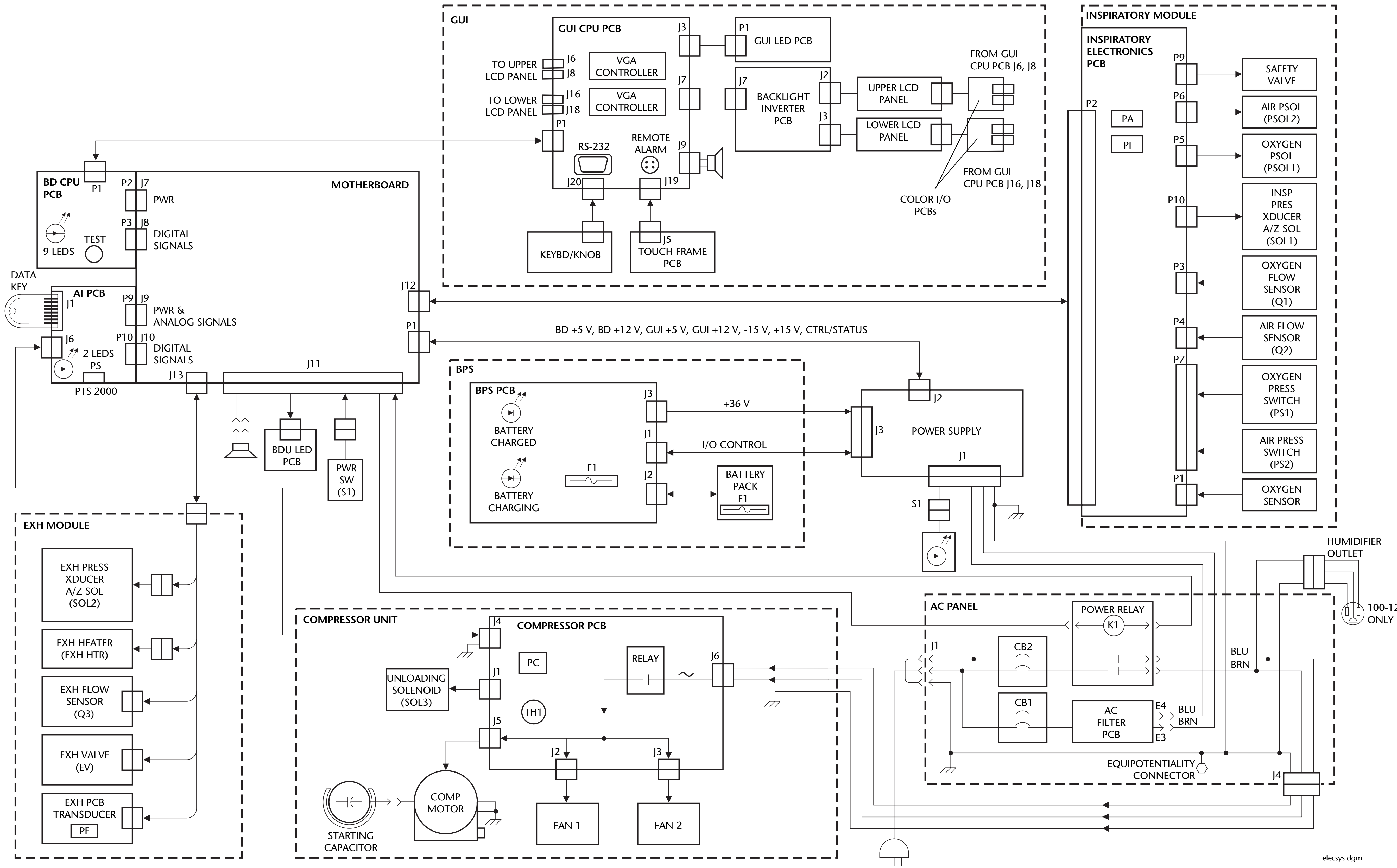


Figure 2-41. Electrical system block diagram

2.4.3 ac distribution components

The ac distribution components include

- a power cord
- ac panel
- power switch
- interfacing cables, wires, and components.

Mains (ac) power (or facility power) is applied through the power cord to the ac receptacle and main and auxiliary circuit breakers. From the main circuit breaker, power is applied through the ac filter PCB directly to the power supply. Power to the power supply bypasses the power switch, enabling the power supply to continually charge the BPS. When the power switch is set to off, the secondaries that power the ventilator electronics are not active. From the auxiliary circuit breaker, power is applied via the power relay to the compressor compartment ac receptacle and the humidifier receptacle. The compressor compartment power cord plugs into receptacle J4, supplying ac power to the compressor unit, while the humidifier receptacle is intended to power an optional humidifier.

2.4.3.1 Power cord

The *840* Ventilator System includes a detachable power cord. The power cord has an IEC-standard, three-prong connector. The plug end varies, corresponding to different country requirements.

2.4.3.2 ac panel

The ac panel (Figure 2-42 and Figure 2-43), a single field-replaceable unit (FRU), includes components that apply ac to the ventilator head, compressor unit, and optional humidifier. The ac panel includes ac receptacle J1, circuit breakers CB1 and CB2, ac filter PCB, power relay K1, compressor receptacle J4, and potential equalization connector J2. A humidifier receptacle (J3), which is connected to but is not a part of the ac panel, is on the front of the ventilator.

- The ***ac receptacle*** (***J1***) receives facility ac power via the power cord.

Warning

Ensure that the power cord retainer bracket is properly installed and secures the power cord to the ac receptacle (J1).

- The ac panel houses two push-to-reset type circuit breakers. The 5 A ***main circuit breaker*** (***CB1***) limits current to the power supply. The 10 A (100 – 120 V) or 5 A (220 – 240 V) ***auxiliary circuit breaker*** (***CB2***) limits current to the compressor and humidifier circuits.
- The ***ac filter PCB*** reduces ac line noise to and from the ventilator.
- The ***power relay*** (***K1***) switches power to humidifier receptacle J3 and compressor receptacle J4 when the power switch (S1) is on. The relay is powered from a dedicated +12 V power supply output, which is active when the power switch is on.
- The ***compressor receptacle*** (***J4***) receives ac power via K1 and provides the ac power outlet for the compressor power cord.
- The ***humidifier receptacle*** (***J3***) receives ac power via K1 and provides an ac power outlet for the humidifier power cord.
- The ***potential equalization connector*** (***J2***) interfaces the equipment and the potential equalization bus bar.

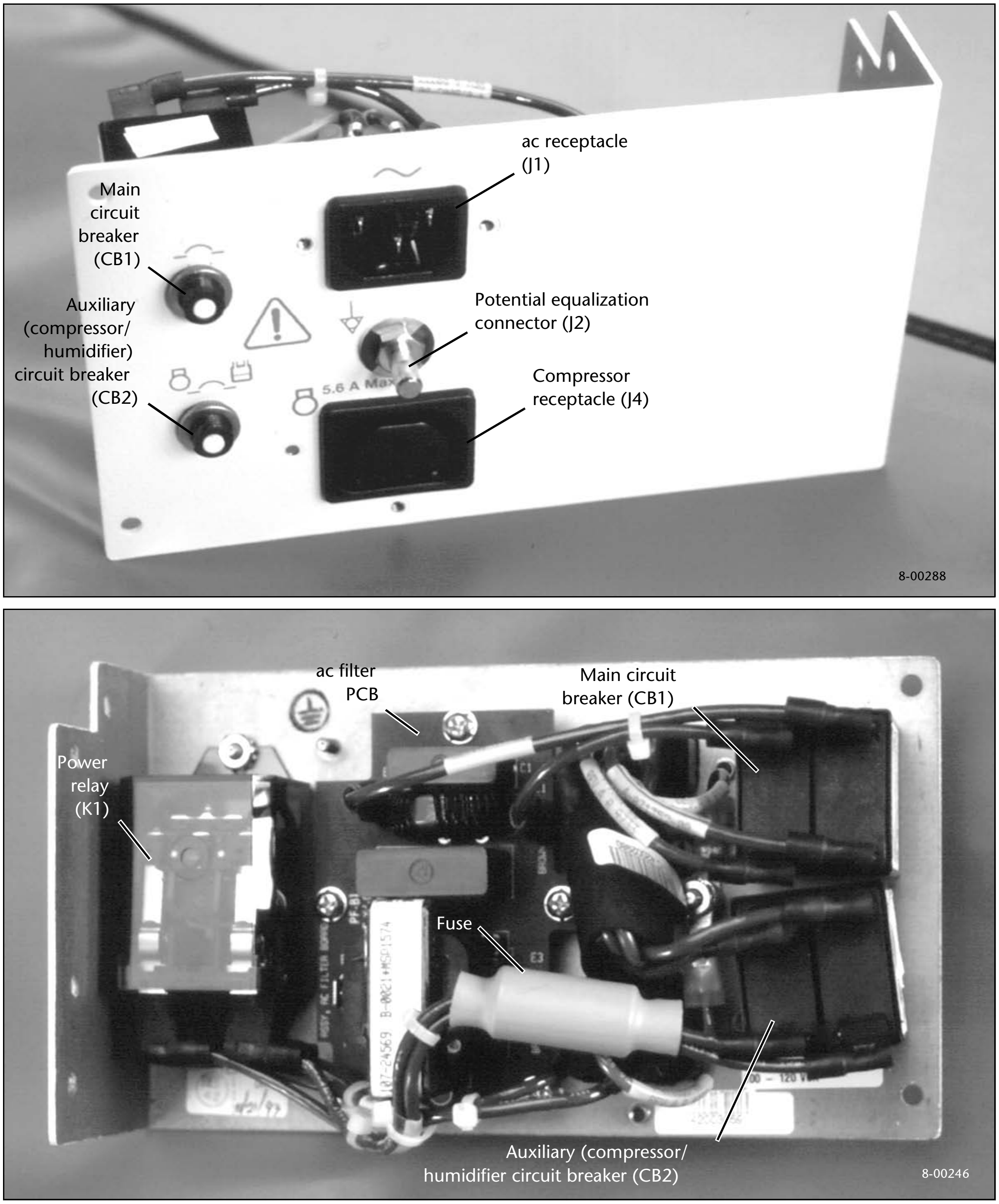
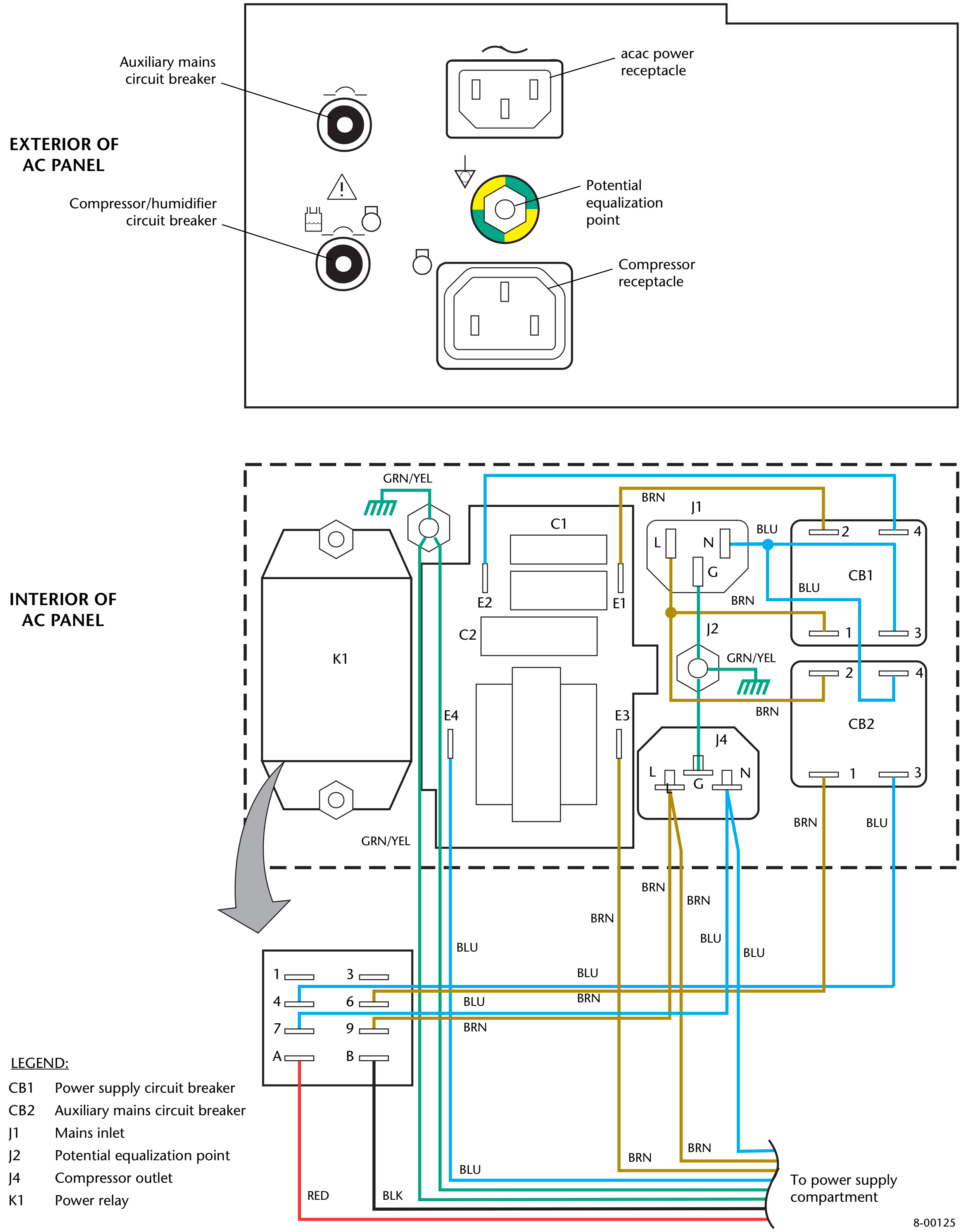


Figure 2-42. ac panel



LEGEND:

CB1	Power supply circuit breaker
CB2	Auxiliary mains circuit breaker
J1	Mains inlet
J2	Potential equalization point
J4	Compressor outlet
K1	Power relay

AC PANEL MODULE

Figure 2-43. 840 Ventilator System interconnect diagram – ac panel

2.4.3.3 Power switch

The logic-driven rocker-type power switch (S1), shown in Figure 2-44, enables the power supply secondary outputs that are used by ventilator electronics. When the power switch is off, the power relay is open, preventing ac distribution to the humidifier and compressor receptacles J3 and J4. Regardless of the power switch position, ac power is supplied directly to the power supply to permit charging of the BPS. Secondary circuits that power ventilator electronics are not active when the power switch is off.

A cover protects the power switch and prevents it from accidentally being turned off. An LED indicator beside the power switch lights to indicate that power is available to the ventilator.

Figure 2-44. Power switch (S1) and indicator

2.4.4 Power supply

The power supply (Figure 2-45 and Figure 2-46), which is a single FRU (Field Reparable Unit), outputs +5, +12, +15, and -15 V to power the ventilator system. It also provides dc power for BPS charging. Power supply inputs are either ac from facility power or BPS dc power (battery power). The power supply accepts inputs of 80 to 269 V ac rms at 47 to 63 Hz. Specifically, the power supply's outputs are as follows:

- VH +5 V (remotely sensed)
- VH +12 V
- VH +15 V
- VH -15 V
- GUI +5 V (remotely sensed)
- GUI +12 V (remotely sensed)
- BPS +36 V
- Relay +12 V (from the primary)

A power fail circuit in the power supply detects the drop of the bulk +31.5 V (the input to the power supply's main converter) and notifies the BD CPU PCB. The BD CPU PCB in turn generates a nonmaskable interrupt (NMI) signal.

The ac monitor circuit provides an analog voltage scaled to the ac input voltage. This voltage is fed to the AI PCB and monitored by software. The power supply is protected against nominal line transients, overtemperature, overload, and short circuit conditions.

The power supply has no test points, and cannot be field-adjusted. Power supply voltages are displayed during the analog data display test in EST.

Figure 2-45. Power supply assembly

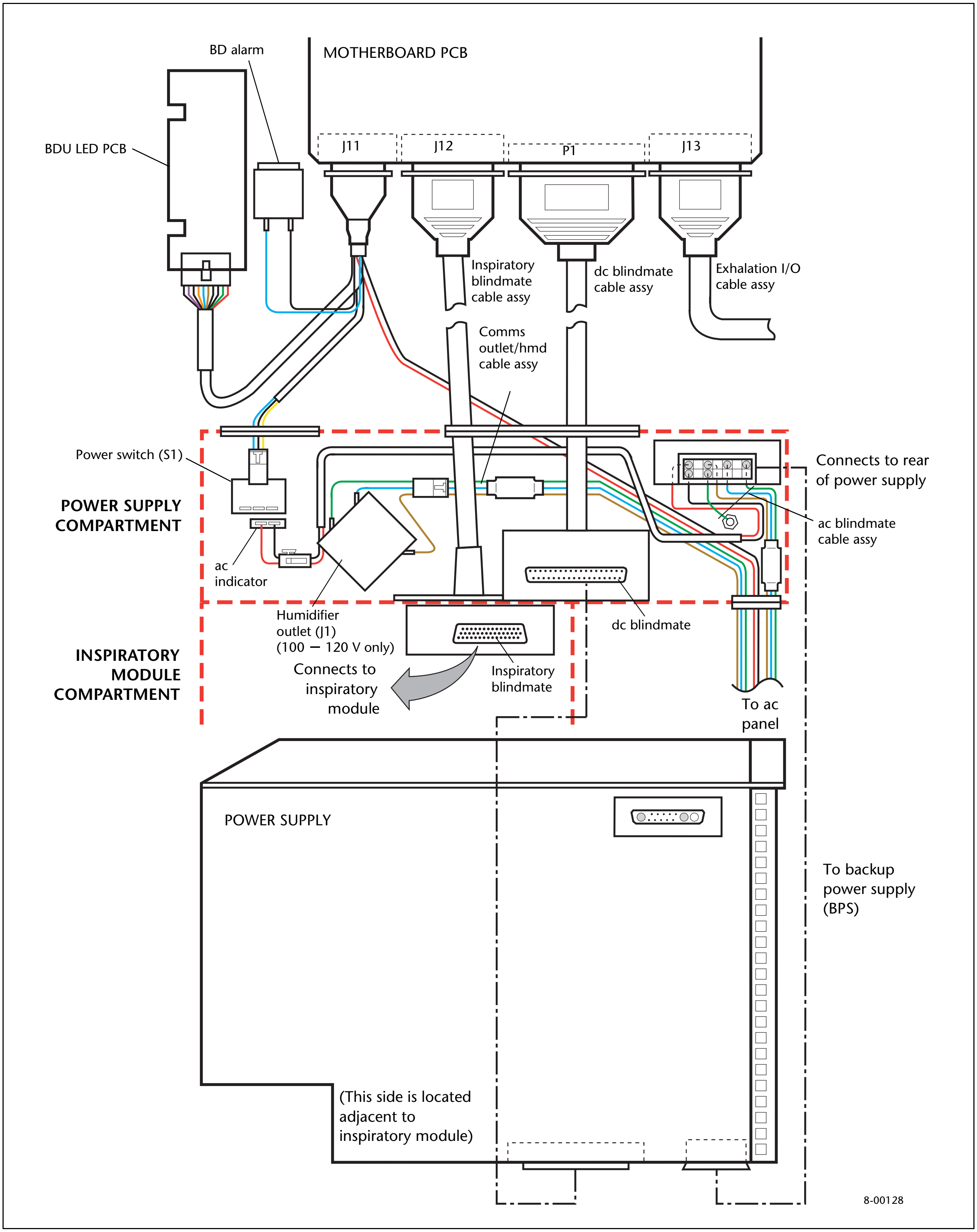


Figure 2-46. *840* Ventilator System interconnect diagram – Power distribution

2.4.5 BPS

The BPS, shown in Figure 2-47, provides a dc power source during a brief ac line failure or temporary disconnect. A fully charged BPS supplies at least 30 minutes of power backup to the ventilator. The BPS does not power the optional compressor or humidifier; these operate from ac line power.

NOTE:
It is assumed that the ventilator is powered from an outlet connected to the hospital's emergency generator ac backup system.

When the ventilator power switch (S1) is on, the BPS provides a +19 to +30 V supply voltage to the power supply. The ventilator software monitors this voltage to determine whether the battery is present and the battery status. The software triggers a medium-urgency alarm if the battery capacity falls below 2 minutes runtime.

The BPS electronics charge the battery pack as necessary whenever ac is present and sufficient (> 80 V), even if the power switch is off. An indicator displays the batteries' charging status: yellow means the batteries are charging, and green means the batteries are are approximately 75% charged relative to nominal. Good batteries can be charged within 8 hours. The BPS has overcurrent (overcharging) protection.

NOTE:
Battery packs, BPS assemblies, or units with BPS's that are unused or in storage for over 6 months, or have been depleted by continuous usage require a minimum of 8 hours to recharge the battery pack.

The BPS contains a battery pack (Figure 2-48) (which includes two +12 V, lead-acid batteries and a 15 A fuse) and a PCB (Figure 2-49).

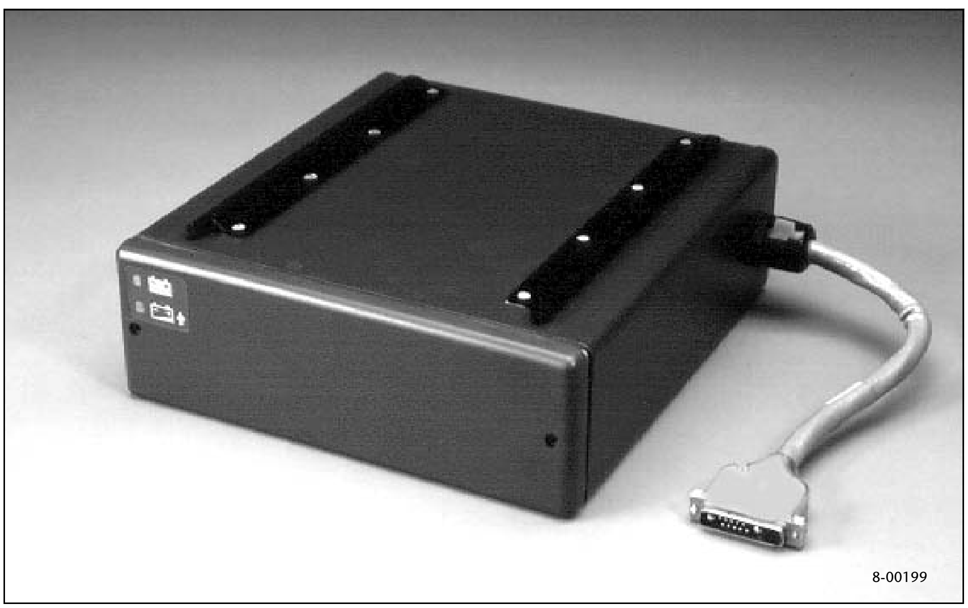


Figure 2-47. BPS

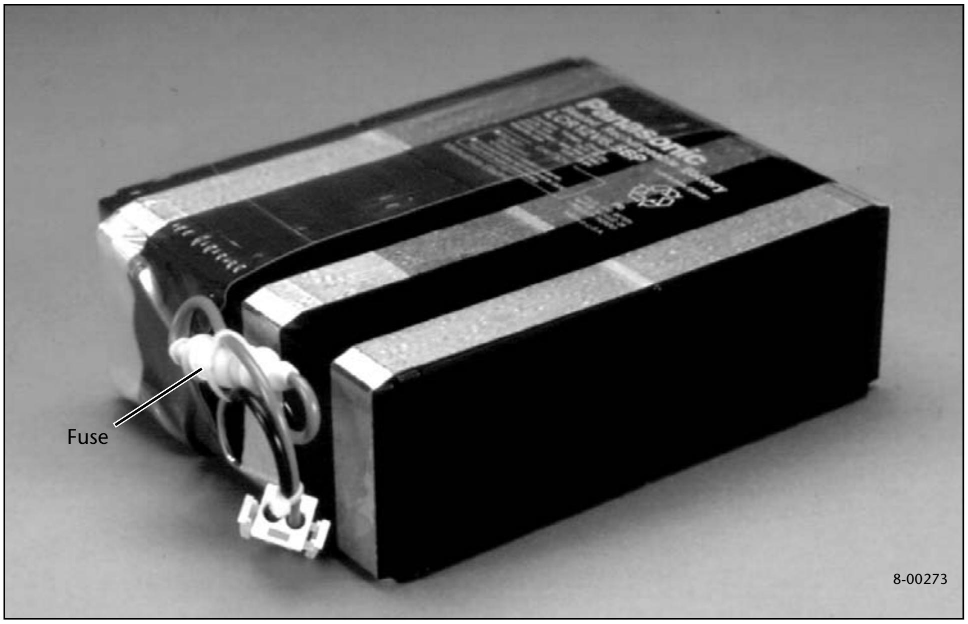


Figure 2-48. BPS battery pack

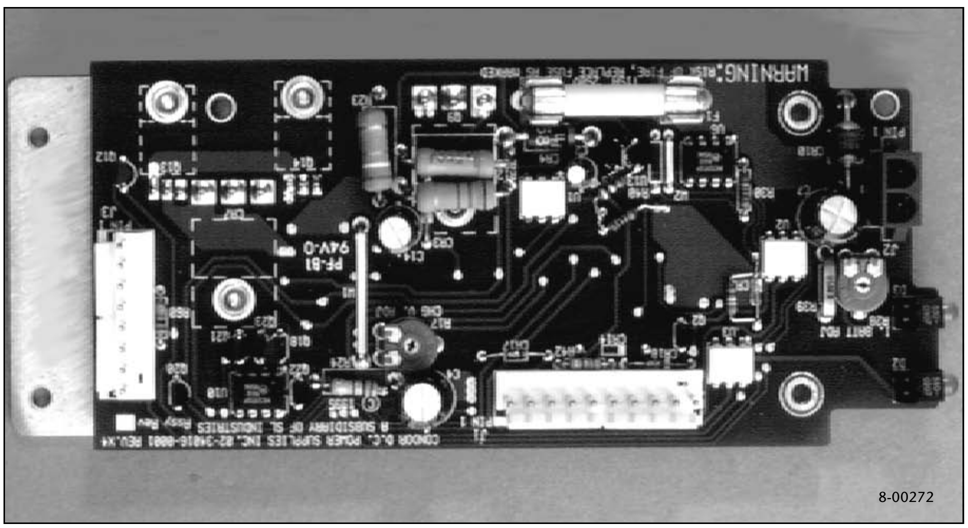


Figure 2-49. BPS PCB

2.4.6 Card Cage

The card cage, shown in Figure 2-50 and Figure 2-51, includes the motherboard PCB, the BD CPU PCB, and the AI PCB.

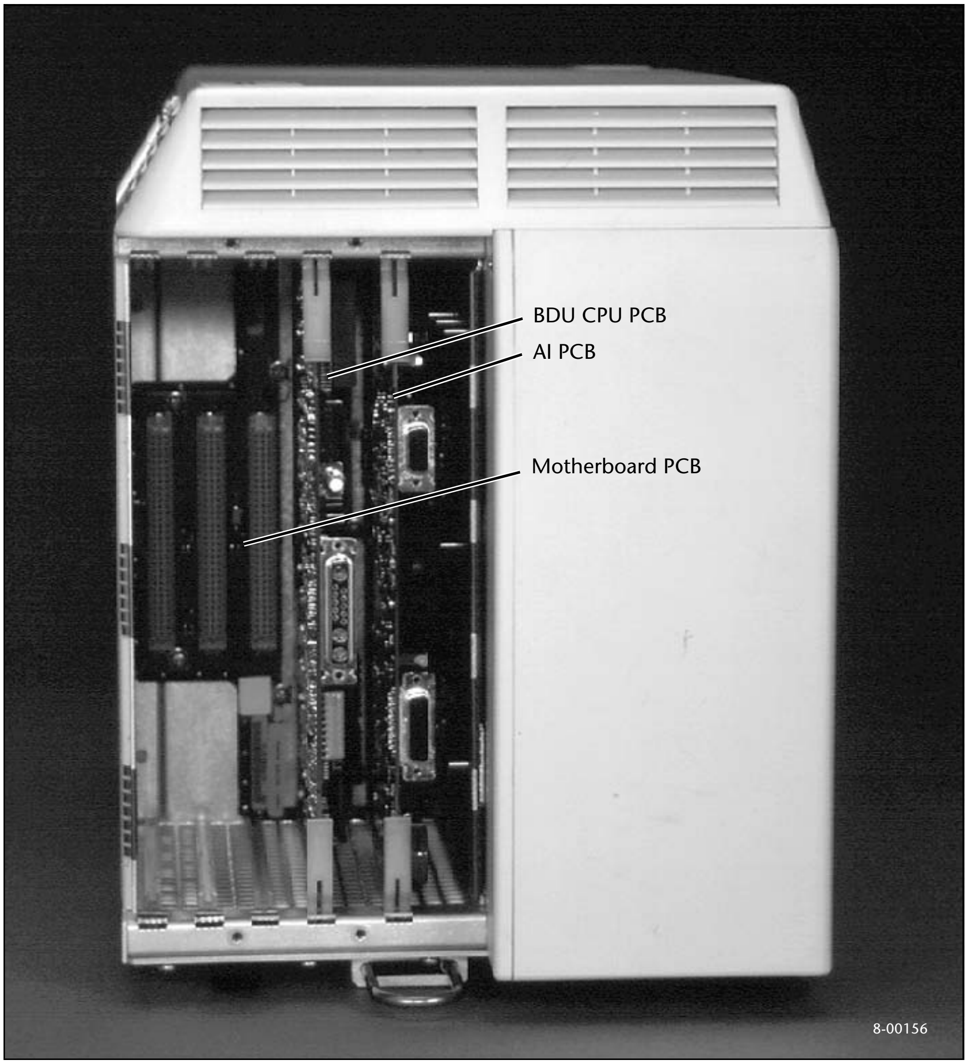


Figure 2-50. Card cage with all PCBs installed

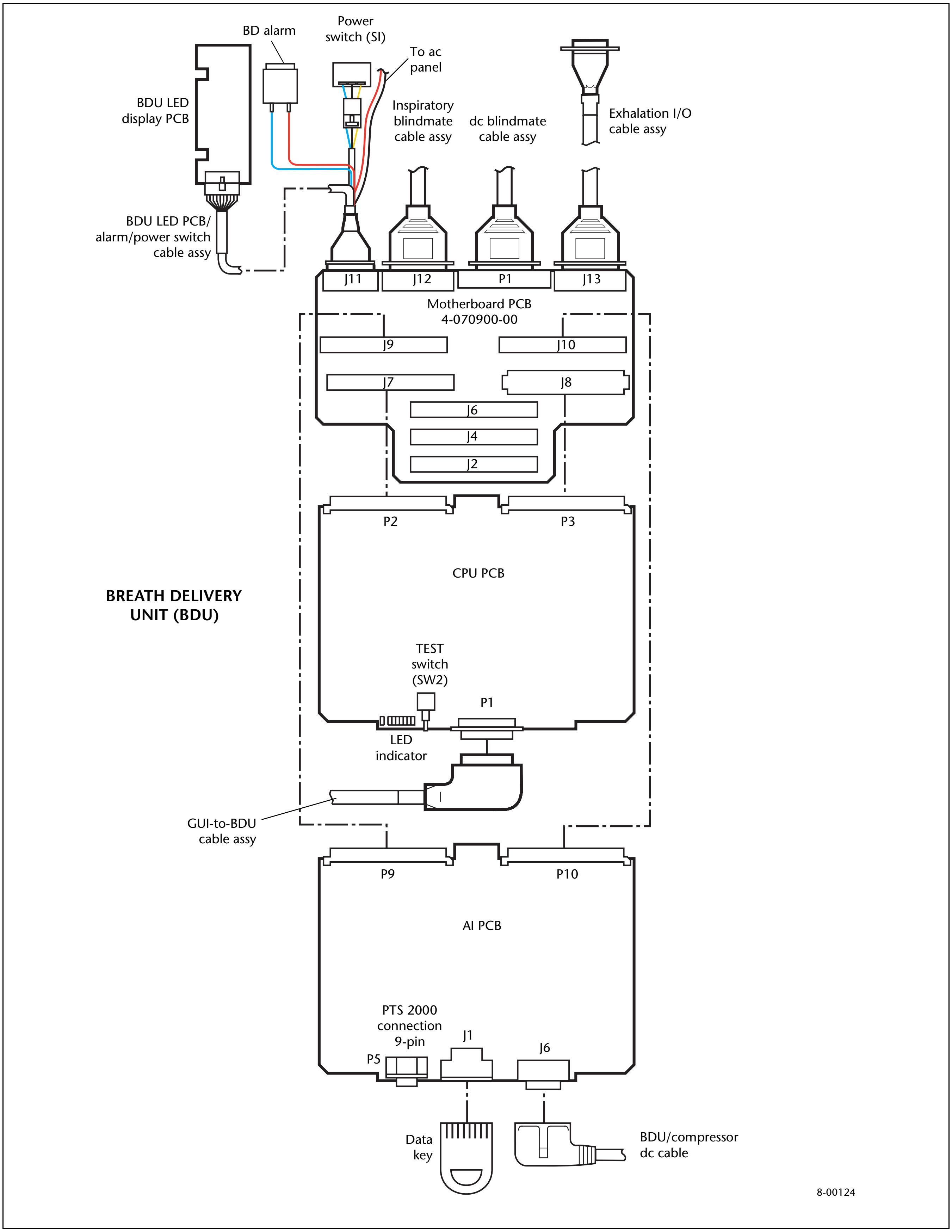


Figure 2-51. ***840*** **Ventilator System interconnect diagram – Card cage**

2.4.6.1 Motherboard PCB

The motherboard PCB, shown in Figure 2-52, Figure 2-53, and Figure 2-54, resides in the card cage. It is the primary electrical interconnect for the plug-in PCBs, power supply, and BDU electronics. The motherboard PCB consists of a multilayer PCB, connectors for plug-in boards and I/O interface, and related electrical filters and protective devices.

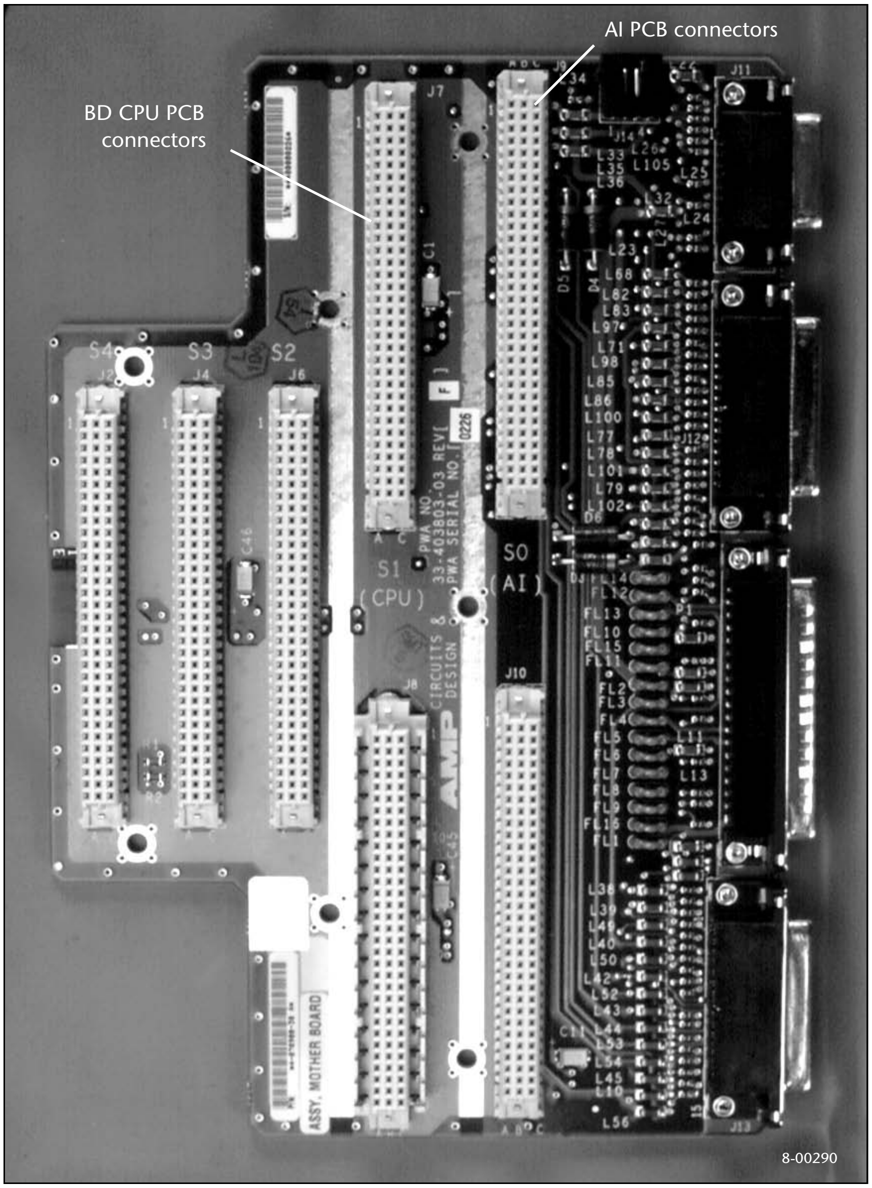


Figure 2-52. Motherboard PCB

Figure 2-53. Motherboard PCB in place

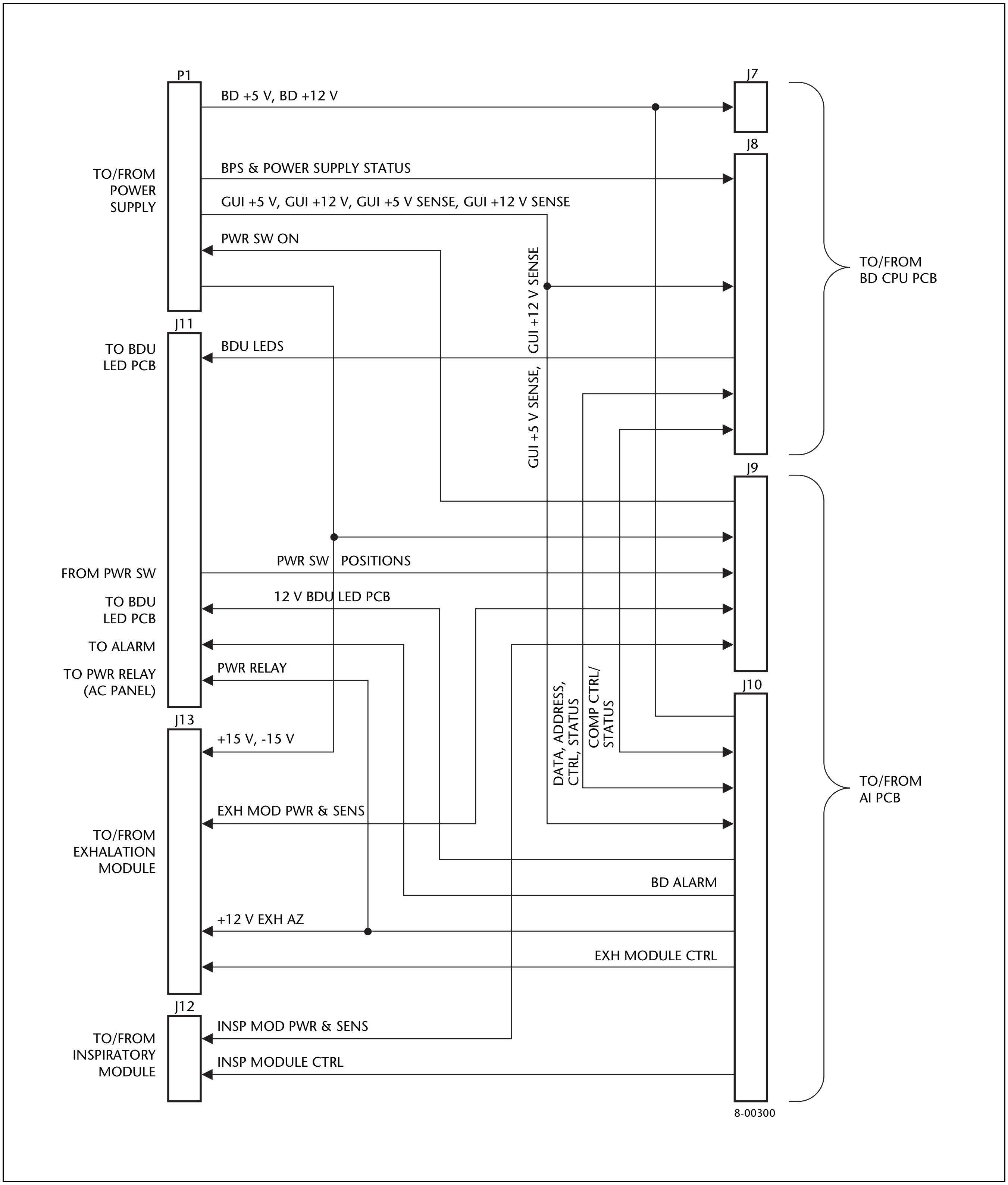


Figure 2-54. Motherboard PCB block diagram

2.4.6.2 BDU CPU PCB

The BD CPU PCB (Figure 2-55), in conjunction with the AI PCB, provides microprocessor control of all breath delivery functions for the 840 Ventilator System. It also communicates with the GUI CPU PCB for display and control information from the operator. All analog signals to and from the sensors and actuators of the system are controlled by software running in the BD CPU.

The PCB resides within the card cage, next to the AI PCB. These two boards are closely coupled and provide the main intelligence and drive for all the mechanical devices and electronic sensors used in ventilation.

The BD CPU PCB plugs into the motherboard using two standard DIN 96-pin connectors. The first connector (P2) is used for power. The second connector (P3) is an Enhanced Eurocard DIN 96 connector with additional connections for power and ground.

The BD CPU PCB controls and monitors the status of ventilator power, the BPS, the compressor, the AI PCB, and the option PCBs. The BD CPU PCB includes these circuits, which perform the indicated functions:

- The ***CPU and control circuits*** include a Motorola 68040 microprocessor (which includes an onboard math coprocessor), operating at 24 MHz, along with supporting devices to perform ventilator control functions. In addition to executing instructions, these functions include passing data back and forth between memory and I/O devices; generating address signals used to access memory locations; generating read/write, timing, and other control signals; and processing interrupts from the various system devices.
- The PCB's ***memory*** includes 2 MB of flash memory (soldered; no sockets) that contains the operational software for the BD. This software is downloadable via a PC. A boot memory PROM contains the ventilator's initialization and POST code and provides a basic communications program to permit downloading of system software. Downloaded software is not written to the boot memory PROM; it cannot be written to in the field. 4 MB of dynamic random access memory (DRAM) is used for ongoing calculations and data storage and as a message and command buffer for the Ethernet controller.
- 16 KB of ***NOVRAM circuit*** (nonvolatile RAM) stores essential, persistent variables and configuration information; current breath mode settings (for obtaining default parameters at power on); POST and extended self test (EST) fault information; the reset stack pointer; and others (see Table 2-4). The NOVRAM devices are soldered in place (no sockets). Although information in these devices is lost when the BD CPU PCB is replaced, much of this data is updated during POST and EST. Critical data specific to a particular unit (including system serial numbers) is stored on a data key device which stays with the unit.

  Each NOVRAM device consists of an internal flash memory device (which has the advantages of being able to retain data without the application of power, and which also can be easily written to) and a static RAM device. Upon power-up, the data stored in flash memory is retrieved and stored in static RAM. During normal operation, the NOVRAM behaves like static RAM. Upon detecting low supply voltage, the NOVRAM stores data from static RAM into internal flash memory for nonvolatile storage. This operation takes 2.5 ms. The BD CPU PCB provides an isolated, decoupled power supply (V_{CAP}), independent of the +5 V supply, to the NOVRAM to ensure the power-down ramp is long enough to store the static RAM contents.

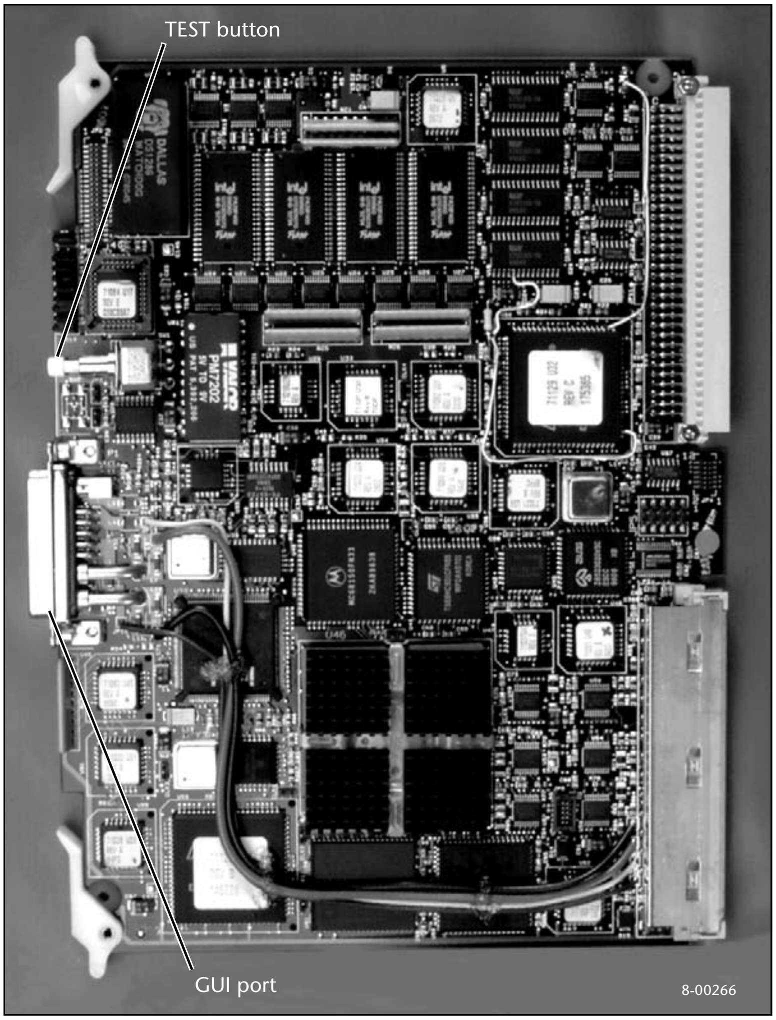


Figure 2-55. BD CPU PCB

- The ***real-time clock*** tracks the ventilator operational time and short-duration power losses (up to 60 minutes). When the ventilator is operating, the real-time clock is powered by V_{CC}. When power is lost or removed, a built-in battery powers the clock. This battery has a 10-year life expectancy.
- The ***watchdog circuit*** monitors the BD CPU for safe operation. When a time-out occurs, indicating a lack of bus activity, a system reset occurs. Problems with the CPU, clock, or software can cause a watchdog time-out.
- The ***GUI-BDU interface*** provides for Ethernet communication between both BD and GUI CPU PCBs. This controller sends an interrupt to the BD CPU to inform it of a communication from the GUI CPU. Commands and messages to be transferred (via direct memory access, DMA) are stored in DRAM. The GUI-BDU interface uses isolation transformers and an isolated power supply, but is connected to standard system ground. There is no isolation from any external device that may be attached.
- An ***RS-232C channel*** is available for developmental use only.
- A ***diagnostic LED array*** (with supporting circuitry) indicates the status of the BD CPU PCB. During POST, they indicate the current test step. A ninth LED displays the supervisory mode status of the CPU.

- The ***power fail detection circuit*** causes an NMI to be generated if the power supply generates a power fail signal. The power supply generates a power fail signal if the output of the bulk supply is less than 19.30 V.
- The ***digital I/O interface circuit*** provides these outputs:
  - A signal (redundant) to declare a ventilator inoperative condition and to light an LED.
  - A signal to place the BDU hardware into a safety valve open (SVO) state and to light an LED.
  - BD LED PCB control signals, including loss of user interface (LOUI) LED, safety valve open (SVO) LED, and ventilator inoperative (VENT INOP) LED.
  - Compressor control signals (representing on, standby, and off). The on command runs the compressor continuously when the ventilator is operating on compressed air (that is, when the wall air supply has dropped below 14 psig). Standby causes the compressor to cycle to maintain accumulator pressure; wall air pressure drops to between 14 and 26 psig, and the compressor supplements the wall air pressure. The off command overrides the compressor automatic cycling control (to maintain accumulator pressure) to ensure the compressor is off for self test purposes.
  - Power mode signal suspends battery charging to allow a true reading of battery voltage.
  - Low ac power signal (ac < 80% of nominal) to compressor.
  - Signals to place the ventilator into the service mode (in conjunction with a momentary push-button switch) and to disable the two POST 10-s timers (necessary to allow test mode).

  The digital I/O interface provides these inputs:
  - Compressor status signals, including: compressor present; compressor compartment overtemperature; ac input to compressor low; compressor accumulator pressure adequate for ventilation; compressor in standby mode, compressor off, or compressor on.
  - BPS status signals including: battery being charged, battery in use, and battery fully charged.
  - Service mode enabled
- The ***AI PCB interface*** provides for communication between the BD CPU and the AI PCB.
- The ***BDU LED display drivers*** interface the BDU LED PCB.
- The ***service mode switch*** is a push-button on the board edge used to activate this mode.

The BD CPU PCB generates an NMI under any of these conditions:

- Ethernet parity error detected
- Power fail signal
- A/D converter system error

Table 2-3: NOVRAM contents

Parameter	Notes	Where data are stored
Background alarm status	Status of all DEVICE ALERT alarms	BD alarm statuses are stored in BD NOVRAM. GUI alarm statuses are stored in GUI NOVRAM.
Ventilator settings		All settings are stored in GUI NOVRAM. BD-applicable settings (that is, nominal line voltage, patient circuit type, and a subset of the breath-related settings) are stored in BD NOVRAM.
Diagnostic logs	This includes the System Diagnostic Log, System Information Log, and EST/SST Diagnostic Log (which are actually stored in two separate locations -- one for EST, one for SST).	BD events are stored in BD NOVRAM. GUI events are stored in GUI NOVRAM.
Alarm history log	History of alarm events for the current/previous patient **NOTE:** The alarm history log is automatically cleared upon successful completion of a new patient setup. (A new patient setup is required to start normal ventilation after exiting the service mode.)	GUI NOVRAM
EST and SST result information	Result and status information for each EST and SST test	BD information is stored in BD NOVRAM. GUI information is stored in GUI NOVRAM.
Ventilator and compressor operational hours		BD NOVRAM
POST test status	Status of each of the POST/kernel tests	BD statuses are stored in BD NOVRAM. GUI statuses are stored in GUI NOVRAM.
PSOL lift-off information	Calculated during EST	BD NOVRAM
Compliance calibration	Calculated during SST	BD NOVRAM
Inspiratory and expiratory resistance	Calculated during SST	BD NOVRAM
Oxygen and air flow sensor (Q1 and Q2) offsets	Calculated during EST	BD NOVRAM
Absolute pressure transducer (PA) offset	Calculated during PA calibration	BD NOVRAM

2.4.6.3 Analog interface (AI) PCB

The AI PCB (Figure 2-56) provides an interface between the ventilator's microprocessor circuits and its analog systems via an IP bus. These analog systems include the compressor, dc electronics, valves, BD (continuous-tone) audio alarm, and transducers. The compressor control and dc status signals and dc power pass through the AI PCB. The PCB includes these circuits, which perform the indicated functions:

- The ***digital interface circuit*** provides for communication between the BD CPU PCB and the analog circuits on the AI PCB.
- The ***pressure and flow sensor filters*** minimize pneumatic noise in these components' readings.
- The ***+10 V reference*** produces a reference voltage for use by analog-to-digital and digital-to-analog converters and pressure transducers (inspiratory electronics PCB and exhalation transducer PCB).
- The ***data key interface*** provides clock and data latches to handle the flow of data between the BD CPU and data key.
- The ***thermistor amplifiers*** amplify input signals from the manifold heater thermistor and the motor magnet thermistor, both located in the exhalation compartment.
- The ***valve control and drive circuit*** provides drive signals for the PSOLs, EV, and the EV stabilizer device.

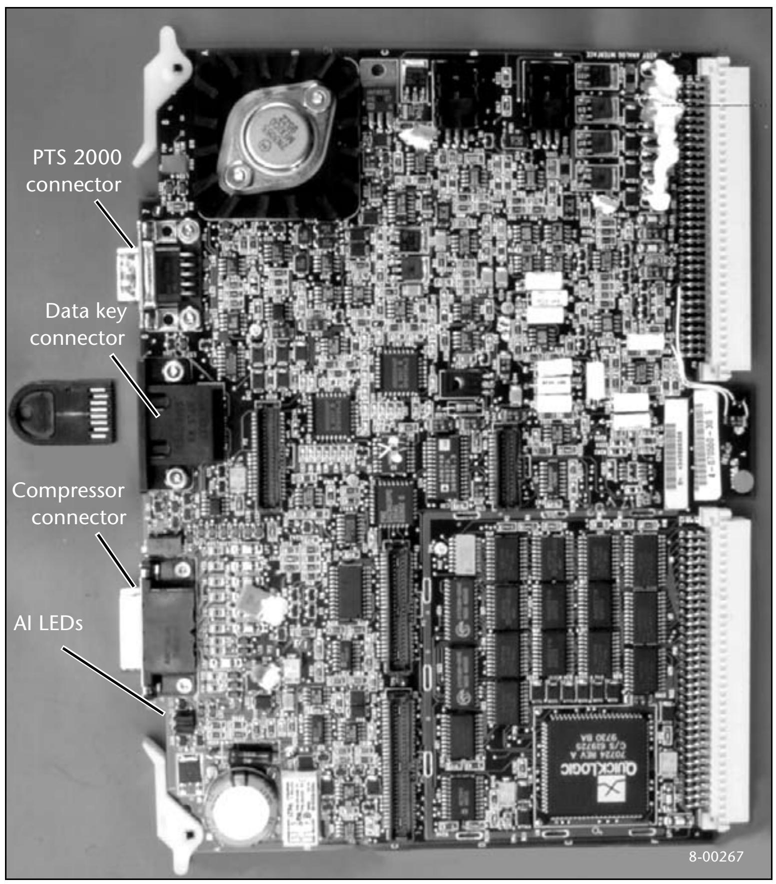


Figure 2-56. AI PCB

- The ***BD alarm circuit*** activates the BD alarm. The alarm is activated under any of these conditions:
  - A ventilator inoperative condition is declared
  - The BD CPU detects a loss of communication with the GUI
  - A GUI alarm fault is detected
  - The power switch fails
  - The +5 V sentry on the AI PCB detects a low voltage condition

  Under most conditions, the +5 V powers the alarm. If the +5 V sentry circuit on the AI PCB detects a power failure, a power fail capacitor powers the alarm for a minimum of 2 min.
- The ***PSOL power disconnect circuit*** removes power from the PSOL drivers when the ventilator is in the safety valve open state.
- The ***exhalation valve circuit*** drives the exhalation valve motor. Pressure readings provide feedback to the software that determines the amount of valve dampening required. The circuit includes power disconnect circuitry, which removes power from the exhalation valve driver when the ventilator is in the safety valve open state.
- The ***safety valve circuit*** controls and drives the safety valve. Full power to the safety valve pulls the valve closed. After a short interval, power is reduced to keep the valve closed. The safety valve circuit ensures full power is applied in the event of a loss of +12 V (required to reopen the valve).
- The ***voltage sentry circuit*** creates signals that are proportional to voltages used in the system. These signals are used in software monitoring of these voltages: +10 V reference and +5, +12, +15, and -15 V supply voltages.

  In addition, the sentry circuit generates a global reset if +5 V is out of range. A relay, which is part of the sentry circuit, ensures that a power fail reset occurs during voltage transients.
- The ***BPS model signal buffer*** provides a signal THAT yields BPS model type information in an analog form. The software reads this signal to determine whether the BPS is currently connected to the ventilator.
- Other ***buffers*** provide conditioning for various ventilator signals.
- The ***compressor interface circuit***, in conjunction with the compressor PCB, controls and monitors the compressor operation.

2.4.7 Data key subsystem

NOTE:

Call your Puritan Bennett representative if the data key requires replacement due to loss or failure.

The *840* Ventilator System uses a data key (Figure 2-57) to record data specific to a particular ventilator unit. The data key provides a way to retain data when PCBs or the battery are removed from the ventilator. The data key plugs into a receptacle on the ventilator. Data is read from or written to flash memory on the data key. This serial data is transferred to the BD CPU through the data key interface. *The data key must always be installed in the ventilator for proper operation.*

The data key stores this data:

- Serial numbers of the GUI and BDU.
- Hours of ventilator operation.

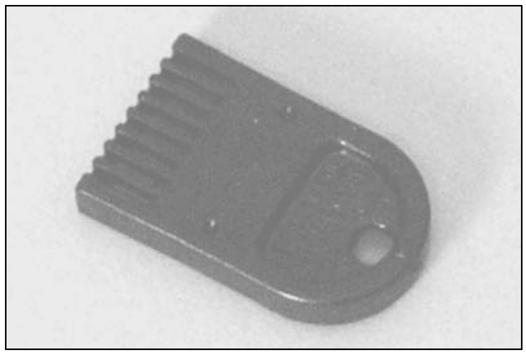


Figure 2-57. Data key

2.4.8 GUI

The GUI (Figure 2-60), which detaches from the ventilator head for servicing, is an enclosure that houses the GUI CPU PCB, keyboard, GUI LED PCB, backlight inverter PCBs, knob, two 10.4-inch or 9.4-inch color LCD flat panels, a touch frame PCB, and an alarm speaker.

2.4.8.1 GUI CPU PCB

The GUI CPU PCB, shown in Figure 2-58 and Figure 2-59, provides microprocessor control and monitoring of the display and user interface system. The board is based on the Motorola 68040 microprocessor.

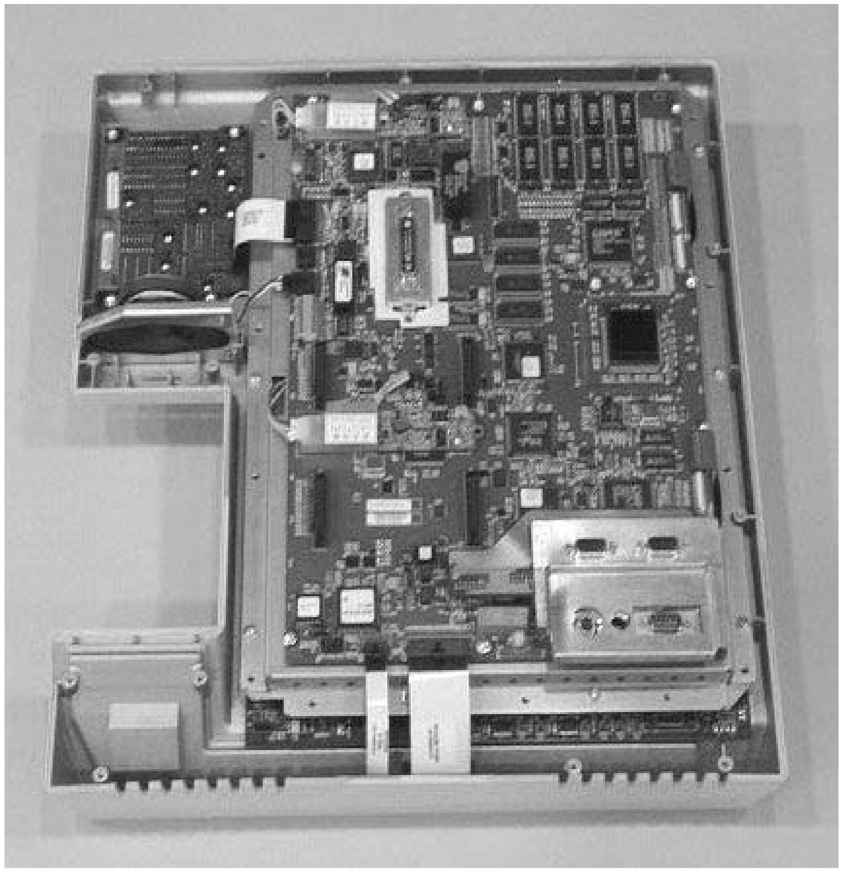


Figure 2-58. 10.4″ GUI CPU PCB

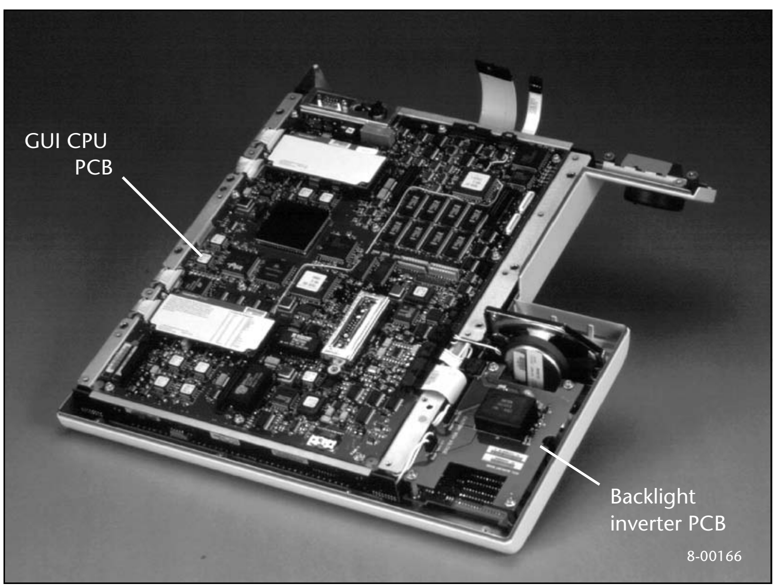


Figure 2-59. 9.4″ GUI CPU PCB and backlight inverter PCB in place

The GUI CPU PCB includes these circuits, which perform the indicated functions:

- The ***CPU and control circuit*** includes a Motorola 68040 microprocessor (which includes an onboard math coprocessor), operating at 24 MHz, along with supporting devices to perform ventilator control functions. In addition to executing instructions, these functions include passing data back and forth between memory and I/O devices; generating address signals used to access memory locations; generating read/write, timing, and other control signals; and processing interrupts from the various system devices.
- The PCB's ***memory*** includes 4 MB of flash memory (soldered; no sockets) that contains the operational software for the GUI. A boot PROM contains ventilator initialization and POST code and provides a basic communications program to permit downloading of system software. Downloaded software is not written to the boot memory PROM; the PROM cannot be written to in the field. 4 MB of DRAM is used for ongoing calculations and data storage and as a message and command buffer for the Ethernet controller.
- 64 KB of ***NOVRAM*** (nonvolatile RAM) stores essential, persistent variables and configuration information; current breath mode settings (for obtaining default parameters at power on); POST and EST fault information; the reset stack pointer; and others (see Table 2-3). The NOVRAM devices are soldered in place (no sockets). Although information in these devices is lost when the GUI CPU PCB is replaced, much of this data is updated during POST and EST. Critical data specific to a particular unit (including system serial number) is stored on a data key device, which stays with the unit.

  Each NOVRAM device consists of an internal flash memory device (which has the advantages of being able to retain data without the application of power, and which also can be easily written to) and a static RAM device. During power on, data stored in the flash memory is retrieved and stored in static RAM. During normal operation, the NOVRAM behaves like static RAM. Upon detecting low supply voltage, the NOVRAM stores data from static RAM into internal flash memory for nonvolatile storage. This operation takes 10 ms. The GUI CPU PCB provides an isolated, decoupled power supply (V_{CAP}), independent of the +5 V supply, to the NOVRAM to ensure the power-down ramp is long enough to store the static RAM contents.
- The ***real-time clock*** tracks the ventilator's operational time and short-duration power losses (up to 60 minutes). When the ventilator is operating, the real-time clock is powered by V_{CC}. When power is lost or removed, a built-in battery powers the clock. This battery has a 10-year life expectancy. The real-time clock can be removed from its socket for field replacement.
- ***+5 and +12 V monitors*** signal the microprocessor (via a nonmaskable interrupt) when +5 V is too high or +12 V is out of range. This circuit also generates a power fail reset if the +5 V output drops below +4.8 V.
- The ***watchdog circuit*** monitors the CPU for safe operation. When a time-out occurs, indicating a lack of bus activity, a system reset occurs. Problems with the CPU, clock, or software can cause a watchdog time-out.
- The ***GUI-BDU controller*** provides for Ethernet communication between both BD and GUI CPU PCBs. The controller sends an interrupt to the GUI CPU to inform it of a communication from the BD CPU. Commands and messages to be transferred (via DMA) are stored in DRAM. The GUI-BDU interface uses isolation transformers and an isolated power supply, but is connected to standard system ground. There is no isolation from any external device that may be attached to it.
- Three ***RS-232 C channels*** provide output for digital communications interface and external communications for service mode. They are electrically isolated for safety. The 9.4-inch GUI has only one RS-232 channel, also electrically isolated.

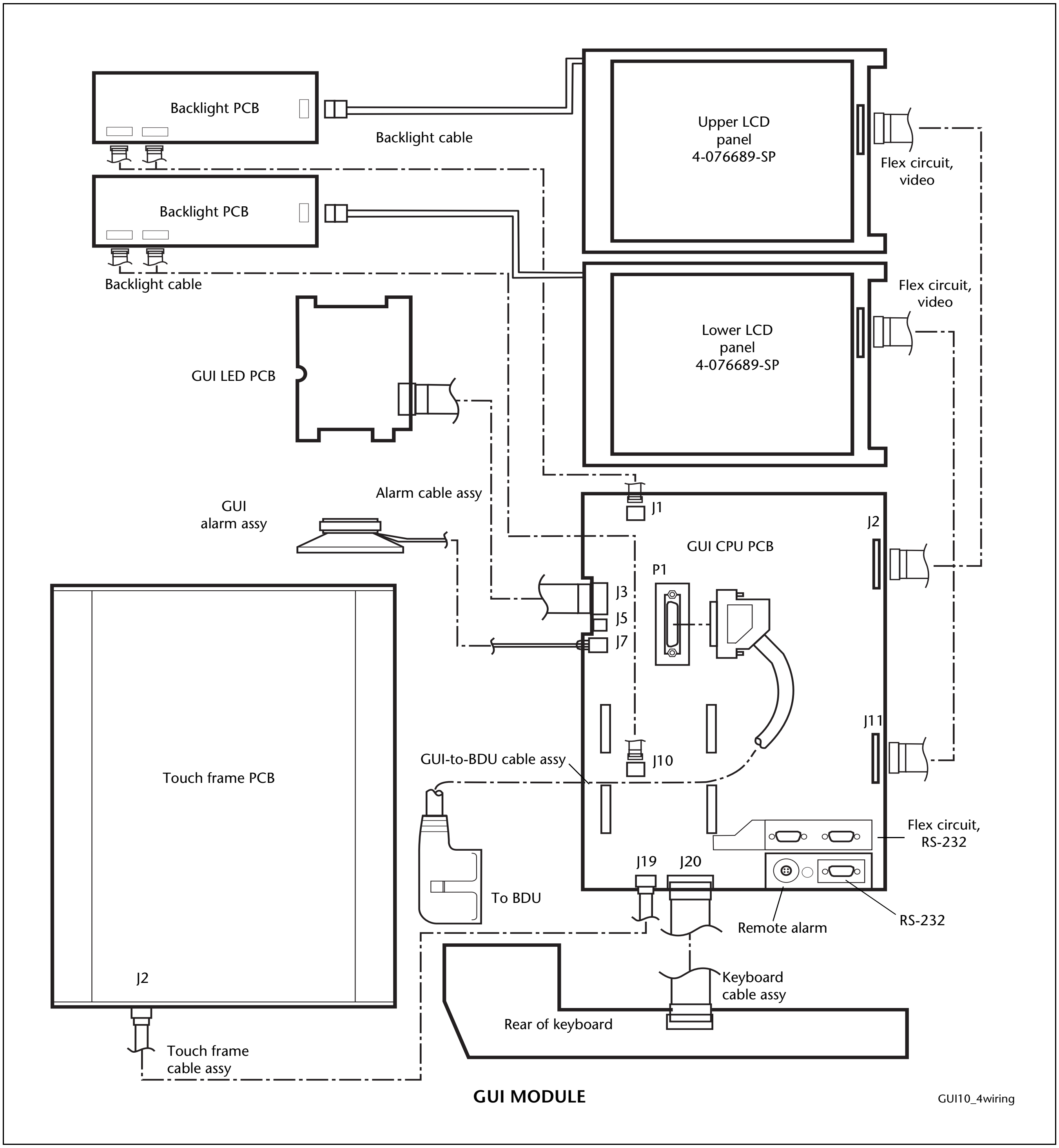


Figure 2-60. ***840*** **Ventilator System interconnect diagram – GUI 10.4-inch LCD panels**

- ***Diagnostic LED array*** uses eight discrete LEDs, in conjunction with supporting circuitry, to indicate the status of the GUI. During POST, the array indicates the current test step. A ninth LED displays the supervisory mode status of the CPU, and a 10th LED indicates power on.
- The ***VGA video control circuit***, comprising two VGA LCD controller ICs with 1 MB video RAM, interfaces the two 640 x 480 x 256K color 10.4-inch LCD panels. Older GUI versions with 9.4-inch, 4K color or monochrome (16 greyscale levels) displays containing the older GUI CPU board contain plug-in IP interface VGA LCD controllers that interface the LCD panels.
- An ***infrared touch scanner interface***, which includes its own microcontroller, monitors the touch screen.
- The ***LED PCB interface*** lets the microprocessor control the discrete LEDs on the GUI LED PCB.
- The ***LCD backlight control circuit*** controls the brightness of the two fluorescent lamps that light the flat panels based on software input. It generates a pulse width modulated signal to the backlight inverter PCB(s) (two PCBs on 10.4-inch GUIs; one PCB on 9.4-inch GUIs), which controls the brightness of both LCD panels. There is no user-adjustable brightness control on color displays.
- The ***remote alarm relay interface*** enables/disables an external alarm device (such as a nurse's call). The relay contacts are closed when the unit is in a normal ventilation state and opened when the unit is off or in an alarm state.
- The ***sound generator interface*** produces the ventilator's alarm sounds. Consisting of a microcontroller and audio signal processing hardware, the interface produces ISO-standard alarm sounds and provides keyboard entry audible feedback.
- The ***rotary encoder/decoder circuit*** determines the direction and amount of knob movement. The optical encoder incorporates an emitter section, two codewheels, and a detector section. Each codewheel has a pattern photographically plated on it. As the knob shaft revolves, the codewheels rotate with respect to the emitter and photodetector sections, causing the light beam to be interrupted by the pattern of spaces and bars on the codewheels. The detectors are positioned such that a light period on one photodetector corresponds to a dark period on the other photodetector. Using the photodetector outputs, the decoder can determine the knob position.
- The ***keyboard interface*** reads the keyswitches and controls the lighting of the LEDs on the keyboard.

The GUI CPU PCB generates an NMI under any of these conditions:

- GUI +5 V is high
- GUI +12 V is out of range
- Ethernet parity error detected
- SAAS microcontroller failure

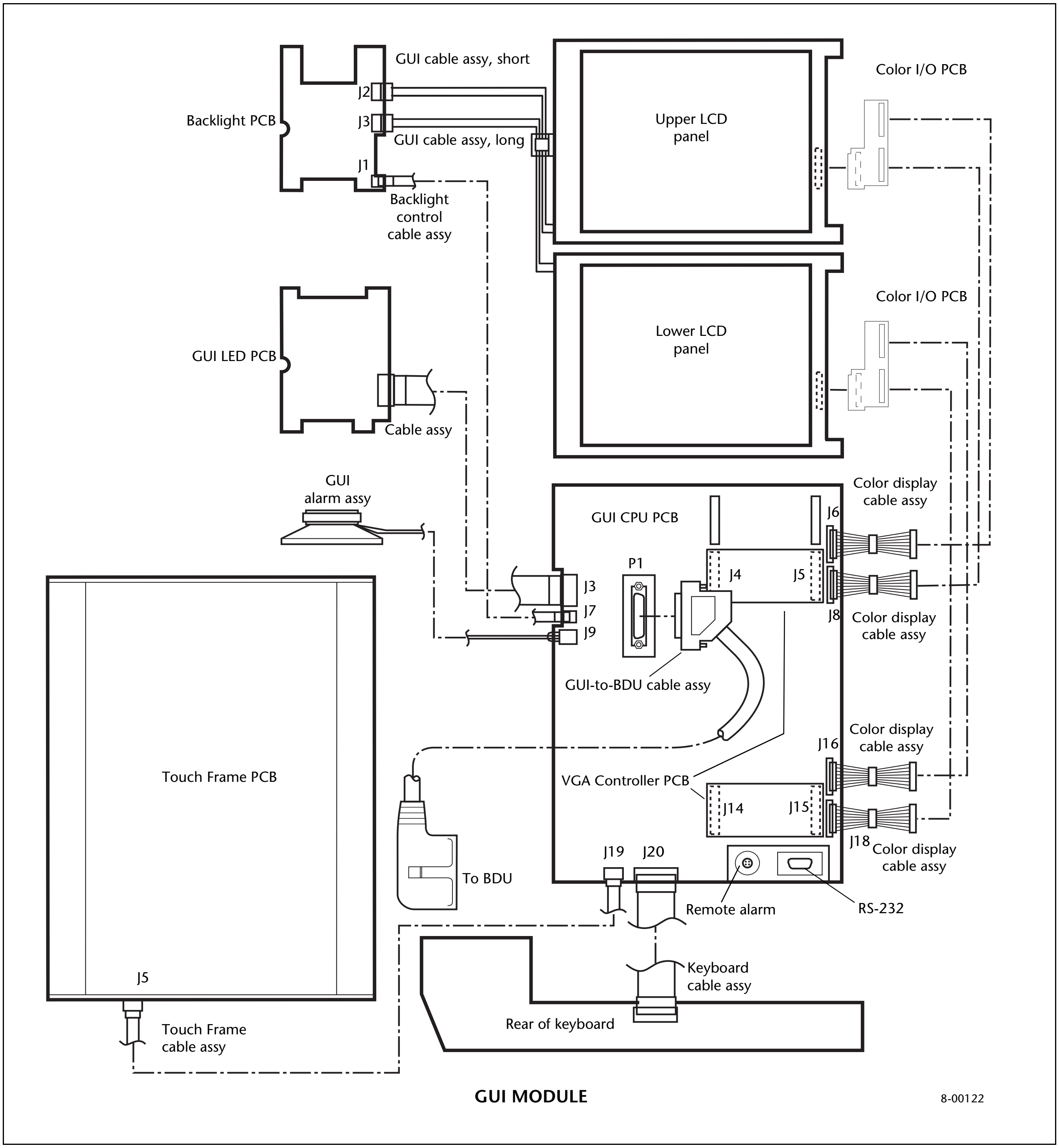
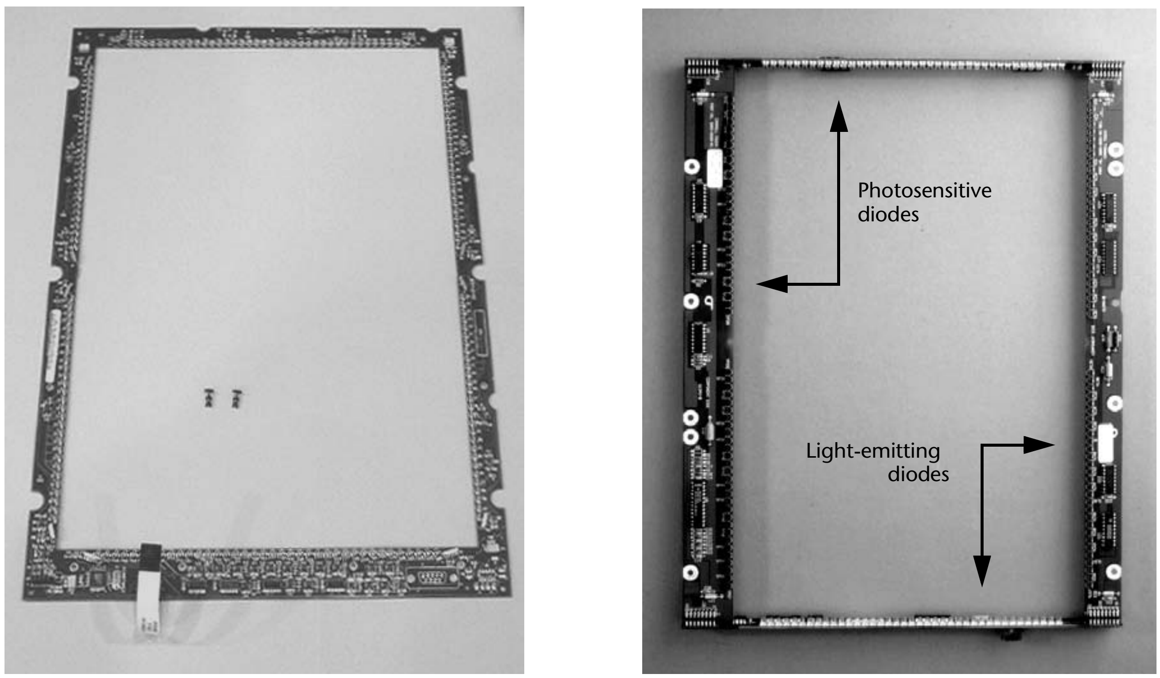


Figure 2-61. ***840*** **Ventilator System interconnect diagram – GUI 9.4-inch LCD panels**

2.4.8.2 Touch frame PCB

The touch frame PCB is responsible for detecting operator inputs on the GUI screen. Different touch frame designs are used in the 10.4-inch GUI and the 9.4-inch GUI.

On the 10.4-inch GUI, the touch frame PCB communicates with the GUI CPU PCB using a serial interface, and operates from a single 5V supply, drawing no more than 100mA. Infrared (IR) transmitting LEDs are mounted on all sides of the PCB and IR detectors, at which invisible IR light beams are aimed, are located at strategic points around the PCB. This arrangement of LEDs and detectors define an intersecting pattern of light beams that is used to determine the location of an input on the GUI screen. See Figure 2-62.



10.4″ GUI 9.4″ GUI

Figure 2-62. Touch Frame PCB

A micro-controller located on the touch frame PCB scans the touchscreen for operator inputs by switching on the LEDs one at a time in a pseudo random pattern, and then sampling the output results from the logically associated IR detectors. A complete scan of all the LEDs occurs 39 times per second. When the GUI screen is touched, some of the light beams don't reach their associated IR detectors, and as a result, there is no output from those detectors and they are considered "blocked." The microcontroller checks pairs of LEDs and IR detectors for blocked beams, uses a mathematical coordinate conversion routine to locate the touch in the intersecting area of light beams, and sends the information to the GUI CPU board for processing.

To improve touch frame reliability, each LED output is received by two IR detectors. The blocked beams are detected simultaneously in different intersecting areas providing redundancy which allows continued operation of the touch frame in the event an LED or IR detector burns out. During normal conditions, when all LEDs and IR detectors are functioning properly, the redundant detectors are used to provide a more accurate output by averaging the locations of the blocked beams.

On the 9.4-inch GUI, the touch frame communicates with the GUI CPU PCB via a Carroll-Touch propri-*+9I CPU PCB sequentially pulses the LEDs, creating an invisible grid of IR light beams just in front of the display surface. The phototransistors sense these light beams.

When the screen is touched, the light beams from certain LEDs are obstructed and do not reach their corresponding phototransistors. The interface constantly monitors the presence, or in this case the absence, of the IR light beams received by the phototransistors and can thus determine the X- and Y-coordinates of the touch activation.

On both the 10.4-inch and 9.4-inch GUIs, the touch frame is attached to the face of the display, where it is concealed behind an IR-transparent bezel (a type of enclosure that is opaque to the eye, but that allows IR light to pass through).

2.4.8.3 Keyboard assembly with knob

A membrane keyboard assembly (Figure 2-63) is attached to the GUI CPU PCB. A software debounce routine protects against unintended multiple keystrokes.

The multiposition knob assembly, which is part of the keyboard assembly, permits ventilator setting selections or changes. Knob encoder/decoder circuitry on the GUI CPU PCB determines the direction and position of the shaft based on encoder outputs.

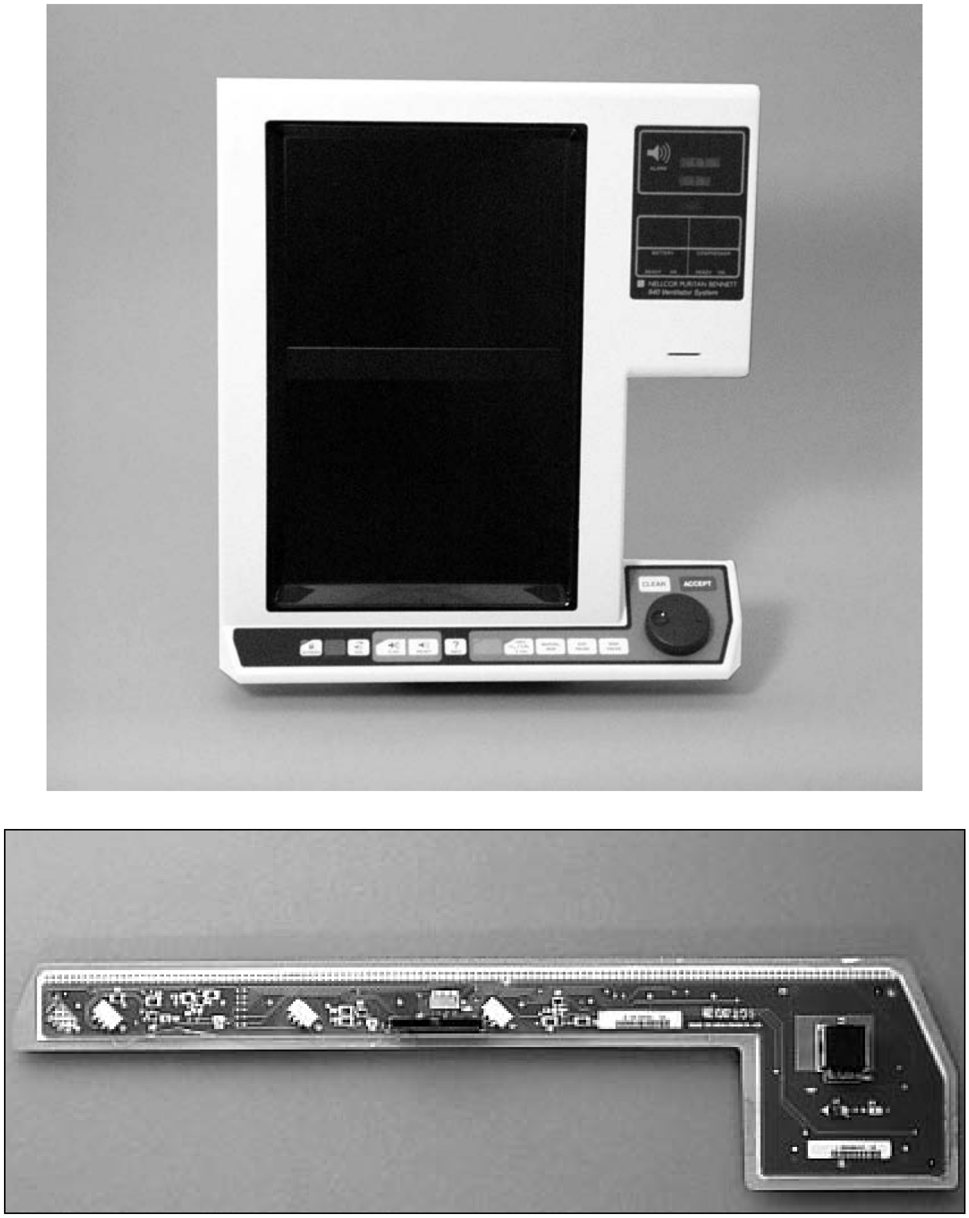


Figure 2-63. Keyboard assembly

2.4.8.4 GUI LED PCB

The GUI LED PCB, shown in Figure 2-64, contains ten LED-based visual indicators and LED drivers. These components operate under control of the GUI CPU PCB. The indicators illuminate (backlight) specific messages/icons on the GUI LED panel.

Each indicator consists of one or more LED light bars, made up of individual LEDs. Light bars of different sizes are used to accommodate the different-size icons that make up the indicator panel display. The indicators are color-coded red, yellow, or green to show status. Each indicator (except "compressor operating" and "on BPS power") includes redundant LED strings so the indicators will stay lit if an LED bar burns out.

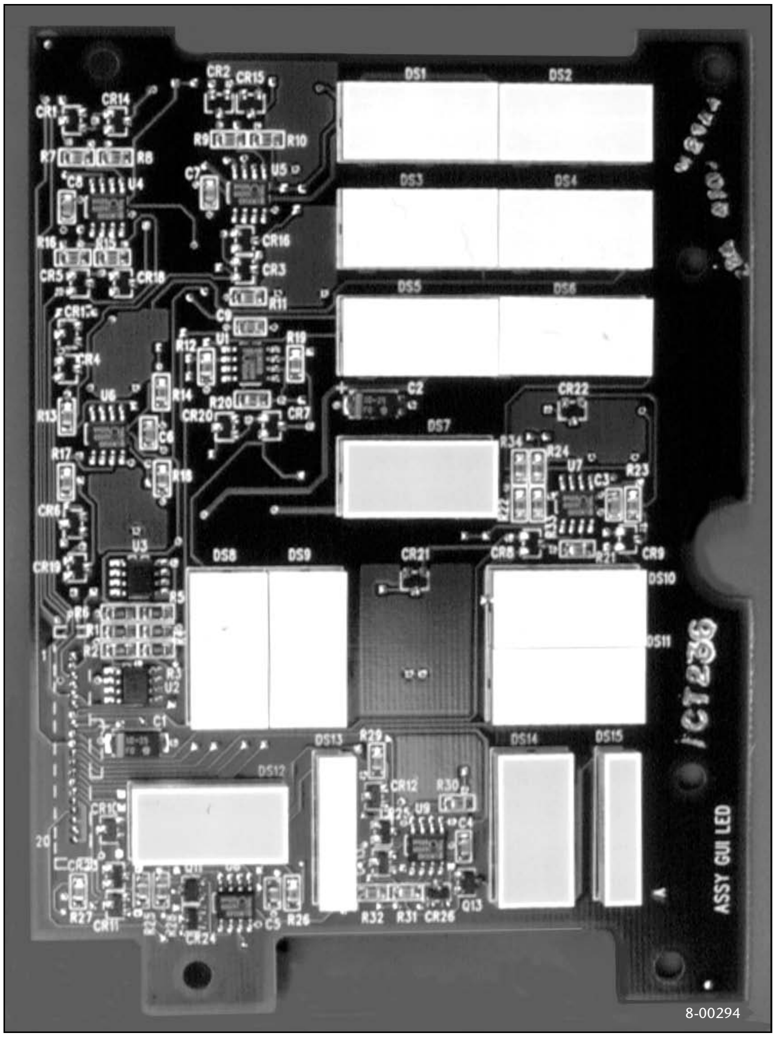


Figure 2-64. GUI LED PCB

2.4.8.5 Backlight inverter PCB and LCD lamps

The 10.4-inch GUI uses two backlight inverter PCBs to convert +12V to a high-voltage ac level that individually powers the fluorescent lamp tubes in the upper and lower displays. These lamps backlight the LCD flat panels. Individual pulse-width modulated signals from the GUI CPU PCB determine the magnitude of the voltage, which in turn determines the brightness of each LCD panel. (There is no user-accessible brightness or contrast adjustment available with color LCD panels.) The lamps on the 10.4-inch LCD panels do not require replacement.

The 9.4-inch GUI uses one backlight inverter PCB to perform the same function described above, and controls the backlight for both LCD panels simultaneously. The LCD lamps are part of the 10,000-hour preventive maintenance kit on the 9.4-inch GUI.

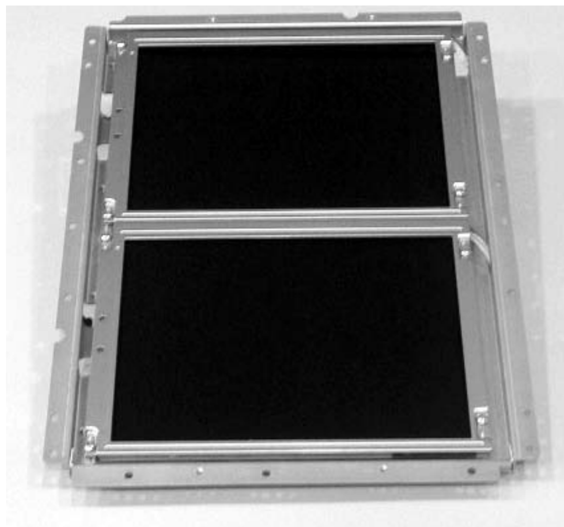


Figure 2-65. 10.4″ GUI LCD panels

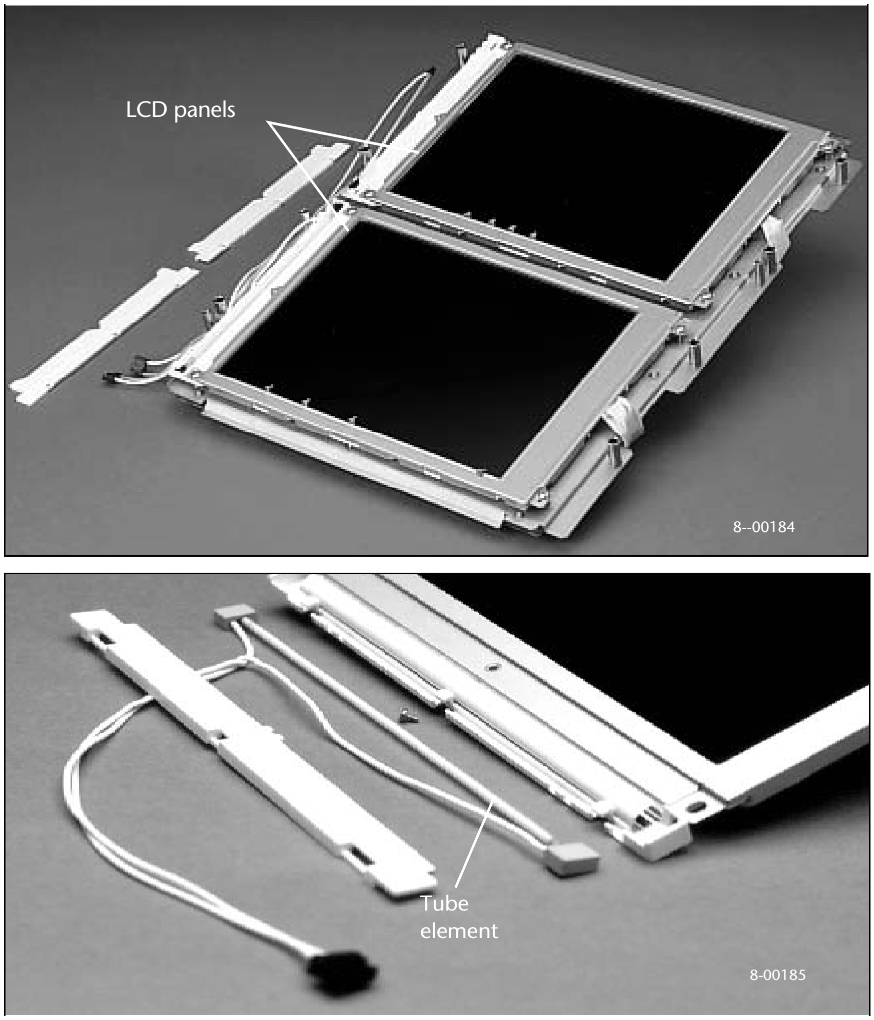


Figure 2-66. 9.4-inch LCD panels and backlight tubes

2.4.8.6 GUI alarm assembly

The GUI alarm assembly (Figure 2-67), the ventilator's primary alarm, emits alarm sounds under control of the GUI CPU PCB.

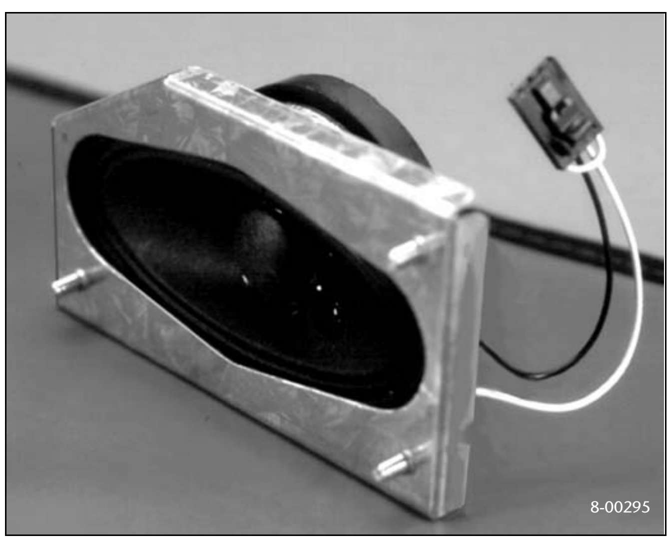


Figure 2-67. GUI alarm assembly

2.4.9 BDU LED PCB

The BDU LED PCB (vent head LED PCB), shown in Figure 2-68, contains three LED-based visual indicators and LED drivers. These components operate under control of the BD CPU PCB. The indicators (safety valve open, ventilator inoperative, and loss of GUI) backlight the ventilator head status panel. All backlights are powered from +12 V.

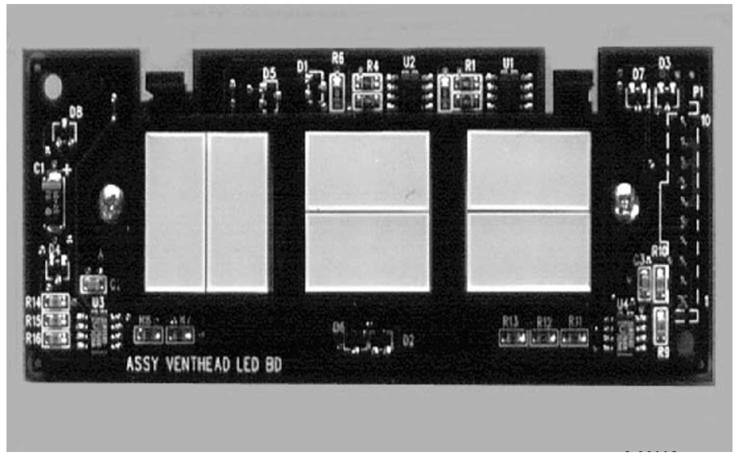


Figure 2-68. BDU LED PCB

2.4.10 Inspiratory electronics PCB

The inspiratory electronics PCB (Figure 2-69 and Figure 2-70), which is housed in the inspiratory module, serves as an electrical interface between the card cage electronics and the electronics in the inspiratory module. The PCB contains inspiratory and atmospheric (absolute) pressure transducers (PI and PA). It also contains an interface circuit for the oxygen concentration sensor, which mounts to the PCB. In addition, proportional solenoid valve, safety valve, inspiratory pressure transducer autozero solenoid (SOL1), pressure switch, and flow sensor signals pass through the PCB.

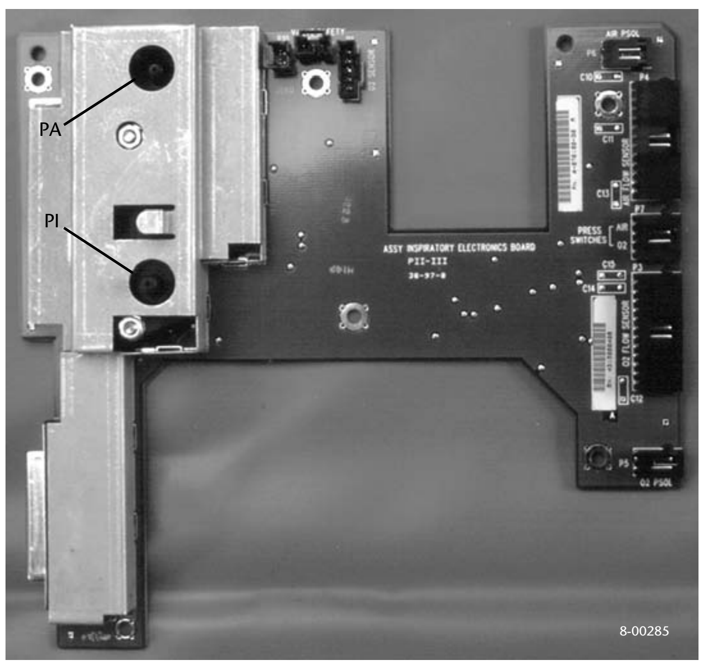


Figure 2-69. Inspiratory electronics PCB

The PCB includes these circuits, which perform the indicated functions:

- The ***inspiratory pressure transducer (PI)*** senses the inspiratory pressure difference relative to ambient air pressure. Pressure is sensed at the inspiratory module.
- The ***absolute pressure transducer (PA)*** senses absolute pressure in the inspiratory module. It is used to determine atmospheric pressure for volume delivery.
- The ***oxygen sensor (OS) amplifier*** provides an interface for the oxygen concentration sensor mounted on the PCB.

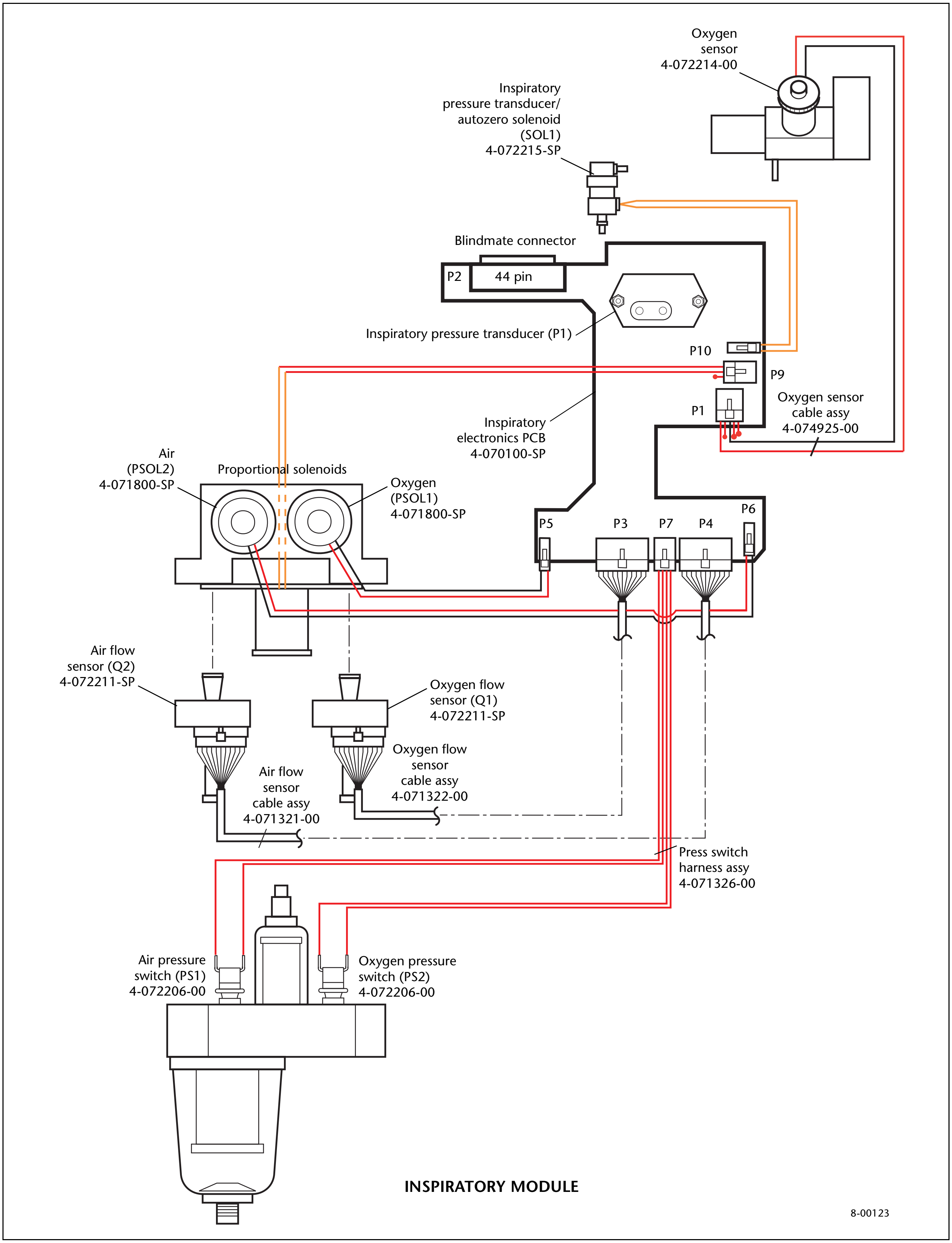


Figure 2-70. *840* Ventilator System interconnect diagram – Inspiratory module

2.4.11 Exhalation transducer PCB

The exhalation transducer PCB (Figure 2-71 and Figure 2-72), which is housed in the exhalation module, produces a voltage signal representing the patient pressure in the exhalation circuit. This signal is routed to the AI PCB and used by software. The expiratory pressure transducer (PE), which is on this PCB, senses the pressure difference in the exhalation circuit relative to ambient air pressure. The PCB uses a +10 V reference.

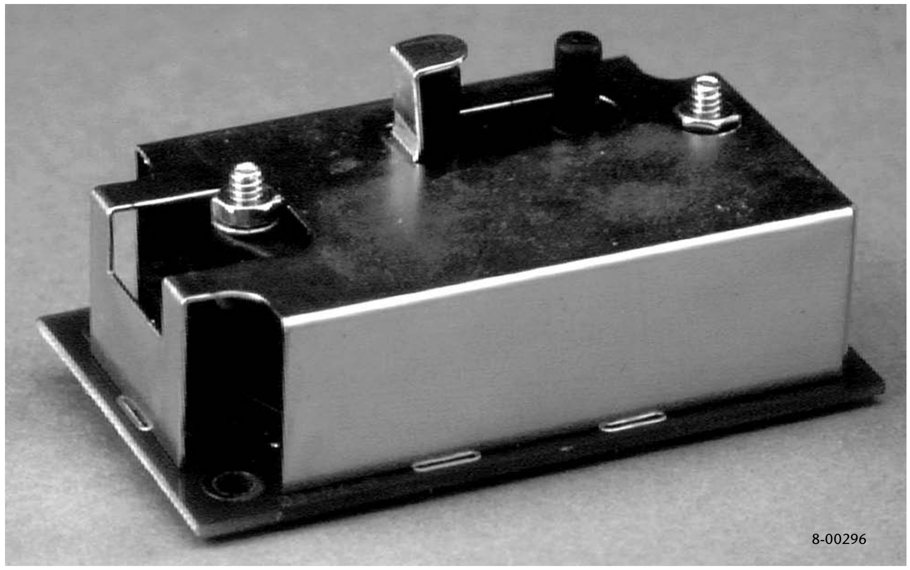


Figure 2-71. Exhalation transducer PCB

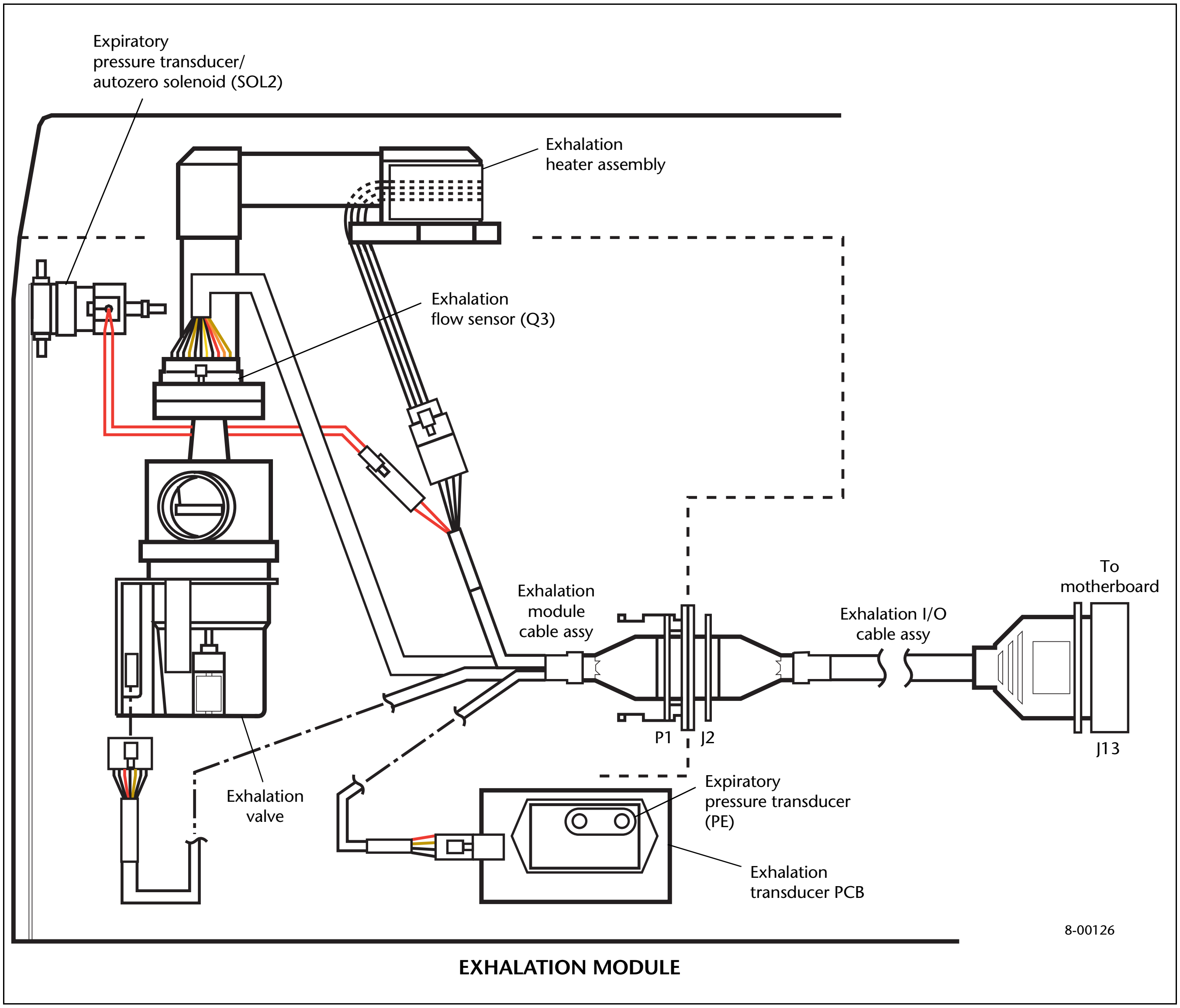


Figure 2-72. ***840*** **Ventilator System interconnect diagram – Exhalation module**

2.4.11.1 BD (continuous-tone) alarm assembly

The BD (continuous-tone) alarm assembly is shown in Figure 2-73. It is activated under the conditions described in Section 2.4.6.2.

Under most conditions, the +5 V powers the alarm. If the +5 V sentry circuit on the AI PCB detects a power failure, a power fail capacitor powers the alarm for a minimum of 2 minutes.

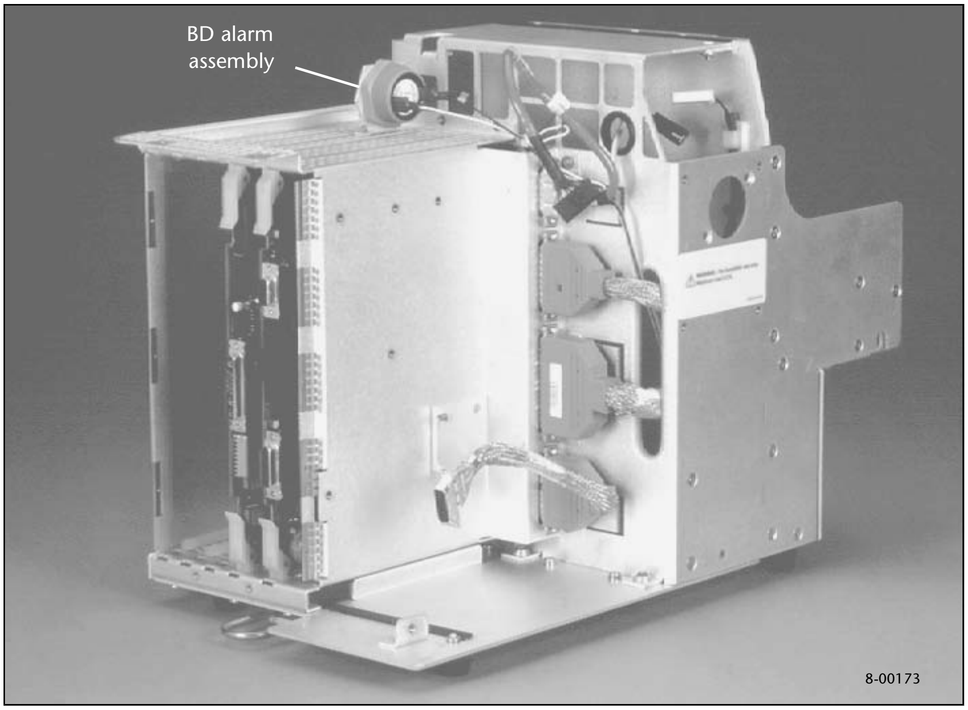


Figure 2-73. BD alarm assembly

2.4.12 806 Compressor unit

The 806 compressor unit's electrical components include: ac power distribution components, a compressor motor, and a compressor PCB. The compressor unit is shown in Figure 2-74.

Figure 2-74. 806 compressor

2.4.12.1 806 compressor unit ac power distribution components and motor

Mains power is applied to the compressor receptacle J4 through power relay K1 when the power supply is on.

The ac power to the compressor unit is provided by a field-replaceable power cord plugged into receptacle J4. The ac-powered fans (Figure 2-75), and motor receive power via the compressor PCB and are protected from overtemperature conditions by a thermostat (TH1). The fans operate whenever the compressor is on. Circuit breaker, CB2, protects the compressor from over-current conditions.

The motor compressor uses a 25 µF (100 V units), 15 µF (120 V units), or a 12.5 µF (220 – 240 V, 50/60 Hz units) starting capacitor.

Figure 2-75. 806 Compressor fans

2.4.12.2 806 compressor PCB

The 806 compressor PCB (Figure 2-76, Figure 2-77, and Figure 2-78) provides electronic control of compressor compartment devices, including the compressor motor, cooling fans, and unloading solenoid (SOL3). It is located in the compressor compartment. The compressor PCB's primary function is to control the pressure of the air delivered to the ventilator when wall air is not present or is insufficient.

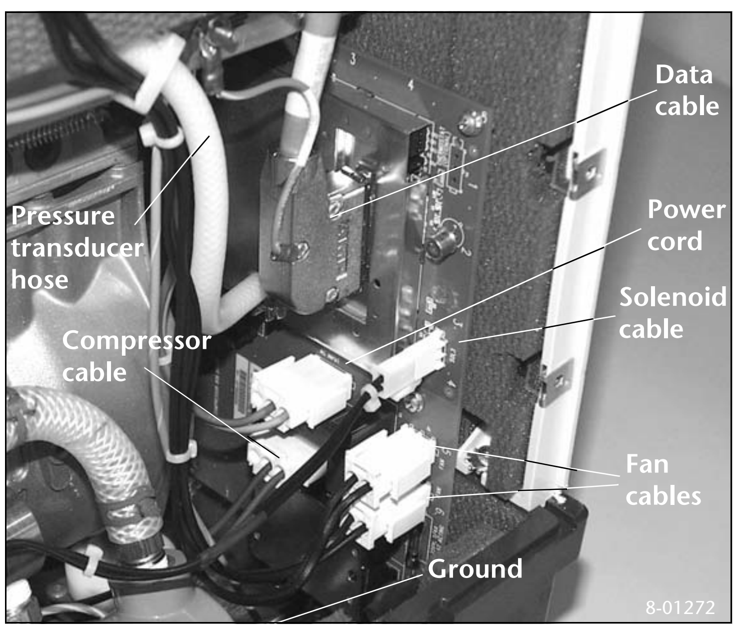


Figure 2-76. 806 compressor PCBA installed

The PCB includes these circuits, which perform the indicated functions:

- The ***flash memory circuits*** include a flash memory device, an elapsed time counter, and circuits to permit serial data transfer between the AI PCB and the compressor PCB. The counter monitors (in seconds) compressor motor operation. The counter value is periodically read by the ventilator, which then stores the total elapsed time (in hours) in compressor flash memory. During a power-on reset, the ventilator loads the current compressor flash memory value into the counter. The flash memory device also contains other compressor-specific information, including the compressor identification (ID).
- The ***motor start-up circuit*** includes a relay, timers, and logic that together orchestrate the motor start-up sequence. This sequence involves energizing SOL3, which vents compressor output, and then energizing the relay to apply power to the compressor. (Venting compressor output momentarily reduces the load on the compressor.)
- The ***compressor pressure transducer (PC) circuit*** monitors accumulator pressure via several comparators in the circuit. When a comparator detects an accumulator pressure equal to or greater than predefined trip points, it signals the compressor control logic.
- The ***compressor control logic*** controls the motor, fans, and SOL3. It also provides compressor status signals. Section 2.4.12.3 describes how this logic controls compressor component operation. This logic shuts off the compressor when ac is inadequate or the thermostat on the PCB detects overtemperature.

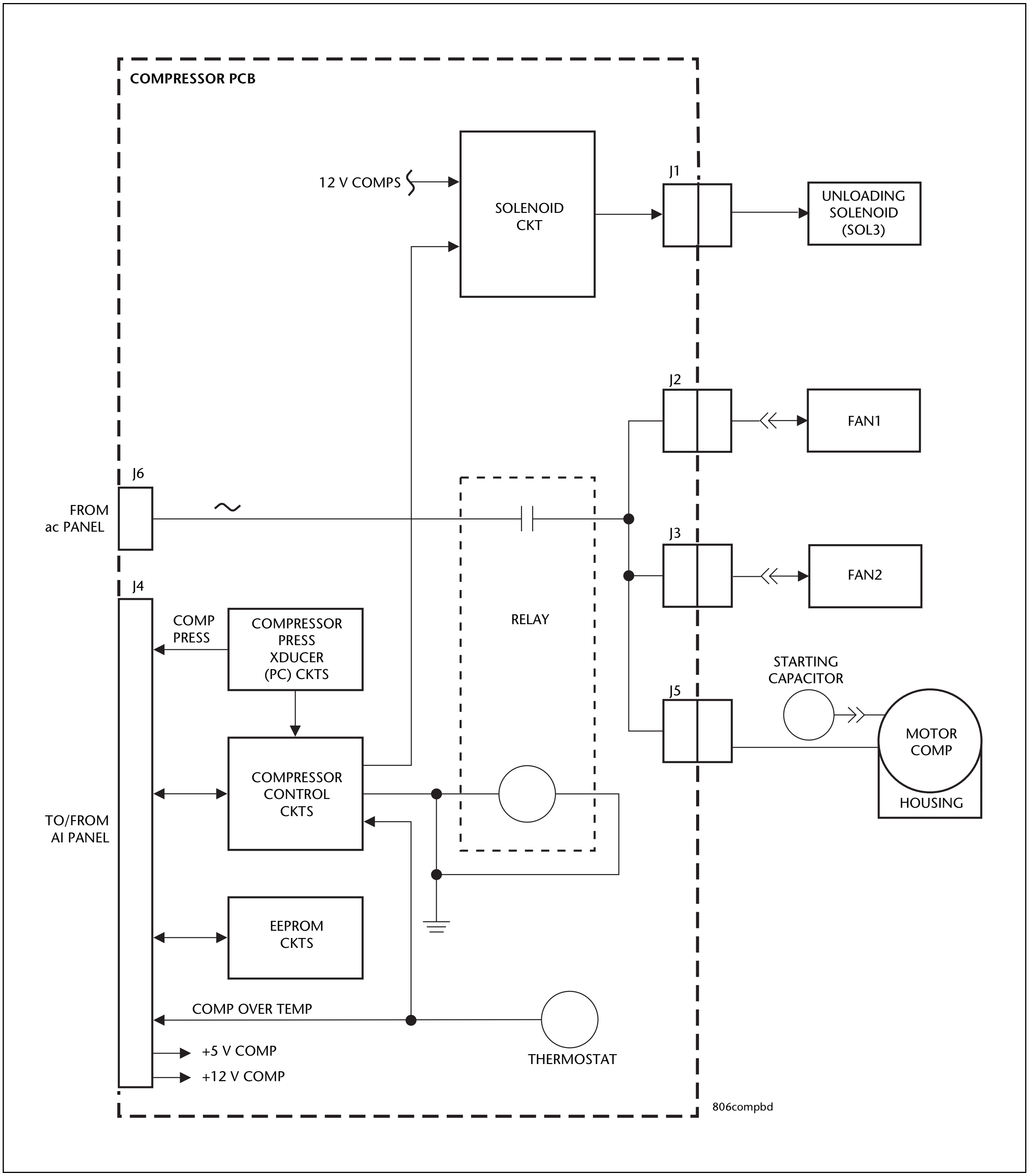


Figure 2-77. 806 compressor PCB block diagram

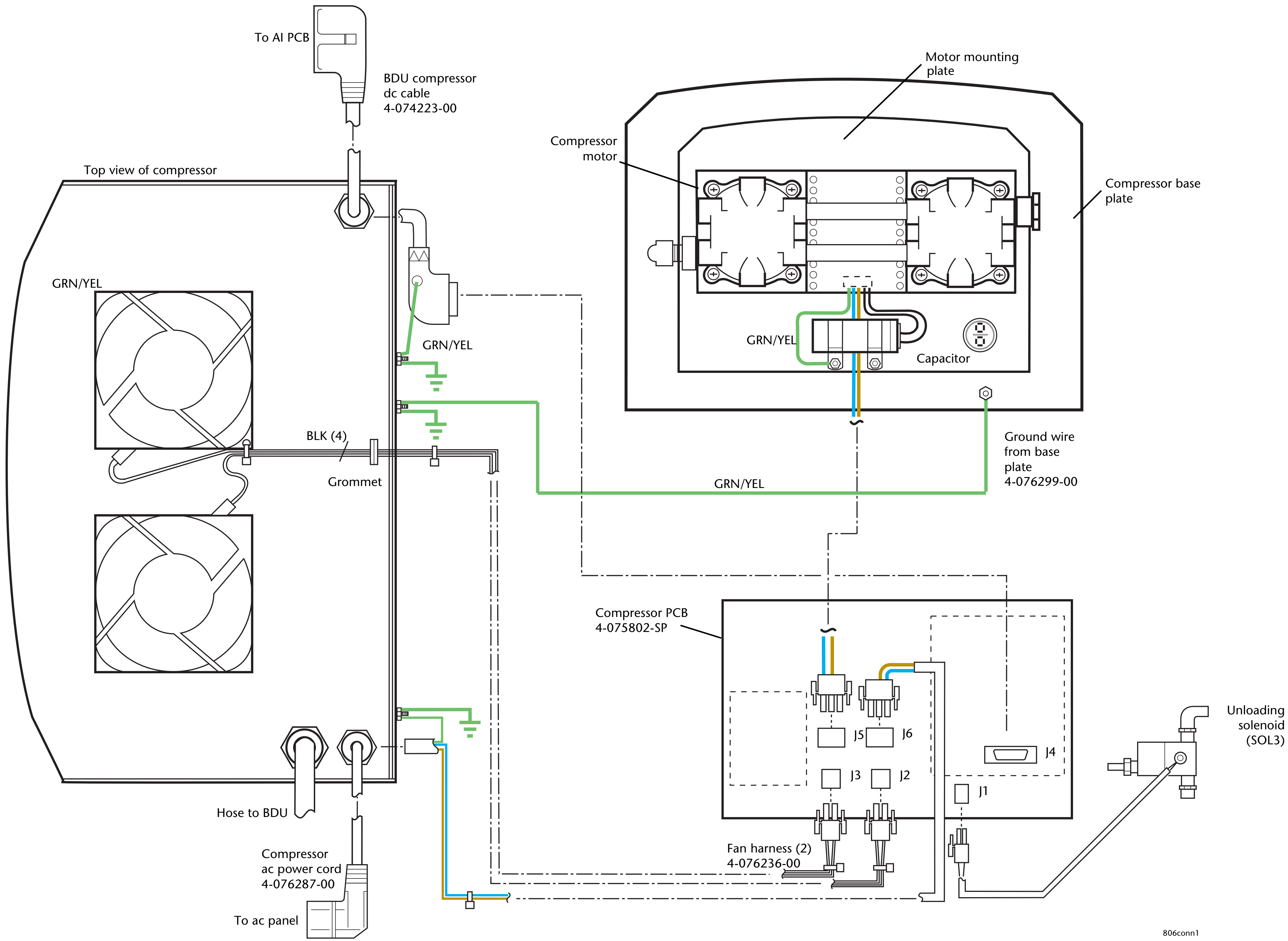


Figure 2-78. **840 Ventilator System interconnect diagram – Compressor unit**

2.4.12.3 806 Compressor unit operation

The 806 compressor operates in two modes: run and standby. A special start-up sequence ensures that the motor starts with an unloaded compressor head.

2.4.12.3.1 Run mode

When ac mains power is > 80% of nominal, the compressor is available for use if wall air is unavailable or the pressure is < 26 psig. In run mode, the compressor acts as the air source for the ventilator, continuously supplying air to meet the ventilator's full flow requirements (200 L/min peak flow, 2.5 L breath volume). When accumulator pressure reaches 27 psig, SOL3 is energized, venting excess flow to assist transporting water vapor out of the air dryer. The solenoid becomes de-energized when the pressure drops below 22.5 psig (see Figure 2-79). This cycle repeats as pressure rises and falls in the accumulator.

2.4.12.3.2 Standby mode

The compressor enters stand-by mode when there is sufficient wall air pressure to supply the ventilator. When the ventilator is powered up, it runs through POST and detects the presence of the compressor. The compressor turns on and pressurizes the accumulator. During this cycle, the green compressor ready indicator on the GUI illuminates when the accumulator pressure reaches at least 13 psig. When the accumulator pressure reaches 27 psig, the compressor turns off. If pressure in the accumulator drops below 22.5 psig (due to small leaks in the system or cooling of compressed air), the compressor starts and recharges the accumulator to 27 psig (see Figure 2-79).

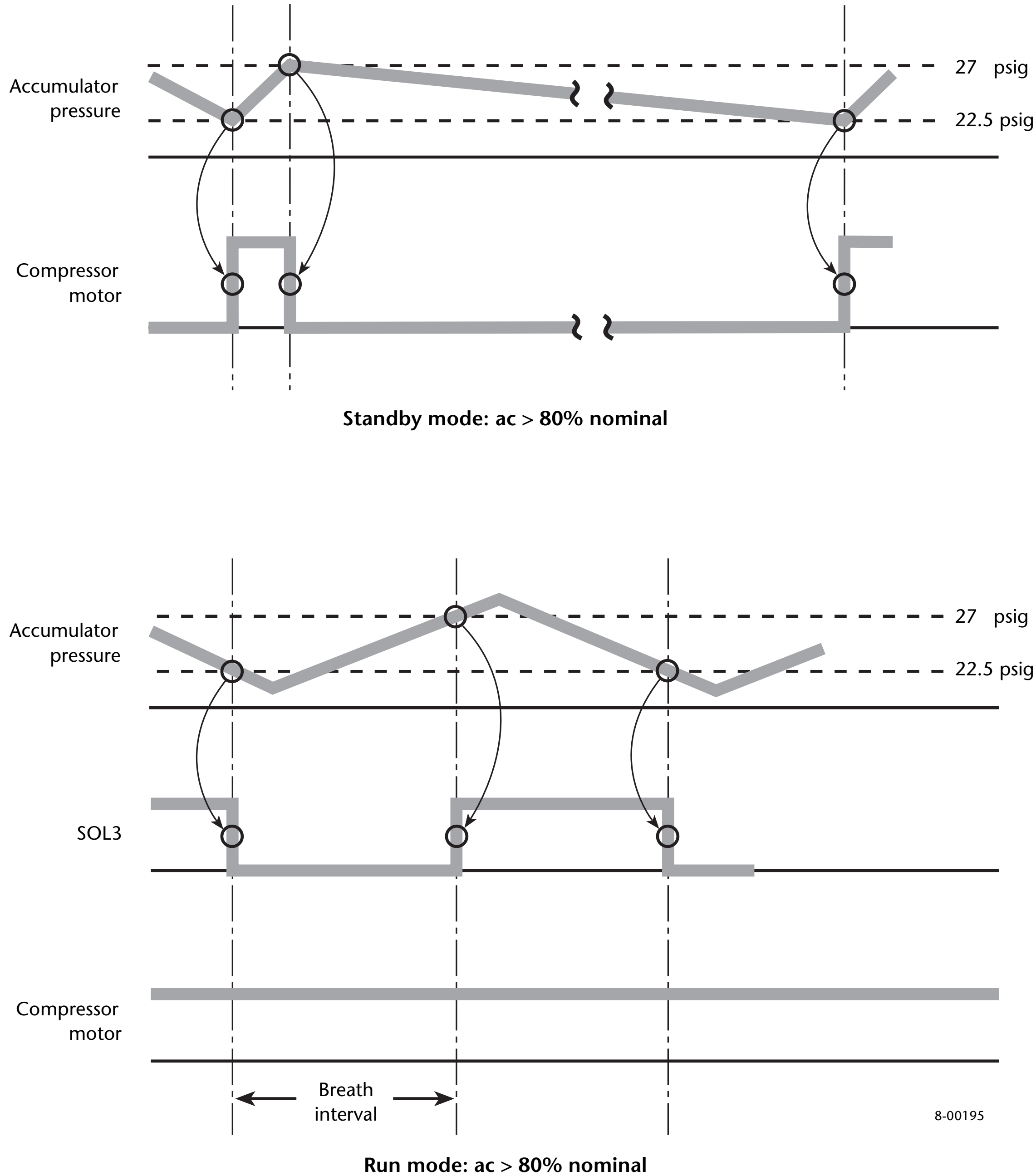


Figure 2-79. Compressor operational sequence

2.4.12.3.3 Compressor start-up

Any time the compressor motor is needed (run mode), a start-up sequence (Figure 2-79) ensures that the motor starts with an unloaded compressor head. Logic on the compressor PCB starts a timer and energizes unloading solenoid (SOL3). Energizing SOL3 relieves pressure on the compressor pump and, because of its orientation, prevents the accumulator from losing pressure during start-up. After 1 second, a solid-state relay on the PCB is energized. After another 0.5 seconds, SOL3 is de-energized.

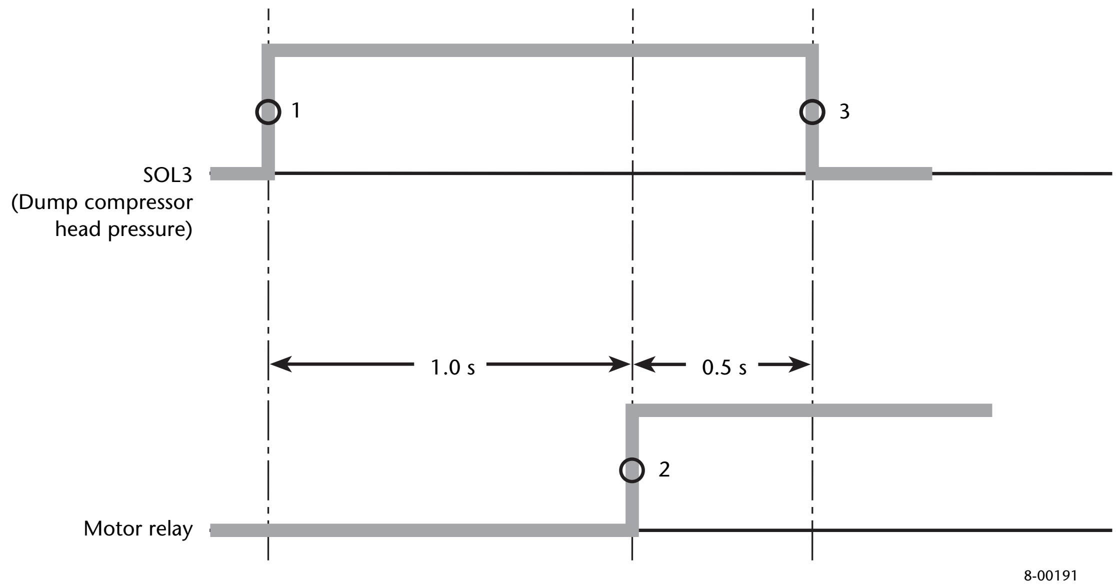


Figure 2-80. Compressor unit start-up sequence

2.5 Breath delivery

The ventilator delivers two types of breath: *mandatory* and *spontaneous*. A breath cycle includes *inspiration* and *exhalation* phases. The ventilator uses operator settings input through the GUI to determine breath type and parameters.

Consult the *840 Ventilator System Operator's and Technical Reference Manual* for a clinical perspective on breath delivery.

NOTE:

- Inspiratory and expiratory flows and tidal volumes in the ventilator are compliance-compensated and corrected to body temperature and pressure, saturated (BTPS).
- Exhaled volumes delivered/measured by the ventilator meet specified accuracies when conventional humidification, heated wire systems, and heat-moisture exchangers (HMEs) are used and SST is successfully completed.

2.5.1 Inspiration

During inspiration (Figure 2-81), the exhalation valve (EV) is energized closed and gas flows to the patient.

An inspiration is triggered when any of the following happens:

- The ventilator senses patient inspiratory effort (pressure or flow triggering).
- The ventilator's breath timing dictates.
- The operator presses the MANUAL INSP key.
- The ventilator's software otherwise dictates (such as apnea time-out).

NOTE:

The ventilator does not autocycle when pressure sensitivity is greater than 1 cmH2O or when flow sensitivity is greater than 1 L/min for pediatric patients or 1.5 L/min for adult patients.

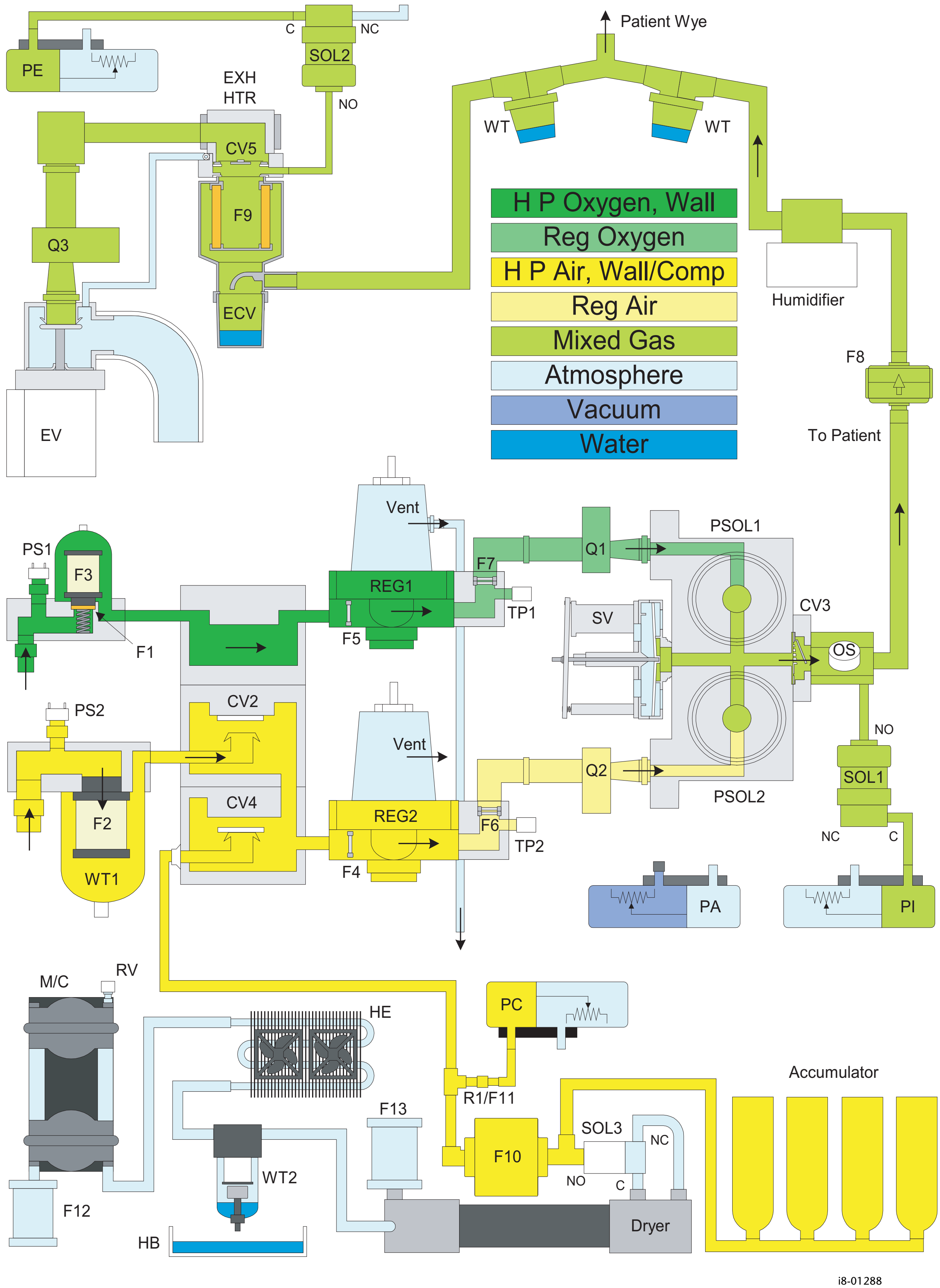


Figure 2-81. Inspiration gas flow diagram

2.5.1.1 Pressure triggering

As the patient draws gas from the patient circuit, the airway pressure drops below baseline. When airway pressure drops below baseline by at least the value selected for pressure sensitivity, the BD CPU initiates a patient-triggered inspiration.

2.5.1.2 Flow triggering

When flow triggering is selected, the BDU maintains a constant flow of gas through the patient circuit (called base flow) during the latter part of exhalation. (During exhalation, the base flow is 1.5 L/min greater than the operator-selected value for flow sensitivity.)

As the patient inspires from the base flow, the exhalation flow sensor (Q3) measures less exhaled flow, while delivered flow (monitored by inspiration flow sensors Q1 and Q2) remains constant. As the patient continues to inspire, the difference between the flows measured by the inspiration and exhalation flow sensors increases. When the flow inspired by the patient (that is, the difference between the measured flows) is equal to or greater than the operator-selected flow sensitivity value, the ventilator declares an inspiration. (If the patient is not inspiring, any difference between the delivered and exhaled flow is due to sensor inaccuracy or patient system leaks.)

2.5.1.3 Time-cycling method

In some cases, the ventilator's breath timing dictates when an inspiration is triggered. For example, when the ventilator is in the SIMV mode, a certain minimum respiratory rate may be guaranteed. To maintain the rate, in the absence of patient effort, the ventilator may have to deliver ventilator-initiated mandatory (VIM) breath. This is called time-cycled inspiration. If, however, the patient's inspiratory efforts reach the pressure or flow sensitivity setting before the breath cycle has elapsed, the ventilator delivers a PIM.

2.5.1.4 Operator triggering

The operator can trigger an operator-initiated mandatory (OIM) breath by pressing the MANUAL INSP key. The ventilator will not deliver an OIM during an ongoing inspiration, the restricted phase of exhalation, or while occlusion and disconnect alarms are active.

2.5.2 Exhalation

During patient exhalation (Figure 2-82), the exhalation valve (EV) opens (maintaining PEEP) and gas expelled from the patient is heated, filtered, and vented to the atmosphere.

The ventilator declares exhalation based on internal triggers or backup exhalation limits.

The ventilator software can trigger exhalation (internally triggered exhalation) using:

- The time-cycling method (monitoring elapsed time)
- The end-inspiratory flow method (monitoring end-inspiratory flow)
- The airway pressure method (monitoring airway pressure at the end of inspiration)

Backup limits (time, circuit pressure, and ventilator pressure) prevent inspirations of excessive duration or pressure. If a particular breath is subject to more than one backup limit, exhalation is triggered by whichever method goes into effect first.

2.5.2.1 Time-cycling method

During pressure- and volume-based mandatory breaths, the time-cycling method operates. This method uses a specified inspiratory time to terminate inspiration and transition to exhalation. The ventilator terminates inspiration based on the set or computed value for inspiratory time.

2.5.2.2 End-inspiratory flow method

During spontaneous breaths (with or without pressure support), the ventilator can use measurements of end-inspiratory flow to initiate exhalation. The ventilator monitors delivered flow throughout the inspiratory phase at flow sensors Q1 and Q2. Regardless of whether the patient begins to exhale, delivered flow decreases due to the decreasing pressure gradient in the patient wye measured at PE. When the flow is equal to or less than (peak flow x E_{SENS} %)/100, the ventilator initiates exhalation.

2.5.2.3 Airway pressure method

The ventilator can use airway pressure to initiate exhalation when spontaneous inspirations are delivered to a patient. The ventilator monitors airway pressure throughout the inspiratory phase at PE, and initiates a normal exhalation when the pressure equals the inspiratory pressure target value plus an incremental value of 1.5 cmH_2O, and 600 ms of the breath have elapsed.

2.5.2.4 Time limit

The time limit applies only to spontaneous breaths, which normally have no inspiratory time limit. If exhalation has not been triggered by the time (1.99 + 0.02 x IBW) seconds of inspiration have elapsed, the ventilator initiates exhalation.

2.5.2.5 High circuit pressure limit

The high circuit pressure limit applies to all breaths. If the airway pressure (measured at PE) equals or exceeds the operator-selected high circuit pressure limit during any inspiration, the ventilator terminates the inspiration and initiates exhalation.

2.5.2.6 High ventilator pressure limit

The high ventilator pressure limit applies to volume-based mandatory breaths only. If the inspiratory pressure (measured at PI) equals or exceeds 100 cmH_2O, the ventilator transitions to exhalation.

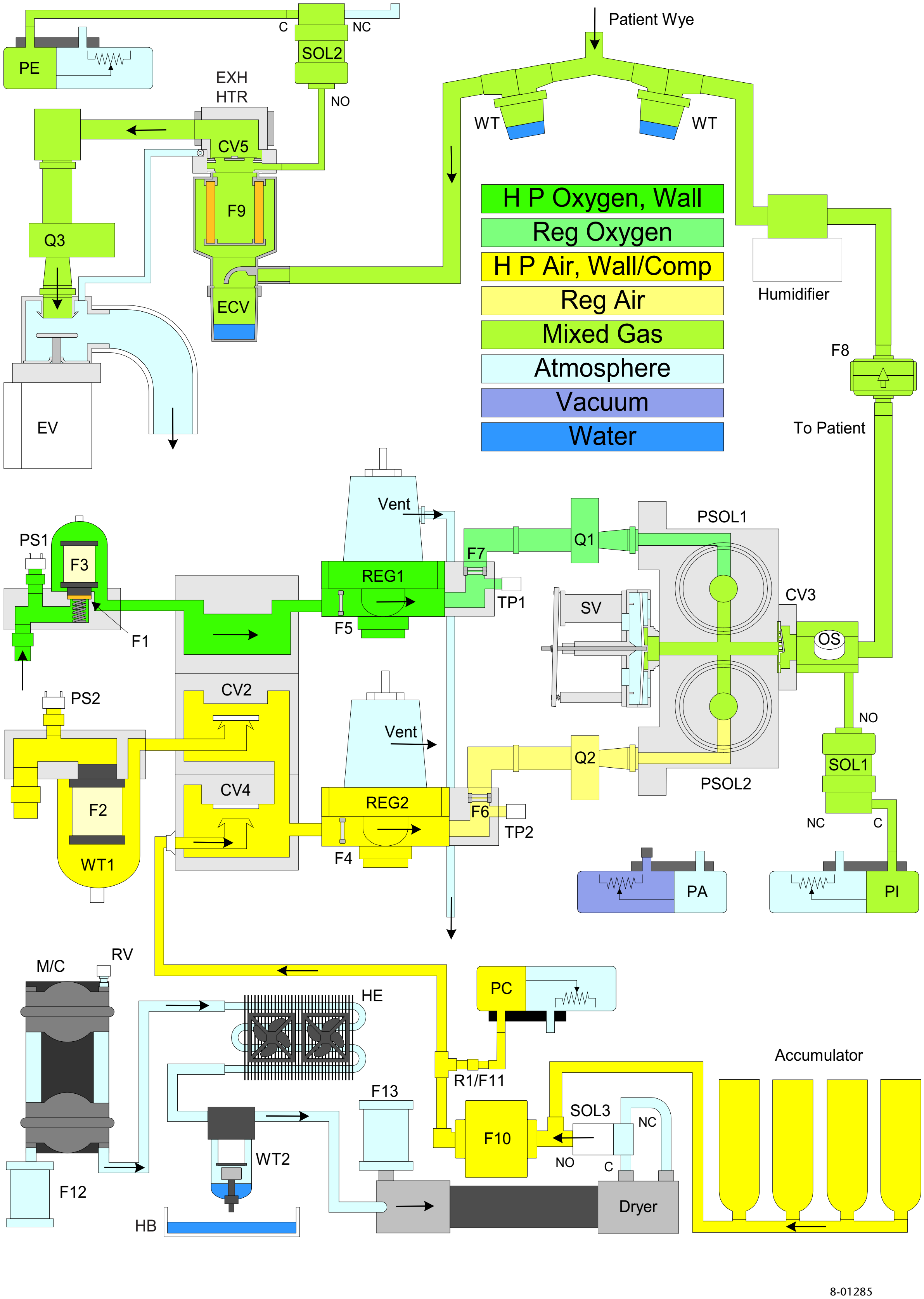


Figure 2-82. Exhalation gas flow diagram

2.6 Other hardware operations

2.6.1 Gas supply and control

To deliver its air/oxygen mixture, the ventilator needs high-pressure oxygen and air from external sources. Oxygen comes from a bottled or wall source. Air comes from an optional compressor unit or a bottled or wall source.

The BD CPU monitors gas source availability through oxygen and air pressure switches PS1 and PS2 and the compressor pressure transducer (PC). If a compressor is present, the ventilator uses it as either the backup or primary air source, based on state of PS2. If the wall air source is restricted, it is supplemented or replaced by the compressor unit without the ventilator alarming. If either oxygen or air is totally lost, however, the ventilator alarms, although ventilation continues on a single gas. If both gas sources are totally lost, the ventilator enters the SVO state.

2.6.2 Data monitoring

Breaths are delivered based on operator-selected ventilator settings and ventilator-monitored parameters. Many of these monitored parameters are displayed by the upper screen during ventilation. These parameters and their sources are listed in Table 2-4.

Table 2-4: Monitored data

Parameter	Meaning	Source	Range
Breath type	Indicates the type and phase of the breath being delivered.		Type: Control, assist, or spontaneous Phase: Inspiration or exhalation
Delivered O_2% (O_2%)	Percentage of oxygen in the gas delivered to the patient. The high and low O_2% alarms are set internally and are based on the set O_2% value.	Oxygen sensor (OS)	0 to 103%
End expiratory pressure ($P_{E\ END}$)	Pressure at end of previous breath's expiratory phase. Reflects level of any active lung PEEP.	Based on expiratory and inspiratory pressure transducer (PE and PI) readings	-20.0 to 100 cmH_2O
End inspiratory pressure ($P_{I\ END}$)	Pressure at end of current breath's inspiratory phase. If plateau is active, it reflects level of end-plateau pressure.	Based on expiratory and inspiratory pressure transducer (PE and PI) readings	-20.0 to 130 cmH_2O
Exhaled minute volume ($\dot{V}_{E\ TOT}$)	Calculated total of exhaled volumes for mandatory and spontaneous breaths for previous 1-minute interval. It is compliance- and BTPS-compensated.	Net flow, based on exhalation (Q3), oxygen (Q1), and air (Q2) flow sensor readings	0.00 to 99.9 L
Exhaled tidal volume (V_{TE})	Exhaled volume for previous mandatory or spontaneous breath. It is compliance- and BTPS-compensated. **NOTE:** A significant change to the O_2% setting can cause the V_{TE} (exhaled tidal volume) to be transiently displayed as lower or higher than the actual exhaled volume. This is a result of initial spirometry calculations and does not reflect actual volume exhaled by the patient.	Net flow, based on exhalation (Q3), oxygen (Q1), and air (Q2) flow sensor readings	0 to 6000 mL

Table 2-4: Monitored data (continued)

Parameter	Meaning	Source	Range
I:E ratio	Ratio of inspiratory time to expiratory time for the previous breath, regardless of type. Due to limitations in setting the I:E ratio in pressure control ventilation, the monitored data display and the setting may not match precisely.		≥ 1:599 and ≤ 9.99:1
Mean airway pressure (P_{MEAN})	Average airway pressure over entire breath cycle of previous breath, regardless of type.	Based on expiratory and inspiratory pressure transducer (PE and PI) readings	-20.0 to 120 cmH_2O
Maximum circuit pressure (P_{PEAK})	Indicates the maximum pressure during the previous breath, relative to the patient wye, including the inspiratory and expiratory phases. Updated at the beginning of the next inspiration.	Based on expiratory and inspiratory pressure transducer (PE and PI) readings	-20.0 to 130 cmH_2O
Spontaneous minute volume ($V_{E\ SPONT}$)	Displays a calculated total of the volumes exhaled by the patient for spontaneous breaths for the previous 1-minute interval. Values for mandatory breaths during this period are not included. The displayed value is compliance- and BTPS-compensated. Updated at the beginning of the next inspiration.	Net flow, based on exhalation (Q3), oxygen (Q1), and air (Q2) flow sensor readings	0.00 to 99.9 L
Total respiratory rate (f_{TOT})	Displays a calculated value of the number of mandatory and spontaneous breaths delivered to the patient for the previous 1-minute interval. Updated at the beginning of the next inspiration.		0 to 200 breaths/min

2.6.3 Pressure transducer autozero

The inspiratory pressure transducer (PI) is zeroed by autozero solenoid SOL1. The expiratory pressure transducer (PE) is zeroed by autozero solenoid SOL2. The two autozero transducers are zeroed during two consecutive breaths. The voltage corresponding to the zero pressure differential is recorded in DRAM. The recorded voltage is used as an offset for transducers. Figure 2-83 depicts the autozero sequence.

Autozeroing is performed at the beginning of exhalation. PI and PE require autozeroing less often as the ventilator warms up. Autozeroing is performed every minute for 20 minutes; every 2 minutes after 20 minutes, up to one hour; and every 5 minutes after 1 hour.

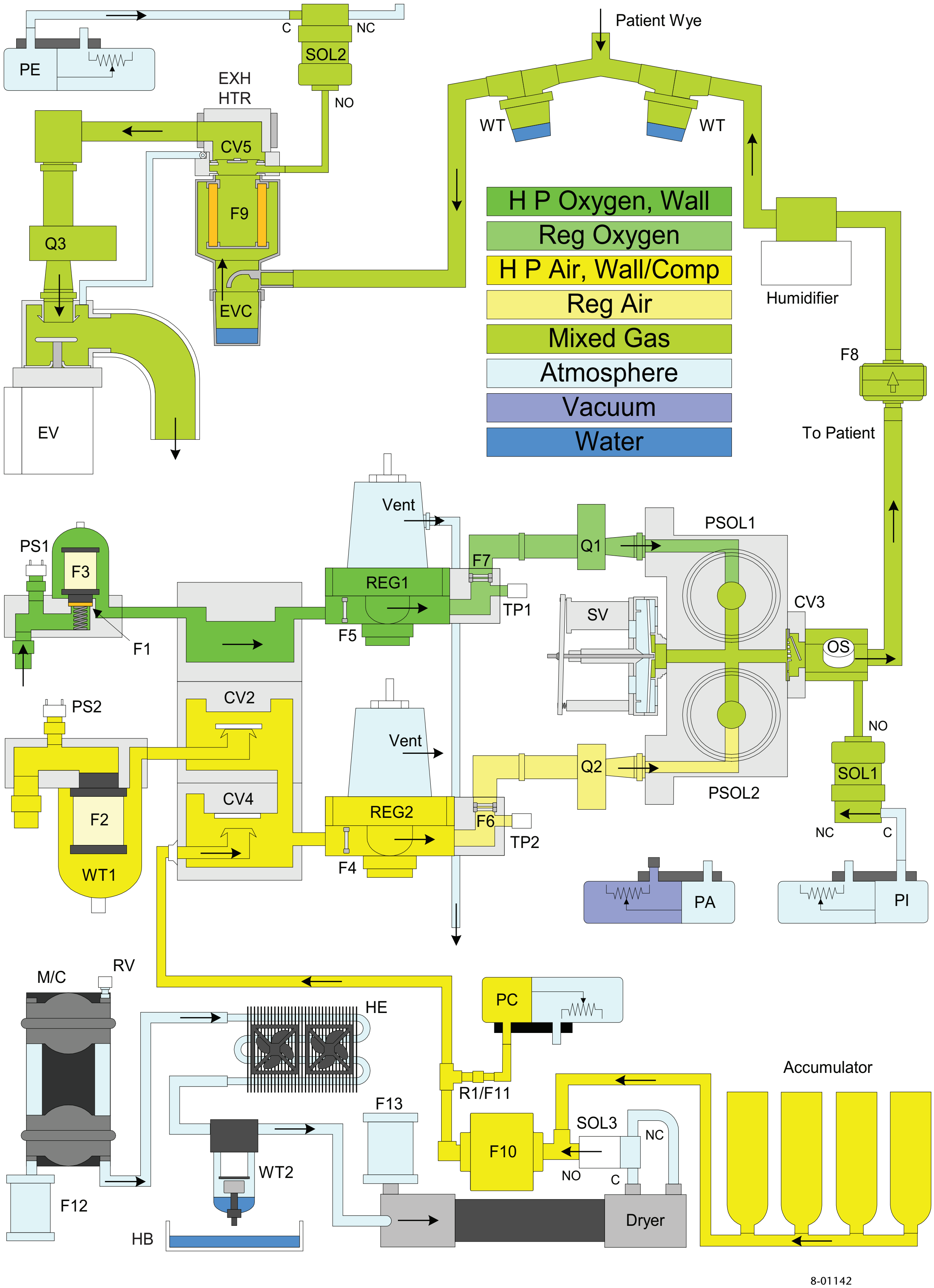


Figure 2-83. Pressure transducer autozero mode gas flow diagram

2.6.4 Power monitoring and power fail handling

2.6.4.1 Loss of power source

Power to the dc/dc converter in the power supply is either derived from facility ac power or it is dc from the BPS. If ac power is available and adequate, the power supply converts it to +31.5 V nominal and outputs it from a bulk supply. If the bulk supply's output is insufficient (< +31.5 V, equivalent to < 80 V ac), however, the dc/dc converter uses the or BPS power (+19 to +30 V).

ac power loss and BPS switchover (Figure 2-84). An ac monitor generates a voltage scaled to the ac input voltage. It feeds this ac monitor voltage to the AI PCB for reading by the software. When this ac monitor voltage falls so that the ventilator can no longer support the compressor, the software disables the compressor and signals from the power supply and BPS PCB turn on the appropriate BPS battery switch. The software continually samples the BPS status lines, and when it determines that the BPS is powering the ventilator, the ventilator immediately annunciates a low-urgency alarm. The GUI displays the alarm messages "ac POWER LOSS" and "Operating on battery." (A new, fully charged BPS can power the ventilator (BDU), excluding the compressor and humidifier, for at least for at least 30 minutes.) When the ventilator estimates that 2 minutes of battery power remain, the alarm level escalates to medium urgency, and the ventilator changes the message "Operating on battery" to "Operational time < 2 minutes."

Total loss of power. When the BPS discharges to a point where the BDU is no longer operational (< +19.30 V), a power fail circuit in the power supply detects the loss of the bulk supply (the input to the power supply's main converter) and notifies the BD CPU PCB. The BD CPU PCB in turn generates a nonmaskable interrupt (NMI). The software triggers a continuous-tone high-urgency alarm. The capacitor-driven BD alarm is sounded. Although the BDU is nonfunctional at this point of power loss, there is enough power for the GUI to continue to display text and, with the LED array, the current alarm state.

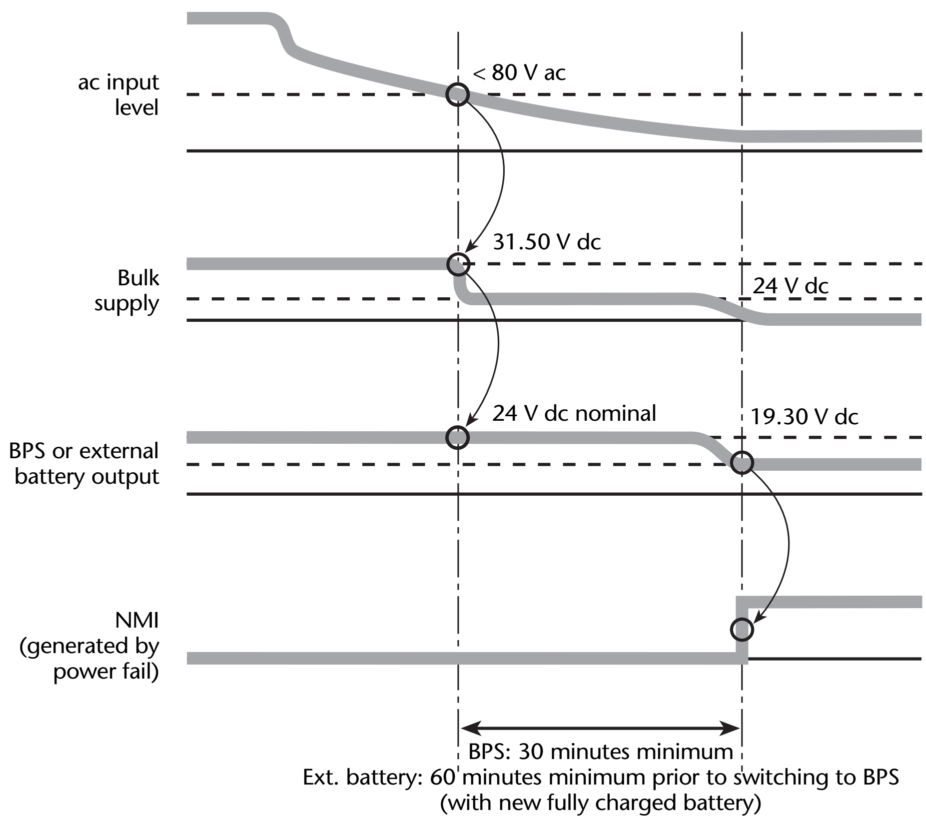


Figure 2-84. Power loss sequence

2.6.4.2 Supply voltage monitoring

The ventilator checks for and responds to out-of-tolerance supply voltages, as follows:

Table 2-5: Out-of-tolerance supply voltages

Voltage	Source	Where monitored	Notes
BD +5 V	Power supply	AI PCB	• A hardware circuit checks for a low voltage. If voltage is low, it (1) issues a global reset and (2) sounds the BD alarm (capacitor-driven). The global reset results in a ventilator inoperative condition being declared. A relay, which is part of the sentry circuit, ensures that a power fail reset occurs during voltage transients. • Converted into a scaled voltage for reading by software during background and other checks.
GUI +5 V		AI PCB	Converted into a scaled voltage for reading by software during background and other checks.
		GUI CPU PCB	If voltage is low, this circuit issues a PCB reset. If voltage is high, an NMI is generated.
BD +12 V		AI PCB	Converted into a scaled voltage for reading by software during background and other checks.
GUI +12 V		AI PCB	Converted into a scaled voltage for reading by software during background and other checks.
		GUI CPU PCB	If voltage is low or high, an NMI is generated.
+15 V		AI PCB	Converted into a scaled voltage for reading by software during background and other checks.
-15 V		AI PCB	Converted into a scaled voltage for reading by software during background and other checks.
+10 V reference	AI PCB	AI PCB	Converted into a scaled voltage for reading by software during background and other checks.

2.7 Emergency modes of operation

This subsection describes how the ventilator operates under unexpected conditions.

2.7.1 Safety valve open (SVO) state

The safety valve has two important functions. First, if outlet pressure exceeds the maximum operating pressure of the patient circuit, the safety valve passively relieves the excess pressure. The actual relief pressure varies depending on the patient flow rate. Second, if the control system detects a catastrophic failure, the safety valve is opened and the patient can freely breathe room air.

When the ventilator is in the SVO state (Figure 2-85), a patient can spontaneously breathe room air and exhale. Check valves in the inspiratory and exhalation modules (CV3 and CV5) minimize rebreathing exhaled gas during SVO. When the safety valve is commanded during SVO, the ventilator:

- Displays the elapsed time since the loss of ventilatory support on the GUI
- Does *not* display patient data, including waveforms, on the GUI
- Does *not* detect patient circuit occlusion or disconnect conditions

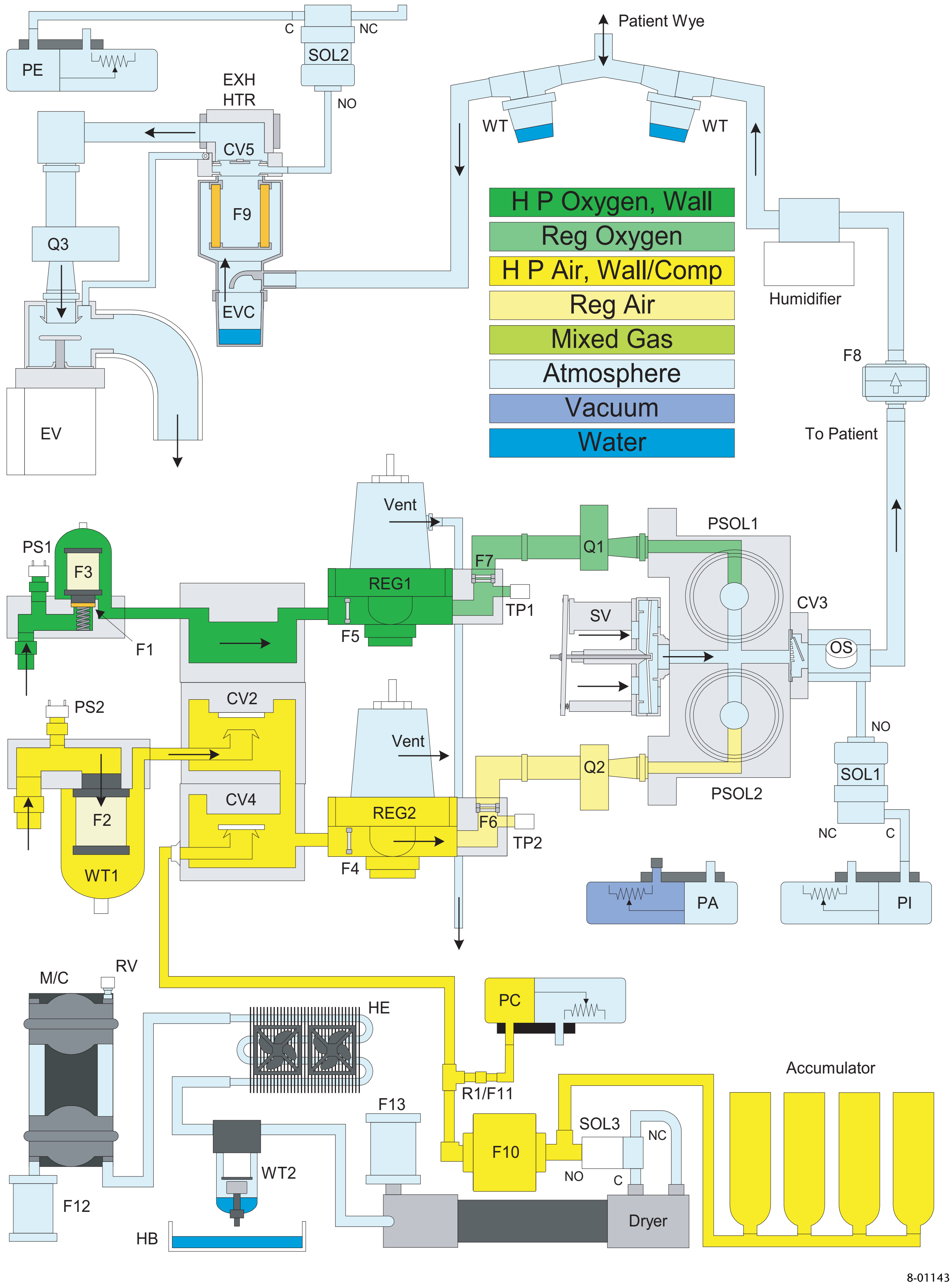


Figure 2-85. Safety valve open diagram

2.7.2 Occlusion handling

The ventilator detects severe patient circuit occlusions to protect the patient against excessive airway pressures over extended periods of time. The ventilator is also designed to detect patient circuit disconnects, because they can cause the patient to receive little or no gas from the ventilator, and require immediate clinical attention. Figure 2-86 depicts the ventilator pneumatics during occlusion handling.

2.7.2.1 When the ventilator declares an occlusion

The ventilator declares a severe occlusion if all these are true:

- The inspiratory or expiratory tube is completely occluded.
- The ventilator EXHAUST port or device attached to it is fully blocked.
- The exhalation valve fails in the closed position (occlusion detection at the FROM PATIENT port begins after 195 ms of exhalation have passed).

The ventilator does *not* declare a severe occlusion if any of these are true:

- The pressure difference between the inspiratory limb and the expiratory limb is less than or equal to 5 cmH_2O.
- Water in a lazy loop of the patient tubing (inspiratory or expiratory) does not completely occlude the lumen.
- The exhalation valve fails in the closed position and the pressure in the exhalation limb is less than 2 cmH_2O.
- A Wright spirometer or 6 ft of silicone tubing is attached to the EXHAUST port of the ventilator.

2.7.2.2 Occlusion detection and handling

The ventilator checks the patient circuit for occlusions during all modes of breathing (except idle mode, safety valve open and during pressure transducer autozeroing) at every breath delivery cycle. Once the circuit check begins, the ventilator detects a severe occlusion of the patient circuit within 200 ms.

The ventilator checks the EXHAUST port for occlusions during the expiratory phase of every breath (except while the ventilator is in disconnect ventilation, in the SVO condition, during an inspiratory/expiratory pause, or during pressure transducer autozeroing). Once the EXHAUST port check begins, the ventilator detects a severe occlusion within 100 ms.

Once a severe occlusion is detected, the ventilator annunciates an occlusion alarm. It terminates normal ventilation and acts to minimize airway pressure by entering the safety valve open state (PSOLs and exhalation valve de-energized and safety valve open) for 15 seconds or until inspiratory pressure drops to 5 cmH_2O or less, whichever comes first. The ventilator initiates occlusion status cycling (OSC).

While the ventilator is in OSC, it periodically attempts to deliver a pressure-based breath while monitoring the inspiration and expiration phases for the existence of a severe occlusion.

If the condition that caused a severe occlusion is corrected, the ventilator declares the occlusion corrected after two complete breath cycles with no occlusion detected. The ventilator resets the occlusion alarm and reinstates breath delivery according to current settings.

NOTE:

During a severe occlusion, apnea detection, expiratory pause, manual inspirations, and maneuvers are suspended, and the $\uparrow P_{MEAN}$ (high airway pressure) alarm limit is disabled. The GUI does allow you to change ventilator settings.

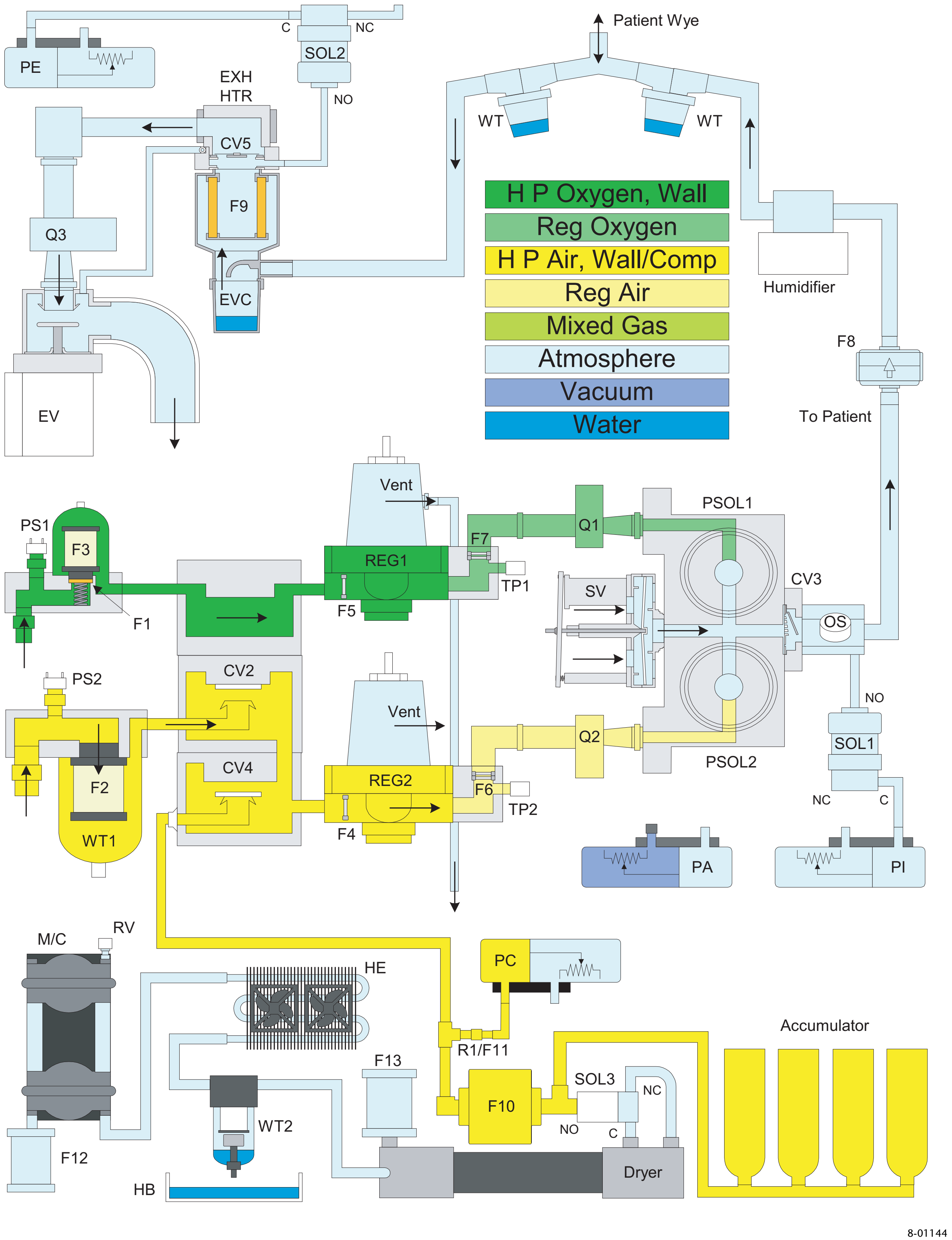


Figure 2-86. Pressure release, patient circuit occluded diagram

SECTION 3

Self tests

3.1 Introduction

This section describes the *840* Ventilator System built-in self tests, including how to run them. For a listing of ventilator diagnostic codes and messages generated during these self tests, refer to Section 6.

3.2 How to enter Service Mode

In order to access the Extended Self Test (EST) and other service functions, you must first bring the ventilator up in Service Mode, as follows:

Enter service mode and initiate EST as follows:

1. Turn on power to ventilator. (If power is already on, turn it off, then back on.)
2. While BDU ventilator inoperative indicator is lit and alarm briefly ceases, press TEST button within one second. (The TEST button is located on the right side panel.)

   The ventilator automatically enters the service mode. *Do not continue to depress or cycle the TEST button while entering service mode.*

3.3 Self tests and background checks

The *840* Ventilator has self test capabilities that include POST (power-on self test), SST (short self test), EST (extended self test), and background checks. These self test operations are described in Table 3-1, and Table 3-2 details the components tested by various self tests.

3.3.1 POST

POST tests the integrity of the ventilator's electronics without operator intervention. It is executed when the ventilator is powered up, before it enters service mode, or if the ventilator detects selected fault conditions. Breath delivery cannot start until the ventilator completes POST with no major errors.

3.3.2 SST

The SST is a short (about 3 minutes) and simple sequence of tests that verifies proper operation of breath delivery hardware (including pressure and flow sensors), checks the patient circuit (including tubing, humidification device, and filters) for leaks, and measures the circuit compliance and resistance. SST also checks the exhalation filter resistance. SST is a user-initiated check primarily intended for use by the operator. The ventilator does not begin SST if it senses that a patient is connected.

3.3.3 EST

EST is a user-initiated self test, intended to be run by the service technician, that verifies the integrity of the ventilator's subsystems using operator participation. EST checks the pneumatics, memory, safety system, front panel controls, indicators, digital and analog electronics, power supplies, transducers and options. EST requires a "gold standard" test circuit, available from Puritan-Bennett. All required software support to perform an EST is resident on the ventilator. EST testing, excluding tests of optional equipment, such as the compressor, takes about 15 minutes to complete.

3.3.4 Background checks

Background checks are continually performed during ventilation. When an error is detected during a background check, the ventilator annunciates a DEVICE ALERT alarm. As it does for any alarm, the ventilator displays a message, invokes audio and visual alarms, and logs the error information.

The System Diagnostic Log shows the code that triggered the DEVICE ALERT. The alarm log also indicates that there was a DEVICE ALERT. Ventilation may or may not be affected, depending on the severity of the condition. Some device alerts are automatically reset if the triggering condition disappears. In general, device alerts are caused by analog device problems.

3.3.5 When self tests are run

Several self tests may check the same component; however, these checks may not be equivalent. For example, while POST might perform a voltage check of a component, EST might perform a system-level test of the same component.

Table 3-1 describes the purpose of each self test and when each is run.

Table 3-1: Self tests

Name	Purpose	When it is run
POST (long)	Verifies the integrity of the ventilator electronics, including compressor, if applicable. After long POST, the ventilator requests new patient settings. Long POST lasts under 10 seconds.	Automatically • after the user cycles power • when power is restored from an inadvertent power-down, if power has been off for 5 minutes or more[1] • before the ventilator enters service mode • after an intentional ventilator reset (for example, after certain fault conditions are detected, after SST or EST is run)
POST (short)	Verifies the integrity of the ventilator electronics. It does not include a full test of the BDU, nor a test of the compressor. Short POST lasts under 5 seconds.	Automatically • after an unintentional ventilator reset • when power is restored after a short interruption (< 5 min.)[1]
SST	A short sequence of tests intended to be run primarily by the operator. Checks pneumatics and electronics. SST also characterizes system leaks and system/tubing compliance to compensate during breath delivery. POST is run as part of SST, both at the start and end.	• Before patient is connected to ventilator • After patient circuit or humidifier is changed • When ventilator is serviced • Every 15 days

1. POST will run only if there is no BPS installed, or if the BPS battery is discharged. Otherwise, during a temporary loss of ac power, the vent will automatically switch to BPS power, and POST will not run.

Table 3-1: Self tests (continued)

Name	Purpose	When it is run
EST	Tests operational integrity of ventilator, both electronics and pneumatics. POST is run as part of EST, both at the start and end. **NOTE:** • SST is not run as part of EST. To determine patient circuit resistance and compliance, run SST. • The performance verification, described in Section 5 of this manual, is a more thorough test of the ventilator to verify specifications are met.	• When ventilator is serviced • As part of ventilator performance verification (every six months)
Ongoing background checks	Includes these checks: memory, power supply, dc voltages, pressure transducers, analog input validity, and more. These checks do not disrupt normal operation.	Automatically, continually during ventilation

3.4 Power on self test (POST)

Table 3-2: Components tested by self tests

Component tested	Background checks	POST	SST	EST	Service mode calibrations
Power supply/voltage checks					
ac monitor voltage		X			
Supply voltages (including BDU and GUI voltages)	X	X			
BPS supply voltage/current	X	X		X	
BPS charging and discharging	X			X	
BPS model	X	X			

Table 3-2: Components tested by self tests (continued)

Component tested	Background checks	POST	SST	EST	Service mode calibrations
Patient system					
Patient circuit leak			X		
Patient circuit occlusions/resistance			X		
Patient circuit compliance			X		
Expiratory filter occlusion/resistance			X		
Pneumatics					
System leak				X	
Oxygen and air pressure switches	X			X	
Oxygen and air flow and temperature sensors	X	X	X	X	
Oxygen and air/exhalation flow sensor cross-check			X	X	
Inspiratory check valve operation				X	
Oxygen and air PSOL current	X	X	X	X	
Oxygen and air PSOL forward leak		X	X	X	
Oxygen and air PSOLs stuck open or stuck in other position	X	X	X	X	
Inspiration and exhalation pressure transducer autozero solenoids	X		X	X	
Inspiration pressure transducer	X	X	X	X	
Exhalation pressure transducer	X	X	X	X	
Inspiration and exhalation pressure transducer cross-check			X	X	

Table 3-2: Components tested by self tests (continued)

Component tested	Background checks	POST	SST	EST	Service mode calibrations
Pneumatics (continued)					
Oxygen sensor reading	X	X			
Safety valve operation				X	
Safety valve current	X	X		X	
Safety valve opening/closing	X			X	
Safety valve peak and cracking pressure				X	
Exhalation valve motor current	X	X		X	
Exhalation valve coil temperature	X	X		X	
Exhalation valve operation	X			X	X
Expiratory valve seal and poppet				X	
Expiratory valve velocity transducer				X	
Expiratory valve calibration check				X	
Exhalation manifold heater	X	X		X	
Exhalation flow sensor and temperature sensors	X	X		X	
Compressor subsystem, including timer, pressure switch, operating states, and leak. Pressure test for worst-case delivery.	X			X	
Atmospheric pressure transducer	X	X			X
Electronics					
CPU kernel electronics (processor, memory, time-of-day clock, timers and counters)	X partially	X			
Audio alarm and user interface sound-producing subsystem	X	X		X	
Alarm cable (BDU)	X	X		X	
Nurse's call relay				X	
+10 V reference (used by ADCs and DACs)	X	X		X	
ADC/DAC functionality	X	X			
Power fail capacitor	X	X		X	

Table 3-2: Components tested by self tests (continued)

Component tested	Background checks	POST	SST	EST	Service mode calibrations
Electronics (continued)					
Keyboard	X partially			X	
Knob				X	
GUI and BDU LEDs (operator test)		X		X	
GUI and BDU audio (operator test)		X		X	
GUI touch screen	X			X	
Ethernet controller	X	X			
GUI serial port				X	
Safety system					
Ventilator inoperative signal and safe-state verification	X	X		X	X

NOTE:
A fault identified in POST indicates that the ventilator or an associated component is defective. A defective ventilator or associated component should be repaired before the ventilator is returned to service, unless it can be determined with certainty that the defect cannot create a hazard for the patient, or add to the risks which may arise from other hazards.

There are two versions of POST: long POST, which is run when the user cycles power, and short POST, which is run following an unintended hardware reset.

NOTE:
The graphic user interface (GUI) indicates a POST is in progress but does not indicate a long or short POST.

The graphic user interface (GUI) and the breath delivery unit (BDU) subsystems each has its own POST that tests the major hardware electronics systems. POST does not check the ventilator's pneumatics, options, or accessories that are not directly related to ventilation. POST is designed to detect major problems before proceeding to normal ventilation, and to provide a confidence check before a patient is connected to the ventilator.

POST routines are ordered so that each routine requires successively more operational hardware than the last. This sequence allows POST to systematically exclude electronic components as causes of system malfunctions.

3.4.1 Safety

The ventilator does not provide ventilatory support to the patient during POST. The ventilator alarms if POST lasts longer than 10 seconds or if an unexpected fault is detected. POST is designed to minimize the delay until normal ventilation begins and to provide immediate notification in case a fault is detected.

During POST the ventilator proportional solenoid valves (PSOLs) are closed and the exhalation valve and safety valve are open to allow the patient to breathe room air, and the ventilator displays a message that POST is in progress.

Once POST is complete, ventilator startup (following power-up) or normal ventilation begins, unless service mode is requested or the ventilator detects any of the following:

- An uncorrected major system fault.
- An uncorrected major POST fault.
- An uncorrected short self test (SST) failure or non-overridden SST alert.
- An uncorrected extended self test (EST) failure or non-overridden EST alert.
- The ventilator is turned on for the first time following a software download, but has not yet successfully completed one of the following: exhalation valve calibration, flow sensor calibration, atmospheric pressure transducer calibration, SST, or EST.
- An uncompleted system initialization.

NOTE:

When a compressor is installed and wall air is not present, there may be a short interval following a successful POST before the compressor achieves operational pressures. If so, the ventilator annunciates a NO AIR SUPPLY alarm, which resets as soon as the compressor charges the system to operational pressure.

3.4.2 POST characteristics

POST runs automatically when you cycle power to the ventilator. If possible, the ventilator displays the revision of the installed software in the Vent Configuration screen. Each processor in the ventilator runs its own POST. Upon completion, each processor reports its test results to the GUI processor. POST starts with the software kernel, then tests the hardware that directly interfaces to the kernel. POST then tests the rest of the hardware. Hardware that is linked to each processor through a communication channel is checked once the communication link is verified.

The main characteristics of POST are:

- The kernel of every subsystem is designed to include the smallest number of components possible, and each kernel can run independently of the rest of the system.
- POST verifies system integrity by checking that all main electrical connectors are correctly attached and that interfaces to all electronic subsystems (such as the keyboard or audible alarm) are functional. POST performs all electrical hardware checks that do not require operator intervention.
- POST checks safety hardware, such as the watchdog circuitry and bus time-out monitoring circuitry.
- POST’s memory test preserves all data necessary to determine ventilator settings and initializes the remaining memory to a predefined state.
- Any other processors in the system initiates its own POST and reports the test results to the host processor.

To ensure that there is an alarm if the central processing unit (CPU) fails, audio, visual, and remote alarms are normally on, and turn off once system initialization (that is, the process that occurs between POST completion and the start of ventilation) is completed and communication is established.

An alarm turns on if POST lasts more than 10 seconds or if POST restarts three times without completion. The 10-second timer is a redundant check in case POST fails to alarm upon detecting a fault. The check for three restarts can detect a continuous loop, and prevents POST from running for more than 10 seconds.

3.4.3 POST following power interruptions

If there is no BPS installed or the BPS battery is discharged, POST is invoked under the following conditions:

- The ventilator executes long POST following a power interruption of 5 minutes or more while the power switch is on. The ventilator runs a full POST after a long power interruption under the assumption that the patient would have been disconnected and ventilated by other means, and because circumstances that cause a lengthy power loss warrant a full POST.
- The ventilator runs a short POST (which tests the BDU only) if power is interrupted for less than 5 minutes. After a short power interruption (during which the status of the patient cannot be assumed), the ventilator resumes normal ventilation as soon as possible, in case the patient remains connected. Running a short POST (3 seconds or less from return of ac power to beginning breath delivery) allows for short power interruptions due to common events (for example, switching to generator power) that do not require a normal POST, and assumes that a patient may still be connected to the ventilator. Short POST checks the software kernel, verifies checksums for code, and determines what event invoked POST.

NOTE:

Puritan Bennett recommends that a BPS is always installed on the ventilator. If there is a loss of ac power with a charged BPS installed, the ventilator will switch to the dc source and will not run POST upon restoration of ac power.

3.4.4 POST user interface

POST includes these visual indicators:

- A Safety Valve Open (SVO) indicator signals that the ventilator is not delivering breaths.
- Discrete visual indicators on the BDU and GUI CPU PCBs that indicate the current test and step number.
- The VENT INOP indicator on the BDU signals that the user can press TEST to trigger service mode.
- If possible, a display of fault information in case POST detects a failure.

During the different phases of POST, specific LEDs are illuminated on the GUI LED array and the BDU LED array. Audio, visual, and remote alarms are turned on then off after the software kernel is verified (Phase 1) to ensure an alarm sounds if a CPU failure occurs. Refer to Table 3-3 to see which indicators are active during each phase of POST.

3.4.5 Structure of POST

When POST is started, two "POSTs" actually run simultaneously: the graphic user interface (GUI) and the breath delivery unit (BDU) POSTs. These two POSTs run independently of each other.

The following phases comprise the GUI POST and BDU POST:

Phase 1 (kernel) - Tests the microcontrollers and associated circuitry. For each POST, this section of code resides in a single PROM along with kernel operating system and download utility. This part of POST is not downloadable. It is identical for both the GUI and BDU POSTs, with the exception of the rolling thunder test, which is confined to the BDU CPU.

Phase 2 - Tests components outside of the kernel. This portion of POST differs for the GUI and BDU subsystems.

Phase 3 - Consists of tests common to both CPUs, and those that depend on the ventilator operating system to initialize some hardware components before the test.

Table 3-3 compares the BDU and GUI POST sequences, indicates the tests performed and shows which indicators are active during each phase.

Table 3-4: POST outcomes

Symptoms		How to respond
What you see and hear	**What is happening**	
• POST stops. • Ventilator inoperative alarm (audible and visible). • Each CPU attempts to sound its own alarm. • No ventilation if there is a BDU failure.	• Major failure detected. • Ventilator inoperative condition declared. • Communication with other CPU prevented.	• If possible, check LEDs on BDU or GUI CPU PCBs to determine which test failed and its error code; troubleshoot. Otherwise, replace BDU or GUI CPU PCB, as appropriate.
• POST continues to end. • Ventilator inoperative alarm (audible and visible). • Ventilation disallowed.	• Previous run of POST failed and was not corrected, although POST passed subsequent run. • Ventilator inoperative condition declared.	• Run EST/service ventilator.
	• Although POST ran to end, it detected a condition requiring service. • Ventilator inoperative condition declared.	• Run EST/service ventilator.
• POST continues to end. • Ventilation proceeds. • A DEVICE ALERT is annunciated.	• Minor fault detected.	• Check System Diagnostic Log for any associated error codes. • Rerun POST/EST.

Table 3-3: POST Structure

	POST (7.25 seconds)			
	Phase 1 (2 s)	**Phase 2 (2 s)**	**Phase 3 (2 s)**	**POST end (1.25 s)**
GUI CPU POST	• Initializes processor • Tests power, GUI CPU, time of day clock, kernel DRAM/NOVRAM, boot PROM, interrupt timer, watchdog timer, flash memory checksum, EEPROM checksum	• Tests GUI on-board electronics, GUI 5V sentry, GUI 12V sentry, POST NOVRAM, bus timer, DRAM, SAAS, Ethernet controller, unexpected reset umpire test	• Tests GUI CPU memory management and floating point units, download OS boot, application boot	• Updates NOVRAM • Initializes hardware
	No communication occurs between GUI and BDU CPU boards during Phases 1 and 2		• GUI and BDU CPUs establish communication	• Ventilator begins flowing air at 10 L/min to check for patient connection
BDU CPU POST	• Initializes processor • Tests power, BDU CPU, time of day clock, kernel DRAM/NOVRAM, boot PROM, interrupt timer, watchdog timer, flash memory checksum, EEPROM checksum, rolling thunder test	• Tests BDU on-board electronics, VH 5V, VH 12V, POST NOVRAM, bus timer, DRAM, vent INOP, Ethernet controller, service mode switch, unexpected reset umpire test, • AI PCB test • Analog devices test: PS1/PS2 Q1/Q2/Q3 PSOL1/PSOL2 PA/PI/PE O_2 sensor safety valve exhalation valve exh. valve heater • ADC and DAC tests • ac voltage test	• Tests BDU CPU memory management and floating point units, download OS boot, application boot	• Initializes hardware
Visual and audible indicators	• GUI LEDs: SVO LED ON • BDU LEDs: SVO LED ON, loss of UI LED ON • BDU continuous tone alarm ON	• GUI LEDs: all LEDs ON • BDU LEDs: all LEDs ON • BDU continuous tone alarm OFF	• GUI LEDs: all OFF except green "normal" indicator • BDU LEDs: all OFF • GUI audible alarm turned on then off (2 beeps if OK) • BDU continuous tone alarm turned on and off twice	• GUI: start-up screen displays if POST passes • BDU: all LEDs off if POST passes • No audible alarms/ LEDs active[1]
AI PCB LEDs	Red LED ON	Red LED ON	Green LED ON	Green LED flashing

1. This is true only if both air and O_2 supplies are connected and have adequate pressure, and the patient circuit is *not* connected, and no failures or fault conditions are detected by ongoing diagnostics (including POST 10 second timer).

3.5 SST (short self test)

Warning

- Always disconnect the ventilator from the patient before running SST. Running SST while the ventilator is connected to the patient can injure the patient
- When running SST, make sure the patient circuit is configured exactly as it will be used on the patient (for example, with same accessories). If accessories are changed or added to the patient circuit after SST has completed, you must run SST again with the new configuration installed to calculate for compliance and check for leaks.
- An ALERT identified in SST indicates that the ventilator or an associated component is defective. A defective ventilator or associated component should be repaired before the ventilator is returned to service, unless it can be determined with certainty that the defect cannot create a hazard for the patient, or add to the risks which may arise from other hazards.

NOTE:

- If the ventilator has not reached operating temperature from recent usage, allow it to warm up for at least 10 minutes in service mode before running SST, to ensure accurate testing.
- Puritan Bennett recommends that you run SST every 15 days, between patients, after a major service or repair (refer to Table 5-2 on page 6), and when you change the patient circuit. Puritan Bennett recognizes that the protocol for running SST varies widely among health care institutions. It is not possible for Puritan Bennett to specify or require specific practices that will meet all needs, or to be responsible for the effectiveness of those practices.
-

Table 3-6 lists the tests that comprise SST. For more details about these tests and associated diagnostic codes, see Section 6 of this manual. For a theory of operation of SST, consult the *840 Ventilator System Operator's and Technical Reference Manual*.

3.5.1 When to run

The operator runs SST in the following situations:

- Every 15 days, between patients
- When changing the patient circuit
- When changing the patient circuit configuration

Changes to the patient circuit configuration include:

- Changing the humidifier type
- Adding or removing an in-line water trap
- Using a different type or style of patient circuit
- Installing a new or sterilized exhalation filter

The service technician runs SST after servicing the ventilator and as needed to verify the integrity of the bacteria filters and patient circuit.

3.5.2 Hardware requirements

Running SST requires the equipment listed in Table 3-5.

Table 3-5: Hardware requirements for SST

Description	Manufacturer or model or Puritan Bennett part number
Patient circuit	Varies **NOTE:** To ensure that compliance compensation functions correctly, the user must run SST with the circuit configured as intended for use on the patient.
Stopper, wye (no. 2)	4-009523-00
[1]Compressed air source, 35 to 100 psi (241 to 690 kPa) or the compressor option **NOTE:** Due to the excessive restriction of Air Liquide, Dräger, and SIS air/oxygen hose assemblies, certain SST tests may fail when supply pressures < 50 psi (345 kPa) are used in conjunction with these hoses.	Local supplier 806 Compressor Unit
Oxygen source, 35 to 100 psi (241 to 690 kPa) **NOTE:** Due to the excessive restriction of Air Liquide, Dräger, and SIS air/oxygen hose assemblies, certain SST tests may fail when supply pressures < 50 psi (345 kPa) are used in conjunction with these hoses.	Local supplier

1. If necessary, the compressor can be used as the only gas source. However, only the gas pathway, flow sensor, and PSOL of the single gas (air or O2) will be verified during SST.

3.5.3 Running SST

1 If attached, remove gold standard circuit (test circuit designed for use with EST) from ventilator. Install the circuit to be used on patient. (Figure 3-1).

Do not attach a test lung or a humidifier to the circuit at this time.

NOTE:

To ensure accurate circuit resistance measurement, check that the circuit is not obstructed and is properly connected to the ventilator.

2 Ensure that patient is not connected to circuit and that patient wye is unblocked.

3 Turn on power switch to start normal ventilation.

4 Verify that the ventilator is operating on full ac power before running SST. If full ac power is not present, test failures may result.

5 At *Ventilator Startup* screen (lower GUI screen), touch SST, then press TEST button (on side of ventilator) within 5 seconds. Waiting longer than 5 seconds cancels the SST prompt.

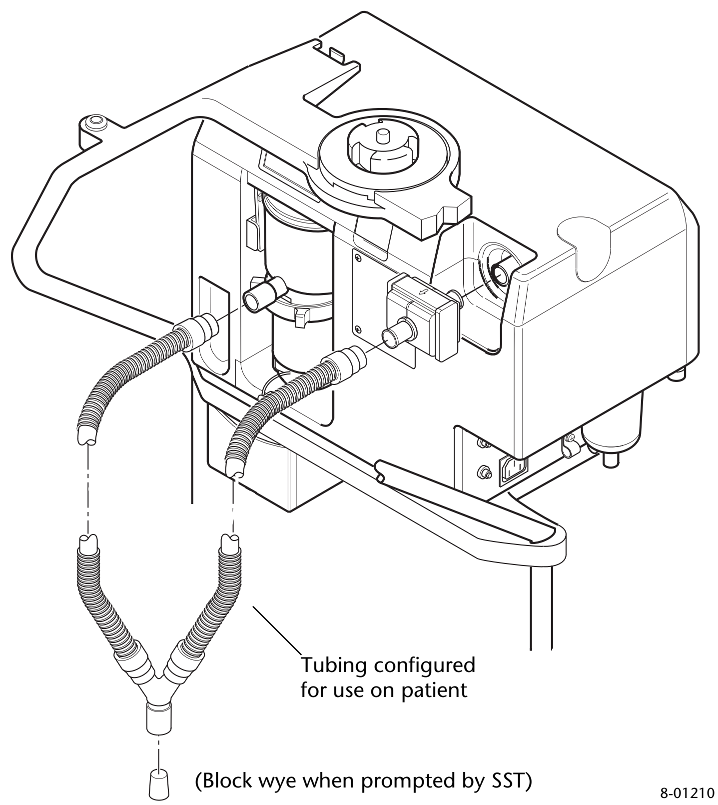


Figure 3-1. Patient circuit setup for SST

6 At *SST Setup* screen (lower GUI screen), select patient circuit and humidification types, then press ACCEPT.

Warning

Incorrectly specifying the patient circuit type or humidifier during SST setup, or changing either type after you have run SST can affect the accuracy of compliance calculation and the delivered and measured exhaled tidal volumes. You must rerun SST after changing the patient circuit type, installing a new patient circuit, or after adding or changing accessories.

NOTE:

During ventilation, the humidification type can be changed by touching the OTHER SCREENS button, then the More Settings button. However, the preferred operation in this case is to rerun SST after making such a change.

7 The ventilator automatically initiates the test sequence (Table 3-6).

Installation of humidifier: The SST Flow Sensor test will pause during execution and prompt for installation of humidifier. If applicable, fill the humidifier with water and connect as shown in Figure 3-1. (The humidifier must be filled with water to ensure proper compliance compensation.) Press ACCEPT to continue SST.

The SST Expiratory Filter, Circuit Resistance, and Compliance Calibration tests require your intervention, and will wait indefinitely for your response. Respond when prompted; then press ACCEPT. Otherwise you don't need to do anything until a test result is ALERT or FAILURE, or SST is complete.

8 As each test is performed, the *SST Status* screen shows test results (see Table 3-7). SST results can be viewed in service mode in the *SST Results* subscreen. You can also review resulting error information through the EST/SST Diagnostic Log after SST is completed (refer to Section 6).

9 You can touch EXIT SST during SST to halt testing. You can touch EXIT SST again to resume testing, or press ACCEPT to restart the ventilator (if SST has not detected an ALERT or FAILURE).

Warning

- To ensure ventilation that correctly compensates for circuit resistance and compliance, do not exit SST and begin normal ventilation until the **entire** SST has been successfully completed with the circuit to be used on the patient installed.
- To ensure reliable SST results, *do not* repeat an individual test with a different patient circuit if the test result is FAILURE or ALERT. If you suspect a defective patient circuit, restart SST from the beginning with a different patient circuit.

NOTE:

- If SST is interrupted, you can restart normal ventilation as long as no errors have occurred that would otherwise prevent it.
- Tests that result in an alert or failure and are successfully rerun are not written into the EST/SST Diagnostic Log if they are successfully rerun during the same SST test sequence.

10 When all of the tests in SST are complete, the *SST Status* screen displays all individual test results and SST outcome. Table 3-8 summarizes overall SST outcomes and how to proceed in each case.

11 To begin normal ventilation (if SST has not detected an ALERT or FAILURE), touch EXIT SST, then press ACCEPT. The ventilator reruns POST, then displays the *Ventilator Startup* screen.

Table 3-6: SST tests

Test step	Function	Comments
SST Flow Sensor Test	1. Verifies that at least one gas is connected. (If only one gas is connected then only that gas pathway (flow sensor and PSOL) is verified during SST.) 2. Cross-checks air and oxygen flow sensors against exhalation flow sensor at four different gas flows. 3. Verifies that proportional solenoid (PSOL) command current is in range for each test flow.	When prompted, do the following: • Make sure inspiratory filter is installed. • Connect patient circuit with inspiratory filter, but without the humidifier. • Block wye. • When later prompted, and If applicable, install the humidifier with jar filled with water. **NOTE:** To ensure proper compliance compensation when using a humidifier, make sure the jar is full of water. FAILURE if not passed (cannot be overridden).
Circuit Pressure Test	1. Verifies that system is running on ac. 2. Exercises air and oxygen PSOLs. 3. Checks inspiration and exhalation autozero solenoids. 4. Cross-checks inspiration and exhalation pressure transducers at various pressures.	FAILURE if not passed (cannot be overridden).
Circuit leak	Displays drop in circuit pressure in 10 s. (Determines ability of circuit to hold pressure.)	Overriding an ALERT could cause improper compliance compensation, inaccurate tidal volume delivery, or autocycling. FAILURE reported if test detects excessive leak.
Expiratory filter	Displays pressure drop across expiratory filter.	Connect and disconnect tubing when prompted. Overriding an ALERT could cause inaccurate patient pressure estimation. FAILURE if test detects exhalation compartment occlusion, expiratory filter occlusion or damage, or you did not follow prompts to detach and reattach tubing correctly.

Table 3-6: SST tests (continued)

Test step	Function	Comments
Circuit Resistance	Displays pressure drop across inspiratory and expiratory limbs, including effect of all devices on each limb (filters, humidifier, water traps).	Unblock wye when prompted. Overriding an ALERT could cause inaccurate patient pressure estimation. FAILURE if test detects excessive or low limb resistance, or if you did not follow the prompt to unblock the wye.
Compliance calibration	Displays patient circuit compliance.	Block and unblock wye when prompted. Overriding an ALERT could cause improper compliance compensation or inaccurate tidal volume delivery. FAILURE if test detects out of range compliance.

Table 3-7: SST individual test results

If the test result is:	It means:	Do this:
Passed	No faults found.	Nothing, unless prompted by the ventilator.
ALERT	Test results not ideal, but not critical. SST halts.	**Repeat test** by touching REPEAT. **Skip to next test** by touching NEXT. **Repeat SST from the beginning** by touching RESTART SST. **Exit SST** in order to service ventilator by touching EXIT SST.
FAILURE	A critical problem has been detected, and SST cannot complete until the ventilator passes the failed test.	**Repeat failed test** by touching REPEAT. **Repeat SST from the beginning** by touching RESTART SST. **Exit SST** in order to service ventilator by touching EXIT SST.

Table 3-8: Overall SST outcomes

If the SST outcome is:	It means:	Do this:
Passed	All tests passed.	Touch EXIT SST.
ALERT	One or more faults were detected. If it can be determined with certainty that this cannot create a hazard for the patient, or add to the risks which may arise from other hazards, the user can choose to override the ALERT status and authorize ventilation.	**Repeat SST from the beginning** by touching RESTART SST. **Override ALERT**, as allowed by your institution’s protocol, by touching OVERRIDE, followed by EXIT SST.
FAILURE	One or more critical faults were detected. A ventilator inoperative condition is declared.	**Repeat SST from the beginning** by pressing RESTART SST. **Exit SST** in order to service ventilator or review error codes by pressing EXIT SST.
OVERRIDDEN	An ALERT status was overridden, and ventilation is authorized.	Touch EXIT SST.

3.6 EST (extended self test)

Warning

- Always disconnect the ventilator from the patient before running EST. Running EST while the ventilator is connected to the patient can injure the patient.
- A fault identified in EST indicates that the ventilator or an associated component is defective. A defective ventilator or associated component should be repaired before the ventilator is returned to service, unless it can be determined with certainty that the defect cannot create a hazard for the patient, or add to the risks which may arise from other hazards.

NOTE:

- If the ventilator has not reached operating temperature from recent usage, allow it to warm up for at least 10 minutes in service mode before running EST to ensure accurate testing.
- Be aware that each time EST is performed, the patient alarm log is cleared.

3.6.1 Description

Table 3-10 lists the tests that comprise EST. For more details about these tests and associated diagnostic codes, see Section 6. For a theory of operation of EST, consult the *840 Ventilator System Operator's and Technical Reference Manual*.

3.6.2 When to run

Run EST before placing the ventilator into operation following service and as part of the ventilator's routine performance verification.

3.6.3 Hardware requirements

Running EST requires the equipment listed in Table 3-9. Both air and oxygen gas are required for this testing.

Table 3-9: Hardware requirements for EST

Description	Manufacturer or model or Puritan Bennett part number
Test (gold standard) circuit	4-018506-00
Stopper, wye (no. 2)	4-009523-00
Compressed air source, 241 to 690 kPa (35 to 100 psi) or compressor option **NOTE:** Due to excessive restriction of Air Liquide, Dräger, and SIS air/oxygen hose assemblies, certain EST tests may fail when supply pressures < 50 psi (345 kPa) are used in conjunction with these hoses.	Local supplier
Oxygen source, 241 to 690 kPa (35 to 100 psi) **NOTE:** Due to excessive restriction of Air Liquide, Dräger, and SIS air/oxygen hose assemblies, certain EST tests may fail when supply pressures < 50 psi (345 kPa) are used in conjunction with these hoses.	Local supplier

3.6.4 Running EST

1 Ensure that the patient is NOT connect to ventilator.

2 Before running EST, you must verify the following:

- The ventilator is operating on full ac power.
- The green BPS ready LED is lit, indicating that the batteries are charged to 95% of nominal.
- Air and oxygen gas sources are connected to the ventilator and pressures are within the range of 35 - 100psi (241-690 kPa).

Failure to ensure that all three conditions are true will cause EST to fail.

3 Enter service mode and initiate EST as follows:

a. Turn on power to ventilator. (If power is already on, turn it off, then back on.)

b. While BDU ventilator inoperative indicator is lit and alarm briefly ceases, press TEST button within one second. The ventilator automatically enters the service mode. *Do not continue to depress or cycle the TEST button while entering service mode.*

c. On lower screen, touch EST.

d. Install the gold standard circuit between *To patient* and *From patient* ports (Figure 3-2). *Do not install an inspiratory filter.*

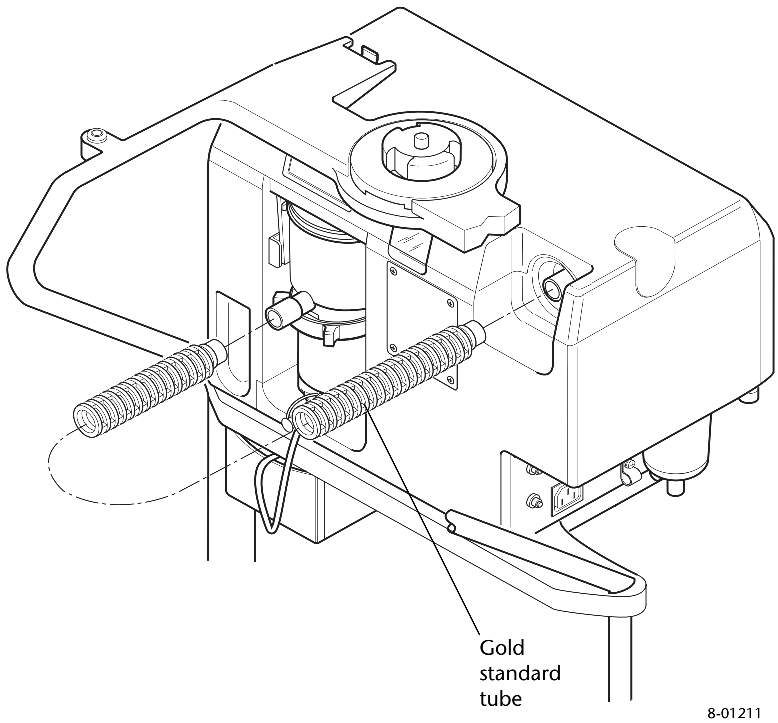


Figure 3-2. EST setup

4 The ventilator automatically starts the test sequence (Table 3-10). Some tests require your intervention, and will wait indefinitely for your response. Others, such as the GUI Knob test and the GUI Keyboard test, require your response within a 15-second timeout period. Failure to respond before the timeout period expires will result in test failure or alert.

Otherwise, you don't need to do anything until a test result is ALERT or FAILURE, or EST is complete.

5 As each test is performed, the displays resemble those in Figure 3-3, with test data displayed on the upper GUI. Overall test results are shown in the "Result" column (see Table 3-11). Error codes beginning with an A indicate an alert and error codes beginning with an F indicate a failure. You can review resulting error information through the EST/SST Diagnostic Log after EST is completed (see Section 6).

6 You can touch EXIT EST during EST to halt testing. You can touch EXIT EST again to resume testing, or press ACCEPT to restart the ventilator (if EST has not detected an ALERT or FAILURE).

NOTE:

- If EST is interrupted, you can restart normal ventilation as long as no errors have occurred that would otherwise prevent it. You must press the EXIT button on the GUI screen then the ACCEPT key to exit EST properly.
- Tests that result in an alert or failure and are successfully rerun during the same test sequence are not written into the EST/SST Diagnostic Log.
- It may be useful to complete EST even with errors, because information on multiple errors can facilitate troubleshooting.

7 When all of the tests in EST are complete, the *Extended Self Test* screen displays all individual test results and EST outcome. Refer to Tables Table 3-10, Table 3-11, and Table 3-12 for additional information.

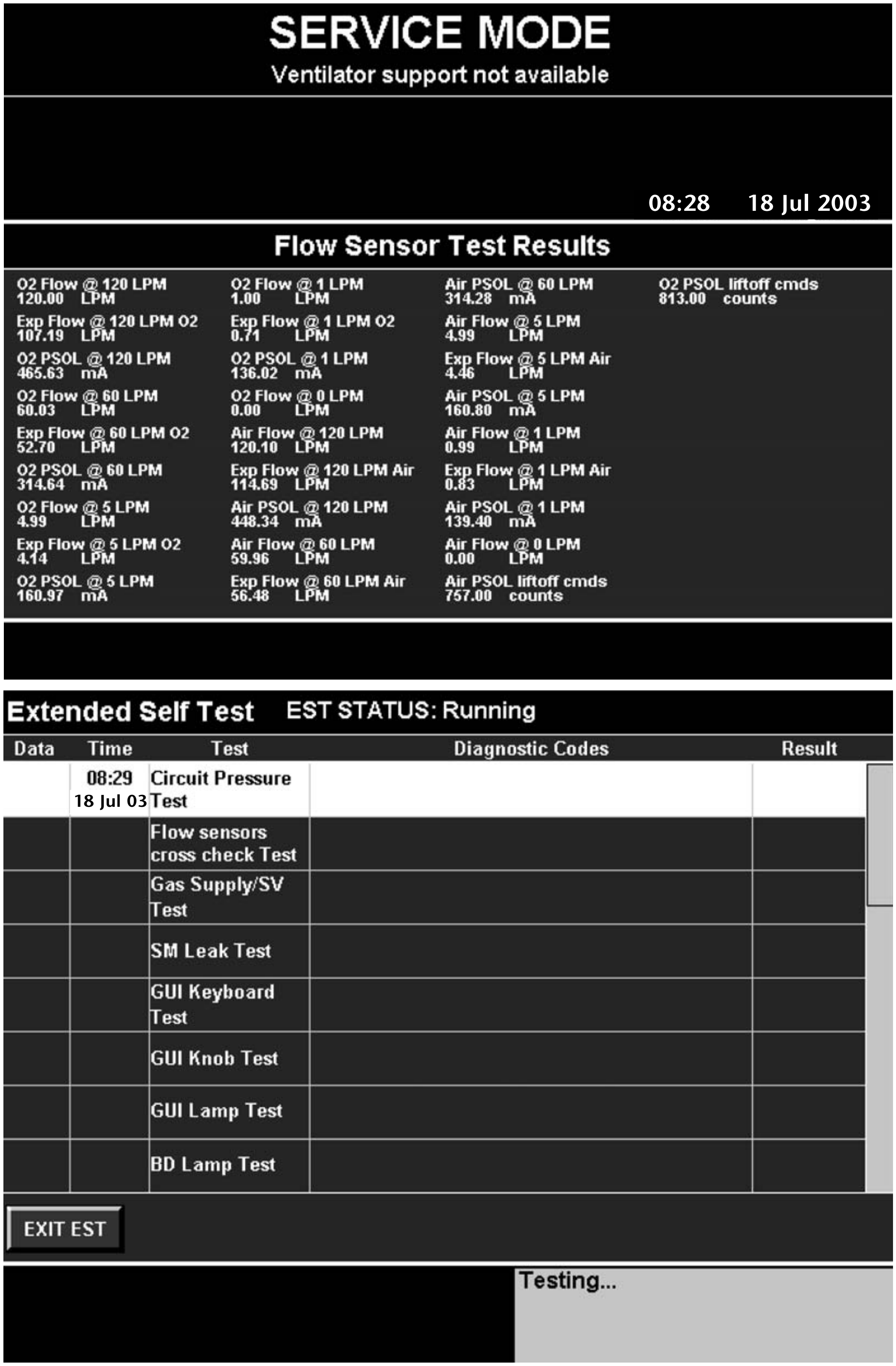


Figure 3-3. EST screens during testing

NOTE:

These screens are examples only. Your unit may vary slightly in appearance.

Table 3-10: EST tests

Test step	Function	Comments
Circuit Pressure Test	Checks that the system is running on ac power, prompts user to set up the vent for EST, and exercises the PSOLs. Calibrates inspiratory and exhalation transducers to atmospheric pressure. Cross-checks inspiration and exhalation pressure transducers at various pressures. Checks inspiration and exhalation autozero solenoids.	• Leaks or occlusions in the expiratory filter or elsewhere will cause this test to fail. • Connect ac power if ventilator is running on battery power and ac is not connected. • Make sure green BPS ready indicator is lit on GUI LED panel. • Make sure air and oxygen are connected. • Remove inspiratory filter and connect gold standard circuit as directed.
Flow Sensors Cross Check Test	Cross-checks air and oxygen flow sensors against exhalation flow sensor at five different gas flows. Verifies that proportional solenoid (PSOL) command current is in range for each test flow. Performs air/O_2 PSOL lift-off current calibration.	• Leaks or occlusions in the expiratory filter or elsewhere will cause this test to fail. • Low source gas pressures may also cause this test to fail. • Exhalation flow sensor has separate air and O_2 calibration tables. During EST, the system uses the calibration table(s) appropriate for the source gas(es) used during EST.
Gas Supply/SV Test	Tests air and oxygen pressure switch gross functionality, tests PSOL forward leak, tests safety valve cracking pressure, and tests flow sensor zero offsets.	• Leaks or occlusions will cause this test to fail. • Block and unblock *To patient* port as directed. • Disconnect and reconnect air and oxygen as directed.
SM Leak Test	Checks for system leaks by pressurizing the system and verifying that pressure drops by no more than 5 cmH_2O in 10 s.	• Leaks or occlusions in the expiratory filter or elsewhere will cause this test to fail.
GUI Keyboard Test	Verifies that GUI keys are functioning by prompting the operator to press a key.	Press keys within 15 s when prompted.
GUI Knob Test	Verifies GUI knob rotation direction by prompting the operator to rotate the knob in one direction, then the other.	Turn GUI knob as prompted, within 15 s.
GUI Lamp Test	Verifies that GUI LEDs are functioning by prompting the operator to acknowledge that the LEDs are turned on.	Observe GUI indicators and press ACCEPT (if on) or CLEAR (if not on).
BDU Lamp Test	Verifies that BDU lights are functioning. **NOTE:** The ventilator inoperative and safety valve open LEDs on the GUI are hard-wired to the BDU and are considered BDU LEDs.	Observe BDU indicators and press ACCEPT (if on) or CLEAR (if not on).
GUI Audio Test	Verifies that GUI audio is functioning by prompting the operator to listen for the alarm sound.	Listen for GUI audio. Press ACCEPT (if on) or CLEAR (if not on).

Table 3-10: EST tests (continued)

Test step	Function	Comments
GUI Nurse Call	Verifies that nurse's call relay is functioning.	If not testing nurse's call, press CLEAR. If testing nurse's call, press ACCEPT, then verify nurse's call operation as prompted.
BDU Audio Test	Verifies that BDU audio is functioning. Also verifies that power fail capacitor can operate loss-of-power alarm for at least 2 minutes.	Listen for BDU audio alarm.
PSOL Loopback Test	Checks PSOL loopback and command currents at three different points by comparing the difference between the two currents with the maximum allowable difference.	
Safety System Test	Tests safety valve and inspiratory check valve operation by checking for occlusions when the safety valve is open, checking safety valve loopback current, and checking inspiratory check valve reverse flow.	
Exp Valve Loopback Test	Checks exhalation valve loopback and command current at three different points by comparing the difference between the two currents with the maximum allowable difference.	
Exp Valve Pressure Accuracy Test	Verifies that exhalation valve seal and poppet friction are acceptable.	
Exp Valve Test	Verifies that current versus pressure values in flash memory correspond with actual installed exhalation valve.	
EV Velocity Transducer Test	Checks that the velocity transducer is sending a signal and that the control circuit recognizes the signal. It does not verify the quality of the signal.	
Exp Heater Test	Verifies that gas flow temperature increases and decreases in response to commanding the heater on and off.	
Compressor Test	Tests compressor operation. This test checks the timer, compressor pressure switch, and compressor operating states (run, standby, and disabled).	• If wall air is connected, disconnect wall air as directed. • If ac is not connected, connect ac power as directed.
Compressor Load Test	Tests compressor operation. This test checks the compressor's ability to maintain sufficient air pressure during worst-case breath delivery (200 lpm).	
Compressor Leak Test	Verifies that a fully charged compressor (if installed) does not leak enough to cause the compressor to turn on within 1 minute while in standby mode with wall air connected.	• Disconnect and connect wall air as directed. • Test takes 1 minutes to complete.
Analog Data Display	Reads and displays analog data channels in engineering units.	O_2 sensor data is displayed in DAC counts.
GUI Touch Test	Checks for GUI touch screen errors.	
GUI Serial Port Test	Verifies that GUI serial port can send and receive data.	
Battery Test	With ac disconnected, tests BPS under discharging and charging conditions.	Test takes 5 minutes to complete.

Table 3-11: EST individual test results

If the test result is:	It means:	Do this:
Passed	No faults found.	Nothing, unless prompted by the ventilator.
ALERT	Test results not ideal, but not critical. EST halts.	**Repeat test** by touching REPEAT. **Skip to next test** by touching NEXT. **Repeat EST from the beginning** by touching RESTART EST. **Exit EST** in order to service ventilator or review error codes by touching EXIT EST.
FAILURE	A critical problem has been detected, and EST cannot complete until the ventilator passes the failed test.	**Repeat failed test** by touching REPEAT. **Skip to next test** by touching NEXT. **Repeat EST from the beginning** by touching RESTART EST. **Exit EST** in order to service ventilator or review error codes by touching EXIT EST.

Table 3-12: Overall EST outcomes

If the EST outcome is:	It means:	Do this:
Passed	All tests passed.	Touch EXIT EST.
ALERT	One or more faults were detected.	**Repeat EST from the beginning** by touching RESTART EST. **Override the alert** in order to service ventilator or review error codes by touching OVERRIDE, followed by EXIT EST. **NOTE:** Although you can override an alert in EST, normal ventilation is not allowed until the problem is corrected and all EST tests passed.
FAILURE	One or more critical faults were detected. A ventilator inoperative condition is declared.	**Repeat EST from the beginning** by touching RESTART EST. **Exit EST** in order to service ventilator or review error codes by touching EXIT EST.
OVERRIDDEN	An ALERT status was overridden.	Touch EXIT EST.

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SECTION

4

Service mode

The *840* Ventilator System operates in two modes: patient ventilation and service mode. The service mode is intended for use by a trained service technician to aid in ventilator testing and troubleshooting and to perform system calibrations.

This section details the service mode, including prompts and expected system responses.

Warning

Do not enter the service mode while a patient or other person is connected to the ventilator. To do so may cause patient injury or death. Normal ventilator operation is not accessible while in the service mode.

4.1 Accessing service mode

Access service mode as follows:

1 Ensure a patient is not attached to ventilator and that the patient circuit is disconnected.

2 Turn on power to ventilator. (If power is already on, turn it off, then back on.)

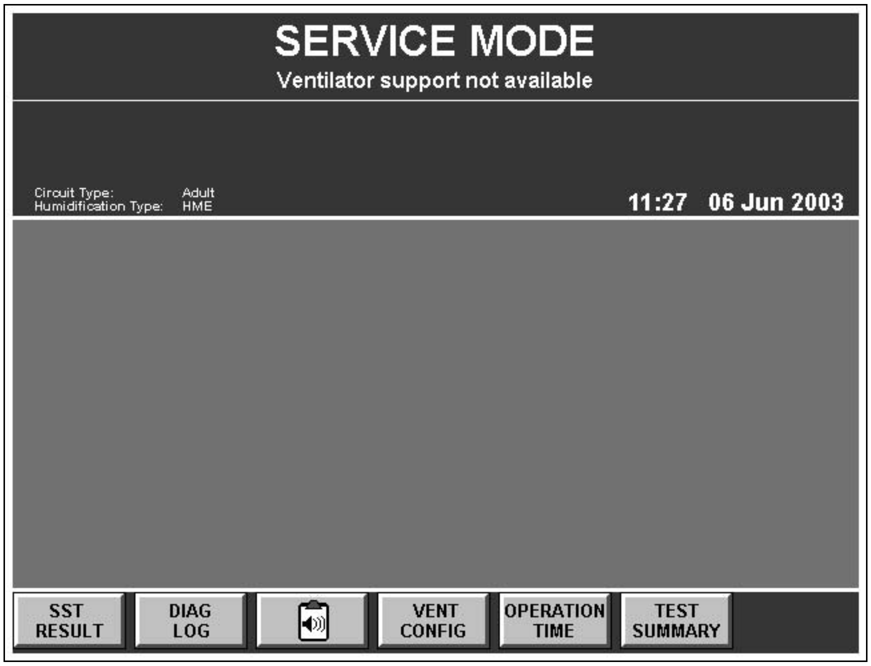
3 While audible alarm briefly ceases and BDU ventilator inoperative indicator is lit, press TEST key within one second. (The TEST key is located on the left side of the BDU above the GUI cable connection.)

The ventilator automatically enters the service mode (see Figure 4-1). *Do not hold TEST button in while entering service mode.*

4 At the Service Mode screen, touch the desired selection, then follow on-screen prompts.

NOTE:

During service mode startup, certain functions may automatically execute to program data into BDU and/or GUI NOVRAM. Refer to Section 4.2.16 for details. While in the Service Mode, normal ventilation is not allowed.



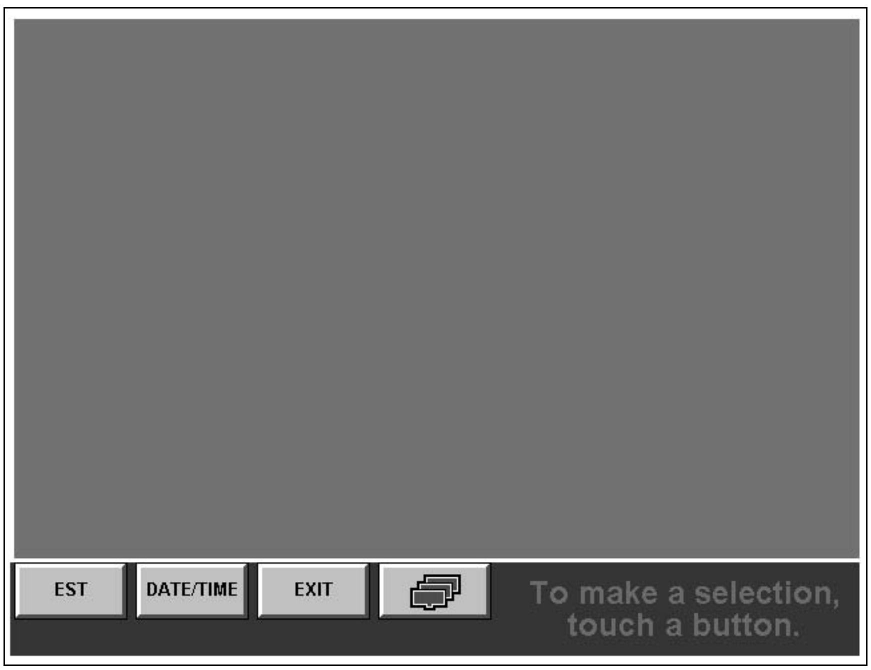


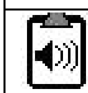
Figure 4-1. ***SERVICE MODE* screens**

4.2 Service mode functions

Table 4-1 summarizes the ventilator's service mode functions. Figure 4-2 shows how to navigate among the functions.

It is important to always run the first four EST tests before performing any ventilator sensor calibrations. All system leaks must be eliminated before proceeding with any calibrations.

Table 4-1: Service mode functions

Function	Purpose
Upper screen	
SST RESULT	Displays the latest SST test results, including test name, date and time each test was last run, individual test results, and overall test outcome. **NOTE:** When reviewing SST results, be aware that not all of the results for each SST test may be from the same date and time run.
DIAG LOG	Displays the contents of System Diagnostic Log, System Information Log, and EST/SST Diagnostic Log.
 **Alarm log**	Displays the history of most recent ventilator alarms for the previous patient. **NOTE:** Running EST or selecting New Patient will erase this log.
VENT CONFIG	Displays software revisions and serial numbers. Software revisions displayed include: GUI and BDU boot PROM and application software as well as GUI audible alarm subsystem (SAAS). Serial numbers displayed are for BDU, GUI, and compressor unit (if installed); these serial numbers are read from the data key and compressor (if installed).
OPERATION TIME	Displays accumulated ventilator and compressor operational time, in hours.
TEST SUMMARY	Displays the latest EST and SST test results, including date and time each was last run and overall test outcome.
Lower screen	
EST	Displays the details of the last EST run. Runs EST to thoroughly test the operational integrity of the ventilator, both electronics and pneumatics.
DATE/TIME	Adjusts current date and time.
EXIT	Exits service mode.
Other Screens	Performs miscellaneous service, test, and calibration functions.

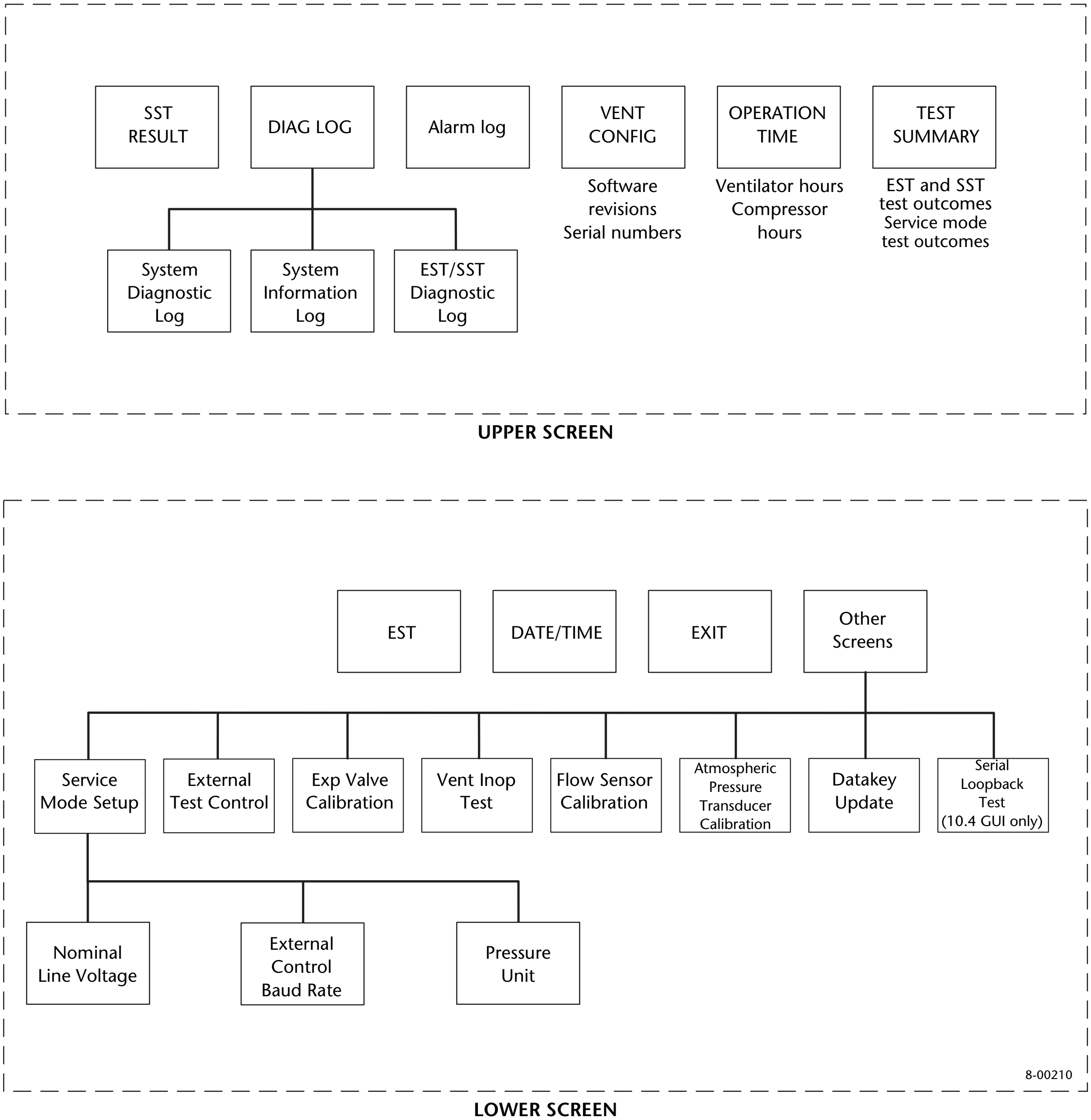


Figure 4-2. Service mode functions

4.2.1 SST RESULT: Displaying SST results

This function lets you read the latest SST test results, including: test name, date and time each test was last run, individual test results, and overall test outcome.

NOTE:

SST lets you exit and resume patient ventilation if required. Thus, the results shown are not necessarily all from the same SST run. If a partial SST run is performed, the results of the first few tests might be more recent than the results of later tests.

4.2.2 DIAG LOG: Displaying error and status logs

NOTE:

System Diagnostic Information and EST/SST Diagnostic logs can only be erased by using the 840 VTS Breath Labs Software. The alarm log is automatically erased each time a new patient is setup is selected and when EST is run.

This function lets you read the contents of the ventilator's error and status logs. The logs are as follows:

- The **System Diagnostic Log** stores data on unexpected conditions detected during POST, background checks. This includes alerts and failures.
- The **System Information Log** (Figure 4-3) stores data on ventilator events, including details on GUI/BDU communication.
- The **EST/SST Diagnostic Log** (Figure 4-4) stores data on overall test outcomes and events during SST and EST.

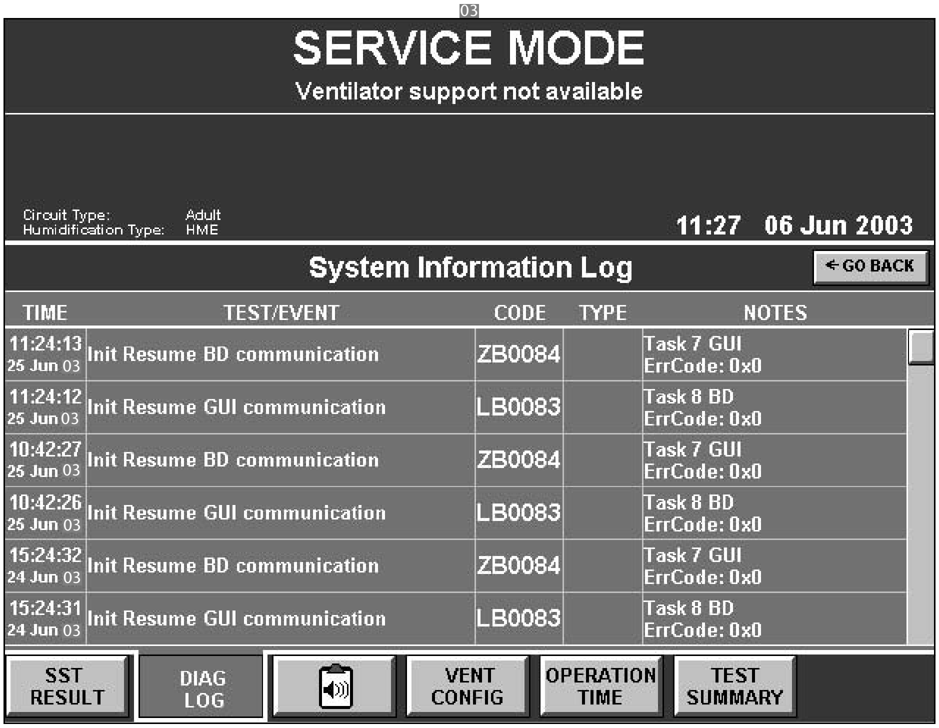


Figure 4-3. System Information Log

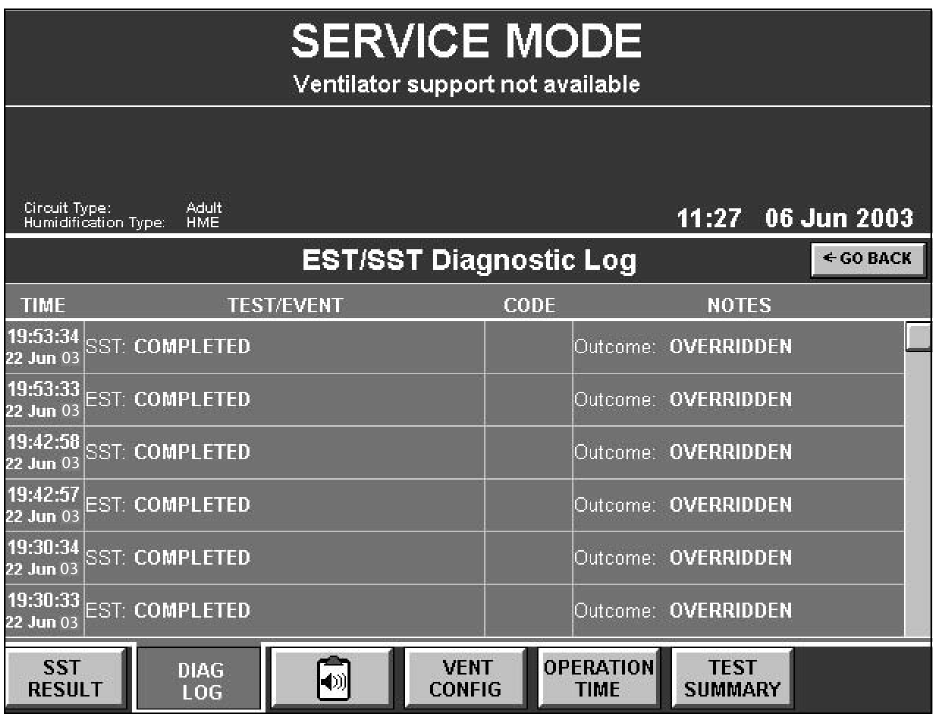


Figure 4-4. EST/SST Diagnostic Log

4.2.3 Alarm log: Displaying the alarm history

This function lets you read the history of the most recent ventilator alarm events. This includes such information as autoreset, user reset, alarm silence, and changes in urgency. The alarm log is automatically cleared when a new patient setup is completed. When you exit the service mode to start ventilation, a new patient setup is required.

See Section 7 to interpret the events in the alarm log.

4.2.4 VENT CONFIG: Displaying software revisions and serial numbers

This function displays software revisions and serial numbers. Software revisions displayed include: GUI and BDU boot PROM and application software as well as GUI audible alarm subsystem (SAAS). Serial numbers displayed are for BDU, GUI, and compressor unit (if installed); these serial numbers are read from the data key.

4.2.5 OPERATION TIME: Displaying ventilator and compressor elapsed hours

This function displays accumulated ventilator and compressor operational time, in hours. This helps determine when preventive maintenance is needed.

4.2.6 TEST SUMMARY: Displaying results from EST and SST

This function displays the latest EST and SST overall test outcomes, including date and time each was last run.

4.2.7 EST: Extended self test

This function lets you run the full EST. It shows details of the last execution of each individual EST test. For details on the EST function and other ventilator testing, refer to Section 3.

NOTE:

The performance verification, described in Section 5 of this manual, is a more thorough test of the ventilator to verify it meets specifications.

4.2.8 DATE/TIME: Adjusting date and time

This function lets you adjust the current date and time. Any change is recorded in the information and diagnostic logs.

4.2.9 EXIT: Exiting service mode

This function lets you exit the service mode.

4.2.10 Other screens

This function (Table 4-2) lets you perform miscellaneous service, test, and calibration functions. Table 5-2 tells you when and in what order to perform these functions.

Table 4-2: Other screens

Function	Purpose
Serial Loopback Test (10.4-inch GUI only)	Tests the serial communication ports on the 10.4-inch GUI.
Datakey Update	Transfers the operational hours from the ventilator to the new datakey. For use after software options have been installed.
Service Mode Setup	Lets you adjust nominal line voltage lower limit, baud rate for RS-232 port, and lets you choose the unit for display of pressures (cmH_2O or hPa).
External Test Control	Lets you test the ventilator using a computer, 840 VTS Breath Labs Software, and *PTS 2000* tester, to run performance verification. Also used to download new application software to the 840.
Exp Valve Calibration	Performs calibration. For use after a new exhalation valve, AI PCB, or BDU CPU PCB is installed, or as part of the performance verification.
Vent Inop Test	Exercises ventilator inoperative circuitry during five test phases.
Flow Sensor Calibration	Performs calibration. For use after a flow sensor replacement or as part of the performance verification.
Atmospheric Pressure Transducer	Performs calibration. For use after an Inspiratory or Expiratory Electronics PCB replacement, new vent installation, if the vent has been moved ± 1000 feet in elevation, or as part of the performance verification.

4.2.11 Service Mode Setup

This function lets you adjust the settings indicated in Table 4-3.

Table 4-3: Service Mode Setup

Function	Purpose
Nominal Line Voltage	Nominal line voltage lower limit. This setting is used to detect low power alarm conditions. It has no direct effect on power supply function. Improper line voltage settings will cause a Device Alert, preventing normal operation.
External Control Baud Rate	For GUI RS-232 port. The baud rate takes effect when you restart the ventilator in the service mode.
Pressure Unit	Unit for display of pressures (cmH_2O or hPa).

4.2.12 External Test Control: Performing remote ventilator testing

This function lets you test the ventilator using a computer to conduct the ventilator performance verification. Refer to Section 5 for details. When the External Text Control mode is active, press the Other Screens button or power the ventilator off then on to exit the function.

4.2.13 Exp Valve Calibration

NOTE:
- If the ventilator has not reached operating temperature from recent usage, allow it to warm up for at least 10 minutes in service mode before performing this calibration, to ensure a successful calibration.
- Ensure that the ventilator has passed the Leak Test in EST prior to performing this calibration.

This function builds the exhalation valve calibration table. This table lists exhalation valve DAC commands versus exhalation pressure. The exhalation valve calibration requires a gold standard test circuit and lasts approximately 3 minutes.

If the calibration fails, try rerunning it. If it continues to fail, refer to Table 4-4 to troubleshoot any errors. Run EST to assist in troubleshooting.

NOTE:

A system leak is a common source of failure, particularly expiratory filter leaks. Make sure the expiratory filter collector vial is secured tightly, the drain port is capped, and the filter is mounted securely to the ventilator. Make sure the test circuit is securely attached.

4.2.13.1 Running Exp Valve Calibration

1. Make sure patient is not connected to the ventilator.
2. Enter service mode and select the Other Screens button.
3. Ensure air and oxygen are connected to the ventilator.
4. Connect the gold standard circuit between the To Patient and From Patient ports. (Do not use a patient filter.)
5. On the lower screen, select the Exp Valve Calibration button.
6. Press the Start button.
7. Press Accept.

The ventilator automatically starts the calibration. When the calibration is complete, press the Other Screens button again to return to the Other Screens menu.

Table 4-4: Exhalation valve calibration errors

Message displayed	Error type	Additional information
ac power not connected	Failure	Verify ac power is connected.
Bad exp valve loopback current	Failure	Exhalation valve and/or analog interface PCB may be out of specification. Try cleaning the exhalation valve if inspection warrants and re-run the calibration.
Both insp and exp autozero failed	Failure	Analog Interface PCB may be out of specification.
Calibration failed: current limit exceeded	Failure	Exhalation valve and/or analog interface PCB may be out of specification.
Calibration failed: gain resolution	Failure	Exhalation valve and/or analog interface PCB may be out of specification.

Table 4-4: Exhalation valve calibration errors (continued)

Message displayed	Error type	Additional information
Calibration failed: Pressure build time-out.	Failure	Verify that gold standard circuit is still connected and expiratory filter is locked in place. Verify that seal is placed over collector vial drain and vial is securely fastened to expiratory filter.
Exhalation pressure transducer autozero failed	Failure	Exhalation pressure transducer DAC count at 0 cmH_2O is out of range.
Exhalation valve temperature out of range	Failure	Exhalation valve temperature out of range.
Flow sensor cross-check: unable to establish flow	Failure	Flow controller is not able to establish a 5 L/min test flow via the air flow sensor.
Flow sensor cross-check failed	Failure	Exhalation air flow is out of range with respect to the 5 L/min inspiration-controlled test flow. Verify gold circuit is connected. Check for expiratory filter leaks.
Flow sensor info invalid	Failure	Flow sensor calibration table checksum error occurred.
Inspiration autozero failed	Failure	Inspiration pressure transducer DAC count at 0 cmH_2O is out of range.
No air connected	Failure	Wall and compressor air pressure switches detect no air connected. Verify air is connected.
Pressure sensor cross-check: unable to build pressure	Failure	Pressurization algorithm is unable to pressurize system to one or more of five test pressures via the inspiration pressure transducer. Check for expiratory filter leaks.
Pressure sensor cross-check alert: approaching spec limit	Alert	Pressure cross-check alert occurred at one or more of five test pressures, no cross-check failures occurred.
Pressure sensor cross-check failed	Failure	Pressure transducer cross-check failed at one or more of these five test pressures (5, 25, 50, 75, and 100 cmH_2O).
Unable to establish flow	Failure	Flow controller is not able to establish a 5 L/min test flow via the exhalation flow sensor.
Unable to program flash	Failure	Unable to program calibration table into BDU NOVRAM. Check BDU +12 V supply and BDU CPU PCB.

4.2.14 Vent Inop Test

This function exercises the ventilator inoperative circuitry.

4.2.14.1 Running the Vent Inop Test

1. Enter Service Mode and select the Other Screens button.
2. Ensure air and oxygen are connected to the ventilator.
3. Connect the gold standard circuit between the To Patient and From Patient ports.
4. Select the Vent Inop Test button and press Accept.
5. The Vent Inop Test is composed of the phases indicated in Table 4-5. At the end of each test phase, turn the ventilator power off, then on and restart Service Mode as instructed. Observe the audio and visual alarms and respond as prompted.

Table 4-5: Vent Inop Test phases

Test phase	Vent inop indicators tested
GUI Vent Inop test	1. BDU alarm on (user prompt). 2. Ventilator inoperative and safety valve open LEDs on (user prompt). 3. PSOLs/exhalation valve/safety valve inactive.
Vent Inop A test	PSOLs/exhalation valve/safety valve inactive.
Vent Inop B test	PSOLs/exhalation valve/safety valve inactive.
Vent Inop A ten second test	PSOLs/exhalation valve/safety valve inactive.
Vent Inop B ten second test	PSOLs/exhalation valve/safety valve inactive.

If a test phase fails (“Vent Inop Test failed” message in lower screen), powering the ventilator down and back up into service mode will invoke the normal service mode. Troubleshoot as indicated in Table 4-6. You must repeat the Vent Inop Test and pass it with no failures before ventilation is allowed.

Table 4-6: Vent Inop Test troubleshooting

Test phase	Type of failure	Corrective action
GUI vent inop test phase	BDU alarm (alone)	Check BDU alarm or AI PCB.
	Ventilator inoperative or SVO LED failure (alone)	Check appropriate BDU or GUI LED panel, BD CPU PCB, BDU-GUI cable, or GUI CPU PCB. **NOTE:** The BD CPU PCB controls the ventilator inoperative and safety valve open LEDs on both the BDU and GUI CPU PCBs, sending the two LED signals to the GUI via the BDU-GUI cable.
	BDU alarm *and* ventilator inoperative and safety valve open LEDs	Check BDU-GUI cable, BD CPU PCB, or GUI CPU PCB.
	PSOLs/exhalation valve/safety valve inactive	Check BD CPU PCB or AI PCB. If alarm and/or LED failure occurred also, check BDU-GUI cable, GUI CPU.
Any other test phase	Any	Check BD CPU PCB or AI PCB.

4.2.14.2 Flow Sensor Calibration

NOTE:

- If the ventilator has not reached operating temperature from recent usage, allow it to warm up for at least 10 minutes in service mode before performing this calibration, to ensure a successful calibration.
- It is very important that the ventilator passes the leak test during EST prior to running a flow sensor calibration.
- A system leak is a common source of failure, particularly expiratory filter leaks. Make sure the expiratory filter collector vial is secured tightly, the drain port is capped, and the filter is mounted securely to the ventilator. Make sure the test circuit is securely attached.
- Use both air and oxygen gas sources to run Flow Sensor calibration.

This function builds a table of exhalation flow sensor (Q3) offsets. The flow sensor calibration requires a gold standard test circuit.

If the calibration fails, make sure that the test circuit is attached and that the expiratory filter is securely connected and free of leaks, then try rerunning it. If the calibration continues to fail, refer to Table 4-7 to troubleshoot any errors.

4.2.15 Running Flow Sensor Calibration

1. Enter Service Mode.
2. Ensure both air and oxygen are connected to the ventilator.
3. Connect the gold standard circuit between the To Patient and From Patient ports.
4. Ensure that there are no leaks or occlusions by running EST and ensure that the ventilator passes the EST Leak Test. Once this test has passed, exit EST.
5. Select the Other Screens button.
6. Select Flow Sensor Calibration.
7. Press the Start button and press Accept.

The ventilator automatically starts the calibration. When the calibration is complete, press the Other Screens button again to return to the Other Screens menu.

Table 4-7: Flow sensor calibration errors

Message displayed	Error type	Additional information
ac power not connected	Failure	Verify ac power is connected.
Air offset out of range	Failure	1. Replace air flow sensor (Q2). 2. Replace exhalation flow sensor (Q3). 3. Replace AI PCB.
Cannot achieve minimum air flow	Failure	System cannot sustain a minimum 60 L/min flow. Check air supply pressure and REG2.
Cannot achieve minimum O_2 flow	Failure	System cannot sustain a minimum 60 L/min flow. Check oxygen supply pressure and REG1.
No air connected	Failure	Wall air pressure switch (PS2) detects no air connected. Verify air is connected.
No O_2 connected	Failure	Oxygen pressure switch (PS1) detects no oxygen connected. Verify oxygen is connected.
O_2 offset out of range	Failure	1. Replace oxygen flow sensor (Q1). 2. Replace exhalation flow sensor (Q3). 3. Replace AI PCB.

4.2.15.1 Atmospheric Pressure Transducer

NOTE:

When calibrating the atmospheric pressure transducer, make sure that the pressure in the room is stable and not subject to pressure changes caused by door closures, heavy foot traffic, or the startup of an air conditioning system. Any such environmental changes will result in an incorrect adjustment being made to the ventilator.

This function calibrates the atmospheric pressure transducer using an external barometer. Refer to Table 1-5 for barometer accuracy specifications.

Allow the barometric pressure reading to stabilize, then input the pressure (in mmHg) measured by this external barometer, as prompted.
(1 mmHg = 1.333 mbars = 133.33 Pa = 0.019 psia.)

If the calibration fails, try rerunning it, making sure you correctly input the barometric pressure. If the calibration continues to fail, try rerunning EST, then replacing the inspiratory pressure transducer autozero solenoid (SOL1) and then the inspiratory electronics PCB.

4.2.16 Automatically executed service mode functions

Before allowing ventilation, the ventilator must have valid serial numbers, flow sensor calibration data, and exhalation valve calibration data in BDU and GUI NOVRAM. If the ventilator determines that this data is not available, it invokes certain functions as required to copy this data into the appropriate CPU's NOVRAM. These functions are described below.

4.2.16.1 Initialize Flow Sensor

This function copies flow sensor calibration data from each flow sensor's serial EEPROM to BDU NOVRAM. It automatically runs when the flow sensor calibration data in BDU NOVRAM does not match the corresponding data in the serial EEPROM of one or more of the flow sensors (for example, when BDU NOVRAM is cleared due to downloading of new software or when a flow sensor is changed). This function is always followed by the Cal Info Duplication function described below.

If this function fails, refer to Table 4-8 to troubleshoot any errors.

Table 4-8: Initialize Flow Sensor errors

Message displayed	Additional information
Unable to read air flow sensor	Error reading air flow sensor (Q2) serial EEPROM data. Check Q2 and AI PCB.
Unable to read O_2 flow sensor	Error reading oxygen flow sensor (Q1) serial EEPROM data. Check Q1 and AI PCB.
Unable to read the expiratory flow sensor	Error reading exhalation flow sensor (Q3) serial EEPROM data. Check Q3 and AI PCB.
Unable to program flash	BDU NOVRAM cannot be successfully programmed. Check BDU +12 V supply and BD CPU PCB.

4.2.16.2 Cal Info Duplication

This function copies flow sensor and exhalation valve calibration data from BDU NOVRAM to GUI NOVRAM. It automatically runs whenever calibration data in GUI NOVRAM is invalid or does not match the corresponding data in BDU NOVRAM (for example, after flow sensor initialization or after exhalation valve calibration).

If this function fails, refer to Table 4-9 to troubleshoot any errors.

Table 4-9: Cal Info Duplication errors

Message displayed	Additional information
Unable to receive flash data	GUI did not receive all calibration data from BDU within 10 s. Check BDU/GUI cable, BD CPU PCB, or GUI CPU PCB.
Unable to burn flash	GUI NOVRAM cannot be successfully programmed. Check GUI CPU PCB.

4.2.17 Serial number setup

This function copies the serial numbers on the data key into NOVRAM. This copy operation is performed only if BDU or GUI NOVRAM contains a default serial number (for example, after the BDU and/or GUI CPU PCB is replaced or after new software is downloaded).

4.2.17.1 Running Serial Number Setup

1. Enter service mode following CPU PCB replacement or software download.
2. Serial number setup automatically starts.
3. Follow on-screen prompts. If this function fails, refer to Table 4-10 to troubleshoot any errors.

NOTE:

- You are given the option to "Proceed without setting serial number." You may want to use this option for troubleshooting purposes. For example, if a new BDU or GUI CPU PCB is inserted temporarily for testing, you may find it useful to maintain the default serial number on that PCB; otherwise, by setting the serial number the test CPU PCB will become "committed" to the ventilator used to initialize it. If you choose not to initialize the serial numbers, be aware that ventilation is not allowed until serial numbers are copied from the data key.
- It is possible to have one CPU with a valid serial number in NOVRAM but the other CPU containing the default serial number. For example, when the BDU only is downloaded with new software, the BDU serial number in NOVRAM is set to the default, but the GUI serial number in NOVRAM is unaffected.
- Do not use the same data key to initialize the serial numbers in more than one ventilator.

Table 4-10: Serial number setup errors

Message displayed	Additional information
Cannot program flash	BDU and/or GUI NOVRAM cannot be successfully programmed. Check BDU and GUI +12 V supplies, BD CPU PCB, and GUI CPU PCB.
Data key is not installed	If a data key is installed but not being detected, try inserting the key into a known good ventilator whose serial numbers have already been initialized. Then power the ventilator up into service mode and verify that the ventilator sees an invalid data key (that is, the message “Serial number(s) doesn’t match the data key” is displayed). If the data key is still not detected, replace it; otherwise, replace the AI PCB. Alternatively, try using a known good data key in the suspect ventilator and verify that it is detected. **NOTE:** If no data key is inserted, you can proceed with service mode but ventilation is not allowed.
Serial number(s) doesn’t match the data key	Press ACCEPT to confirm and proceed with service mode. **NOTE:** If an invalid data key is inserted, you can proceed with service mode but ventilation is not allowed.

4.2.18 Datakey Update

A new datakey is supplied when software options are added to the ventilator. This datakey must be updated with the correct ventilator operational hours after the software containing the options has been downloaded, serial number setup is complete, and all calibrations performed.

NOTE:

If the datakey is updated before calibrations have been run, the operational hours will be lost or become corrupted.

Running Datakey Update

1. Enter Service Mode.
2. Press the Other Screens button.
3. Press the Datakey Update button.
4. Follow the prompts.
5. When you have completed the update, exit Service Mode and check the operational hours by pressing the Other Screens button, then the Operational Time Log button. The correct operational hours should be displayed.

If the wrong operational hours are displayed, refer to Table 4-11 to correct the problem.

Table 4-11: Datakey update error

Problem	Additional Information
Invalid value displayed when operational hours are accessed.	Proceed as follows: 1. Reinstall original datakey. 2. Reinstall ventilator software to erase NOVRAM. 3. Accept serial number and verify correct hours. 4. If correct, repeat the datakey update. 5. If problem persists, you must obtain a duplicate datakey containing the correct serial numbers and software options from your Puritan Bennett representative.

4.2.19 Serial Loopback Test

On the 10.4-inch GUI only, use the Serial Loopback Test to check the function of the serial ports on the back of the GUI.

Required Equipment: Null modem cable (p/n 4-075361-00) or equivalent.

Running the Serial Loopback Test

1. Enter Service Mode.
2. Select the Other Screens button.
3. Select the Serial Loopback Test button.
4. Follow the on-screen prompts. If this function fails, refer to Table 4-12 to troubleshoot any errors.

Table 4-12: Serial Loopback Test error

Problem	Additional Information
Serial Loopback Test failed	1. Check null modem test cable. 2. Replace Serial Port Flex Circuit. 3. Replace GUI CPU PCB.

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Performance verification

Conduct the performance verification to check the performance of the *840* Ventilator System. Field performance verification testing includes electrical safety tests, the extended self test (EST), plus specific performance verification tests, using the Puritan Bennett *PTS 2000* Performance Test System with 840 VTS software. A manual ventilator check can be performed to check general ventilator performance.

NOTE:

Performance verification procedures do not apply to ventilator accessories. Refer to the specific accessory operator's or service manual for performance verification information. Malfunctioning accessories may affect some ventilator functions and may result in false test results.

5.1 Tools, test equipment, and service materials

In addition to the standard set of tools listed in Section 1 of this manual, the test equipment and materials listed in Table 5-1 are required for performance verification procedures. Specific parts required for conducting the performance verification, using the *PTS 2000* Performance Test System with BreathLab® 840 Ventilator Test Software (VTS), are indicated with "X" in the third column.

5.2 When to run

Run the entire performance verification after servicing or repairing the ventilator. The left-hand column of Table 5-2 lists the types of service activity that require performance verification. In addition, run the electrical safety tests, which are part of the performance verification, in accordance with your hospital's requirements.

Table 5-1: Tools, equipment, and service materials required for performance verification

Description	Manufacturer/model or Puritan Bennett part number	Required for *PTS 2000* use?
Pentium 166 Mhz computer, equipped, at a minimum, with the following: • 32 MB RAM (64 MB for NT systems) • 800x600 screen display resolution with 256 colors • Two available serial ports • Windows® 95, 98, 2000, XP or NT 4.0 operating system • Mouse or equivalent pointer device • 2x or higher CD-ROM drive • 1 Gigabyte available hard disk space • One available TCP/IP network port with BNC connector (if software download desired)	Local supplier	X
840 VTS (Ventilator Test Software)	4-075359-00 and current revision Software Download CD-ROM	X
EtherLink III 3C589C LAN PC card for 10BASE-T or later revision, or equivalent card		Software Download only
EtherLink III 3C589C Combo Cable for EtherLink III PC Card or equivalent		Software Download only
840 Software Download Cable (BNC to BNC)	4-075731 or Local Supplier	Software Download only
840 Software Download Box	4-075497-00	Software Download only
Adapter, patient pressure (“T” connector)	*4-011521-00	X
Cable, trigger	*4-075360-00	X
Cable, null modem	*4-075361-00	X
Connector, barbed	*4-000845-00	X
Coupling, barbed connector (quantity = 2)	*4-003443-00	X
Digital multimeter (DMM) accurate to 3 decimal places, with test leads	Fluke Model 87 or equivalent	
Disinfectant/cleaner	See Table 1-5 for acceptable products.	
Double banana jack for ground isolation test	Pomona Electronics, P/N 1330-2	

* These parts may be purchased individually or by ordering an 840 VTS Accessories Kit, P/N 4-076599-00.

Table 5-1: Tools, equipment, and service materials required for performance verification (continued)

Description	Manufacturer/model or Puritan Bennett part number	Required for *PTS 2000* use?
Electrical safety analyzer capable of measuring ground resistance and leakage current	Dale Model 600, Dale Technology Inc., P.O. Box 196, 401 Claremont Ave., Thornwood, NY 10594 USA, 800.544.3253 http://www.daletech.com/ or equivalent	
Exhalation port text hose assembly	*4-076704-00	X
Filter, inspiratory, *Re/Flex* (for use on *PTS 2000* port)	4-074600-00	X
Finger cots or gloves	Local supplier	
Fitting, Luer, bulkhead	*4-012470-00	
Gold standard tube [flex tube, 21.0 in. (53.4 cm)] (quantity = 2)	*4-018506-00	X
Hose, regulator calibration	*4-079050-00 (quick disconnect) 4-079051-00 (female)	X (4-079050-00 only)
Luer fitting, female	Local supplier	X
Patient circuit, adult (reusable, without water traps or heated wire) (quantity = 2)	*N-4401008	X
Patient circuit, pediatric (reusable, without traps or heated wire)	G-061223-00	
Patient circuit, neonatal (disposable)	Allegiance Healthcare PN 7441-452	
Mounting plate, NeoMode	4-076405-00	
Filter, expiratory bacteria filter	DAR 351P19005	
Filter, expiratory bacteria filter, reusable (Re/X800)	4-070305-00	X
Pneumatic calibration analyzer or equivalent devices capable of measuring oxygen percent, flow, BTPS volume, pressure, and barometric pressure. Oxygen analyzer connector tee. Required accuracies: • Flow: 2.75% of reading ±0.05 slpm • Volume: 2% of reading or ±1 digit • Low pressure (-150 to +150 cmH_2O): 0.75% of reading ±0.04 cmH_2O • High pressure (0 to 150 psig): 1.0% of reading ±0.1 psi • Oxygen percentage: ±2% oxygen • Barometric pressure: Range: 10 to 16 psia; resolution: 0.0 to 1 psia; operating temperature: 10 to 40 °C; measurement accuracy: ±0.75 of reading; response: ≤ 100 ms	Puritan Bennett *PTS 2000* Performance Test System (4-074686-00) (includes accessory kit with serial cable) for performance verification; or equivalent device for manual ventilator check	X (also requires 840 VTS software)
Serial Card, Socket I/O Ruggedized or equivalent (Provides second serial port)	Socket Communications Corp. Newark, CA http://www.socketcom.com/	

* These parts may be purchased individually or by ordering an 840 VTS Accessories Kit, P/N 4-076599-00.

Table 5-1: Tools, equipment, and service materials required for performance verification (continued)

Description	Manufacturer/model or Puritan Bennett part number	Required for *PTS 2000* use?
Resistor for ground isolation test, 1K ± 1%	Allied Electronics, P/N 697-3356 or equivalent	
Static-dissipative field service kit (includes wrist strap, static dissipative mat, and earth (ground) cord)	4-018149-00	
Stoppers, no. 1, 5, and 5.5 (with center bore and luer fitting: 4-071856-00)	Local supplier	X
Stopper, no. 1 (quantity = 1)	*4-009523-00	
Stopper, no. 5	*4-076828-00	X
Stopper, no. 5.5 with center bore and Fitting, luer, bulkhead	4-076467-00 4-012470-00	
Test lung, 0.5 L	4-000612-00	X
Test lung, 3 L	N-3800006	X
Test lung, 4 L	4-075578-00	X
Tubing, silicone, 3/16 in. ID x 5/16 in. OD, 36 in. (91.4 cm)	4-008577-00	X
Tubing, silicone, 1/8 in. ID x 1/4 in. OD, 4.75 in. (12.1 cm)	*4-008578-00	X
Vacuum cleaner, ESD-safe, with 0.2 µm filter (rated for photocopiers and laser printers)	Local supplier	
Wye, patient circuit	*4-000338-00	X

* These parts may be purchased individually or by ordering an 840 VTS Accessories Kit, P/N 4-076599-00.

5.3 Preliminary ventilator cleaning and inspection

Clean and inspect the ventilator as follows:

Warning

To prevent disease transmission, use personal protective equipment when handling contaminated bacterial filters or other patient accessories. Refer to the *840 Ventilator System Operator's and Technical Reference Manual* for instructions on sterilizing patient system parts.

Caution

Do not soak any portion of the ventilator in solvent, alcohol, or any other cleaning agent. Soaking ventilator components may damage the ventilator.

1. Clean ventilator exterior using an approved cleaner/disinfectant.
2. Remove any water from humidifier jar and collector vial; dry. Reattach collector vial.
3. Inspect air and external water trap assemblies. Clean or replace as required.
4. Visually inspect ventilator exterior for obvious problems such as missing or broken parts; loose assemblies; or disconnected wires, connectors, or tubing. Repair as needed.

5.4 Preliminary ventilator setup

NOTE:
A humidification device is not necessary for performance verification, but is required for completion of SST.

Set up the ventilator for performance verification as follows:

1. Install expiratory filter and collector vial.
2. Connect ventilator to air and oxygen sources (35 to 100 psi).
3. Connect ventilator power cord to ac power source.
4. Make sure BPS is securely attached and connected.
5. If ventilator is equipped with optional compressor, verify all electrical and pneumatic connections with BDU.

5.5 Preliminary calibrations and tests

Before running the performance verification tests, perform the applicable calibrations and tests in Table 5-2. The numbers in the columns indicate the sequence in which the calibrations/tests **must** be performed.

Table 5-2: Pre-performance verification testing and calibration requirements

Type of service / Test or calibration	Ventilator warm-up cycle[1]	Software Download	Flow sensor calibration	Expiratory valve calibration	Atmospheric pressure transducer calibration	Extended self test (EST)	Vent inop test	Short self test (SST)	Oxygen sensor (OS) calibration	Performance verification testing (PVT)
Ventilator installation	1	--	2	3	4	5	6	7	8	9[2]
Software update or software option installation	1	2	3	4	5	6	7	8	9	--[3]
10,000-hour preventive maintenance (ventilator or compressor)	1	--	2	3	4	5	6	7	8	9
Oxygen sensor								2	1	
PSOL1, PSOL2, flow sensors, expiratory valve, safety valve, SOL1, SOL2, AI PCB, inspiratory electronics PCB, exhalation transducer PCB, regulators', power supply, BPS PCB, battery pack, alarms, motherboard, all blindmate cables, BDU and GUI LED PCBs, touchframe PCB, LCD panels, backlight inverters, keyboard, knob	1	--	2	3	4	5	6	7	8	9
Compressor 15,000 hour preventative maintenance						1				2[4]
Compressor, compressor PCB, keyboard assembly, LED panel, VGA controller PCB, backlight inverter PCB	--	--	--	--	--	1	--	--	--	--
BD CPU PCB or GUI CPU PCB replacement	1	2	3	4	5	6	7	8	9	10
6 month ventilator check	1	--	--	--	--	2	--	--	--	--
Yearly ventilator check	1	--	2	3	4	5	6	7	8	--

1. Warm-up **must** be done in the service mode.
2. Perform the electrical safety test only.
3. Performance verification testing (PVT) is *not* required for simple software updates, provided **all** of the following conditions exist:
   The ventilator passes the Extended Self Test *before* the software is updated.
   The reason for service is software update or software option installation *only*.
   There are no events or entries in the ventilator's diagnostic logs that indicate a need for hardware repair.
   No functional hardware repairs are conducted or required during the software update service call.
   Unless the ventilator meets *all* of these requirements, PVT **must** be performed following the repair.
4. Perform EST and electrical safety testing only.

5.6 Performance verification guidelines

NOTE:

To ensure that the ventilator performs within specifications, Puritan Bennett recommends that you use the Puritan Bennett *PTS 2000* Performance Test System in conjunction with the BreathLab 840 Verification Test Software. If this equipment is not available, you can use an alternative test that checks some parameters but does not guarantee the integrity of the entire system. Refer to Table 5-3 to determine the approximate test limits if you use equipment other than the *PTS 2000* Performance Test System.

To ensure systematic performance verification and logical fault diagnosis, perform tests in the order given. Follow these general guidelines when running the performance verification:

Warning

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

- If a problem is encountered during the performance verification, verify that procedures have been correctly followed before attempting to repair the ventilator.
- Do not change the control settings during performance verification procedures, unless specifically instructed.
- Malfunctions detected during performance verification must be corrected before the unit is returned to service. Refer to Section 8 for required repairs. When repairs are completed, repeat the performance verification tests.

5.7 Performance verification tests

Run the following performance verification tests in the sequence given. *Before performing these tests, be sure you have cleaned and inspected the ventilator (Section 5.3).*

Warning

Do not enter the service mode while a patient or other person is connected to the ventilator. To do so may cause patient injury or death. While in the service mode, normal ventilator operation is not accessible.

NOTE:

The procedures that follow do *not* verify the performance of accessories. Verify the performance of accessories using the appropriate procedures in the applicable operator's or service manual.

5.7.1 Electrical safety test

The electrical safety test verifies ground continuity and verifies that forward leakage current are within safe limits. Perform this test whenever the ventilator is serviced and in accordance with hospital requirements.

Warning

If the ventilator fails an electrical safety test, do not proceed to the next electrical safety test until the problem is corrected and the ventilator is retested.

Caution

To prevent possible equipment damage, do not attempt to perform HI-POT testing on the ventilator. The ventilator design incorporates high-voltage protective devices that may be damaged if HI-POT testing is performed on the entire system. The ventilator is HI-POT-tested during manufacturing, using processes that do not damage the protective devices.

NOTE:

- After servicing the ventilator, perform an electrical safety test before putting the unit back into operation.
- Before performing the electrical safety test, make sure the compressor unit (if installed) and all accessories are connected and operational.

1. Verify that ventilator power switch is off.
2. Verify that ground resistance is < 0.1 Ω.
3. Turn on ventilator.
4. If ventilator has a compressor unit installed, disconnect external air supply from ventilator and verify that pressure from hose has been relieved.
5. Verify that compressor unit (if applicable) is running. Failure to do so will produce an inaccurate total leakage current reading.
6. Verify that forward-current and reverse-current leakage to earth ground is ≤ 300 µA (100 – 120 V ac) or ≤ 500 µA (220 – 240 V ac).
7. Turn off ventilator.
8. Reattach external air supply, if applicable.

5.7.2 Ground isolation check

This check verifies that the digital ground has not been disrupted. It requires a DMM, test leads, and a 1K resistor placed in parallel between the leads.

1. With the ventilator power cord disconnected from ac and the ventilator turned off:
   a. Set the DMM to the 1Ω setting and VERIFY that resistance between pin 3 of *PTS 2000* tester port (on the AI PCB) and ventilator chassis (at the power supply cooling fins) is > 975Ω.
2. With the ventilator power cord connected to ac and the ventilator turned on:
   a. Set the DMM to the ac setting and verify the reading is < 100 mV ac.
   b. Set the DMM to the dc setting and verify the reading is < 100 mV dc.
3. Turn the ventilator off and disconnect the test leads.

5.7.3 Extended self test (EST)

NOTE:
- A test (gold standard) patient circuit and a no. 1 stopper are required to perform EST.
- The nurse's call circuit is tested during EST and may be bypassed by selecting the CLEAR button.
- If the ventilator has not reached operating temperature from recent usage, allow it to warm up for at least 10 minutes in service mode before running EST, to ensure accurate testing.

1 Enter service mode. (Refer to Section 3.2 for instructions.)

2 On lower screen, select *EST*, and follow prompts to being testing.

The test currently running is highlighted, and any measurement data is displayed on the upper screen. (This information may also be viewed later by pressing the individual test button to repopulate the upper screen with the data parameters.) All lower and upper screen select buttons and the EST subscreen *TEST SELECT* buttons are hidden. The date/time and outcome are shown only for tests that have already run.

NOTE:

During testing, it is sometimes necessary for the user to perform test-related tasks, such as disconnecting a gas supply or blocking the *To Patient* port. For each such step, messages are displayed in the prompt area.

3 Verify that EST completes all test with a PASS result. Performance verification is not complete if any EST test results in an ALERT, OVERRIDE, or FAILURE. If a test fails, refer to Section 8 for repair information.

5.7.4 Regulator setting verification

Caution

To prevent damage to ESD-sensitive components, always follow ESD guidelines when performing this procedure.

NOTE:

Regulator performance must be verified each time performance verification or a manual ventilator check is performed. Use the appropriate type of regulator calibration hose (see Table 5-1).

1 Remove inspiratory cover from BDU.

2 Attach appropriate regulator calibration hose to pneumatic analyzer, and verify that analyzer does not register pressure.

3 Remove air side test port cover and set aside. Attach hose to test port. Verify that analyzer reads 10.5 ± 1.5 psi.

4 Remove hose from test port, and verify that analyzer does not register pressure. Replace test port cover.

5 Repeat steps 3 and 4 for oxygen side.

NOTE:

If regulators are out of specification, refer to Section 8 for service and repair of the inspiratory module.

5.7.5 Serial loopback test (10.4-inch GUI only)

A serial loop back test can be accessed through the service mode other screen function. This test is only required when performing PVT on a 10.4-inch GUI.

1 Connect a null modem cable between the two top serial ports.

2 Follow the on-screen test prompts.

5.7.6 Performance verification using *PTS 2000* Performance Test System and BreathLab 840 VTS software

1 Assemble test equipment indicated in Table 5-1. (Software installation instructions are provided with BreathLab 840 VTS Software.)

2 Turn on computer, and bring up the VTS program.

3 Turn ventilator on, and bring up in service mode.

4 Using ventilator test program, press START TEST to begin test application.

5 Follow prompts displayed on computer screen to complete performance verification. Access the 840 VTS Software Help Screen for additional information.

5.7.7 Manual ventilator check using equipment other than *PTS 2000* Performance Test System

NOTE:

- To ensure proper ventilator performance, Puritan Bennett recommends that you use the Puritan Bennett *PTS 2000* Performance Test System along with the BreathLab 840 VTS software.
- If you are using a pneumatic analyzer other than the *PTS 2000* Performance Test System, you must also have an oxygen analyzer available.
- The manual ventilator check (i.e., without PTS 2000 PTS and 840 VTS software) **does not** satisfy the manufacturer's performance testing requirements. The manual ventilator check can be used as a general indicator of ventilator condition.

1 Before beginning your ventilator check, perform these alarm tests:

a. Verify that remote alarm (nurse's call) relay is functional by invoking an alarm and verifying that your nurse's call system registers appropriate alarm.

b. Verify that the BDU annunciates the "loss of GUI" alarm when GUI is disconnected.

c. Verify that low-, medium-, and high-urgency alarms sound by creating an alarmed event for each of these. Refer to *Operator's and Technical Reference Manual* for assistance.

2 Measure ventilator parameters, and verify that they meet specifications in Table 5-3.

NOTE:

To accurately measure the parameters listed in Table 5-3, add the tolerance of your measurement device to the target value of the ventilator. The test results you obtain are approximate and may not guarantee the accuracy of the ventilator.

Table 5-3: Manual ventilator check target values

Ventilation parameter	Range	Accuracy
Volume[1]	25 to 2500 ml 5 to 315 ml[2]	±10 ml +10% of setting ± 4 mL + 10% of setting for neonatal circuits
Pressure control	5 to 90 cmH_2O	±3 +4% of setting[3]
Pressure support	5 to 70 cmH_2O	±3 +4% of setting[2]
Breath rate	1 to 100 breaths/min	±0.5 breaths/min
Oxygen concentration	21 to 100% O_2	±3%
PEEP	0 to 45 cmH_2O	±2 +4% of setting[4]
Spirometry	0 to 6000 ml	±10 ml +10% of reading
Inspiratory/expiratory pressure	-20 to 100 cmH_2O	±2 + 4% of reading
BPS	10 to 30 min[5]	Verified during EST

1. Compliance- and BTPS-compensated where T_E = time to exhale 90% of exhaled volume
2. When equipped with NeoMode software and accessories
3. End inspiratory pressure at patient wye after 1 second
4. PEEP measured at patient wye with return flow less than 5 L/min
5. These values are for a new fully charged battery. Actual duration depends on ventilation parameters, battery age, and level of battery charge.

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SECTION

6 Diagnostic codes

6.1 Introduction

This section contains information to assist in the interpretation of diagnostics codes, indicated in the ventilator's error and status logs, as well as diagnostic codes reported by the diagnostic LED arrays on the BD CPU PCB and the GUI CPU PCB.

The ventilator's diagnostic and status logs also contain other information that can be useful when troubleshooting the ventilator. The logs are:

- **System Diagnostic Log: S**tores data on unexpected conditions detected during POST, background checks, and calibrations. This includes alerts and failures.
- **System Information Log:** Stores data on ventilator events, including details on GUI/BD communication.
- **EST/SST Diagnostic Log:** Stores data on unexpected conditions detected during SST and EST, along with overall results at completion of SST and EST.

You access these logs through the service mode, as described in Section 4.2.2.

6.2 Reference Tables

This section contains the following reference tables:

6.3 Troubleshooting

The table of diagnostic codes (Table 6-2) lists repair and replacement actions that are sequenced to correct the most probable malfunction or to present the most efficient corrective action first. (The proposed fixes listed, however, may not always correct the particular problem.)

Also, keep the following in mind when troubleshooting the ventilator:

- Verify secure connections of cables and ventilator modules.
- If possible, run full EST, bypassing any failures or faults that may occur, to further diagnose a problem.
- Replace BD or GUI CPU PCB only after all other remedies have been attempted. Contact Puritan-Bennett Technical Support for further assistance.
- Check for system leaks, particularly at the expiratory filter. Make sure the expiratory filter collector vial is secured tightly, the drain port is capped, and the filter is mounted securely to the ventilator. Make sure the test circuit is securely attached.
- Before running SST or EST, ensure that the unit has been warmed up for at least 10 minutes in ambient temperature. Failure to warm up the ventilator may result in false flow sensor or pressure transducer failures.
- When troubleshooting SST or EST, always use a known good patient circuit or gold standard circuit and filter(s).

6.4 POST fault handling

During POST (or a background check), either the BD or the GUI processor uses its corresponding CPU LED array to display a unique test code for each self test as it executes. If POST is running in a no-fault state, the LED array(s) display discrete and changing LED patterns.

NOTE:

The alphanumeric diagnostic code for each of the self tests is not identified in this manual. This information is not necessary for field service repairs.

If the system detects a fault during POST (or a background check), each of the four pairs of LEDs in the corresponding LED array will light, in sequence, creating a flashing effect. The same LED array then displays the diagnostic code corresponding to the detected fault. This LED pattern of display—flashing LED pairs followed by a diagnostic code—cycles continuously and is a visual indicator of a system fault. Use the tables in this section to convert the diagnostic code LED pattern to an alphanumeric diagnostic code.

Additionally, under a fault condition, the processor of the corresponding CPU PCB attempts to log the fault information, with a time-stamp, in its nonvolatile random access memory (NOVRAM). Upon completion of its POST, each processor reports its test results to the GUI processor for display and transfer into the System Diagnostics Log.

POST failures are classified as minor or major faults:

Minor POST fault is a fault that does not affect ventilation or patient safety checks. A minor fault does not interrupt the regular POST sequence. The GUI displays POST fault information and logs it into NOVRAM of the corresponding CPU PCB. The System Diagnostic Log displays an alert. Normal ventilation will begin if POST detects a minor fault.

Major POST fault is a fault that affects ventilation or patient safety checks. A major fault interrupts the regular sequence of POST and causes a VENT INOP condition. Fault information is sent to the GUI (if possible) and to the LED array on the corresponding CPU PCB (BD or GUI). The safety valve and exhalation valve remain open to allow the patient to breathe room air. The software does not permit normal ventilation while a major fault exists. To clear a major fault, both CPU processors must complete their respective POST, with no major POST faults. If only a minor fault exists, normal ventilation will begin.

6.5 Diagnostic CPU LED arrays

The diagnostic LED arrays, resident on the BD and GUI CPU PCBs, report diagnostic codes for background check and POST self test faults that may assist in troubleshooting the 840 ventilator.

To view the BD diagnostic LED array, you must disconnect the GUI cable from the BDU and remove the BDU exhalation module cover (Section 8.15.9.2). The BD LED array is visible on the outside edge of the BD CPU PCB. (See Figure 6-1 below.)

The GUI CPU diagnostic LED array is visible directly through the clear window on the rear panel of the newer style 10.4-inch GUI. The earlier 9.4-inch GUI requires removal of the GUI rear panel to view its CPU PCB diagnostic LED array. (See Section 8.14.6 for removal of the 9.4-inch rear cover.)

The pattern of the eight LEDs (lit and unlit) in each LED array represents a diagnostic code. Always read the LED arrays from top to bottom. You will notice that there are ten, rather than eight LEDs present on the 10.4-inch GUI LED array. Ignore the top-most and the bottom-most LEDs and use the eight LEDs in between to determine the diagnostic code.

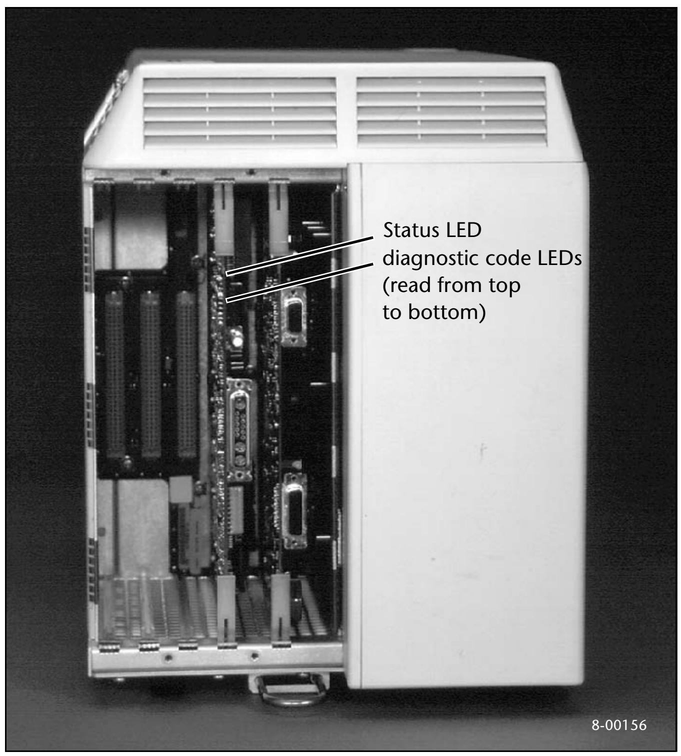


Figure 6-1. Location of BD LED array

6.6 Diagnostic codes

When a fault occurs, the software, records a six-digit alphanumeric diagnostic code in the System Diagnostic Log, if possible.

Diagnostic codes for some of the POST kernal test faults cannot be displayed by the GUI and are reported only by the diagnostic LED array on the applicable CPU PCB. The system is unable to record these particular faults in the System Diagnostic Log.

6.6.1 How to interpret diagnostic codes

The first letter of a diagnostic code in the System Diagnostic Log identifies the module (BD or GUI) where the fault was detected and whether it was minor or major. First letters in a diagnostic code of L and K denote BD CPU minor and major faults, respectively, while the letters Z and X denote GUI CPU minor and major faults.

The second letter in the six-digit code indicates where the fault occurred in the software. The last four diagnostic code characters can provide additional error code information.

XXXS below outlines the possible values of certain digits in the alphanumeric diagnostic code and provides top-level interpretations.

a b cccc

- cccc — Error identifier
- b — Diagnostic type
- a — Reportability classification

Table 6-1: Values of diagnostic code digits

where:	may be...	which means...
a	A	Alert (during SST/EST)
	D or H	BDU problem that resulted in soft reset during operation (as opposed to during POST)
	E	BDU user event (not an error)
	F	Failure (during SST/EST)
	G	BDU illegal instruction trap, watchdog reset, or illegal address trap that resulted in BDU soft reset
	J	BDU watchdog umpire (3 “strikes” in 24 hours) caused Safety Valve Open (SVO)
	K	BDU failure (during POST or background check) caused SVO
	L	POST or background check alert or communication error in BDU
	S	GUI user event
	U or V	GUI problem that resulted in soft reset during operation
	X	GUI failure (during POST or background check) caused GUI or ventilator inoperative condition
	Z	POST or background check alert or communication error in GUI

Table 6-1: Values of diagnostic code digits

where:	may be...	which means...
b	B	Background check
	C	Communications test
	E	EST
	N	Nonmaskable interrupt
	P	POST or initialization software
	S	SST
	T	Hardware-detected failure (trap)
	Y	GUI watchdog umpire (3 “strikes” in 24 hours) causes GUI inoperative condition
	(None)	Soft fault (assertion)
cccc	(Varies)	Other error identification information

6.7 Organization of diagnostic codes table

Table 6-2 is a comprehensive summary of the diagnostic codes that the *840* software can report. The organization of the information in this table is as follows:

- The first column lists, in alphanumeric order, the codes.
- The second column lists the accompanying message.
- The third column lists the part of software that was running when the error was detected.
- The fourth column lists the ventilator’s response to the condition, as follows:

ALERT
Test result not ideal, but not critical.

In POST: POST continues to end and ventilation starts. A DEVICE ALERT alarm is annunciated (Section 7).

In SST/EST: SST/EST continues to end. You can override the alert and start ventilation.

In a background check: Ventilation continues, and a DEVICE ALERT alarm is annunciated.

FAILURE
Critical problem detected.

In POST: Ventilator inoperative condition is declared.

In SST/EST: You can continue trying to pass SST or EST, but if test does not pass, ventilator inoperative condition is declared.In a background check: Ventilator inoperative condition is declared.

BDU RESET
Circuitry in the BDU is reset, which causes BDU POST to be rerun. If POST passes, ventilation continues. If POST fails, it generates an alert or failure.

GUI RESET
Circuitry in the GUI is reset, which causes GUI POST to be rerun. If POST passes, GUI operation resumes. If GUI POST does not pass, it declares a GUI inop condition.

VENT INOP
Ventilator is put into SVO state, permitting patient to breathe room air.

ALERT	Test result not ideal, but not critical. In POST: POST continues to end and ventilation starts. A DEVICE ALERT alarm is annunciated (Section 7). In SST/EST: SST/EST continues to end. You can override the alert and start ventilation. In a background check: Ventilation continues, and a DEVICE ALERT alarm is annunciated.
FAILURE	Critical problem detected. In POST: Ventilator inoperative condition is declared. In SST/EST: You can continue trying to pass SST or EST, but if test does not pass, ventilator inoperative condition is declared.In a background check: Ventilator inoperative condition is declared.
GUI INOP	The BDU alarms, ventilator settings are locked, and a message is displayed.
STATUS	Code/message listed for information only; requires no action.

- The fifth column provides additional information and/or identifies possible causes.
- The sixth column suggests how to correct the condition. These actions are sequenced to correct the most probable malfunction or to present the most efficient corrective action first. The proposed fixes listed, however, may not always correct the particular problem.

In addition to the actions suggested in the tables in this section, keep the following in mind when troubleshooting the ventilator:

- Verify secure connections of cables and ventilator modules.
- If possible, run full EST, bypassing any failures or faults that may occur, to further diagnose a problem.
- Replace BD or GUI CPU PCB only after all other remedies have been attempted. Contact Puritan-Bennett Technical Support for further assistance.
- Check for system leaks, particularly at the expiratory filter. Make sure the expiratory filter collector vial is secured tightly, the drain port is capped, and the filter is mounted securely to the ventilator. Make sure the test circuit is securely attached.
- Before running SST or EST, ensure that the unit has been warmed up for at least 10 minutes in ambient temperature. Failure to warm up the ventilator may result in false flow sensor or pressure transducer failures.

When troubleshooting SST or EST, always use a known good patient circuit or gold standard circuit and filter(s).

Table 6-2: *840* Ventilator diagnostic codes

Code	Message displayed	Test	Response	Information / Possible cause	Corrective action
AE0110	Unable to establish O_2 flow	EST Flow sensors cross check Test	Alert	Flow controller unable to establish and control oxygen flow at 120 L/min.	1. Make sure oxygen supply is connected and unrestricted. 2. Verify oxygen regulator pressure is set between 9-12 psi. 3. Switch PSOLs to see if failure transfers to the other gas side. If yes, return the air PSOL to its original position and replace the oxygen PSOL. 4. Run the leak test in EST to check for leaks/occlusions. 5. Perform a flow sensor calibration. 6. Replace Q1. 7. Replace the Inspiratory Electronics PCB. 8. Replace the AI PCB.
AE0111	Unable to establish air flow	EST Flow sensors cross check Test	Alert	Flow controller unable to establish and control air flow at 120 L/min.	1. Make sure air supply is connected and unrestricted. 2. Verify air regulator pressure is set between 9-12 psi. 3. Switch PSOL's to see if failure transfers to the other gas side. If yes, return Oxygen PSOL to its original position and replace the Air PSOL. 4. Run the leak test in EST to check for leaks/occlusions. 5. Perform a flow sensor calibration. 6. Replace Q2. 7. Replace the Inspiratory Electronics PCB. 8. Replace the AI PCB.
AE0213	Air PSOL leak	EST Gas Supply/SV Test	Alert	Air PSOL (PSOL2) forward leak was detected via excessive pressure buildup ($>$ 50 cmH_2O but $<$ 100 cmH_2O) in blocked inspiratory module.	1. Check for leaks around the Q2 O-rings. 2. Make sure air supply is connected and unrestricted. 3. Reseat Air PSOL. 4. Replace Air PSOL. 5. Replace AI PCB.
AE0214	O_2 PSOL leak	EST Gas Supply/SV Test	Alert	Oxygen PSOL (PSOL1) forward leak was detected via excessive pressure buildup ($>$ 50 cmH_2O but $<$ 100 cmH_2O) in blocked inspiratory module.	1. Check for leaks around the Q1 O-rings. 2. Make sure oxygen supply is connected and unrestricted. 3. Reseat oxygen PSOL. 4. Replace oxygen PSOL. 5. Replace AI PCB.

Table 6-2: *840* Ventilator diagnostic codes (continued)

Code	Message displayed	Test	Response	Information / Possible cause	Corrective action
AE0306	Test circuit not connected	EST Leak Test	Alert	Pressure not detected on expiratory side	1. Make sure test circuit is properly connected. 2. Replace expiratory bacteria filter. 3. Check for leaks around the Q3 flow sensor. 4. Check/replace the exhalation valve. 5. Replace the expiratory pressure transducer PCB.
AE0601	GUI High Alarm LED fails.	EST GUI Lamp Test	Alert	CLEAR key pressed to indicate LED not on.	1. Check/replace interconnect cable between the GUI LED PCB and the GUI CPU PCB. 2. Replace the GUI LED PCB.
AE0602	GUI Medium Alarm LED fails.	EST GUI Lamp Test	Alert	CLEAR key pressed to indicate LED not on.	1. Check/replace interconnect cable between the GUI LED PCB and the GUI CPU PCB. 2. Replace the GUI LED PCB.
AE0603	GUI Low Alarm LED fails.	EST GUI Lamp Test	Alert	CLEAR key pressed to indicate LED not on.	1. Check/replace interconnect cable between the GUI LED PCB and the GUI CPU PCB. 2. Replace the GUI LED PCB.
AE0604	GUI Normal LED fails.	EST GUI Lamp Test	Alert	CLEAR key pressed to indicate LED not on.	1. Check/replace interconnect cable between the GUI LED PCB and the GUI CPU PCB. 2. Replace the GUI LED PCB.
AE0605	GUI Batt Backup LED fails.	EST GUI Lamp Test	Alert	CLEAR key pressed to indicate LED not on.	1. Check/replace interconnect cable between the GUI LED PCB and the GUI CPU PCB 2. Replace the GUI LED PCB.
AE0606	GUI On Batt Pwr LED fails.	EST GUI Lamp Test	Alert	CLEAR key pressed to indicate LED not on.	1. Check/replace interconnect cable between the GUI LED PCB and the GUI CPU PCB. 2. Replace the GUI LED PCB.
AE0607	GUI Compressor Ready LED fails.	EST GUI Lamp Test	Alert	CLEAR key pressed to indicate LED not on.	1. Check/replace interconnect cable between the GUI LED PCB and the GUI CPU PCB. 2. Replace the GUI LED PCB.
AE0608	GUI Compressor Operating LED fails.	EST GUI Lamp Test	Alert	CLEAR key pressed to indicate LED not on.	1. Check/replace interconnect cable between the GUI LED PCB and the GUI CPU PCB. 2. Replace the GUI LED PCB.
AE0609	GUI 100% O_2 LED fails.	EST GUI Lamp Test	Alert	CLEAR key pressed to indicate LED not on.	1. Check/replace interconnect cable between the GUI LED PCB and the GUI CPU PCB. 2. Replace keyboard.
AE0610	GUI Alarm Silence LED fails.	EST GUI Lamp Test	Alert	CLEAR key pressed to indicate LED not on.	1. Check/replace interconnect cable between the GUI LED PCB and the GUI CPU PCB. 2. Replace the GUI LED PCB.

Table 6-2: *840* Ventilator diagnostic codes (continued)

Code	Message displayed	Test	Response	Information / Possible cause	Corrective action
AE0611	GUI Screen Lock LED fails.	EST GUI Lamp Test	Alert	CLEAR key pressed to indicate LED not on.	1. Check/replace interconnect cable between the GUI LED PCB and the GUI CPU PCB. 2. Replace the GUI LED PCB.
AE0702	Bad Vent inop LED	EST BD Lamp Test	Alert	CLEAR key pressed to indicate one or both ventilator inoperative LEDs not on.	Replace BD LED PCB.
AE0703	Bad SVO LED	EST BD Lamp Test	Alert	CLEAR key pressed to indicate one or both SVO LEDs not on.	Replace BDU LED PCB.
AE0704	Bad Loss of GUI LED	EST BD Lamp Test	Alert	CLEAR key pressed to indicate loss of GUI LED not on.	Replace BDU LED PCB.
AE1001	Air PSOL loopback current OOR	EST PSOL Loopback Test	Alert	Air PSOL (PSOL2) loopback current out of range of drive current.	1. Verify that the air supply is good. 2. Verify air regulator pressure set to between 9 and 12 psi. 3. Switch PSOLs to see if failure transfers to the other gas side. If yes, return oxygen PSOL (PSOL1) to its original position and replace PSOL2. 4. Switch Q1 and Q2, run a flow sensor calibration and rerun test. If the problem transfers to the other gas side, return Q1 to its original position and replace Q2. 5. Replace the AI PCB. 6. Replace the Inspiratory Electronics PCB.
AE1002	O_2 PSOL loopback current OOR	EST PSOL Loopback Test	Alert	Oxygen PSOL (PSOL1) loopback current out of range of drive current.	1. Verify that the oxygen supply is good. 2. Verify oxygen regulator pressure set to between 9 and 12 psi. 3. Switch PSOLs to see if failure transfers to the other gas side. If yes, return the air PSOL to its original position and replace PSOL1. 4. Switch Q1 and Q2, run a flow sensor calibration and rerun test. If the problem transfers to the other gas side, return Q2 to its original position and replace Q1. 5. Replace the AI PCB. 6. Replace the Inspiratory Electronics PCB.

Table 6-2: *840* Ventilator diagnostic codes (continued)

Code	Message displayed	Test	Response	Information / Possible cause	Corrective action
AE1104	Insp check valve test failed	EST Safety System Test	Alert	It took too little time to relieve excess pressure through open safety valve, indicating inspiratory check valve (CV3) may be damaged or incorrectly mounted.	1. Make sure test circuit is connected. 2. Make sure CV3 is not installed backward. 3. Replace CV3.
AE1201	Exp valve loopback current OOR	EST Exp Valve Loopback Test	Alert	Exhalation valve loopback current is out of range of drive current.	1. Verify that the system has no leaks or occlusions by running the leak test in EST. 2. Clean exhalation valve diaphragm. 3. Calibrate the exhalation valve. 4. Clean/replace the exhalation valve. 5. Replace the AI PCB.
AE1305	Seal test failed	EST Exp Valve Seal Test	Alert	Seal test Δ pressure is above alert level but below failure level.	1. Verify that the system has no leaks or occlusions by running the leak test in EST. 2. Clean the exhalation valve. 3. Calibrate exhalation valve. 4. Replace the exhalation valve. 5. Replace the AI PCB.
AE1600	Compressor Test - Not installed	EST Compressor Test	Status	Ventilator did not sense a compressor attached and skipped test.	No action required.
AE1601	Wall air pressure detected	EST Compressor Test	Alert	Wall air pressure switch (PS2) detected air after user was prompted to disconnect air.	1. Make sure air supply is disconnected. 2. Disconnect PS2 and rerun test. If test passes, replace PS2.
AE1602	ac power not connected	EST Compressor Test	Alert	System is still running on battery power after prompting user to connect ac power. Compressor can only run on ac (facility) power.	1. Plug in ventilator power cord and check the cord connection at the ventilator. 2. Check ac. 3. Disconnect BPS to isolate problem. 4. Replace power supply.
AE1603	Compressor pressure not detected	EST Compressor Test	Alert	Compressor pressure transducer (PC) indicates that compressor air is not present, although compressor motor is on.	1. Run compressor leak test to check for leaks. a. Use leak detector to check for leaks at the accumulator fittings and other tubing connections. b. Verify no leaks at CV2 within the ventilator by plugging the air inlet fitting. 2. Replace compressor PCB. 3. Contact Puritan-Bennett Technical Support.

Table 6-2: *840* Ventilator diagnostic codes (continued)

Code	Message displayed	Test	Response	Information / Possible cause	Corrective action
AE1604	Run mode time OOR	EST Compressor Test	Alert	Compressor timer is not running while compressor motor is on.	Listen for motor. If motor is on, replace compressor PCB. Otherwise, replace compressor.
AE1606	Compressor pressure detected	EST Compressor Test	Alert	Compressor pressure transducer (PC) indicates that compressor air is present after compressor motor is disabled and accumulator drained.	Replace compressor PCB.
AE1607	Disabled mode time OOR	EST Compressor Test	Alert	Compressor timer is running while compressor motor is off.	Replace compressor PCB.
AE1608	Unable to test standby mode	EST Compressor Test	Alert	Compressor standby mode check cannot be run, because of inability to verify timer functionality during compressor run and disabled tests.	1. Troubleshoot code AE1604 or AE1607, if present. 2. Replace compressor PCB.
AE1609	Standby mode time OOR	EST Compressor Test	Alert	Compressor motor is still running. During standby mode test phase, compressor motor should eventually turn off.	Replace compressor PCB.
AE1610	Unable to perform compressor load test	EST Compressor Test	Alert	Compressor load test cannot be run, because of inability to verify PC during compressor run and disabled tests.	Troubleshoot code AE1603 or AE1606.
AE1611	Compressor load test failed	EST Compressor Test	Alert	Compressor unable to maintain minimum pressure under worst-case breath delivery waveform.	1. Run compressor leak test to check for compressor leak. a. Use leak detector to check for leaks at the accumulator fittings and other tubing connections. b. Verify no leaks at CV2 within the ventilator by plugging the air inlet fitting. 2. Replace compressor. 3. Replace compressor PCB.
AE1700	Compressor Leak Test - Not installed	EST Compressor Leak Test	Status	Ventilator did not sense a compressor attached and skipped test.	No action required.

Table 6-2: *840* Ventilator diagnostic codes (continued)

Code	Message displayed	Test	Response	Information / Possible cause	Corrective action
AE1701	Unable to perform compressor leak test	EST Compressor Leak Test	Alert	Compressor leak test cannot be run, because of inability to verify timer functionality.	1. Troubleshoot accompanying code AE1604 or AE1607. 2. Replace compressor PCB.
AE1702	Wall air pressure detected	EST Compressor Leak Test	Alert	Wall air pressure switch (PS2) detected air presence after user was prompted to disconnect air.	1. Make sure air supply is disconnected. 2. Disconnect PS2 and rerun test. If test passes, replace PS2.
AE1703	Wall air pressure not detected	EST Compressor Leak Test	Alert	Wall air pressure switch (PS2) did not detect air presence after user was prompted to connect air.	1. Make sure air supply is connected. 2. Run Gas Supply/SV Test.
AE1704	Compressor leak detected	EST Compressor Leak Test	Alert	Compressor leak was detected using compressor timer to detect compressor turning on momentarily during test.	Troubleshoot compressor compartment or inspiratory module for leaks.
AE1901	GUI touch: Error	EST GUI Touch Test	Alert	Touch screen error occurred (e.g., blocked beam or low-level error), buffer cannot be read, or report is invalid.	1. Clean touch screen, removing any obstructions. 2. Replace touch frame PCB. 3. Replace GUI CPU PCB.
AE2001	Bad GUI serial port	EST GUI Serial Port Test	Alert	While in loopback mode, failed to verify received message was identical to transmitted message.	Replace GUI CPU PCB.
AE2101	Battery not charged	EST Battery Test	Alert	BPS not fully charged at start of test.	1. Allow BPS to fully charge, then repeat test. 2. Replace BPS PCB. 3. Replace battery pack. 4. Replace BD CPU PCB.
AE2102	Battery not discharging	EST Battery Test	Alert	BPS not discharging after ac power was disconnected.	1. Verify ac power is disconnected when prompted. 2. Replace BPS PCB. 3. Replace battery pack. 4. Replace BD CPU PCB.

Table 6-2: *840* Ventilator diagnostic codes (continued)

Code	Message displayed	Test	Response	Information / Possible cause	Corrective action
AE2103	Bad Backup Power Supply	EST Battery Test	Alert	While BPS was discharging, BPS voltage dropped below accepted level or dropped too quickly.	1. Ensure that the battery pack is fully charged by checking that the green LED on the BPS is lit prior to initiating an EST. If the amber LED is lit, allow the unit to charge the batteries prior to rerunning EST. 2. Replace the battery pack. 3. Replace the BPS PCB. 4. Replace the AI PCB. 5. Replace the power supply.
AE2104	Battery not charging	EST Battery Test	Alert	BPS not charging after ac power was reconnected.	1. Verify that ac power is reconnected when prompted and that ac is good. 2. Replace BPS PCB. 3. Replace the battery pack. 4. Replace the power supply. 5. Replace the BD CPU. 6. Replace the AI PCB.
AE2300	GUI Nurse Call Test - Not installed	EST Test	Status	User pressed CLEAR to indicate nurse's call device not installed. Test was skipped.	No action required.

Table 6-2: *840* Ventilator diagnostic codes (continued)

Code	Message displayed	Test	Response	Information / Possible cause	Corrective action
AS0010	Unable to establish O_2 flow	SST flow sensor test	Alert	Flow controller unable to establish and control oxygen flow at 120 L/min.	1. Make sure oxygen supply is connected and unrestricted. 2. Verify that the oxygen supply meets minimum pressure requirements. 3. Verify that the patient circuit system has no leaks or occlusions. If not sure, run the first four tests in EST to get to the leak test. If the leak test passes in EST, exit out of EST. Correct the leak or occlusion in the patient circuit used in SST and rerun or try another patient circuit. 4. Check the oxygen inlet filter assembly. 5. Verify that the oxygen regulator pressure is set between 9-12 psi. 6. Run a flow sensor calibration. 7. Switch Q1 and Q2. Rerun the flow sensor calibration and EST. If the failure transfers to the air side, return Q2 back to its original position and replace Q1. 8. Switch PSOLs to see if the failure transfers to the air side. If yes, return PSOL2 back to its original position and replace PSOL1.

Table 6-2: *840* Ventilator diagnostic codes (continued)

Code	Message displayed	Test	Response	Information / Possible cause	Corrective action
AS0011	Unable to establish air flow	SST flow sensor test	Alert	1. Flow controller unable to establish and control air flow at 120 L/min.	1. Make sure air supply is connected and unrestricted. 2. Verify that the air supply meets minimum pressure requirements. 3. Verify that the patient circuit system has no leaks or occlusions. If not sure, run the first four tests in EST to get to the leak test. If the leak test passes in EST, exit out of EST. Correct the leak or occlusion in the patient circuit used in SST and rerun or try another patient circuit. 4. Check the air inlet filter (F2). 5. Verify that the air regulator pressure is set between 9-12 psi. 6. Run a flow sensor calibration. 7. Switch Q1 and Q2. Rerun the flow sensor calibration and EST. If the failure transfers to the oxygen side, return Q1 back to its original position and replace Q2. 8. Switch PSOLs to see if the failure transfers to the oxygen side. If yes, return PSOL1 back to its original position and replace PSOL2.
AS0012	O_2 pressure not detected	SST flow sensor test	Alert	Oxygen pressure not detected via PS1. Only air available for SST.	Make sure oxygen supply is connected.
AS0013	Wall air pressure not detected	SST flow sensor test	Alert	Air pressure not detected via PS2 or PC. Only oxygen available for SST.	Make sure air supply is connected.
AS0202	Excessive leak	SST Circuit leak	Alert	Pressure drops to 85 cmH_2O in 10 s, then in 10 s more by $\geq$ 10 cmH_2O.	1. Make sure patient circuit is connected and is not leaking. 2. Check exhalation valve operation. 3. Verify connections of bacteria filters and humidifier are secure.
AS0305	Occluded expiratory filter	SST Expiratory filter	Alert	Pressure drop across filter > 2 cmH_2O, but < 3 cmH_2O.	Consider replacing expiratory filter.
AS0308	Occluded expiratory compartment	SST Expiratory filter	Alert	Exhalation compartment pressure > 3 cmH_2O but < 4 cmH_2O.	1. Check compartment for obstruction. 2. Verify exhalation valve operation by running EST.

Table 6-2: *840* Ventilator diagnostic codes (continued)

Code	Message displayed	Test	Response	Information / Possible cause	Corrective action
AS0311	Low expiratory filter ΔP	SST Expiratory filter	Alert	Pressure drop across expiratory filter < 0.4 cmH_2O, but > 0.1 cmH_2O.	1. Repeat test, following directions more closely. 2. Replace filter.
AS0403	Occluded inspiratory limb	SST Circuit Resistance	Alert	Inspiratory limb pressure > 8.5 cmH_2O (adult) or 5.5 cmH_2O (pediatric), but < 12.5 cmH_2O (adult) or 7.5 cmH_2O (pediatric), indicating occlusion.	Check for occluded patient tubing.
AS0406	Occluded exhalation limb	SST Circuit Resistance	Alert	Expiratory limb pressure > 8.5 cmH_2O (adult) or 5.5 cmH_2O (pediatric) but > 12.5 cmH_2O (adult) or 7.5 cmH_2O (pediatric), indicating occlusion.	Check for occluded patient tubing.
AS0407	Unable to reach min peak flow	SST Circuit Resistance	Alert	During characterization of total circuit resistance over a range of flows, peak flow < 80 L/min but > 60 L/min.	Check for kinked or occluded patient tubing.
AS0411	Unable to reach min peak flow	SST Circuit Resistance	Alert	During characterization of total circuit resistance over a range of flows, peak flow was less than alert threshold.	Check for kinked or occluded patient tubing.
AS0413	Insp limb resistance low	SST Circuit Resistance	Alert	Inspiratory limb pressure < 0.6 cmH_2O (adult) or 5.5 cmH_2O (pediatric), but > 0.2 cmH_2O.	1. Make sure inspiratory filter is installed. 2. Repeat test, following directions more closely. 3. Replace inspiratory filter. 4. Replace patient circuit.
AS0414	Exp limb resistance low	SST Circuit Resistance	Alert	Expiratory limb pressure < 0.6 cmH_2O (adult) or 0.5 cmH_2O (pediatric), but > 0.2 cmH_2O.	Replace patient circuit.
AS0505	Excessive compliance	SST Compliance calibration	Alert	High compliance >6 mL/cmH_2O (adult) or 4.5 mL/cmH_2O (pediatric), but <12 mL/cmH_2O (adult) or 9 mL/cmH_2O (pediatric).	1. Make sure correct patient tubing type was specified in SST. 2. Replace patient circuit.

Table 6-2: *840* Ventilator diagnostic codes (continued)

Code	Message displayed	Test	Response	Information / Possible cause	Corrective action
AS0507	Compliance low	SST Compliance calibration	Alert	High compliance falls below 1.56 mL/cmH_2O (adult) or 1.34 mL/cmH_2O (pediatric) but not lower than 1.05 mL/cmH_2O.	1. Make sure correct patient tubing type was specified in SST. 2. Replace patient circuit with a known good circuit and filter set. 3. Run EST to check the operation of PI and PE during the Circuit Pressure Test. Replace applicable pressure transducer. 4. Run Atmospheric Pressure Transducer calibration.
AS0509	Excessive compliance	SST Compliance calibration	Alert	Low compliance > 6 mL/cmH_2O (adult) or 4.5 mL/cmH_2O (pediatric), but < 12 mL/cmH_2O (adult) or 9 mL/cmH_2O (pediatric).	1. Make sure correct patient tubing type was specified in SST. 2. Replace patient circuit with a known good circuit and filter set. 3. Run EST to check the operation of PI and PE during the Circuit Pressure Test. Replace applicable pressure transducer. 4. Run Atmospheric Pressure Transducer calibration.
AS0511	Compliance low	SST Compliance calibration	Alert	Low compliance falls below 1.56 mL/cmH_2O (adult) or 1.34 mL/cmH_2O (pediatric), but not below 1.05 mL/cmH_2O.	1. Make sure correct patient tubing type was specified in SST. 2. Replace patient circuit with a known good circuit and filter set. 3. Run EST to check the operation of PI and PE during the Circuit Pressure Test. Replace applicable pressure transducer. 4. Run Atmospheric Pressure Transducer calibration.
Dxxxxx	Assertion	Background Checks (BD)	Failure that results in a POST or a reset	System generated a reset to correct a boundary check or possible data corruption of control variables.	Replace the BDCPU PCB.
DT0002	Bus error / Access fault	Background Checks (BD)	Failure that results in a POST or a reset	Hardware trap from an access fault due to a bad memory chip, bad control line, or a hardware timing issue.	Replace the BD CPU PCB.
Exxxxx	Varies	Background Checks (GUI)	Status	A status message indicating an event that was intentionally caused.	

Table 6-2: *840* Ventilator diagnostic codes (continued)

Code	Message displayed	Test	Response	Information / Possible cause	Corrective action
NOTE: For all "FE" codes (failures reported during EST), diagnose the problem and perform the repair. Run a complete EST to reset the EST test failure in memory. If there is a failed EST test result in memory, normal operation is prevented until the failed EST test is rerun and passes.					
FE0001	Inspiratory autozero out of range	EST Circuit Pressure Test	Failure	Inspiratory pressure transducer ADC count at 0 cmH_2O is out of range.	1. Replace SOL1. 2. Replace Inspiratory Electronics PCB. 3. Replace AI PCB.
FE0002	Expiratory autozero out of range	EST Circuit Pressure Test	Failure	Exhalation pressure sensor ADC count at 0 cmH_2O is out of range.	1. Replace SOL2. 2. Replace exhalation transducer PCB. 3. Replace AI PCB.
FE0003	Failed to reach test pressure	EST Circuit Pressure Test	Failure	Unable to build pressure (air) to 10 cmH_2O at 5 L/min within time-out period.	1. Make sure that test circuit is installed and air supply or compressor is available and good. 2. Verify that the air regulator pressure is set between 9-12 psi. 3. Verify that the patient circuit system has no leaks or occlusions by running the first four tests in EST to get to the leak test.
FE0004	Cross-check failed	EST Circuit Pressure Test	Failure	Inspiratory/expiratory pressure transducer readings at 10 cmH_2O test pressure are too far apart.	1. Verify that the system has no leaks or occlusions. If not sure, run the first four tests in EST to run the leak test 2. If the leak test passes in EST, exit out of EST. Review the data for the Circuit Pressure Test to determine which pressure transducer is out of range: PI or PE. Replace applicable pressure transducer. 3. Replace AI PCB.
FE0005	Bad insp autozero solenoid	EST Circuit Pressure Test	Failure	Inspiratory pressure reading (taken after inspiratory pressure transducer autozero solenoid (SOL1) actuated) out of range (-0.60 to 0.60 cmH_2O).	1. Replace SOL1. 2. Replace Inspiratory Electronics PCB. 3. Replace AI PCB.
FE0006	Bad exp autozero sol	EST Circuit Pressure Test	Failure	Expiratory pressure reading (taken after expiratory pressure transducer autozero solenoid (SOL2) actuated) out of range (-0.60 to 0.60 cmH_2O).	1. Replace SOL2. 2. Replace exhalation transducer PCB. 3. Replace AI PCB.

Table 6-2: *840* Ventilator diagnostic codes (continued)

Code	Message displayed	Test	Response	Information / Possible cause	Corrective action
FE0007	Cross-check failed	EST Circuit Pressure Test	Failure	Inspiratory/expiratory pressure transducer measurements at 50 or 100 cmH_2O test pressure are too far apart.	1. Replace the expiratory bacteria filter. 2. Verify that the system has no leaks or occlusions. If not sure, run the first four tests in EST to run the leak test. 3. If the leak test passes in EST, exit out of EST. Review the data for the Circuit Pressure Test to determine which pressure transducer is out of range: PI or PE. Replace applicable pressure transducer. 4. Replace AI PCB.
FE0008	Failed to reach test pressure	EST Circuit Pressure Test	Failure	Unable to build pressure (air) to 50 or 100 cmH_2O at 5 L/min within time-out period.	1. Make sure air supply or compressor is available. 2. Check for system leak at the expiratory bacteria filter or O2 sensor. If not sure, run the first four tests in EST to run the leak test.
FE0010	ac power not connected	EST Circuit Pressure Test	Failure	System is still running on battery power after prompting user to connect ac power. EST can only run on ac (facility) power.	1. Plug in ventilator power cord. 2. Disconnect BPS to isolate problem. 3. Replace power supply.
FE0101	O_2 flow sensor cross check failed	EST Flow sensors cross check Test	Failure	Oxygen flow sensor (Q1) cross-check failed.	1. Make sure oxygen supply is connected and unrestricted. 2. Verify that the oxygen supply is good. 3. Verify that the system has no leaks or occlusions. If not sure, run the first four tests in EST to run the leak test. 4. Run a flow sensor calibration.6. Switch Q1 and Q2. Rerun the flow sensor calibration and EST. If the failure transfers to the air side, return Q2 back to its original position and replace Q1. 5. Switch PSOLs to see if the failure transfers to the air side. If yes, return PSOL2 back to its original position and replace PSOL1. 6. Replace exhalation flow sensor (Q3) 7. Replace AI PCB.

Table 6-2: *840* Ventilator diagnostic codes (continued)

Code	Message displayed	Test	Response	Information / Possible cause	Corrective action
FE0102	O_2 PSOL current out of range	EST Flow sensors cross check Test	Failure	Oxygen PSOL (PSOL1) current is out of range with respect to flow sensor (Q1).	1. Make sure oxygen supply is connected and unrestricted. 2. Verify that the oxygen supply is good. 3. Verify that the system has no leaks or occlusions. If not sure, run the first four tests in EST to run the leak test. 4. Switch PSOLs to see if the failure transfers to the air side. If yes, return PSOL2 back to its original position and replace PSOL1. 5. Run a flow sensor calibration. 6. Switch Q1 and Q2. Rerun the flow sensor calibration and EST. If the failure transfers to the air side, return Q2 back to its original position and replace Q1.
FE0103	Air flow sensor cross check failed	EST Flow sensors cross check Test	Failure	Inspiratory module air flow sensor (Q2) cross-check failed.	1. Make sure air supply is connected and unrestricted. 2. Verify that the air supply is good. 3. Verify that the system has no leaks or occlusions. If not sure, run the first four tests in EST to run the leak test. 4. Run a flow sensor calibration. 5. Switch Q1 and Q2. Rerun the flow sensor calibration and EST. If the failure transfers to the oxygen side, return Q1 back to its original position and replace Q2. 6. Switch PSOLs to see if the failure transfers to the air side. If yes, return PSOL back to its original position and replace PSOL2 7. Replace exhalation flow sensor (Q3). 8. Replace AI PCB.

Table 6-2: *840* Ventilator diagnostic codes (continued)

Code	Message displayed	Test	Response	Information / Possible cause	Corrective action
FE0104	Air PSOL current out of range	EST Flow sensors cross check Test	Failure	Air PSOL (PSOL2) current is out of range with respect to air flow sensor (Q2).	1. Make sure air supply is connected and unrestricted. 2. Verify that the air supply is good. 3. Verify that the system has no leaks or occlusions. If not sure, run the first four tests in EST to run the leak test. 4. Switch PSOLs to see if the failure transfers to the air side. If yes, return PSOL back to its original position and replace PSOL2 5. Run a flow sensor calibration. 6. Switch Q1 and Q2. Rerun the flow sensor calibration and EST. If the failure transfers to the oxygen side, return Q1 back to its original position and replace Q2.
FE0106	Unable to establish O_2 flow	EST Flow sensors cross check Test	Failure	Flow controller unable to establish and control oxygen flow at 60, 5, and 1 L/min.	1. Make sure oxygen supply is connected. 2. Check regulated oxygen pressure. 3. Replace PSOL1 or Q1. 4. Replace AI PCB.
FE0107	Unable to establish air flow	EST Flow sensors cross check Test	Failure	Flow controller unable to establish and control air flow at 60, 5, and 1 L/min.	1. Make sure air supply is connected. 2. Check regulated air pressure. 3. Perform flow sensor calibration. 4. Replace PSOL2 or Q2. 5. Replace AI PCB.
FE0108	O_2 zero flow check failed	EST Flow sensors cross check Test	Failure	Inspiratory flow > 0.153 L/min with oxygen PSOL (PSOL1) commanded to 0 (closed).	1. Verify no leaks at the Q1 O-rings. 2. Run EST Gas Supply Test to check for PSOL1 leak. Remove and then reseat PSOL1 3. Replace PSOL1. 4. Perform a flow sensor calibration. 5. Replace Q1.
FE0109	Air zero flow check failed	EST Flow sensors cross check Test	Failure	Inspiratory flow > 0.153 L/min with air PSOL (PSOL2) commanded to 0 (closed).	1. Verify no leaks at the Q2 O-rings. 2. Run EST Gas Supply Test to check for PSOL2 leak. Remove and then reseat PSOL2 3. Replace PSOL2. 4. Perform a flow sensor calibration. 5. Replace Q2.

Table 6-2: *840* Ventilator diagnostic codes (continued)

Code	Message displayed	Test	Response	Information / Possible cause	Corrective action
FE0204	Wall air pressure not detected	EST Gas Supply/SV Test	Failure	Wall air not detected initially and wall air still not detected after user was prompted to connect wall air.	1. Make sure air supply is connected. 2. Check PS2: Remove the wiring connectors from PS2 and jumper the connectors to each other. If the system now recognizes the air supply, replace PS2.
FE0205	O_2 pressure not detected	EST Gas Supply/SV Test	Failure	Oxygen pressure not detected initially and oxygen pressure still not detected after user was prompted to connect oxygen.	1. Make sure oxygen supply is connected. 2. Check PS1: Remove the wiring connectors from PS1 and jumper the connectors to each other. If the system now recognizes the air supply, replace PS1.
FE0206	O_2 pressure detected (O_2 not disconnected)	EST Gas Supply/SV Test	Failure	Oxygen pressure switch detected presence of oxygen after user was prompted to disconnect oxygen.	1. Make sure oxygen supply is disconnected. 2. Replace Inspiratory Electronics PCB. 3. Replace PS1.
FE0207	Air PSOL leak	EST Gas Supply/SV Test	Failure	Air PSOL (PSOL2) forward leak was detected via excessive pressure buildup (> 100 cmH_2O) in blocked inspiratory module.	1. Check for leaks around the Q2 O-rings. 2. Verify that the safety valve relieves pressures above 100 cmH_2O. Listen for the pressure relief while watching the numeric digital display of system pressure in the upper screen. If the safety valve does not crack open, replace the safety valve. 3. Replace PSOL2.
FE0208	Wall air pressure detected	EST Gas Supply/SV Test	Failure	Wall air pressure switch (PS2) detected wall air after user was prompted to disconnect it.	1. Make sure air supply is disconnected. 2. Replace Inspiratory Electronics PCB. 3. Replace PS2.
FE0209	O_2 PSOL leak	EST Gas Supply/SV Test	Failure	Oxygen PSOL (PSOL1) forward leak was detected via excessive pressure buildup (> 100 cmH_2O) in blocked inspiratory module.	1. Check for leaks around the Q1 O-rings. 2. Verify that the safety valve relieves pressures above 100 cmH_2O. Listen for the pressure relief while watching the numeric digital display of system pressure in the upper screen. If the safety valve does not crack open, replace the safety valve. 3. Replace PSOL1.

Table 6-2: *840* Ventilator diagnostic codes (continued)

Code	Message displayed	Test	Response	Information / Possible cause	Corrective action
FE0210	SV pressure relief failed	EST Gas Supply/SV Test	Failure	Safety valve cracking pressure and/or peak steady-state pressure is out of range.	1. Make sure *To patient* port is blocked. 2. Check for leaks at the O_2 sensor, SOL1 or PI. 3. Replace the safety valve. 4. Replace PI.
FE0211	O_2 pressure not detected	EST Gas Supply/SV Test	Failure	PS1 did not detect oxygen after user was prompted to connect it.	1. Make sure oxygen supply is connected. 2. Replace Inspiratory Electronics PCB.
FE0212	Compressor pressure detected	EST Gas Supply/SV Test	Failure	Compressor pressure transducer (PC) detected that compressor was pressurized.	Replace compressor PCB.
FE0215	Air zero flow check failed	EST Gas Supply/SV Test	Failure	During zero-flow check, air flow sensor (Q2) reads > 0.05 L/min.	1. Make sure gas supplies are disconnected. 2. Make sure compressor is not running. 3. Verify no leaks at the Q2 O-rings. 4. Check for PSOL2 leak. 5. Remove and then reseat PSOL2. 6. Perform a flow sensor calibration. 7. Replace PSOL2. 8. Replace Q2.
FE0216	O_2 zero flow check failed	EST Gas Supply/SV Test	Failure	During zero-flow check, oxygen flow sensor (Q1) reads > 0.05 L/min.	1. Make sure gas supplies are disconnected. 2. Make sure compressor is not running. 3. Verify no leaks at the Q2 O-rings. 4. Check for PSOL2 leak. 5. Remove and then reseat PSOL2. 6. Perform a flow sensor calibration. 7. Replace PSOL2. 8. Replace Q2.
FE0217	Exp zero flow check failed	EST Gas Supply/SV Test	Failure	During zero-flow check, exhalation flow sensor (Q3) reads > 0.1 L/min.	1. Make sure gas supplies are disconnected. 2. Make sure compressor is not running. 3. Verify no leaks at the Q3 O-rings. 4. Perform a flow sensor calibration. 5. Replace Q3.

Table 6-2: *840* Ventilator diagnostic codes (continued)

Code	Message displayed	Test	Response	Information / Possible cause	Corrective action
FE0301	Excessive leak	EST Leak Test	Failure	System pressure dropped below failure pressure level.	1. Make sure test circuit is connected and is not leaking. 2. Check for system leaks or occlusions especially at the O2 sensor and expiratory filter. 3. Verify secure connection of expiratory filter. 4. Check exhalation valve operation.
FE0305	Unable to establish pressure	EST Leak Test	Failure	System cannot attain leak test starting pressure using oxygen or air within time-out period.	1. Make sure test circuit is connected and is not leaking. 2. Check exhalation valve operation, and verify secure connection of expiratory filter.
FE0401	Accept key fails.	EST GUI Keyboard Test	Failure	Wrong key pressed or key not pressed within 15 s.	1. Repeat test. 2. Replace keyboard.
FE0402	Clear key fails.	EST GUI Keyboard Test	Failure	Wrong key pressed or key not pressed within 15 s.	1. Repeat test. 2. Replace keyboard.
FE0403	Insp. Pause key fails.	EST GUI Keyboard Test	Failure	Wrong key pressed or key not pressed within 15 s.	1. Repeat test. 2. Replace keyboard.
FE0404	Exp. Pause key fails.	EST GUI Keyboard Test	Failure	Wrong key pressed or key not pressed within 15 s.	1. Repeat test. 2. Replace keyboard.
FE0405	Man Insp fails.	EST GUI Keyboard Test	Failure	Wrong key pressed or key not pressed within 15 s.	1. Repeat test. 2. Replace keyboard.
FE0406	100% O_2/CAL key fails.	EST GUI Keyboard Test	Failure	Wrong key pressed or key not pressed within 15 s.	1. Repeat test. 2. Replace keyboard.
FE0407	Info key fails.	EST GUI Keyboard Test	Failure	Wrong key pressed or key not pressed within 15 s.	1. Repeat test. 2. Replace keyboard.
FE0408	Alarm Reset key fails.	EST GUI Keyboard Test	Failure	Wrong key pressed or key not pressed within 15 s.	1. Repeat test. 2. Replace keyboard.
FE0409	Alarm Silence key fails.	EST GUI Keyboard Test	Failure	Wrong key pressed or key not pressed within 15 s.	1. Repeat test. 2. Replace keyboard.
FE0410	Alarm Volume key fails.	EST GUI Keyboard Test	Failure	Wrong key pressed or key not pressed within 15 s.	1. Repeat test. 2. Replace keyboard.
FE0411	Screen brightness fails.	EST GUI Keyboard Test	Failure	Wrong key pressed or key not pressed within 15 s.	1. Repeat test. 2. Replace keyboard.

Table 6-2: *840* Ventilator diagnostic codes (continued)

Code	Message displayed	Test	Response	Information / Possible cause	Corrective action
FE0412	Screen contrast key fails.	EST GUI Keyboard Test	Failure	Wrong key pressed or key not pressed within 15 s.	1. Repeat test. 2. Replace keyboard.
FE0413	Screen lock key fails.	EST GUI Keyboard Test	Failure	Wrong key pressed or key not pressed within 15 s.	1. Repeat test. 2. Replace keyboard.
FE0501	Bad knob	EST GUI Knob Test	Failure	Knob was not turned in direction as prompted within 15 s.	1. Repeat test. 2. Replace keyboard.
FE0801	SAAS *(Safety Audible Alarm System)* test failed	EST GUI Audio Test	Failure	CLEAR key pressed to indicate GUI audio diagnostic failed.	1. Verify the GUI alarm cable connection to the GUI CPU PCB. 2. Replace GUI alarm assembly. 3. Replace GUI CPU PCB.
FE0901	Bad alarm cable	EST BDU Audio Test	Failure	Alarm cable voltage is out of range (< 3.5 or > 5.05 V).	1. Make sure BD alarm cable is connected. 2. Replace BD alarm. 3. Replace AI PCB. 4. Replace BD alarm cable.
FE0902	Bad power fail cap	EST BDU Audio Test	Failure	Power failure capacitor initial voltage is out of range (< 4.5 or > 5.05 V).	1. Make sure BD alarm cable is connected. 2. Replace BD alarm. 3. Replace AI PCB. 4. Replace BD alarm cable. 5. Replace Motherboard PCB.
FE0903	Bad power fail cap	EST BDU Audio Test	Failure	Power failure capacitor final voltage is out of range or RC constant < 60 s.	1. Make sure BD alarm cable is connected. 2. Replace BD alarm. 3. Replace AI PCB.
FE0904	Bad BD audio	EST BDU Audio Test	Failure	CLEAR key pressed to indicate user did not hear alarm, although alarm was active.	1. Make sure BD alarm cable is connected. 2. Replace BD alarm. 3. Replace AI PCB. 4. Replace BD alarm cable.
FE1101	Safety valve occluded	EST Safety System Test	Failure	Excessive safety valve back pressure when safety valve is open.	Replace safety valve.
FE1102	Bad safety valve driver or loopback	EST Safety System Test	Failure	Safety valve loopback current is out of range during one or more of timed test points.	1. Replace safety valve. 2. Replace AI PCB. 3. Replace Inspiratory Electronics PCB.
FE1103	Insp check valve test failed	EST Safety System Test	Failure	It took too long to relieve excess pressure through open safety valve, indicating inspiratory check valve (CV3) is occluded or test circuit is too large.	1. Make sure proper test circuit is used. 2. Make sure CV3 is not installed backward. 3. Replace CV3. 4. Replace Safety Valve (SV).

Table 6-2: *840* Ventilator diagnostic codes (continued)

Code	Message displayed	Test	Response	Information / Possible cause	Corrective action
FE1105	Unable to establish flow	EST Safety System Test	Failure	Flow controller unable to establish and control gas flow at 60 L/min.	1. Make sure air supply is connected and unrestricted. 2. Check air regulator pressure. 3. Run flow sensor calibration. 4. Switch PSOLs to see if test passes. If it does, return PSOL1 to its original position and replace PSOL2. 5. Replace Q2.
FE1301	Seal test failed	EST Exp Valve Seal Test	Failure	Seal test Δ pressure is above failure level.	1. Clean exhalation valve. 2. Calibrate exhalation valve. 3. Run flow sensor calibration. 4. Replace exhalation valve. 5. Replace AI PCB. 6. Replace PE.
FE1302	Exp valve temp OOR	EST Exp Valve Seal Test	Failure	Exhalation valve magnet temperature out of range (10 to 100^{o}C).	1. Ensure the unit has been warmed up at ambient temperature for at least 10 minutes. 2. Calibrate the exhalation valve (EV). 3. Replace exhalation valve (EV). 4. Replace AI PCB.
FE1303	Unable to establish exp flow	EST Exp Valve Seal Test	Failure	Flow controller unable to establish and control air flow measured by exhalation flow sensor (Q3).	1. Make sure proper test circuit it used and that there are no leaks or occlusions. 2. Make sure air supply is still connected. 3. Run flow sensor calibration. 4. Replace Q3. 5. Replace Q2. 6. Replace the exhalation valve.
FE1304	Exp valve not calibrated	EST Exp Valve Seal Test	Failure	Exhalation valve table checksum is not valid or last calibration performed was not completed successfully.	1. Check for leaks or occlusions. Correct and then run the exhalation valve calibration. 2. Replace the exhalation valve. 3. Replace the AI PCB. 4. Replace Q3. 5. Replace Q2.
FE1401	Bad calibration	EST Exp Valve Test	Failure	Measured system pressure at one or more test points is out of range.	1. Calibrate exhalation valve. 2. Replace exhalation valve. 3. Replace AI PCB. 4. Replace the Exhalation Pressure Transducer PCB.
FE1402	Exp valve not calibrated	EST Exp Valve Test	Failure	Exhalation valve table checksum is not valid or last calibration performed was not completed successfully.	1. Check for leaks or occlusions. Correct and then run the exhalation valve calibration. 2. Replace the exhalation valve. 3. Replace the AI PCB. 4. Replace Q3. 5. Replace Q2.

Table 6-2: *840* Ventilator diagnostic codes (continued)

Code	Message displayed	Test	Response	Information / Possible cause	Corrective action
FE1403	Unable to establish exp flow	EST Exp Valve Test	Failure	Flow controller unable to establish and control air flow measured by exhalation flow sensor (Q3).	1. Check for leaks or occlusions. Correct and then run the exhalation valve calibration. 2. Replace the exhalation valve. 3. Replace the AI PCB. 4. Replace Q3. 5. Replace Q2.
FE1501	Unable to establish air flow	EST Exp Heater Test	Failure	Flow controller unable to establish and control 60 L/min air flow.	1. Make sure air supply is connected and unrestricted. 2. Check air regulator pressure. 3. Run flow sensor calibration. 4. Switch PSOLs to see if test passes. If it does, return PSOL1 to its original position and replace PSOL2. 5. Replace Q2.
FE1502	Bad exp heater	EST Exp Heater Test	Failure	Exhalation heater temperature did not rise sufficiently when heater was turned on.	1. Replace exhalation heater. 2. Replace AI PCB. 3. Replace interconnect cable between exhalation compartment and motherboard.
FE1503	Bad exp heater	EST Exp Heater Test	Failure	Heater temperature did not drop sufficiently during an interval after heater was turned off.	1. Replace exhalation heater. 2. Replace AI PCB.
FE2201	Low exp ΔP	EV Velocity Transducer Test	Failure	Expiratory Δ P too low, indicating velocity transducer not responding properly.	1. Check for leaks or occlusions. Correct and then run the exhalation valve calibration. 2. Run flow sensor calibration. 3. Replace exhalation valve. 4. Replace Q3. 5. Replace Q2.
FE2301	Nurse call stuck on	EST GUI Nurse Call Test	Failure	CLEAR key pressed to indicate nurse's call (remote alarm) relay is stuck on when it should be off.	1. Make sure test equipment is connected properly to remote alarm port. 2. Replace GUI CPU PCB.
FE2302	Nurse call stuck off	EST GUI Nurse Call Test	Failure	CLEAR key pressed to indicate nurse's call (remote alarm) relay is stuck off when it should be on.	1. Make sure test equipment is connected properly to remote alarm port. 2. Replace GUI CPU PCB.

Table 6-2: *840* Ventilator diagnostic codes (continued)

Code	Message displayed	Test	Response	Information / Possible cause	Corrective action
NOTE: For all "FS" codes (failures reported during SST), if the corrective action indicated is to run an EST to further diagnose the problem, perform the repair after the EST, verify the fix in EST, and then rerun SST in order to enter normal ventilator operation. If there is a failed SST test result in memory, normal operation until is prevented until the failed SST test is rerun and passes.					
FS0001	O_2 flow sensor cross check failed	SST Flow Sensor Test	Failure	Oxygen flow sensor (Q1) cross-check failed.	1. Correct the leak or occlusion in the SST patient circuit and rerun or try known good patient circuit and filter set. 2. Verify that the ventilator system has no leaks or occlusions by running the first four tests in EST to run the leak test. a. If the leak test fails in EST, troubleshoot the expiratory filter or ventilator system for leaks or occlusions. b. If the leak test passes in EST, troubleshoot the SST patient circuit. 3. Run a flow sensor calibration. 4. Switch Q1 and Q2. Rerun the flow sensor calibration and EST. If the failure transfers to the air side, return Q2 back to its original position and replace Q1. 5. Replace Q3 6. Switch PSOLs to see if the failure transfers to the air side. If yes, return PSOL2 back to its original position and replace PSOL1.
FS0002	O_2 PSOL current out of range	SST Flow Sensor Test	Failure	Oxygen PSOL (PSOL1) command current is out of range with respect to oxygen flow sensor (Q1).	1. Make sure oxygen supply is connected and unrestricted. 2. Verify that the oxygen supply is good. 3. Verify that the system has no leaks or occlusions. If not sure, run the first four tests in EST to run the leak test. 4. Run a flow sensor calibration. 5. Switch Q1 and Q2. Rerun the flow sensor calibration and EST. If the failure transfers to the air side, return Q2 back to its original position and replace Q1. 6. Replace Q3. 7. Switch PSOLs to see if the failure transfers to the air side. If yes, return PSOL2 back to its original position and replace PSOL1.

Table 6-2: *840* Ventilator diagnostic codes (continued)

Code	Message displayed	Test	Response	Information / Possible cause	Corrective action
FS0003	Air flow sensor cross check failed	SST Flow Sensor Test	Failure	Air flow sensor (Q2) cross-check failed.	1. Correct the leak or occlusion in the SST patient circuit and rerun or try known good patient circuit and filter set. 2. Verify that the ventilator system has no leaks or occlusions by running the first four tests in EST to run the leak test. 3. If the leak test fails in EST, troubleshoot the expiratory filter or ventilator system for leaks or occlusions. 4. If the leak test passes in EST, troubleshoot the SST patient circuit. 5. Run a flow sensor calibration. 6. Switch Q1 and Q2. Rerun the flow sensor calibration and EST. If the failure transfers to the oxygen side, return Q1 back to its original position and replace Q2. 7. Replace Q3. 8. Switch PSOLs to see if the failure transfers to the oxygen side. If yes, return PSOL1 back to its original position and replace PSOL2.
FS0004	Air PSOL current out of range	SST Flow Sensor Test	Failure	Air PSOL (PSOL2) command current is out of range with respect to air flow sensor (Q2).	1. Make sure air supply is connected and unrestricted. 2. Verify that the air supply is good. 3. Verify that the system has no leaks or occlusions. If not sure, run the first four tests in EST to run the leak test. 4. Run a flow sensor calibration. 5. Switch Q1 and Q2. Rerun the flow sensor calibration and EST. If the failure transfers to the oxygen side, return Q1 back to its original position and replace Q2. 6. Replace Q3. 7. Switch PSOLs to see if the failure transfers to the oxygen side. If yes, return PSOL1 back to its original position and replace PSOL2.
FS0005	Gas not connected	SST Flow Sensor Test	Failure	No gas is available (neither PS1, PS2, nor PC detects pressure).	Connect gas supply.

Table 6-2: *840* Ventilator diagnostic codes (continued)

Code	Message displayed	Test	Response	Information / Possible cause	Corrective action
FS0006	Unable to establish O_2 flow	SST Flow Sensor Test	Failure	Flow controller unable to establish and control oxygen flow at 60, 5, and 1 L/min.	1. Make sure oxygen supply is connected and unrestricted. 2. Verify that the oxygen supply is good. 3. Check regulated oxygen pressure. 4. Verify that the system has no leaks or occlusions. If not sure, run the first four tests in EST to run the leak test. 5. Run a flow sensor calibration. 6. Switch Q1 and Q2. Rerun the flow sensor calibration and EST. If the failure transfers to the air side, return Q2 back to its original position and replace Q1. 7. Replace exhalation flow sensor (Q3). 8. Switch PSOLs to see if the failure transfers to the air side. If yes, return PSOL2 back to its original position and replace PSOL1.
FS0007	Unable to establish air flow	SST Flow Sensor Test	Failure	Flow controller unable to establish and control air flow at 60, 5, and 1 L/min.	1. Make sure air supply is connected unrestricted. 2. Verify that the air supply is adequate. 3. Check regulated air pressure. 4. Verify that the system has no leaks or occlusions. If not sure, run the first four tests in EST to run the leak test. 5. Run a flow sensor calibration. 6. Switch Q1 and Q2. Rerun the flow sensor calibration and EST. If the failure transfers to the oxygen side, return Q1 back to its original position and replace Q2. 7. Replace exhalation flow sensor (Q3). 8. Switch PSOLs to see if the failure transfers to the oxygen side. If yes, return PSOL1 back to its original position and replace PSOL2.

Table 6-2: *840* Ventilator diagnostic codes (continued)

Code	Message displayed	Test	Response	Information / Possible cause	Corrective action
FS0008	O_2 zero flow check failed	SST Flow Sensor Test	Failure	Inspiratory flow > 0.153 L/min with oxygen PSOL (PSOL1) commanded to 0 (closed).	1. Verify no leaks at the Q1 O-rings. 2. Run EST Gas Supply Test to check for PSOL1 leak. 3. Remove and then reseat PSOL1. 4. Replace PSOL1. 5. Perform a flow sensor calibration. 6. Replace Q1.
FS0009	Air zero flow check failed	SST Flow Sensor Test	Failure	Inspiratory flow > 0.153 L/min with air PSOL (PSOL2) commanded to 0 (closed).	1. Verify no leaks at the Q2 O-rings. 2. Run EST Gas Supply Test to check for PSOL2 leak. 3. Remove and then reseat PSOL2. 4. Replace PSOL2. 5. Perform a flow sensor calibration. 6. Replace Q2.
FS0101	Inspiratory autozero out of range	SST circuit pressure test	Failure	Inspiratory pressure transducer ADC count at 0 cmH_2O is out of range.	1. Replace Inspiratory Electronics PCB 2. Replace AI PCB.
FS0102	Expiratory autozero out of range	SST circuit pressure test	Failure	Expiratory pressure transducer ADC count at 0 cmH_2O is out of range.	1. Replace exhalation transducer PCB. 2. Replace AI PCB. 3. Replace SOL1.
FS0103	Failed to reach test pressure	SST circuit pressure test	Failure	Unable to build pressure (air) to 10 cmH_2O at 5 L/min within time-out period.	1. Verify that the patient circuit system has no leaks or occlusions or use a known good patient circuit and filter set. 2. Verify that the air supply or compressor is available and adequate. 3. Verify that the ventilator system has no leaks or occlusions. If not sure, run the first four tests in EST to run the leak test.

Table 6-2: *840* Ventilator diagnostic codes (continued)

Code	Message displayed	Test	Response	Information / Possible cause	Corrective action
FS0104	Cross-check failed	SST circuit pressure test	Failure	Inspiratory/expiratory pressure transducer readings at 10 cmH_20 test pressure are too far apart.	1. Verify that the patient circuit system has no leaks or occlusions or use a known good patient circuit and filter set. 2. Verify that the ventilator system has no leaks or occlusions. If not sure, run the first four tests in EST to run the leak test. 3. If the leak test passes in EST, exit out of EST. Review the data for the Circuit Pressure Test to determine which pressure transducer is out of range: PI or PE. Replace applicable pressure transducer. 4. Replace AI PCB.
FS0105	Bad insp autozero solenoid	SST circuit pressure test	Failure	Inspiratory pressure reading taken after actuating inspiratory pressure transducer autozero solenoid (SOL1) is out of range (-0.60 to 0.60 cmH_2O).	1. Replace SOL1. 2. Replace Inspiratory Electronics PCB. 3. Replace AI PCB.
FS0106	Bad exp autozero sol	SST circuit pressure test	Failure	Expiratory pressure reading taken after actuating expiratory transducer autozero solenoid (SOL2) is out of range (-0.60 to 0.60 cmH_2O).	1. Replace SOL2. 2. Replace exhalation transducer PCB. 3. Replace AI PCB.
FS0107	Cross-check failed	SST circuit pressure test	Failure	Inspiratory/expiratory pressure transducer readings at 50 or 100 cmH_2O test pressure are too far apart.	1. Replace the expiratory bacteria filter. 2. Verify that the system has no leaks or occlusions. If not sure, run the first four tests in EST to run the leak test. 3. If the leak test passes in EST, exit out of EST. Review the data for the EST Circuit Pressure Test to determine which pressure transducer is out of range: PI or PE. Replace applicable pressure transducer. 4. Replace AI PCB.
FS0108	Failed to reach test pressure	SST circuit pressure test	Failure	Unable to build pressure (air) to 50 or 100 cmH_2O at 5 L/min within time-out period.	1. Make sure air supply or compressor is available. 2. Check for system leak.

Table 6-2: *840* Ventilator diagnostic codes (continued)

Code	Message displayed	Test	Response	Information / Possible cause	Corrective action
FS0201	Excessive leak	SST Circuit leak	Failure	System pressure dropped below failure pressure level.	1. Make sure patient circuit is connected and is not leaking. 2. Check exhalation valve operation, and verify secure connections of bacteria filters, water traps, and humidifier.
FS0205	Unable to establish pressure	SST Circuit leak	Failure	Unable to attain leak test starting pressure within time-out period using oxygen or air.	1. Make sure patient circuit is connected and is not leaking. 2. Check exhalation valve operation, and verify secure connections of bacteria filters, water traps, and humidifier.
FS0301	Unable to establish flow	SST Expiratory filter	Failure	Flow controller unable to establish and control gas flow.	Make sure gas supply is still connected.
FS0303	Occluded expiratory compartment	SST Expiratory filter	Failure	Exhalation compartment pressure > 4 cmH_2O.	1. Check compartment for obstruction. 2. Verify exhalation valve operation by running EST.
FS0304	Occluded expiratory filter	SST Expiratory filter	Failure	Pressure drop across filter > 3 cmH_2O.	Replace expiratory filter.
FS0306	Patient circuit not disconnected	SST Expiratory filter	Failure	A test flow was used to verify that circuit was disconnected, and an expiratory flow was detected.	Make sure patient circuit is disconnected at expiratory filter.
FS0307	Patient circuit not reconnected	SST Expiratory filter	Failure	A test flow was used to verify that circuit was reconnected, and an expiratory flow was not detected.	Make sure patient circuit is connected at expiratory filter.
FS0310	Low expiratory filter ΔP	SST Expiratory filter	Failure	Pressure drop across expiratory filter < 0.1 cmH_2O.	1. Repeat test, following directions more closely. 2. Replace filter.
FS0401	Unable to establish flow	SST Circuit Resistance	Failure	Flow controller unable to establish and control gas flow.	Make sure gas supply is connected.
FS0402	Occluded inspiratory limb	SST Circuit Resistance	Failure	Inspiratory limb pressure > 12.5 cmH_2O (adult) or 7.5 cmH_2O (pediatric), indicating occlusion.	Check for occluded patient tubing.
FS0404	Unable to reach min peak flow	SST Circuit Resistance	Failure	During characterization of total circuit resistance over a range of flows, peak flow was less than failure threshold.	Check for kinked or occluded patient tubing.

Table 6-2: *840* Ventilator diagnostic codes (continued)

Code	Message displayed	Test	Response	Information / Possible cause	Corrective action
FS0405	Occluded exhalation limb	SST Circuit Resistance	Failure	Expiratory limb pressure > 12.5 cmH_2O (adult) or 7.5 cmH_2O (pediatric), indicating occlusion.	Check for occluded patient tubing.
FS0408	Insp limb resistance low	SST Circuit Resistance	Failure	Inspiratory limb pressure < 0.2 cmH_2O.	1. Make sure inspiratory filter is installed. 2. Repeat test, following directions more closely. 3. Replace inspiratory filter. 4. Replace patient circuit.
FS0409	Exp limb resistance low	SST Circuit Resistance	Failure	Expiratory limb pressure < 0.2 cmH_2O.	Replace patient circuit.
FS0410	Unable to reach min peak flow	SST Circuit Resistance	Failure	During characterization of total circuit resistance over a range of flows, peak flow was less than failure threshold.	Check for kinked or occluded patient tubing.
FS0412	Wye not blocked	SST Circuit Resistance	Failure	Unable to pressurize system within time-out period.	1. Block wye when prompted. 2. Check for circuit leaks.
FS0501	Unable to pressurize circuit	SST Compliance calibration	Failure	System cannot pressurize to one of the test pressure points.	Check patient circuit for leaks. Replace as necessary.
FS0502	Unable to pressurize circuit	SST Compliance calibration	Failure	System cannot pressurize to one of the test pressure points.	Check patient circuit for leaks. Replace as necessary.
FS0503	Compliance calculation failure	SST Compliance calibration	Failure	Out-of-range pressure ratio calculation.	1. Repeat test, making sure circuit is undisturbed during test. 2. Repeat SST to retest pressure transducers. 3. Run EST and verify all pneumatics tests pass.
FS0504	Excessive compliance	SST Compliance calibration	Failure	High compliance > 12 mL/cmH_2O (adult) or 9 mL/cmH_2O (pediatric).	1. Make sure correct patient tubing type was specified in SST. 2. Replace patient circuit.
FS0506	Compliance low	SST Compliance calibration	Failure	High compliance falls below 1.05 mL/cmH_2O	1. Make sure correct patient tubing type was specified in SST. 2. Replace patient circuit.
FS0508	Excessive compliance	SST Compliance calibration	Failure	Low compliance > 12 mL/cmH_2O (adult) or 9 mL/cmH_2O (pediatric).	1. Make sure correct patient tubing type was specified in SST. 2. Replace patient circuit.
FS0510	Compliance low	SST Compliance calibration	Failure	Low compliance falls below 1.05 mL/cmH_2O	1. Make sure correct patient tubing type was specified in SST. 2. Replace patient circuit.

Table 6-2: *840* Ventilator diagnostic codes (continued)

Code	Message displayed	Test	Response	Information / Possible cause	Corrective action
HN0001	Non-maskable interrupt (NMI): Dynamic random access memory (DRAM) Parity Error	Other (BDU)	BDU reset		Replace BD CPU PCB.
HN0002	NMI: Ethernet Parity Error	Other (BDU)	BDU reset		Replace BD CPU PCB.
HN0016	NMI: Analog Interface Error: analog to digital converter (ADC) Channel Sequencer Fault	Other (BDU)	BDU reset		1. Replace AI PCB. 2. Replace BD CPU PCB.
HN0016	NMI: Analog Interface Error: ADC Timing Fault	Other (BDU)	BDU reset		1. Replace AI PCB. 2. Replace BD CPU PCB.
HN0016	NMI: Analog Interface Error: Hamming Decode Fault	Other (BDU)	BDU reset		1. Replace AI PCB. 2. Replace BD CPU PCB.
HN0080	NMI: Analog Interface Error: ADC Timing Fault	Other (BDU)	BDU reset		Replace AI PCB.
HN0129	NMI: DRAM Parity Error	Other (BDU)	BDU reset		1. Check GUI/BD cable connections. 2. Replace power supply. 3. Replace BD CPU PCB.
HN0130	NMI: Ethernet Parity Error	Other (BDU)	BDU reset		1. Check GUI/BD cable connections. 2. Replace power supply. 3. Replace BD CPU PCB.
KB0001	Bad safety valve switched side	Background check (BDU)	Vent inop	Measured voltage on safety valve switched side indicates valve is not in expected state.	1. Replace safety valve. 2. Replace AI PCB. 3. Replace Inspiratory Electronics PCB. 4. Replace interconnect cable between the mother board and the Inspiratory Electronics PCB.
KB0002	Bad expiratory flow	Background check (BDU)	Vent inop	Exhalation flow sensor (Q3) reading out of range	1. If possible, run EST and use the Flow Sensor Cross Check test to determine if Q3 is failing. Replace Q3 if applicable. 2. Perform flow sensor calibration. 3. Replace AI PCB.

Table 6-2: *840* Ventilator diagnostic codes (continued)

Code	Message displayed	Test	Response	Information / Possible cause	Corrective action
KB0003	Bad O_2 PSOL current	Background check (BDU)	Vent inop	Oxygen PSOL (PSOL1) current out of range	1. If possible, run EST to determine if PSOL1 is failing. Switch PSOLs to see if the failure transfers to the other side. Replace PSOL1 if applicable. 2. Replace AI PCB. 3. Replace Inspiratory Electronics PCB. 4. Replace interconnect cable between the motherboard and the Inspiratory Electronics PCB.
KB0004	Bad air PSOL current	Background check (BDU)	Vent inop	Air PSOL (PSOL2) current out of range	1. If possible, run EST to determine if PSOL2 is failing. Switch PSOLs to see if the failure transfers to the other side. Replace PSOL2 if applicable. 2. Replace AI PCB. 3. Replace Inspiratory Electronics PCB. 4. Replace interconnect cable between the motherboard and the Inspiratory Electronics PCB.
KB0005	Bad exp motor current	Background check (BDU)	Vent inop	Current to exhalation valve motor out of range	1. Perform exhalation valve (EV) calibration. 2. Replace EV. 3. Replace AI PCB.
KB0007	Bad exp pressure	Background check (BDU)	Vent inop	PE reading out of range	1. Replace exhalation transducer PCB. 2. Replace AI PCB.
KB0008	Bad insp pressure	Background check (BDU)	Vent inop	PI reading out of range	1. Replace Inspiratory Electronics PCB. 2. Replace AI PCB.
KB0009	Air flow out of range HIGH	Background check (BDU)	Vent inop	Q2 reading too high	1. Perform flow sensor calibration. 2. Replace Q2. 3. Replace AI PCB.
KB0012	O_2 flow out of range HIGH	Background check (BDU)	Vent inop	Q1 reading too high	1. Perform flow sensor calibration. 2. Replace Q1. 3. Replace AI PCB.
KB0016	Bad BD 10V supply	Background check (BDU)	Vent inop	BDU +10 V supply out of range	Replace AI PCB.
KB0017	Bad BD 12 V supply	Background check (BDU)	Vent inop	BDU +12 V supply out of range	1. Replace AI PCB. 2. Replace power supply or other power input components.
KB0018	Bad BD 15 V supply	Background check (BDU)	Vent inop	BDU +15 V supply out of range	1. Replace AI PCB. 2. Replace power supply or other power input components.

Table 6-2: *840* Ventilator diagnostic codes (continued)

Code	Message displayed	Test	Response	Information / Possible cause	Corrective action
KB0019	Bad BD -15 V	Background check (BDU)	Vent inop	BDU -15 V supply out of range	1. Replace AI PCB. 2. Replace power supply or other power input components.
KB0022	Bad BD 5 V supply	Background check (BDU)	Vent inop	BDU +5 V supply out of range	1. Replace AI PCB. 2. Replace power supply or other power input components.
KB0023	O_2 PSOL stuck	Background check (BDU)	Vent inop	Oxygen PSOL (PSOL1) command current out of range	3. If possible, run EST to determine if PSOL1 is failing. Switch PSOLs to see if the failure transfers to the other side. Replace PSOL1 if applicable. 4. Replace AI PCB. 5. Replace Inspiratory Electronics PCB. 6. Replace interconnect cable between the motherboard and the Inspiratory Electronics PCB.
KB0024	Air PSOL stuck	Background check (BDU)	Vent inop	Air PSOL (PSOL2) command current out of range	1. If possible, run EST to determine if PSOL2 is failing. Switch PSOLs to see if the failure transfers to the other side. Replace PSOL2 if applicable. 2. Replace AI PCB. 3. Replace Inspiratory Electronics PCB. 4. Replace interconnect cable between the motherboard and the Inspiratory Electronics PCB.
KB0025	Air PSOL stuck open	Background check (BDU)	Vent inop	Air PSOL (PSOL2) command current reading indicates PSOL stuck open	1. If possible, run EST to determine if PSOL2 is failing. Switch PSOLs to see if the failure transfers to the other side. Replace PSOL2 if applicable. 2. Replace AI PCB. 3. Replace Inspiratory Electronics PCB. 4. Replace interconnect cable between the motherboard and the Inspiratory Electronics PCB.
KB0026	O_2 PSOL stuck open	Background check (BDU)	Vent inop	PSOL1 command current reading indicates PSOL stuck open	1. If possible, run EST to determine if PSOL1 is failing. Switch PSOLs to see if the failure transfers to the other side. Replace PSOL1 if applicable. 2. Replace AI PCB. 3. Replace Inspiratory Electronics PCB. 4. Replace interconnect cable between the motherboard and the Inspiratory Electronics PCB.

Table 6-2: *840* Ventilator diagnostic codes (continued)

Code	Message displayed	Test	Response	Information / Possible cause	Corrective action
KB0030	Bad safety valve current	Background check (BDU)	Vent inop	Current to safety valve out of range	1. Replace safety valve. 2. Replace AI PCB. 3. Replace Inspiratory Electronics PCB. 4. Replace interconnect cable between the motherboard and the Inspiratory Electronics PCB.
KB0031	Insp pressure stuck	Background check (BDU)	Vent inop	Inspiratory pressure transducer (PI) reading indicates transducer is stuck	1. Replace Inspiratory Electronics PCB. 2. Replace AI PCB.
KB0032	Exp pressure stuck	Background check (BDU)	Vent inop	Expiratory pressure transducer (PE) reading indicates transducer is stuck	1. Replace exhalation transducer PCB. 2. Replace AI PCB.
KB0033	Insp pressure autozero offset failed	Background check (BDU)	Vent inop	Inspiratory pressure transducer (PI) reading following autozero out of range	1. Replace inspiratory pressure transducer autozero solenoid (SOL1). 2. Replace Inspiratory Electronics PCB. 3. Replace AI PCB.
KB0034	Exp pressure autozero offset failed	Background check (BDU)	Vent inop	Expiratory pressure transducer (PE) reading following autozero out of range	1. Replace expiratory pressure transducer autozero solenoid (SOL2). 2. Replace exhalation transducer PCB. 3. Replace AI PCB.
KB0037	Analog-Digital converter failed high	Background check (BDU)	Vent inop	Analog-to-digital converter failure	Replace AI PCB.
KB0038	Analog-Digital converter failed low	Background check (BDU)	Vent inop	Analog-to-digital converter failure	Replace AI PCB.
KB0039	Analog-Digital loopback failed	Background check (BDU)	Vent inop	Analog-to-digital converter failure	Replace AI PCB.
KB0044	BD NOVRAM checksum error	Background check (BDU)	Vent inop	BD NOVRAM failure	Replace BD CPU PCB.
KB0053	BD EEPROM checksum error	Background check (BDU)	Vent inop	BD EEPROM failure	Replace BD CPU PCB.
KB0064	LV Ref out of range	Background check (BDU)	Vent inop	Low-voltage reference out of range	Replace AI PCB.
KB0065	SV current out of range	Background check (BDU)	Vent inop	Safety valve current out of range	1. Replace safety valve. 2. Replace Inspiratory Electronics PCB. 3. Replace AI PCB. 4. Replace interconnect cable between the motherboard and the Inspiratory Electronics PCB.

Table 6-2: *840* Ventilator diagnostic codes (continued)

Code	Message displayed	Test	Response	Information / Possible cause	Corrective action
KB0076	Task Monitor	Background check (BDU)	Vent inop		Replace BD CPU PCB.
KB0079	BK vent inop occurred	Background check (BDU)	Vent inop	Ventilator inoperative signal read by BDU is active. This could mean GUI has declared a ventilator inoperative condition.	1. Run the VENT INOP test. a. If the test passes, run EST to reset the Device Alert. Run the unit for 48 hours and then put back into service if the code cannot be duplicated. b. If the test fails, troubleshoot per Table 6-5, VENT INOP Test troubleshooting.
KB0082	Watchdog failure occurred	Background check (BDU)	Vent inop		Replace BD CPU PCB.
KP0001 ○○○○ ○○○●	Processor Initialization	POST (BDU)	Vent inop		Replace BD CPU PCB.
KP0002 ○○○○ ○○●○	Integer Unit Test	POST (BDU)	Vent inop		Replace BD CPU PCB.
KP0003 ○○○○ ○○●●	DRAM Refresh Timer Test	POST (BDU)	Vent inop		Replace BD CPU PCB.
KP0004 ○○○○ ○●○○	Kernel DRAM Test	POST (BDU)	Vent inop		Replace BD CPU PCB.
KP0005 ○○○○ ○●○●	Boot EPROM Checksum Test	POST (BDU)	Vent inop		Replace BD CPU PCB.
KP0006 ○○○○ ○●●○	POST Phase 2 Initialization	POST (BDU)	Vent inop		Replace BD CPU PCB.
KP0007 ○○○○ ○●●●	Addressing Mode Test	POST (BDU)	Vent inop		Replace BD CPU PCB.

Table 6-2: *840* Ventilator diagnostic codes (continued)

Code	Message displayed	Test	Response	Information / Possible cause	Corrective action
KP0008	Kernel NOVRAM Test	POST (BDU)	Vent inop		Replace BD CPU PCB.
KP0009	Rolling Thunder Test	POST (BDU)	Vent inop	POST has started (but not run to completion) three or more times, for reasons unrelated to power.	1. Replace AI PCB. 2. Replace BD CPU PCB. 3. Replace motherboard.
KP0011	Time of Day Clock Test	POST (BDU)	Vent inop		Replace BD CPU PCB.
KP0012	Timer Test	POST (BDU)	Vent inop	Timer failed comparison test with real-time clock (external timing reference) *or* Timer failed to generate interrupt	Replace BD CPU PCB.
KP0013	Watchdog Timer Test	POST (BDU)	Vent inop	Watchdog timer did not time out as expected	Replace BD CPU PCB.
KP0015	FLASH Memory Checksum Test	POST (BDU)	Vent inop		Replace BD CPU PCB.
KP0081	Memory Management Unit Test	POST (BDU)	Vent inop		Replace BD CPU PCB.
KP0082	Bus Timer Test	POST (BDU)	Vent inop	Activity has ceased on local bus *or* Bus time-out circuit did not generate an interrupt as expected	Replace BD CPU PCB.
KP0083	NMI Source Register Test	POST (BDU)	Vent inop		Replace BD CPU PCB.
KP0084	POST DRAM Test	POST (BDU)	Vent inop		Replace BD CPU PCB.

Table 6-2: *840* Ventilator diagnostic codes (continued)

Code	Message displayed	Test	Response	Information / Possible cause	Corrective action
KP0087 ○●○● ○●●●	Unexpected Reset Umpire Test	POST (BDU)	Vent inop	POST has been invoked three times in 24 operational hours due to unexpected resets.	1. Check associated errors in the System Diagnostic and System Information log to determine why POST was invoked three times within 24 hours. If the codes indicate that the BD CPU generated the resets, replace the BD CPU (Other codes may be present indicating that the GUI lost communications with the BD). 2. Run a complete EST to check for analog device failures.
KP0089 ○●○● ●○○●	Floating Point Unit Test	POST (BDU)	Vent inop		Replace BD CPU PCB.
KP0090 ○●○● ●○●○	DRAM Parity Circuit Test	POST (BDU)	Vent inop		Replace BD CPU PCB.
KP0113 ○●●● ○○○●	Analog Interface PCB Test	POST (BDU)	Vent inop		1. Replace BD CPU PCB. 2. Replace AI PCB. 3. Replace motherboard.
KP0114 ○●●● ○○●○	ADC Test	POST (BDU)	Vent inop	Analog-to-digital converter data not available to CPU as expected	1. Replace AI PCB. 2. Replace motherboard.
KP0115 ○●●● ○○●●	DAC Test	POST (BDU)	Vent inop	Digital-to-analog converter data not as expected	1. Replace AI PCB. 2. Replace motherboard.
KP0116 ○●●● ○●○○	Analog Devices Test	POST (BDU)	Vent inop	Critical analog data out of range	1. Refer to Section 6.8 to identify which analog device is failing. 2. Run EST to get more information on the analog device failure. 3. Replace the AI PCB. 4. Replace the motherboard. 5. Replace the interconnect cable between the Inspiratory Electronics PCB and the motherboard.
KP0117 ○●●● ○●○●	BD Serial Device Test	POST (BDU)	Vent inop		1. Replace AI PCB. 2. Replace BD CPU PCB. 3. Replace the motherboard.

Table 6-2: *840* Ventilator diagnostic codes (continued)

Code	Message displayed	Test	Response	Information / Possible cause	Corrective action
KP0120	Safe State System Test	POST (BDU)	Vent inop	Places PSOLs and exhalation valve into safe state and verifies that they cannot be commanded.	1. Look up associated codes reported in Diagnostic Log and/or the BD CPU LED array to get more information about other possible system, software, or hardware faults. Troubleshoot those codes. 2. Run a Ground Isolation Test to troubleshoot shorts. 3. Try another inspiratory module and see if the code can be reset by running the VENT INOP, EST and POST tests. a. If the unit passes with a known good inspiratory module, replace the Inspiratory Electronics PCB. b. If the unit fails, replace the inspiratory blind mate interconnect cable. 4. Replace the Inspiratory Electronics PCB. 5. Replace the AI PCB. 6. Replace the BD CPU PCB.
KP0128	Download operating system (OS) Boot	POST (BDU)	Vent inop		Replace BD CPU PCB.
KP0129	Application OS Boot	POST (BDU)	Vent inop		Replace BD CPU PCB.
KP0130	PB-MON Boot	POST (BDU)	Vent inop		Replace BD CPU PCB.
KP0131	Application Boot	POST (BDU)	Vent inop		Replace BD CPU PCB.
LB0006	Bad exhalation valve coil temp.	Background check (BDU)	Alert	Exhalation valve coil temperature out of range	1. Replace exhalation valve. 2. Replace AI PCB. 3. Replace interconnect harness between the exhalation compartment connector and the motherboard.
LB0010	Air flow out of range LOW	Background check (BDU)	Alert	Air flow sensor (Q2) reading too low	1. Perform flow sensor calibration. 2. Replace Q2. 3. Replace AI PCB.

Table 6-2: *840* Ventilator diagnostic codes (continued)

Code	Message displayed	Test	Response	Information / Possible cause	Corrective action
LB0011	Bad air flow temperature	Background check (BDU)	Alert	Air flow sensor (Q2) thermistor reading out of range	1. Replace Q2. 2. Replace AI PCB.
LB0013	O_2 flow out of range LOW	Background check (BDU)	Alert	Oxygen flow sensor (Q1) reading too low	1. Ensure that the ventilator has been warmed up for at least 10 minutes in service mode at ambient temperature. 2. Run a flow sensor calibration. 3. Replace Q1.4.Replace the AI PCB.
LB0014	Bad O_2 flow temp.	Background check (BDU)	Alert	Oxygen flow sensor (Q1) thermistor reading out of range	1. Replace Q1. 2. Replace AI PCB.
LB0015	Bad expiratory flow temp	Background check (BDU)	Alert	Expiratory flow sensor (Q3) thermistor reading out of range	1. Replace Q3. 2. Replace AI PCB.
LB0020	Bad GUI 12V supply	Background check (BDU)	Alert	GUI +12 V supply out of range	1. Check cabling from BD CPU PCB to GUI CPU PCB. 2. Replace AI PCB. 3. Replace power supply. 4. Check whether or not the cable from the GUI to the BDU was reconnected to the unit while the ventilator power was on. If yes, run EST to reset the DEVICE ALERT.
LB0021	Bad GUI 5V supply	Background check (BDU)	Alert	GUI +5 V supply out of range.	1. Check cabling from BD CPU PCB to GUI CPU PCB. 2. Replace AI PCB. 3. Replace power supply. 4. Check whether or not the cable from the GUI to the BDU was reconnected to the unit while the ventilator power was on. If yes, run EST to reset the DEVICE ALERT.
LB0027	Bad atmospheric press OOR	Background check (BDU)	Alert	Atmospheric pressure transducer reading out of range	1. Perform atmospheric pressure calibration. 2. Replace Inspiratory Electronics PCB. 3. Replace AI PCB.
LB0028	Bad O_2 sensor OOR	Background check (BDU)	Alert	Oxygen sensor (percentage) reading out of range	1. Calibrate oxygen sensor. 2. Replace oxygen sensor.
LB0029	Bad O_2 sensor OOR reset	Background check (BDU)	Status	A status message indicating that alert was reset	No action required.
LB0035	Bad power fail capacitor voltage	Background check (BDU)	Alert	Power fail capacitor voltage out of range	1. Replace AI PCB. 2. Replace power supply.

Table 6-2: *840* Ventilator diagnostic codes (continued)

Code	Message displayed	Test	Response	Information / Possible cause	Corrective action
LB0036	Alarm cable error	Background check (BDU)	Alert	Alarm cable voltage out of range	1. Check cabling to main alarm. 2. Replace BD alarm. 3. Replace AI PCB.
LB0039	ADC loopback constant	Background checks (BDU)	Alert		Replace AI PCB.
LB0043	ac switch stuck	Background check (BDU)	Alert	Power switch is in off state but power fail NMI did not occur	1. Replace power switch. 2. Replace AI PCB.
LB0045	BD Time of Day failed	Background check (BDU)	Alert	Real-time clock failure	Replace BD CPU PCB.
LB0048	Bad backup power supply voltage	Background check (BDU)	Alert	BPS voltage out of range	1. Replace BPS battery pack. 2. Replace AI PCB. 3. Replace BPS PCB.
LB0049	Bad backup power supply current	Background check (BDU)	Alert	BPS current out of range	1. Replace BPS battery pack. 2. Replace AI PCB. 3. Replace BPS PCB.
LB0050	Bad backup power supply model	Background check (BDU)	Alert	Model information incorrect	Replace BPS PCB.
LB0051	Bad exp heater	Background check (BDU)	Alert	Exhalation heater thermistor reading out of range	1. Replace exhalation heater. 2. Replace AI PCB. 3. Replace interconnect cable between the exhalation compartment and the motherboard.
LB0056	Compressor elapsed timer error	Background check (BDU)	Alert	Compressor timer failure	Replace compressor PCB.
LB0057	Compressor bad eprom data	Background check (BDU)	Alert	Data in compressor EPROM not as expected	Replace compressor PCB.
LB0058	Loss of GUI communication	Background check (BDU)	Alert		1. This code indicates that the BD logged a loss of communications with the GUI. Check for codes generated by the GUI indicating a GUI fault. 2. Check cabling from BD CPU PCB to the GUI CPU PCB. 3. Replace GUI CPU PCB or BD CPU PCB.
LB0060	Resume GUI communication	Background check (BDU)	Status	A status message indicating that communication with GUI was resumed	No action required.
LB0062	Est required	Background check (BDU)	Alert	EST is required, but user cycled power into normal operation, rather than into service mode	Run EST.

Table 6-2: *840* Ventilator diagnostic codes (continued)

Code	Message displayed	Test	Response	Information / Possible cause	Corrective action
LB0075	Data key update failed	Background check (BDU)	Alert		1. Plug in data key. 2. Contact Service or your Puritan Bennett representative for a new data key.
LB0076	Task monitor	Background checks (BDU)	Alert		No action required unless XP0087 error is also present.
LB0080	Breath delivery extended	Background checks (BDU)	Alert		Replace BD CPU PCB.
LB0083	Init Resume GUI Communication	Background check (BDU)	Status	A status message indicating that communication with GUI was resumed	No action.
LB0085	Init Loss GUI Communication	Background check (BDU)	Status	A status message indicating that communication with GUI was lost	No action.
LB0087	Compressor S/N updated	Background check (BDU)	Status		No action.
LB0088	10000 hours stored for elapsed time	Background check (BDU)	Alert	Compressor hours corrupted. Contact your Puritan Bennett representative to reset.	Replace the compressor PCB.
LB0089	Cannot determine datakey size	Background check (BDU)	Alert		Replace data key.
LB0092	Battery Event	Background checks (BDU)	Alert	A status message regarding the state of the battery.	1. Ensure that the green LED is lit on the front of the BPS. a. If the green LED is not lit, allow the BPS to charge until the green LED lights. b. If the green LED does not light (within 6-8 hours or less), replace the battery pack. c. Replace the BPS PCB 2. Once the green LED is lit, run EST to test the BPS and use EST diagnostics to determine if further corrective action is needed.

Table 6-2: *840* Ventilator diagnostic codes (continued)

Code	Message displayed	Test	Response	Information / Possible cause	Corrective action
LC1xxx	Varies	Communi-cations error (BDU)	Alert		1. Ensure that the green LED is lit on the front of the BPS. a. If the green LED is not lit, allow the BPS to charge until the green LED lights. b. If the green LED does not light (within 6-8 hours or less), replace the battery pack. c. Replace the BPS PCB 2. Once the green LED is lit, run EST to test the BPS and use EST diagnostics to determine if further corrective action is needed.
LP0008	Kernel NOVRAM Test	POST (BD)	Alert	Noncritical NOVRAM data failure	Replace the BD CPU PCB.
LP0010	Interrupt Controller Test	POST (BD)	Alert		Replace BD CPU PC.
LP0011	Time of Day Clock Test	POST (BD)	aLERT		Replace BD CPU PCB.
LP0085	Ethernet Self-Test Start	POST (BD)	Alert		Replace BD CPU PCB.
LP0086	Ethernet Self-Test End	POST (BDU)	Alert		Replace BD CPU PCB.
LP0087	Unexpected Reset Umpire Test	POST (BDU)	Alert	POST was invoked due to a watchdog time-out (unexpected reset)	1. Check all logs to see associated errors occurring around the same time and date as this code. 2. Run EST to get more information.
LP0088	POST NOVRAM Test	POST (BDU)	Alert	Noncritical NOVRAM data failure	1. Check all logs to see associated errors occurring around the same time and date as this code. 2. Run EST to get more information.
LP0112	Ventilator INOP Test	POST (BDU)	Alert	Ventilator inoperative signal not in expected state	1. Replace the interconnect cable between the Inspiratory Electronics PCB and the motherboard. 2. Run VENT INOP Test. 3. Replace BD CPU PCB.
LP0114	ADC Test	POST (BD)	Alert		Replace AI PCB.

Table 6-2: *840* Ventilator diagnostic codes (continued)

Code	Message displayed	Test	Response	Information / Possible cause	Corrective action
LP0115	DAC Test	POST (BD)	Alert		Replace AI PCB.
LP0116	Analog Devices Test	POST (BDU)	Alert	Noncritical analog data out of range	1. Refer to Table 6-3: "Address codes for BDU POST analog devices test errors". 2. Replace AI PCB.
LP0121	Service Switch Stuck Test	POST (BDU)	Alert	Service switch appears to be closed. (Only requests to enter service mode made after this test are honored by system.)	1. Turn off ventilator. Release switch. 2. Check for mechanical obstruction to switch. 3. Replace BD CPU PCB.
LP0122	ac Voltage Test	POST (BDU)	Alert	ac monitor voltage not within set nominal line voltage ±20%	1. Make sure ventilator is plugged into ac source. 2. Make sure nominal line voltage is set correctly.
Sxxxxx	*Varies*	Other	Status	Status message that indicates an intentionally caused event	No action required.
Uxxxxx	Assertion Failure	Background check (GUI)	Alert		Check System Information and Patient logs for any messages occurring with a high frequency. Otherwise, no corrective action unless accompanied by XP0087 diagnostic code.
U04004	Assertion Failure	Background check (GUI)	Alert	Can occur if there is an intermittent connection to any digital I/O line.	1. Check all cable connections. 2. Perform Ground Isolation Test. 3. Replace GUI CPU PCB.
U05013	Assertion Failure	Background check (GUI)	Alert	Can occur if there is an intermittent connection to any digital I/O line.	1. Check all cable connections. 2. Perform Ground Isolation Test. 3. Replace GUI CPU PCB.
U08002	Assertion Failure	Background check (BDU)	Alert	Occurs when the GUI is overloaded with invalid data from the serial port. Caused by the host device transmitting bad data that is generating over-run, parity, or framing errors. The GUI generates a soft reset or assertion to clear the condition and resynchronize with the BDU.	1. Check for wet expiratory or inspiratory filter. 2. Check all cable connections: GUI, Serial, Internal cables. 3. Review the ventilator logs, including patient logs, observe any occurrences of rapidly repeating messages. This pattern may contribute to a buffer overflow situation that the ventilator will attempt to clear by running POST. 4. Perform Ground Isolation Test. 5. Replace GUI CPU PCB.
U08012	Assertion Failure	Background check (GUI)	Alert	The GUI generates a soft reset or assertion to clear the condition and re synchronize with the BDU.	1. Check all cable connections. 2. Perform Ground Isolation Test. 3. Replace GUI CPU PCB.

Table 6-2: *840* Ventilator diagnostic codes (continued)

Code	Message displayed	Test	Response	Information / Possible cause	Corrective action
U14019	Assertion Failure	Background check (GUI)	Alert	The GUI generates a soft reset or assertion to clear the condition and resynthesized with the BDU.	1. Check all cable connections. 2. Perform Ground Isolation Test. 3. Replace GUI CPU PCB.
U14021	Assertion Failure	Background check (GUI)	Alert	If the time stamps between the GUI and the BD are out of range, the GUI generates a soft reset or assertion to clear the condition and re synchronize with the BDU.	1. Check all cable connections. 2. Perform Ground Isolation Test. 3. Replace GUI CPU PCB.
UT0002	Assertion Failure	Background check (GUI)	Alert	A reset of the GUI has occurred as a result of a hardware-trap detection.	**NOTE:** Refer to Section 6.10.1 for further information regarding for this error code. 1. Refer to Table 6-3: "Address codes for BDU POST analog devices test errors".
VN0129	NMI: DRAM Parity Error	Other (GUI)	GUI reset		1. Check GUI/BD cable connections. 2. Replace power supply. 3. Replace GUI CPU PCB.
VN0130	NMI: Ethernet Parity Error	Other (GUI)	GUI reset		1. Check GUI/BD cable connections. 2. Replace power supply. 3. Replace GUI CPU PCB.
VN0132	NMI: +5 V dc Overvoltage	Other (GUI)	GUI reset		1. Check GUI/BD cable connections. 2. Replace power supply. 3. Replace GUI CPU PCB.
VN0136	NMI: +12 V dc Overvoltage	Other (GUI)	GUI reset		1. Check GUI/BD cable connections. 2. Replace power supply. 3. Replace GUI CPU PCB.
VN0144	NMI: +12 V dc Undervoltage	Other (GUI)	GUI reset		1. Check GUI/BD cable connections. 2. Replace power supply. 3. Replace GUI CPU PCB.
XB0066	Monitor alarms fail	Background checks (GUI)	Vent inop		Call Technical Support or your Puritan Bennett representative.
XB0067	Monitor apnea alarm fails	Background checks (GUI)	Vent inop		Call Technical Support or your Puritan Bennett representative.
XB0068	Monitor apnea int fails	Background checks (GUI)	Vent inop		Call Technical Support or your Puritan Bennett representative.
XB0069	Monitor hip fails	Background checks (GUI)	Vent inop		Call Technical Support or your Puritan Bennett representative.

Table 6-2: *840* Ventilator diagnostic codes (continued)

Code	Message displayed	Test	Response	Information / Possible cause	Corrective action
XB0070	Monitor insp time fails	Background checks (GUI)	Vent inop		Call Technical Support or your Puritan Bennett representative.
XB0071	Monitor no data	Background checks (GUI)	Vent inop		Call Technical Support or your Puritan Bennett representative.
XB0072	Monitor data corrupted	Background checks (GUI)	Vent inop		Call Technical Support or your Puritan Bennett representative.
XB0073	Monitor O_2 mixture fails	Background checks (GUI)	Vent inop		Call Technical Support or your Puritan Bennett representative.
XB0074	Monitor breath time fails	Background checks (GUI)	Vent inop		Replace GUI CPU PCB.
XP0001 ○○○○ ○○○●	Processor Initialization	POST (GUI)	GUI inop		Replace GUI CPU PCB.
XP0002 ○○○○ ○○●○	Integer Unit Test	POST (GUI)	GUI inop		Replace GUI CPU PCB.
XP0003 ○○○○ ○○●●	DRAM Refresh Timer Test	POST (GUI)	GUI inop		Replace GUI CPU PCB.
XP0004 ○○○○ ○●○○	Kernel DRAM Test	POST (GUI)	GUI inop		Replace GUI CPU PCB.
XP0005 ○○○○ ○●○●	Boot EPROM Checksum Test	POST (GUI)	GUI inop		Replace GUI CPU PCB.
XP0006 ○○○○ ○●●○	POST Phase 2 Initialization	POST (GUI)	GUI inop		Replace GUI CPU PCB.
XP0007 ○○○○ ○●●●	Addressing Mode Test	POST (GUI)	GUI inop		Replace GUI CPU PCB.
XP0008 ○○○○ ●○○○	Kernel NOVRAM Test	POST (GUI)	GUI inop		Replace GUI CPU PCB.
XP0010 ○○○○ ●○●○	Interrupt Controller Test	POST (GUI)	GUI inop		Replace GUI CPU PCB.

Table 6-2: *840* Ventilator diagnostic codes (continued)

Code	Message displayed	Test	Response	Information / Possible cause	Corrective action
XP0011	Time of Day Clock Test	POST (GUI)	GUI inop		Replace GUI CPU PCB.
XP0012	Timer Test	POST (GUI)	GUI inop		Replace GUI CPU PCB.
XP0013	Watchdog Timer Test	POST (GUI)	GUI reset	Watchdog timer did not time out as expected	1. Make sure ventilator is plugged in to wall power and BPS is fully charged. 2. Replace GUI CPU PCB.
XP0015	FLASH Memory Checksum Test	POST (GUI)	GUI inop		Replace GUI CPU PCB.
XP0081	Memory Management Unit Test	POST (GUI)	GUI inop		Replace GUI CPU PCB.
XP0082	Bus Timer Test	POST (GUI)	GUI inop		Replace GUI CPU PCB.
XP0083	NMI Source Register Test	POST (GUI)	GUI inop		Replace GUI CPU PCB.
XP0084	POST DRAM Test	POST (GUI)	GUI inop		Replace GUI CPU PCB.
XP0087	Unexpected Reset Umpire Test	POST (GUI)	GUI inop	POST has been invoked three times in 24 operational hours due to unexpected resets.	Check associated errors in log. Call Technical Support or your Puritan Bennett representative.
XP0089	Floating Point Unit Test	POST (GUI)	GUI inop		Replace GUI CPU PCB.
XP0090	DRAM Parity Circuit Test	POST (GUI)	GUI inop		Replace GUI CPU PCB.
XP0097	SAAS Self-Test Start	POST (GUI)	GUI inop		Replace GUI CPU PCB.

Table 6-2: ***840*** **Ventilator diagnostic codes (continued)**

Code	Message displayed	Test	Response	Information / Possible cause	Corrective action
XP0098	SAAS Self-Test End	POST (GUI)	GUI inop		Replace GUI CPU PCB.
XP0128	Download OS Boot	POST (GUI)	GUI inop		Replace GUI CPU PCB.
XP0129	Application OS Boot	POST (GUI)	GUI inop		Replace GUI CPU PCB.
XP0130	PB-MON Boot	POST (GUI)	GUI inop		Replace GUI CPU PCB.
XP0131	Application Boot	POST (GUI)	GUI inop		Replace GUI CPU PCB.
ZB0040	Touch screen failed	Background checks (GUI)	Alert		Replace touch frame.
ZB0041	Touch screen blocked	Background checks (GUI)	Alert		1. Check for obstruction on screen or clean screen. 2. Replace touch frame.
ZB0042	Touch screen resumed	Background checks (GUI)	Status	A status message indicating that communication with touch screen was resumed	No action required.
ZB0046	GUI Time of Day failed	Background checks (GUI)	Alert		Replace GUI CPU PCB.
ZB0047	GUI NOVRAM checksum error	Background checks (GUI)	Alert	Noncritical NOVRAM data failure	1. Replace GUI CPU PCB. 2. Call Technical Support or your Puritan Bennett representative.
ZB0052	GUI key stuck	Background checks (GUI)	Alert		1. Replace keyboard. 2. Replace GUI CPU PCB.
ZB0054	GUI EEPROM checksum error	Background checks (GUI)	Alert		Replace GUI CPU PCB.
ZB0055	GUI SAAS communication failed	Background checks (GUI)	Alert		Replace GUI CPU PCB.
ZB0059	Loss of BD communication	Background checks (GUI)	Alert		1. Check cabling from BD CPU PCB to GUI CPU PCB. 2. Replace BD CPU PCB or GUI CPU PCB.

Table 6-2: *840* Ventilator diagnostic codes (continued)

Code	Message displayed	Test	Response	Information / Possible cause	Corrective action
ZB0061	Resume BD communication	Background checks (GUI)	Status	A status message indicating that communication with BD was resumed	No action required.
ZB0063	GUI SAAS Audio failed	Background checks (GUI)	Alert		1. Replace GUI alarm assembly. 2. Replace GUI CPU PCB.
ZB0076	Task Monitor	Background checks (GUI)	Alert		No action required unless a XP0087 error is also present.
ZB0077	GUI dropped a waveform packet	Background checks (GUI)	Status	A status message indicating a waveform data packet was lost in transmission from the BD.	No action required.
ZB0084	Init Resume BD communication	Background checks (GUI)	Status	A status message indicating that communication with BD was resumed.	No action required.
ZB0086	Init Loss of BD communication	Background checks (GUI)	Alert	A status message indicating that communication with BD was lost.	See associated error codes.
ZB0090	Touch Screen blocked	Background checks (GUI)	Alert		1. Remove visible items from GUI screen. 2. Clean GUI screen. 3. Replace touchscreen PCB.
ZB0091	Touch Screen resumed	Background checks (GUI)	Status	Status message indicates that a touch screen blocked error is cleared.	
ZC0xxx	*Varies*	Communications error (GUI)	Alert		No action required unless a ZB0059 error is also present.
ZC0xxx	Varies	Communications error (BDU)	Alert		1. Ensure that the green LED is lit on the front of the BPS. a. If the green LED is not lit, allow the BPS to charge until the green LED lights. b. If the green LED does not light (within 6-8 hours or less), replace the battery pack. c. Replace the BPS PCB 2. Once the green LED is lit, run EST to test the BPS and use EST diagnostics to determine if further corrective action is needed.
ZC1xxx	*Varies*	Communications error (GUI)	Alert		No action required unless a ZB0059 error is also present.

Table 6-2: *840* Ventilator diagnostic codes (continued)

Code	Message displayed	Test	Response	Information / Possible cause	Corrective action
ZC2000	DCI parity error	Communica-tions error (GUI)	Alert		Check parity of host device.
ZC2001	DCI input buffer overflow error	Communica-tions error (GUI)	Alert		1. Check cabling between ventila-tor and host. 2. Check baud rate of host device.
ZC2002	DCI command error	Communica-tions error (GUI)	Alert	Undefined command received	1. Check host software for com-patibility with ventilator. 2. Check cabling between ventila-tor and host.
ZC2003	DCI unknown error	Communica-tions error (GUI)	Alert		1. Check host software for com-patibility with ventilator. 2. Check cabling between ventila-tor and host.
ZP0008 ○○○○ ●○○○	Kernel NOVRAM Test	POST (GUI)	Alert	Noncritical NOVRAM data failure	Call Technical Support or your Puritan Bennett representative.
ZP0085 ○●○● ○●○●	Ethernet Self-Test Start	POST (GUI)	Alert	Spec says failure	Replace GUI CPU PCB.
ZP0086 ○●○● ○●●○	Ethernet Self-Test End	POST (GUI)	Alert	Spec says failure	Replace GUI CPU PCB.
ZP0087 ○●○● ○●●●	Unexpected Reset Umpire Test	POST (GUI)	Alert	POST was invoked due to an unexpected reset.	Check associated errors in log. No action required unless other errors are present.
ZP0088 ○●○● ●○○○	POST NOVRAM Test	POST (GUI)	Alert	Noncritical NOVRAM data failure	Replace GUI CPUPCB.

6.8 System Diagnostic Log and BDU POST analog devices test

Analog device errors reported during the BDU POST analog devices test are recorded in the System Diagnostic Log. These errors are reported as diagnostic codes KP0116 and LP0116. Information in the NOTES column of the log identifies the analog channel on which the error occurred.

Using an example of a BDU POST analog device error, as it might be reported in the System Diagnostic Log:

TIME	TEST/EVENT	CODE	TYPE	NOTES
12:55:59 08 Aug 03	ANALOG DEVICE	KP0116	FAILURE	PC: 0x000202DD EV: 0 NMI: 0xC0 Err Code: 0xCC

The error address (NOTES) identifies the analog channel:

PC: 0x0 002 02DD

HEX Code (counts)

Analog Channel (5th and 6th digits), displayed in Hexidecimal

The diagnostic codes, KP0116 (BDU) and LP0116 (GUI), are major faults (VENT INOP) that can occur during the Analog Devices Test (Phase 2 POST).

If there are multiple KP0116 and/or LP0116 diagnostic codes, check the PC channels and determine if they are all the same. If the channels are all the same, replace the associated analog device or the AI PCB. If the channels are different, but originate from the same module, check and/or replace the associated module, interconnect cable or AI PCB.

Using the fifth and sixth digits of error address reported in the System Diagnostic Log and Table 6-3, the analog channel on which the error occurred can be identified.

Table 6-3: Address codes for BDU POST analog devices test errors

If the 5th and 6th digits of the error address are:	Parameter Measured	Replace This:
00	Inspiratory Pressure Filtered	Inspiratory Electronics PCB
01	Expiratory Pressure Filtered	Expiratory PCB
02	Q (O_2) Filtered	Q1 (O_2) Flow Sensor
03	Q (O_2) Temperature	Q1 (O_2) Flow Sensor
04	Q (air) Filtered	Q2 (air) Flow Sensor
05	Q (air) Temperature	Q2 (air) Flow Sensor
06	Q (exh) Filtered	Q3 (exh) Flow Sensor
07	Q (exh) Temperature	Q3 (exh) Flow Sensor
08	SUBMUX 0: DACWRAP	AI PCB
09	Safety Valve Switched Side	Safety Valve (SV) Assembly; check Inspiratory Module connections
0A	12 V GUI Sentry	GUI CPU PCB

Table 6-3: Address codes for BDU POST analog devices test errors

If the 5th and 6th digits of the error address are:	Parameter Measured	Replace This:
0B	Alarm Cable Voltage	GUI CPU PCB or alarm cable assembly
0C	O_2 PSOL Current	O_2 PSOL or AI PCB
0D	Air PSOL Current	Air PSOL or AI PCB
0E	Low Voltage Reference	Power Supply
0F	Atmospheric Pressure Transducer	Inspiratory Electronics PCB
10	Exhalation Coil Temperature	Exhalation Valve
11	Exhalation Pressure Transducer	Expiratory PCB
12	O_2 Sensor	O_2 Sensor
13	GUI 5V dc Sentry	GUI CPU PCB
14	12V dc Sentry	Power Supply
15	Safety Valve Current	Safety Valve or Inspiratory Electronics PCB or AI PCB
16	+15V Sentry	Power Supply or AI PCB
17	-15V Sentry	Power Supply or AI PCB
18	Power Fail Cap Voltage	Power Supply
19	Exhalation Manifold Heater Temp	Exhalation Heater
1A	BPS Battery Voltage Signal	BPS PCB
1B	5V dc Venthead	Power Supply
1C	BPS Battery Current	BPS PCB
1D	ac Line Voltage	Power Supply or AI PCB
1E	Exhalation Motor Current	Exhalation Valve Assembly
1F	10V Sentry	Power Supply

6.9 Diagnostic codes for POST faults

Use the following tables to determine the error code associated with the pattern of either the BD or the GUI LED array when a fault occurs during POST.

Table 6-4: BDU and GUI—Phase 1 (kernal) POST diagnostic codes

Test	Test Description	BD and GUI LED arrays			Fault Type	Corrective Action
		BDU Diag. code	GUI (10.4-inch) Diag. code	GUI (9.4-inch) Diag. code		
Processor Initialization	Prepares the processor for executing instructions	KP0001	XP0001	XP0001	Major	1. Check the diagnostic codes' corrective actions in Table 6-2. 2. Replace affected CPU PCB.
Integer Unit Test	General CPU confidence test	KP0002	XP0002	XP0002	Major	1. Check the diagnostic codes' corrective actions in Table 6-2. 2. Replace affected CPU PCB.
DRAM Refresh Timer Test	Tests DRAM refresh circuitry	KP0003	XP0003	XP0003	Major	1. Check the diagnostic codes' corrective actions in Table 6-2. 2. Replace affected CPU PCB.
Kernel DRAM Test	Tests read/write function of DRAM	KP0004	XP0004	XP0004	Major	1. Check the diagnostic codes' corrective actions in Table 6-2. 2. Replace affected CPU PCB.
Boot PROM Checksum Test	Verifies kernel PROM integrity	KP0005	XP0005	XP0005	Major	1. Check the diagnostic codes' corrective actions in Table 6-2. 2. Replace affected CPU PCB.
Addressing Mode Test	Verifies CPU functions in preparation for tests using multiple addressing modes	KP0007	XP0007	XP0007	Major	1. Check the diagnostic codes' corrective actions in Table 6-2. 2. Replace affected CPU PCB.
Kernel NOVRAM Test	Validates ranges for NOVRAM variables used in later tests	KP0008	XP0008	XP0008	Major	1. Check the diagnostic codes' corrective actions in Table 6-2. 2. Replace affected CPU PCB.
Rolling Thunder Test (BDU only)	Checks for unexpected resets during POST. Three or more resets not related to ac failures causes the test to fail.	KP0009	N/A	N/A	Major	1. Check the diagnostic codes' corrective actions in Table 6-2. 2. Replace AI PCB. 3. Replace BD CPU PCB. 4. Replace mother-board.

Table 6-4: BDU and GUI—Phase 1 (kernal) POST diagnostic codes (continued)

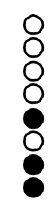
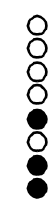
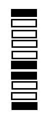
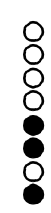
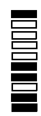
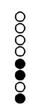
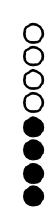
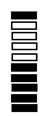
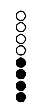
Test	Test Description	BD and GUI LED arrays			Fault Type	Corrective Action
		BDU Diag. code	GUI (10.4-inch) Diag. code	GUI (9.4-inch) Diag. code		
Time of Day Clock Test	Verifies functionality of the Time of Day clock	 KP0011 or LP0011	 XP0011 or ZP0011	 XP0011 or ZP0011	Major or Minor	1. Check the diagnostic codes' corrective actions in Table 6-2. 2. Replace affected CPU PCB.
Timer Test	Compares system timer to Time of Day clock to verify functionality	 KP0012	 XP0012	 XP0012	Major	1. Check the diagnostic codes' corrective actions in Table 6-2. 2. Replace affected CPU PCB.
Watchdog Timer Test	Verifies watchdog timer times out as expected	 KP0013	 XP0013	 XP0013	Major	1. Check the diagnostic codes' corrective actions in Table 6-2. 2. Replace affected CPU PCB.
EEPROM Checksum Test	Verifies integrity of flash memory	 KP0015	 XP0015	 XP0015	Major	1. Check the diagnostic codes' corrective actions in Table 6-2. 2. Replace affected CPU PCB.

Table 6-5: BDU only—Phase 2 POST diagnostic codes

BDU Test	BDU Test Description	BDU Diag. Code	BDU Fault Type	Corrective Action
ac Voltage Test	Compares ac monitor voltage to specified range	LP0122	Minor	1. Check the diagnostic code's corrective actions in Table 6-2. 2. Make sure ventilator is plugged into ac source. 3. Make sure nominal line voltage is set correctly.
ADC Test	Checks analog-to-digital converter data availability	KP0114	Major	1. Check the diagnostic code's corrective actions in Table 6-2. 2. Replace AI PCB.
Analog Devices Test	Performs a range check on each of the 32 analog channels	KP0116 or LP0116	Major or Minor	1. Check the diagnostic code's corrective actions in Table 6-2. 2. Refer to Section 6.8 for additional troubleshooting information regarding this fault. 3. Replace affected component. 4. Replace AI PCB. 5. Call Technical Support or your Puritan Bennett representative.
Analog Interface Test	Tests analog interface circuitry	KP0113	Major	1. Check the diagnostic code's corrective actions in Table 6-2. 2. Replace BD CPU PCB. 3. Replace AI PCB. 4. Replace mother board.
Bus Timer Test*	Monitors activity on the local bus	KP0082	Major	1. Check the diagnostic code's corrective actions in Table 6-2. 2. Replace BD CPU PCB.
DAC Test	Tests digital-to-analog converter data	KP0115	Major	1. Check the diagnostic code's corrective actions in Table 6-2. 2. Replace AI PCB.
DRAM Memory Test*	Tests DRAM by writing and verifying data patterns to memory	KP0084	Major	1. Check the diagnostic code's corrective actions in Table 6-2. 2. Replace BD CPU PCB.
DRAM Parity Error Test*	Checks the ability to detect a parity error upon reading defective parity from memory	KP0090	Major	1. Check the diagnostic code's corrective actions in Table 6-2. 2. Replace BD CPU PCB.

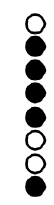
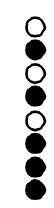
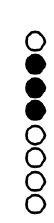
* Tested in Short POST

Table 6-5: BDU only—Phase 2 POST diagnostic codes (continued)

BDU Test	BDU Test Description	BDU Diag. Code	BDU Fault Type	Corrective Action
Ethernet Self-Test End		LP0086	Minor	1. Check the diagnostic code's corrective actions in Table 6-2. 2. Replace BD CPU PCB.
Ethernet Self-Test Start	Internal routine verifies functionality of Ethernet controller	KP0085	Major	1. Check the diagnostic code's corrective actions in Table 6-2. 2. Replace BD CPU PCB.
NMI Register Test*	Verifies NMI source register is in reset state (no bits set)	KP0083	Major	1. Check the diagnostic code's corrective actions in Table 6-2. 2. Replace BD CPU PCB.
Phase 2 Initialization*	Start non-kernel portion of POST	KP0006	Major	1. Check the diagnostic code's corrective actions in Table 6-2. 2. Replace BD CPU PCB.
Phase 2 NOVRAM Test*	Compares NOVRAM data to valid states and ranges	LP0088	Minor	1. Check the diagnostic code's corrective actions in Table 6-2. 2. Call Technical Support or your Puritan Bennett representative.
Safe State Test	Places PSOLs and exhalation valve into safe state and verifies that they cannot be commanded	KP0120	Major	1. Check the diagnostic code's corrective actions in Table 6-2. 2. Replace AI PCB. 3. Replace BD CPU PCB.
Serial Device Test	Writes to serial EEPROM to verify accessibility	KP0117	Major	1. Check the diagnostic code's corrective actions in Table 6-2. 2. Replace AI PCB. 3. Replace BD CPU PCB.
Service Switch Test End*		LP0121	Minor	1. Check the diagnostic code's corrective actions in Table 6-2. 2. Turn off ventilator. Release switch. 3. Check for mechanical obstruction to switch. 4. Replace BD CPU PCB.

* Tested in Short POST

Table 6-5: BDU only—Phase 2 POST diagnostic codes (continued)

BDU Test	BDU Test Description	BDU Diag. Code	BDU Fault Type	Corrective Action
Service Switch Test Start*	Checks that the service mode switch is not stuck, and prevents entry into Service Mode from a power fail condition	 LP0121	Minor	1. Check the diagnostic code's corrective actions in Table 6-2. 2. Turn off ventilator. Release switch. 3. Check for mechanical obstruction to switch. 4. Replace BD CPU PCB.
Unexpected Reset Umpire Test*	Checks for unexpected resets of the CPU. Three resets (strikes) in 24 hours will cause a VENT INOP condition.	 KP0087 or LP0087	Major or Minor	1. Check the diagnostic code's corrective actions in Table 6-2. 2. Check associated errors in the System Diagnostic and System Information log to determine why POST was invoked three times within 24 hours. a. If the codes indicate that the BD CPU generated the resets, replace the BD CPU (Other codes may be present indicating that the GUI lost communications with the BD). b. If the codes indicated that the GUI CPU generated the resets, replace the GUI CPU (Other codes may be present indicating that the BD lost communications with the GUI. 3. Run a complete EST to check for analog device failures.
VENT INOP Test	Checks to see if the ventilator is in the VENT INOP state	 KP0112	Major	1. Check the diagnostic code's corrective actions in Table 6-2. 2. Check cabling from BD CPU PCB to GUI CPU PCB. 3. Replace BD CPU PCB. 4. Call Technical Support or your Puritan Bennett representative.

* Tested in Short POST

Table 6-6: GUI only—Phase 2 POST diagnostic codes

GUI Test	GUI Test Description	GUI (10.4-inch) Diag. code	GUI 9.4-inch) Diag. code	GUI Fault Type	Corrective Action
Bus Timer Test	Monitors activity on the local bus	XP0082	XP0082	Major	1. Check the diag-nostic code's cor-rective actions in Table 6-2. 2. Replace GUI CPU PCB.
DRAM Memory Test	Tests DRAM by writing and verifying data patterns to memory	XP0084	XP0084	Major	1. Check the diag-nostic code's cor-rective actions in Table 6-2. 2. Replace GUI CPU PCB.
DRAM Parity Error Test	Checks the ability to detect a parity error upon reading defective parity from memory	XP0090	XP0090	Major	1. Check the diag-nostic code's cor-rective actions in Table 6-2. 2. Replace GUI CPU PCB.
Ethernet Self-test End		ZP0086	ZP0086	Minor	1. Check the diag-nostic code's cor-rective actions in Table 6-2. 2. Replace GUI CPU PCB.
Ethernet Self-Test Start	Internal routine verifies functionality of Ethernet controller	XP0085	XP0085	Major	1. Check the diag-nostic code's cor-rective actions in Table 6-2. 2. Replace GUI CPU PCB.
NMI Register Test	Verifies NMI source register is in reset state (no bits set)	XP0083	XP0083	Major	1. Check the diag-nostic code's cor-rective actions in Table 6-2. 2. Replace GUI CPU PCB.
Phase 2 Initialization	Start non-kernel portion of POST	XP0006	XP0006	Major	1. Check the diag-nostic code's cor-rective actions in Table 6-2. 2. Replace GUI CPU PCB.
Phase 2 NOVRAM Test	Compares NOVRAM data to valid states and ranges	ZP0088	ZP0088	Minor	1. Check the diag-nostic code's cor-rective actions in Table 6-2. 2. Replace GUI CPU PCB.

Table 6-6: GUI only—Phase 2 POST diagnostic codes (continued)

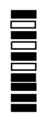
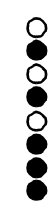
GUI Test	GUI Test Description	GUI (10.4-inch) Diag. code	GUI 9.4-inch) Diag. code	GUI Fault Type	Corrective Action
SAAS Self-test End		 XP0098	 XP0098	Major	1. Check the diagnostic code's corrective actions in Table 6-2. 2. Replace GUI audio alarm. 3. Replace GUI CPU PCB.
SAAS Self-test Start	Detects internal errors of alarm circuitry and lack of audio feedback	 XP0097	 XP0097	Major	1. Check the diagnostic code's corrective actions in Table 6-2. 2. Replace GUI audio alarm. 3. Replace GUI CPU PCB.
Unexpected Reset Umpire Test	Checks for unexpected resets of the CPU. Three resets (strikes) in 24 hours will cause a VENT INOP condition.	 XP0087 or ZP0087	 XP0087 or ZP0087	Major or Minor	1. Check the diagnostic code's corrective actions in Table 6-2. 2. Check associated errors in System Diagnostic Log. 3. Call Technical Support or your Puritan Bennett representative.

Table 6-7: BDU or GUI—Phase 3 POST diagnostic codes

Test Step	Test Description	Diag. code BDU PCB LEDs	Diag. code GUI PCB LEDs (10.4-inch)	Diag. code GUI PCB LEDs (9.4-inch)	Fault Type	Corrective Action
Operating System Initialization*	Loads operating system	KP0129	XP0129	XP0129	Major	1. Check the diagnostic codes' corrective actions in Table 6-2. 2. Replace affected CPU PCB.
Floating Point Unit Test*	Tests floating point functionality of the microprocessor	KP0089	XP0089	XP0089	Major	1. Check the diagnostic codes' corrective actions in Table 6-2. 2. Replace affected CPU PCB.
Memory Management Unit Test*	Tests microprocessor's memory management unit	KP0081	XP0081	XP0081	Major	1. Check the diagnostic codes' corrective actions in Table 6-2. 2. Replace affected CPU PCB.
Application Initialization*	Loads application software	KP0131	XP0131	XP0131	Major	1. Check the diagnostic codes' corrective actions in Table 6-2. 2. Replace affected CPU PCB.

* Tested in Short POST

6.9.1 POST interrupt errors and test failures

Table 6-8 below lists the errors that can occur during particular POST test steps. These errors, reported by the diagnostic LED array on the applicable CPU PCB, are of two types: interrupts and test failures. An interrupt error may indicate that an external event (e.g. a power fail interrupt) occurred during the test step. A test failure indicates that the test failed to meet its specifications.

Table 6-8: Interrupt errors and test failures – POST self tests

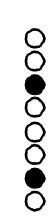
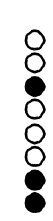
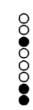
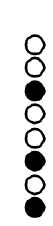
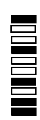
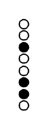
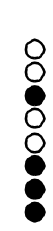
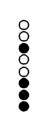
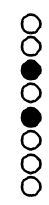
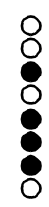
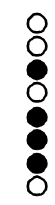
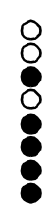
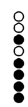
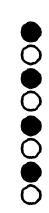
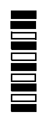
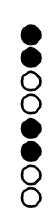
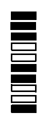
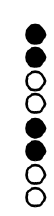
Error	BD and GUI LED arrays			Error Type	May be caused by
	BDU Diag. code	GUI (10.4-inch) Diag. code	GUI (9.4-inch) Diag. code		
Unknown NMI				Interrupt	CPU PCB
Ethernet Parity Error				Interrupt	CPU PCB
DRAM Parity Error				Interrupt	CPU PCB
Analog Interface Error				Interrupt	AI PCB
Power Fail NMI (BDU only)				Interrupt	Loss of ac power during POST
5 Vdc overvoltage (GUI only)				Interrupt	Power Supply
12 Vdc overvoltage (GUI only)				Interrupt	Power Supply
12 Vdc undervoltage (GUI only)				Interrupt	Power Supply

Table 6-8: Interrupt errors and test failures – POST self tests (continued)

Error	BD and GUI LED arrays			Error Type	May be caused by
	BDU Diag. code	GUI (10.4-inch) Diag. code	GUI (9.4-inch) Diag. code		
SAAS NMI				Interrupt	GUI alarm or alarm cabling
Access fault/Bus error				Interrupt	CPU PCB
Other Unexpected interrupt				Interrupt	CPU PCB
POST Internal Software Failure				Interrupt	CPU PCB
Test Failed				Failure	Specific analog device or CPU PCB

6.10 SST and EST test sequences and diagnostic codes

Table 6-9 and Table 6-10 list, in sequence, the tests that comprise SST and EST, respectively, and provide detailed descriptions of each test. The tables include corrective actions for failures that may occur during each test.

Table 6-9: SST diagnostic codes

Test description and failure modes	Code and message	Corrective actions
SST Flow Sensor Test		
Test: Checks oxygen (PS1) and wall air (PS2) pressure switches and compressor pressure transducer (PC) to determine whether any gases are connected.		
Failure: No gas is available (neither PS1, PS2, nor PC detects pressure).	FS0005 Gas not connected	Connect gas supply.
Failure: Only air is available (only PS2 or PC detects pressure).	AS0012 O_2 pressure not detected	Make sure oxygen supply is connected.
Failure: Only oxygen is available (only PS1 detects pressure).	AS0013 Wall air pressure not detected	Make sure air supply is connected.
Prompts user to connect inspiratory filter, connect patient circuit (without humidifier), and block wye.		
Test: Runs test only if oxygen available. For oxygen flows of 120 60, 5, and 1 L/min, verifies that flow is stable.		
Failure: Flow controller unable to establish and control oxygen flow at 120 L/min.	AS0010 Unable to establish O_2 flow	1. Make sure oxygen supply is connected and unrestricted. 2. Verify that the oxygen supply is good. 3. Verify that the patient circuit system has no leaks or occlusions. If not sure, run the first four tests in EST to get to the leak test. If the leak test passes in EST, exit out of EST. Correct the leak or occlusion in the patient circuit used in SST and rerun or try another patient circuit. 4. Verify that the oxygen regulator pressure is set between 9-12 psi. 5. Switch PSOLs to see if the failure transfers to the air side. If yes, return PSOL2 back to its original position and replace PSOL1. 6. Run a flow sensor calibration. 7. Switch Q1 and Q2. Rerun the flow sensor calibration and EST. If the failure transfers to the air side, return Q2 back to its original position and replace Q1.

Table 6-9: SST diagnostic codes (continued)

Test description and failure modes	Code and message	Corrective actions
Failure: Flow controller unable to establish and control oxygen flow at 60, 5, and 1 L/min.	FS0006 Unable to establish O_2 flow	1. Make sure oxygen supply is connected and unrestricted. 2. Verify that the oxygen supply is good. 3. Check regulated oxygen pressure. 4. Verify that the system has no leaks or occlusions. If not sure, run the first four tests in EST to run the leak test. 5. Switch PSOLs to see if the failure transfers to the air side. If yes, return PSOL2 back to its original position and replace PSOL1. 6. Run a flow sensor calibration. 7. Switch Q1 and Q2. Rerun the flow sensor calibration and EST. If the failure transfers to the air side, return Q2 back to its original position and replace Q1. 8. Replace Q3.
Test: Runs test only if oxygen available. For oxygen flows of 120 60, 5, and 1 L/min, verifies that oxygen (Q1) and exhalation (Q3) flow sensor readings are in range. **Failure:** Q1 and Q3 readings are too far apart.	FS0001 O_2 flow sensor cross check failed	1. Check for leak. 2. Verify that safety valve is closed. 3. Perform flow sensor calibration. 4. Replace Q1. 5. Replace Q3. 6. Replace AI PCB.
Test: Runs test only if oxygen available. For oxygen flows of 120, 60, 5, or 1 L/min, verifies that oxygen PSOL (PSOL1) command current is in range. **Failure:** PSOL1 command current is out of range.	FS0002 O_2 PSOL current out of range	1. Check for leak. 2. Verify safety valve is closed. 3. Check regulated oxygen pressure. 4. Replace PSOL1. 5. Replace AI PCB.
Test: Runs test only if oxygen available. Commands oxygen PSOL (PSOL1) to deliver 0 L/min (closed). **Failure:** Oxygen flow > 0.153 L/min.	FS0008 O_2 zero flow check failed	1. Verify no leaks at the Q1 O-rings. 2. Run EST Gas Supply Test to check for PSOL1 leak. 3. Remove and then reseat PSOL1. 4. Replace PSOL1. 5. Perform a flow sensor calibration. 6. Replace Q1.

Table 6-9: SST diagnostic codes (continued)

Test description and failure modes	Code and message	Corrective actions
Test: Runs test only if air available. For air flows of 120, 60, 5, and 1 L/min, verifies that flow is stable.		
Failure: Flow controller unable to establish and control air flow at 120 L/min.	AS0011 Unable to establish air flow	1. Make sure air supply is connected and unrestricted. 2. Verify that the air supply is good. 3. Verify that the patient circuit system has no leaks or occlusions. If not sure, run the first four tests in EST to get to the leak test. If the leak test passes in EST, exit out of EST. Correct the leak or occlusion in the patient circuit used in SST and rerun or try another patient circuit. 4. Verify that the air regulator pressure is set between 9-12 psi. 5. Switch PSOLs to see if the failure transfers to the oxygen side. If yes, return PSOL1 back to its original position and replace PSOL2. 6. Run a flow sensor calibration. 7. Switch Q1 and Q2. Rerun the flow sensor calibration and EST. If the failure transfers to the oxygen side, return Q1 back to its original position and replace Q2.
Failure: Flow controller unable to establish and control air flow at 60, 5, and 1 L/min.	FS0007 Unable to establish air flow	1. Make sure air supply is connected unrestricted. 2. Verify that the air supply is adequate. 3. Check regulated air pressure. 4. Verify that the system has no leaks or occlusions. If not sure, run the first four tests in EST to run the leak test. 5. Switch PSOLs to see if the failure transfers to the oxygen side. If yes, return PSOL1 back to its original position and replace PSOL2. 6. Run a flow sensor calibration. 7. Switch Q1 and Q2. Rerun the flow sensor calibration and EST. If the failure transfers to the oxygen side, return Q1 back to its original position and replace Q2. 8. Replace Q3.

Table 6-9: SST diagnostic codes (continued)

Test description and failure modes	Code and message	Corrective actions
Test: Runs test only if air available. For air flows of 120, 60, 5, and 1 L/min, verifies that air (Q2) and exhalation (Q3) flow sensor readings are in range.		
Failure: Q2 and Q3 readings are too far apart.	FS0003 Air flow sensor cross-check failed	1. Correct the leak or occlusion in the SST patient circuit and rerun or try known good patient circuit and filter set. 2. Verify that the ventilator system has no leaks or occlusions by running the first four tests in EST to run the leak test. 3. If the leak test fails in EST, troubleshoot the expiratory filter or ventilator system for leaks or occlusions. 4. If the leak test passes in EST, troubleshoot the SST patient circuit. 5. Switch PSOLs to see if the failure transfers to the oxygen side. If yes, return PSOL1 back to its original position and replace PSOL2. 6. Run a flow sensor calibration. 7. Switch Q1 and Q2. Rerun the flow sensor calibration and EST. If the failure transfers to the oxygen side, return Q1 back to its original position and replace Q2. 8. Replace Q3.
Test: Runs test only if air available. For air flows of 120, 60, 5, and 1 L/min, verifies that air PSOL (PSOL2) command current is in range.		
Failure: PSOL2 command current out of range.	FS0004 Air PSOL current out of range	1. Make sure air supply is connected and unrestricted. 2. Verify that the air supply is good. 3. Verify that the system has no leaks or occlusions. If not sure, run the first four tests in EST to run the leak test. 4. Switch PSOLs to see if the failure transfers to the oxygen side. If yes, return PSOL1 back to its original position and replace PSOL2. 5. Run a flow sensor calibration. 6. Switch Q1 and Q2. Rerun the flow sensor calibration and EST. If the failure transfers to the oxygen side, return Q1 back to its original position and replace Q2. 7. Replace Q3.

Table 6-9: SST diagnostic codes (continued)

Test description and failure modes	Code and message	Corrective actions
Test: Runs test only if air available. Commands air PSOL (PSOL2) to deliver 0 L/min (closed). **Failure:** Air flow > 0.153 L/min.	FS0009 Air zero flow check failed	1. Verify no leaks at the Q2 O-rings. 2. Run EST Gas Supply Test to check for PSOL2 leak. 3. Remove and then reseat PSOL2. 4. Replace PSOL2. 5. Perform a flow sensor calibration. 6. Replace Q2.
Performs lift-off calibration for PSOL1 and PSOL2, as applicable.		
Prompts user to connect humidifier, if applicable.		
Circuit Pressure Test		
Test: Autozeroes inspiratory pressure transducer (PI), then reads pressure. Stores pressure reading. **Failure:** Inspiratory pressure transducer ADC count at 0 cmH_2O is out of range.	FS0101 Inspiratory autozero out of range	1. Replace Inspiratory Electronics PCB. 2. Replace AI PCB.
Test: Autozeroes expiratory pressure transducer (PE), then reads pressure. Stores pressure reading. **Failure:** Expiratory pressure transducer ADC count at 0 cmH_2O is out of range.	FS0102 Expiratory autozero out of range	1. Replace exhalation transducer PCB. 2. Replace AI PCB. 3. Replace SOL1.
Test: Pressurizes system to 10 cmH_2O using a gas flow of 5 L/min. **Failure:** Unable to build pressure to 10 cmH_2O at 5 L/min within time-out period.	FS0103 Failed to reach test pressure	1. Verify that the patient circuit system has no leaks or occlusions or use a known good patient circuit and filter set. 2. Verify that the air supply or compressor is available and adequate. 3. Verify that the ventilator system has no leaks or occlusions. If not sure, run the first four tests in EST to run the leak test.

Table 6-9: SST diagnostic codes (continued)

Test description and failure modes	Code and message	Corrective actions
Test: Reads inspiratory and expiratory pressure transducers at 10 cmH_2O. **Failure:** Inspiratory/expiratory pressure transducer readings are too far apart.	FS0104 Cross-check failed	1. Verify that the patient circuit system has no leaks or occlusions or use a known good patient circuit and filter set. 2. Verify that the ventilator system has no leaks or occlusions. If not sure, run the first four tests in EST to run the leak test. 3. If the leak test passes in EST, exit out of EST. Review the data for the Circuit Pressure Test to determine which pressure transducer is out of range: PI or PE. Replace applicable pressure transducer. 4. Replace AI PCB.
Test: Opens inspiratory pressure transducer autozero solenoid (SOL1) and reads inspiratory pressure. **Failure:** Inspiratory pressure reading out of range (-0.60 to 0.60 cmH_2O).	FS0105 Bad insp autozero solenoid	1. Replace SOL1. 2. Replace Inspiratory Electronics PCB. 3. Replace AI PCB.
Test: Opens expiratory pressure transducer autozero solenoid (SOL2) and reads expiratory pressure. **Failure:** Expiratory pressure reading out of range (–0.60 to 0.60 cmH_2O).	FS0106 Bad exp autozero sol	1. Replace SOL2. 2. Replace exhalation transducer PCB. 3. Replace AI PCB.
Test: Pressurizes system to 50 and 100 cmH_2O using a gas flow of 5 L/min. **Failure:** Unable to build pressure to 50 or 100 cmH_2O at 5 L/min within time-out period.	FS0108 Failed to reach test pressure	1. Make sure gas source is available. 2. Check for system leak.
Test: Reads inspiratory and expiratory pressure transducers at 50 and 100 cmH_2O. **Failure:** Inspiratory/expiratory pressure transducer readings are too far apart.	FS0107 Cross-check failed	1. Replace the expiratory bacteria filter. 2. Verify that the system has no leaks or occlusions. If not sure, run the first four tests in EST to run the leak test. 3. If the leak test passes in EST, exit out of EST. Review the data for the EST Circuit Pressure Test to determine which pressure transducer is out of range: PI or PE. Replace applicable pressure transducer. 4. Replace AI PCB.

Table 6-9: SST diagnostic codes (continued)

Test description and failure modes	Code and message	Corrective actions
Circuit leak		
Test: Pressurizes system to 90 cmH_2O with either gas using 2 L/min flow.		
Failure: Unable to attain leak test starting pressure within time-out period.	FS0205 Unable to establish pressure	1. Make sure test circuit is connected and is not leaking. 2. Check exhalation valve operation, and verify secure connection of expiratory filter.
Test: Waits for pressure to decay, then verifies adequate inspiratory pressure.		
Failure: System pressure dropped below 85 cmH_2O.	FS0201 Excessive leak	1. Make sure test circuit is connected. 2. Check for system leaks. 3. Check exhalation valve operation. 4. Verify secure connection of expiratory filter.
Test: Waits until inspiratory pressure drops to 85 cmH_2O or until 10 s elapse. If pressure drops to 85 cmH_2O, waits until pressure drops by 5 cmH_2O or until 10 s more elapse. Checks pressure drop. Compares inspiratory and expiratory pressure measurements.		
Failure: Pressure drops to 85 cmH_2O in 10 s, then in 10 s more by ≥ 30 cmH_2O.	FS0201 Excessive leak	1. Make sure patient circuit is connected. 2. Check for system leaks. 3. Check exhalation valve operation. 4. Verify secure connections of bacteria filters and humidifier.
Failure: Pressure drops to 85 cmH_2O in 10 s, then in 10 s more by ≥ 10 cmH_2O.	AS0202 Excessive leak	1. Make sure patient circuit is connected. 2. Check for system leaks. 3. Check exhalation valve operation. 4. Verify secure connections of bacteria filters and humidifier.
Failure: Inspiratory/expiratory pressure transducer readings are too far apart.	AS0206 Test circuit not connected	Make sure test circuit is connected properly.
Expiratory filter		
Prompts user to disconnect circuit from expiratory filter.		
Test: Establishes 60 L/min flow of either gas.		
Failure: Unable to deliver stable gas flow.	FS0301 Unable to establish flow	Make sure gas supply is connected.

Table 6-9: SST diagnostic codes (continued)

Test description and failure modes	Code and message	Corrective actions
Test: Reads inspiratory pressure and expiratory flow. Verifies that circuit was disconnected (expiratory flow ≤ 1 L/min).		
Failure: Expiratory flow detected, indicating that circuit not disconnected.	FS0306 Patient circuit not disconnected	Make sure patient circuit is disconnected at expiratory filter.
Prompts user to reconnect circuit to expiratory filter.		
Test: Establishes 60 L/min flow of either gas.		
Failure: Unable to deliver stable gas flow.	FS0301 Unable to establish flow	Make sure gas supply is connected.
Test: Reads inspiratory and expiratory pressure and expiratory flow. Verifies that circuit was reconnected by checking expiratory flow.		
Failure: Expiratory flow reading indicates that circuit not reconnected.	FS0307 Patient circuit not reconnected	Make sure patient circuit is connected at expiratory filter.
Test: Verifies that pressure drop across exhalation compartment within range.		
Failure: Exhalation compartment pressure > 3 cmH_2O but < 4 cmH_2O.	AS0308 Occluded expiratory compartment	1. Check compartment for obstruction. 2. Verify exhalation valve operation by running EST.
Failure: Exhalation compartment pressure > 4 cmH_2O.	FS0303 Occluded expiratory compartment	1. Check compartment for obstruction. 2. Verify exhalation valve operation by running EST.
Test: Calculates pressure drop across expiratory filter and verifies that filter not occluded.		
Failure: Pressure drop across filter > 2 cmH_2O, but < 3 cmH_2O.	AS0305 Occluded expiratory filter	Consider replacing expiratory filter.
Failure: Pressure drop across filter > 3 cmH_2O.	FS0304 Occluded expiratory filter	Replace expiratory filter.
Failure: Pressure drop across expiratory filter < 0.4 cmH_2O, but > 0.1 cmH_2O.	AS0311 Low expiratory filter ΔP	1. Repeat test, following directions more closely. 2. Replace filter.
Failure: Pressure drop across expiratory filter < 0.1 cmH_2O.	FS0310 Low expiratory filter ΔP	1. Repeat test, following directions more closely. 2. Replace filter.

Table 6-9: SST diagnostic codes (continued)

Test description and failure modes	Code and message	Corrective actions
Circuit Resistance		
Test: If test is being repeated, prompts user to block wye. Pressurizes system to 100 cmH_2O at 60 L/min. **Failure:** Unable to pressurize system within time-out period.	FS0412 Wye not blocked	1. Block wye when prompted. 2. Check for circuit leaks.
Test: Characterizes total circuit resistance over a range of flows using either gas. **Failure:** Peak flow < alert threshold but > failure threshold.	AS0411 Unable to reach min peak flow	Check for kinked or occluded patient tubing.
Failure: Peak flow < failure threshold.	FS0410 Unable to reach min peak flow	Check for kinked or occluded patient tubing.
Prompts user to unblock patient wye.		
Test: Measures pressure drop across inspiratory limb at 60 L/min (adult) or 30 L/min (pediatric). **Failure:** Flow controller unable to establish and control gas flow.	FS0401 Unable to establish flow	Make sure gas supply is connected.
Test: Determines inspiratory limb pressure drop, and checks for an occlusion. **Failure:** Inspiratory limb pressure > 8.5 cmH_2O (adult) or 5.5 cmH_2O (pediatric), but < 12.5 cmH_2O (adult) or 7.5 cmH_2O (pediatric), indicating occlusion.	AS0403 Occluded inspiratory limb	Check for occluded patient tubing.
Failure: Inspiratory limb pressure > 12.5 cmH_2O (adult) or 7.5 cmH_2O (pediatric), indicating occlusion.	FS0402 Occluded inspiratory limb	Check for occluded patient tubing.
Failure: Inspiratory limb pressure < 0.6 cmH_2O (adult) or 5.5 cmH_2O (pediatric), but > 0.2 cmH_2O.	AS0413 Insp limb resistance low	1. Make sure inspiratory filter is installed. 2. Repeat test, following directions more closely. 3. Replace inspiratory filter. 4. Replace patient circuit
Failure: Inspiratory limb pressure < 0.2 cmH_2O.	FS0408 Insp limb resistance low	1. Make sure inspiratory filter is installed. 2. Repeat test, following directions more closely. 3. Replace inspiratory filter. 4. Replace patient circuit

Table 6-9: SST diagnostic codes (continued)

Test description and failure modes	Code and message	Corrective actions
Test: Characterizes inspiratory limb resistance over a range of flows using either gas.		
Failure: Peak flow < 80 L/min but > 60 L/min.	AS0407 Unable to reach min peak flow	Check for kinked or occluded patient tubing.
Failure: Peak flow < 60 L/min.	FS0404 Unable to reach min peak flow	Check for kinked or occluded patient tubing.
Test: Determines expiratory limb pressure drop, and checks for an occlusion.		
Failure: Expiratory limb pressure > 8.5 cmH_2O (adult) or 5.5 cmH_2O (pediatric) but > 12.5 cmH_2O (adult) or 7.5 cmH_2O (pediatric), indicating occlusion.	AS0406 Occluded exhalation limb	Check for occluded patient tubing.
Failure: Expiratory limb pressure > 12.5 cmH_2O (adult) or 7.5 cmH_2O (pediatric), indicating occlusion.	FS0405 Occluded exhalation limb	Check for occluded patient tubing.
Failure: Expiratory limb pressure < 0.6 cmH_2O (adult) or 0.5 cmH_2O (pediatric), but > 0.2 cmH_2O.	AS0414 Exp limb resistance low	Replace patient circuit
Failure: Expiratory limb pressure < 0.2 cmH_2O.	FS0409 Exp limb resistance low	Replace patient circuit
Compliance calibration		
Prompts user to block wye.		
Test: Measures circuit compliance using 10 L/min flow, storing pressure and volume measurements at 5 cmH_2O intervals from 5 to 100 cmH_2O. Uses air as default gas.		
Failure: System cannot pressurize to one of the test pressure points.	FS0501 Unable to pressurize circuit	Check patient circuit for leaks. Replace as necessary.
Test: Measures circuit compliance using a high flow, storing pressure and volume measurements at 5 cmH_2O intervals from 5 to 100 cmH_2O.		
Failure: System cannot pressurize to one of the test pressure points.	FS0502 Unable to pressurize circuit	Check patient circuit for leaks. Replace as necessary.
Failure: Out-of-range pressure ratio calculation.	FS0503 Compliance calculation failure	1. Repeat test, making sure circuit is undisturbed during test. 2. Repeat SST to retest pressure transducers. 3. Run EST and verify all pneumatics tests pass.

Table 6-9: SST diagnostic codes (continued)

Test description and failure modes	Code and message	Corrective actions
Test: Determines compliance and checks its reasonableness.		
Failure: High compliance > 6 mL/cmH_2O (adult) or 4.5 mL/cmH_2O (pediatric), but < 12 mL/cmH_2O (adult) or 9 mL/cmH_2O (pediatric).	AS0505 Excessive compliance	1. Make sure correct patient tubing type was specified in SST. 2. Replace patient circuit.
Failure: High compliance > 12 mL/cmH_2O (adult) or 9 mL/cmH_2O (pediatric).	FS0504 Excessive compliance	1. Make sure correct patient tubing type was specified in SST. 2. Replace patient circuit.
Failure: High compliance falls below 1.56 mL/cmH_2O (adult) or 1.34 mL/cmH_2O (pediatric) but not lower than 1.05 mL/cmH_2O.	AS0507 Compliance low	1. Make sure correct patient tubing type was specified in SST. 2. Replace patient circuit with a known good circuit and filter set. 3. Run EST to check the operation of PI and PE during the Circuit Pressure Test. Replace applicable pressure transducer. 4. Run Atmospheric Pressure Transducer calibration.
Failure: High compliance falls below 1.05 mL/cmH_2O.	FS0506 Compliance low	1. Make sure correct patient tubing type was specified in SST. 2. Replace patient circuit.
Failure: Low compliance > 6 mL/cmH_2O (adult) or 4.5 mL/cmH_2O (pediatric), but < 12 mL/cmH_2O (adult) or 9 mL/cmH_2O (pediatric).	AS0509 Excessive compliance	1. Make sure correct patient tubing type was specified in SST. 2. Replace patient circuit with a known good circuit and filter set. 3. Run EST to check the operation of PI and PE during the Circuit Pressure Test. Replace applicable pressure transducer. 4. Run Atmospheric Pressure Transducer calibration.
Failure: Low compliance > 12 mL/cmH_2O (adult) or 9 mL/cmH_2O (pediatric).	FS0508 Excessive compliance	1. Make sure correct patient tubing type was specified in SST. 2. Replace patient circuit.
Failure: Low compliance falls below 1.56 mL/cmH_2O (adult) or 1.34 mL/cmH_2O (pediatric), but not below 1.05 mL/cmH_2O.	AS0511 Compliance low	1. Make sure correct patient tubing type was specified in SST. 2. Replace patient circuit with a known good circuit and filter set. 3. Run EST to check the operation of PI and PE during the Circuit Pressure Test. Replace applicable pressure transducer. 4. Run Atmospheric Pressure Transducer calibration.
Failure: Low compliance falls below 1.05 mL/cmH_2O.	FS0510 Compliance low	1. Make sure correct patient tubing type was specified in SST. 2. Replace patient circuit.

Table 6-10: EST test sequence

Description	Code and message	Display	Corrective actions
Circuit Pressure Test			
Test: If ventilator is running on battery power, prompts user to connect ac power, then verifies that ventilator is connected to ac. EST can only run on ac (facility) power. **Failure:** System is still running on battery power.	FE0010 ac power not connected		1. Plug in ventilator power cord. 2. Disconnect BPS to isolate problem. 3. Replace power supply.
Prompts user to connect air and oxygen, to remove inspiratory filter, and to install test circuit.			
Test: Autozeroes inspiratory pressure transducer (PI), then reads pressure. Stores pressure reading. **Failure:** Inspiratory pressure transducer ADC count at 0 cmH_2O is out of range.	FE0001 Inspiratory autozero out of range	Inspiratory pressure (counts)	1. Replace SOL1. 2. Replace Inspiratory Electronics PCB. 3. Replace AI PCB.
Test: Autozeroes expiratory pressure transducer (PE), then reads pressure. Stores pressure reading. **Failure:** Expiratory pressure transducer ADC count at 0 cmH_2O is out of range.	FE0002 Expiratory autozero out of range	Expiratory pressure (counts)	1. Replace SOL2. 2. Replace exhalation transducer PCB. 3. Replace AI PCB.
Test: Pressurizes system to 10 cmH_2O using an air flow of 5 L/min. **Failure:** Unable to build pressure (air) to 10 cmH_2O at 5 L/min within time-out period.	FE0003 Failed to reach test pressure	Inspiratory and expiratory pressure (only if test fails)	1. Make sure that test circuit is installed and air supply or compressor is available and good. 2. Verify that the air regulator pressure is set between 9-12 psi. 3. Verify that the patient circuit system has no leaks or occlusions by running the first four tests in EST to get to the leak test.

Table 6-10: EST test sequence (continued)

Description	Code and message	Display	Corrective actions
Test: Reads inspiratory and expiratory pressure transducers at 10 cmH_2O. **Failure:** Inspiratory/expiratory pressure transducer readings are too far apart.	FE0004 Cross-check failed	Inspiratory and expiratory pressure	1. Verify that the system has no leaks or occlusions. If not sure, run the first four tests in EST to run the leak test 2. If the leak test passes in EST, exit out of EST. Review the data for the Circuit Pressure Test to determine which pressure transducer is out of range: PI or PE. Replace applicable pressure transducer. 3. Replace AI PCB.
Test: Opens inspiratory pressure transducer autozero solenoid (SOL1) and reads inspiratory pressure. **Failure:** Inspiratory pressure reading out of range (-0.60 to 0.60 cmH_2O).	FE0005 Bad insp autozero solenoid	Inspiratory pressure	1. Replace SOL1. 2. Replace Inspiratory Electronics PCB. 3. Replace AI PCB.
Test: Opens expiratory pressure transducer autozero solenoid (SOL2) and reads expiratory pressure. **Failure:** Expiratory pressure reading out of range (-0.60 to 0.60 cmH_2O).	FE0006 Bad exp autozero sol	Expiratory pressure	1. Replace SOL2. 2. Replace exhalation transducer PCB. 3. Replace AI PCB.
Test: Pressurizes system to 50 or 100 cmH_2O using an air flow of 5 L/min. **Failure:** Unable to build pressure (air) to 50 or 100 cmH_2O at 5 L/min within time-out period.	FE0008 Failed to reach test pressure	Inspiratory and expiratory pressure (only if test fails)	1. Make sure air supply or compressor is available. 2. Check for system leak at the expiratory bacteria filter or O2 sensor. If not sure, run the first four tests in EST to run the leak test.

Table 6-10: EST test sequence (continued)

Description	Code and message	Display	Corrective actions
Test: Reads inspiratory and expiratory pressure transducers at 50 and 100 cmH_2O.		Inspiratory and expiratory pressure	
Failure: Inspiratory/expiratory pressure transducer readings are too far apart.	FE0007 Cross-check failed		1. Replace the expiratory bacteria filter. 2. Verify that the system has no leaks or occlusions. If not sure, run the first four tests in EST to run the leak test. 3. If the leak test passes in EST, exit out of EST. Review the data for the Circuit Pressure Test to determine which pressure transducer is out of range: PI or PE. Replace applicable pressure transducer. 4. Replace AI PCB.
Flow sensors cross check Test			
Test: For oxygen flows of 120, 60, 5, and 1 L/min, verifies that flow is stable.		Inspiratory and expiratory flow and oxygen PSOL (PSOL1) command current	
Failure: Flow controller unable to establish and control oxygen flow at 120 L/min.	AE0110 Unable to establish O_2 flow		1. Make sure oxygen supply is connected and unrestricted. 2. Verify oxygen regulator pressure is set between 9-12 psi. 3. Switch PSOLs to see if failure transfers to the other gas side. If yes, return the air PSOL to its original position and replace the oxygen PSOL. 4. Run the leak test in EST to check for leaks/occlusions. 5. Perform a flow sensor calibration. 6. Replace Q1. 7. Replace the Inspiratory Electronics PCB. 8. Replace the AI PCB.
Failure: Flow controller unable to establish and control oxygen flow at 60, 5, and 1 L/min.	FE0106 Unable to establish O_2 flow		1. Make sure oxygen supply is connected. 2. Check regulated oxygen pressure. 3. Replace PSOL1 or oxygen flow sensor (Q1). 4. Replace AI PCB.

Table 6-10: EST test sequence (continued)

Description	Code and message	Display	Corrective actions
Test: For oxygen flows of 120 60, 5, and 1 L/min, verifies that oxygen (Q1) and exhalation (Q3) flow sensor readings are in range.		Inspiratory and expiratory flow	
Failure: Q1 and Q3 readings are too far apart.	FE0101 O_2 flow sensor cross check failed		1. Make sure oxygen supply is connected and unrestricted. 2. Verify that the oxygen supply is good. 3. Verify that the system has no leaks or occlusions. If not sure, run the first four tests in EST to run the leak test. 4. Switch PSOLs to see if the failure transfers to the air side. If yes, return PSOL2 back to its original position and replace PSOL1. 5. Run a flow sensor calibration.6. Switch Q1 and Q2. Rerun the flow sensor calibration and EST. If the failure transfers to the air side, return Q2 back to its original position and replace Q1.
Test: For oxygen flows of 120, 60, 5, and 1 L/min, verifies that oxygen PSOL (PSOL1) command current is in range.		POSL1 command current	
Failure: PSOL1 command current is out of range.	FE0102 O_2 PSOL current out of range		1. Make sure oxygen supply is connected and unrestricted. 2. Verify that the oxygen supply is good. 3. Verify that the system has no leaks or occlusions. If not sure, run the first four tests in EST to run the leak test. 4. Switch PSOLs to see if the failure transfers to the air side. If yes, return PSOL2 back to its original position and replace PSOL1. 5. Run a flow sensor calibration. 6. Switch Q1 and Q2. Rerun the flow sensor calibration and EST. If the failure transfers to the air side, return Q2 back to its original position and replace Q1.
Test: Commands oxygen PSOL (PSOL1) to deliver 0 L/min (closed).		Inspiratory flow	
Failure: Oxygen flow > 0.153 L/min.	FE0108 O_2 zero flow check failed		1. Verify no leaks at the Q1 O-rings. 2. Run EST Gas Supply Test to check for PSOL1 leak. Remove and then reseat PSOL1 3. Replace PSOL1. 4. Perform a flow sensor calibration. 5. Replace Q1.

Table 6-10: EST test sequence (continued)

Description	Code and message	Display	Corrective actions
Test: For air flows of 120, 60, 5, and 1 L/min, verifies that flow is stable.		Inspiratory and expiratory flow and air PSOL (PSOL2) command current	
Failure: Flow controller unable to establish and control air flow at 120 L/min.	AE0111 Unable to establish air flow		1. Make sure air supply is connected and unrestricted. 2. Verify air regulator pressure is set between 9-12 psi. 3. Switch PSOL's to see if failure transfers to the other gas side. If yes, return Oxygen PSOL to its original position and replace the Air PSOL. 4. Run the leak test in EST to check for leaks/occlusions. 5. Perform a flow sensor calibration. 6. Replace Q2. 7. Replace the Inspiratory Electronics PCB. 8. Replace the AI PCB.
Failure: Flow controller unable to establish and control air flow at 60, 5, and 1 L/min.	FE0107 Unable to establish air flow		1. Make sure air supply is connected. 2. Check regulated air pressure. 3. Perform flow sensor calibration. 4. Replace PSOL2 or air flow sensor (Q2). 5. Replace AI PCB.
Test: For air flows of 120 60, 5, and 1 L/min, verifies that air (Q2) and exhalation (Q3) flow sensor readings are in range.		Inspiratory and expiratory flow	
Failure: Q2 and Q3 readings are too far apart.	FE0103 Air flow sensor cross check failed		1. Make sure air supply is connected and unrestricted. 2. Verify that the air supply is good. 3. Verify that the system has no leaks or occlusions. If not sure, run the first four tests in EST to run the leak test. 4. Switch PSOLs to see if the failure transfers to the air side. If yes, return PSOL back to its original position and replace PSOL2 5. Run a flow sensor calibration. 6. Switch Q1 and Q2. Rerun the flow sensor calibration and EST. If the failure transfers to the oxygen side, return Q1 back to its original position and replace Q2.

Table 6-10: EST test sequence (continued)

Description	Code and message	Display	Corrective actions
Test: For air flows of 120, 60, 5, or 1 L/min, verifies that air PSOL (PSOL2) command current is in range. **Failure:** PSOL2 command current out of range.	FE0104 Air PSOL current out of range	PSOL2 command current	1. Make sure air supply is connected and unrestricted. 2. Verify that the air supply is good. 3. Verify that the system has no leaks or occlusions. If not sure, run the first four tests in EST to run the leak test. 4. Switch PSOLs to see if the failure transfers to the air side. If yes, return PSOL back to its original position and replace PSOL2 5. Run a flow sensor calibration. 6. Switch Q1 and Q2. Rerun the flow sensor calibration and EST. If the failure transfers to the oxygen side, return Q1 back to its original position and replace Q2.
Test: Commands air PSOL (PSOL2) to deliver 0 L/min (closed). **Failure:** Air flow > 0.153 L/min.	FE0109 Air zero flow check failed	Inspiratory flow	1. Verify no leaks at the Q2 O-rings. 2. Run EST Gas Supply Test to check for PSOL2 leak. Remove and then reseat PSOL2 3. Replace PSOL2. 4. Perform a flow sensor calibration. 5. Replace Q2.
Performs lift-off calibration for PSOL1 and PSOL2.			
EST Gas Supply/SV Test			
Test: Checks to see if wall air connected (pressure switch PS2 closed). If not, prompts user to connect wall air. **Failure:** ACCEPT key was pressed but PS2 still open.	FE0204 Wall air pressure not detected		1. Make sure air supply is connected. 2. Check PS2: Remove the wiring connectors from PS2 and jumper the connectors to each other. If the system now recognizes the air supply, replace PS2.

Table 6-10: EST test sequence (continued)

Description	Code and message	Display	Corrective actions
Test: Checks to see if oxygen connected (pressure switch PS1 closed). If not, prompts user to connect oxygen.			
Failure: ACCEPT key was pressed but PS1 still open.	FE0205 O_2 pressure not detected		1. Make sure oxygen supply is connected. 2. Check PS1: Remove the wiring connectors from PS1 and jumper the connectors to each other. If the system now recognizes the air supply, replace PS1.
Prompts user to block *To patient* port.			
Test: Establishes 1 L/min flow and verifies that it is stable.			
Failure: Stable flow could not be established within allotted time.	FE0210 SV pressure relief failed		1. Make sure *To patient* port is blocked. 2. Check for leaks at the O_2 sensor, SOL1 or PI. 3. Replace the safety valve. 4. Replace PI.
Test: Determines safety valve cracking pressure and verifies it is in range.		Safety valve cracking pressure	
Failure: Cracking pressure out of range.	FE0210 SV pressure relief failed		1. Make sure *To patient* port is blocked. 2. Check for leaks at the O_2 sensor, SOL1 or PI. 3. Replace the safety valve. 4. Replace PI.
Test: Commands air PSOL (PSOL2) to deliver 100 L/min. If PSOL2 cannot deliver this flow within so many counts, commands oxygen PSOL (PSOL1) to deliver this flow instead. Samples inspiratory pressure and determines peak pressure.		Peak pressure	
Failure: Neither PSOL could deliver 100 L/min within prescribed count.	FE0210 SV pressure relief failed		1. Make sure *To patient* port is blocked. 2. Check for leaks at the O_2 sensor, SOL1 or PI. 3. Replace the safety valve. 4. Replace PI.
Failure: Peak pressure is too high.	FE0210 SV pressure relief failed		1. Make sure *To patient* port is blocked. 2. Check for leaks at the O_2 sensor, SOL1 or PI. 3. Replace the safety valve. 4. Replace PI.

Table 6-10: EST test sequence (continued)

Description	Code and message	Display	Corrective actions
Test: Prompts user to disconnect oxygen. Checks to see if oxygen disconnected (pressure switch PS1 open).			
Failure: PS1 closed instead of open.	FE0206 O_2 pressure detected (O_2 not disconnected)		1. Make sure oxygen supply is disconnected. 2. Replace Inspiratory Electronics PCB. 3. Replace PS1.
Test: Opens safety valve, bleeds pressure, then closes it. Reads inspiratory pressure.		Inspiratory pressure	
Failure: Air PSOL (PSOL2) forward leak was detected via excessive pressure buildup (> 50 cmH_2O but < 100 cmH_2O) in blocked inspiratory module.	AE0213 Air PSOL leak		1. Check for leaks around the Q2 O-rings. 2. Make sure air supply is connected and unrestricted. 3. Reseat Air PSOL. 4. Replace Air PSOL. 5. Replace AI PCB.
Failure: Air PSOL (PSOL2) forward leak was detected via excessive pressure buildup (> 100 cmH_2O) in blocked inspiratory module.	FE0207 Air PSOL leak		1. Check for leaks around the Q2 O-rings. 2. Verify that the safety valve relieves pressures above 100 cmH_2O. Listen for the pressure relief while watching the numeric digital display of system pressure in the upper screen. If the safety valve does not crack open, replace the safety valve. 3. Replace PSOL2.
Test: Disables compressor control. If wall air is the air source, prompts user to disconnect air. Verifies that air is disconnected (pressure switch PS2 open).			
Failure: PS2 closed instead of open.	FE0208 Wall air pressure detected		1. Make sure air supply is disconnected. 2. Replace Inspiratory Electronics PCB. 3. Replace PS2.
Test: Verifies that compressor is depressurized by reading compressor pressure transducer (PC).			
Failure: PC indicates that compressor is pressurized.	FE0212 Compressor pressure detected		Replace compressor PCB.

Table 6-10: EST test sequence (continued)

Description	Code and message	Display	Corrective actions
Test: At zero flow, reads air flow sensor (Q2), oxygen flow sensor (Q1), and exhalation flow sensor (Q3).		Q2 reading Q1 reading Q3 reading	
Failure: During zero-flow check, Q2 reads > 0.05 L/min.	FE0215 Air zero flow check failed		1. Make sure gas supplies are disconnected. 2. Make sure compressor is not running. 3. Verify no leaks at the Q2 O-rings. 4. Check for PSOL2 leak. 5. Remove and then reseat PSOL2. 6. Perform a flow sensor calibration. 7. Replace PSOL2. 8. Replace Q2.
Failure: During zero-flow check, Q1 reads > 0.05 L/min.	FE0216 O_2 zero flow check failed		1. Make sure gas supplies are disconnected. 2. Make sure compressor is not running. 3. Verify no leaks at the Q2 O-rings. 4. Check for PSOL2 leak. 5. Remove and then reseat PSOL2. 6. Perform a flow sensor calibration. 7. Replace PSOL2. 8. Replace Q2.
Failure: During zero-flow check, Q3 reads > 0.1 L/min.	FE0217 Exp zero flow check failed		1. Make sure gas supplies are disconnected. 2. Make sure compressor is not running. 3. Verify no leaks at the Q3 O-rings. 4. Perform a flow sensor calibration. 5. Replace Q3.
Test: Prompts user to connect oxygen. Checks to see if oxygen connected (pressure switch PS1 closed).			
Failure: PS1 open instead of closed.	FE0211 O_2 pressure not detected		1. Make sure oxygen supply is connected. 2. Replace Inspiratory Electronics PCB.

Table 6-10: EST test sequence (continued)

Description	Code and message	Display	Corrective actions
Test: Opens safety valve, bleeds pressure, then closes it. Reads inspiratory pressure.		Inspiratory pressure	
Failure: Oxygen PSOL (PSOL1) forward leak was detected via excessive pressure buildup (> 50 cmH_2O but < 100 cmH_2O) in blocked inspiratory module.	AE0214 O_2 PSOL leak		1. Check for leaks around the Q1 O-rings. 2. Make sure oxygen supply is connected and unrestricted. 3. Reseat oxygen PSOL. 4. Replace oxygen PSOL. 5. Replace AI PCB.
Failure: Oxygen PSOL (PSOL1) forward leak was detected via excessive pressure buildup (> 100 cmH_2O) in blocked inspiratory module.	FE0209 O_2 PSOL leak		1. Check for leaks around the Q1 O-rings. 2. Verify that the safety valve relieves pressures above 100 cmH_2O. Listen for the pressure relief while watching the numeric digital display of system pressure in the upper screen. If the safety valve does not crack open, replace the safety valve. 3. Replace PSOL1.
Re-enables compressor control. Prompts user to reconnect wall air, block *To patient* port, and reconnect test circuit.			
Leak Test			
Test: Pressurizes system to 90 cmH_2O with either gas using 2 L/min flow.			
Failure: System cannot attain leak test starting pressure using oxygen or air within time-out period.	FE0305 Unable to establish pressure		1. Make sure test circuit is connected. 2. Check for system leaks. 3. Check exhalation valve operation. 4. Verify secure connection of expiratory filter.
Test: Waits for pressure to decay, then verifies adequate inspiratory pressure.			
Failure: System pressure dropped below 85 cmH_2O.	FE0301 Excessive leak		1. Make sure test circuit is connected. 2. Check for system leaks. 3. Check exhalation valve operation. 4. Verify secure connection of expiratory filter.

Table 6-10: EST test sequence (continued)

Description	Code and message	Display	Corrective actions
Test: Waits until inspiratory pressure drops to 85 cmH_2O or until 10 s elapse. If pressure drops to 85 cmH_2O, waits until pressure drops by 5 cmH_2O or until 10 s more elapse. Checks pressure drop. Compares inspiratory and expiratory pressure measurements.			
Failure: Pressure not detected on expiratory side (inspiratory/expiratory pressure transducer readings are too far apart).	AE0306 Test circuit not connected	Pressure drop in 10 s	1. Make sure test circuit is properly connected. 2. Replace expiratory bacteria filter. 3. Check for leaks around the Q3 flow sensor. 4. Check/replace the exhalation valve. 5. Replace the expiratory pressure transducer PCB.
Failure: Pressure drops to 85 cmH_2O in 10 s, then in 10 s more by ≥ 5 cmH_2O.	FE0301 Excessive leak		1. Make sure test circuit is connected and is not leaking. 2. Check for system leaks or occlusions especially at the O2 sensor and expiratory filter. 3. Verify secure connection of expiratory filter. 4. Check exhalation valve operation.
GUI Keyboard Test			
Test: Prompts user to press key, then reads keyswitch.			
Failure: Wrong key pressed or key not pressed within 15 s.	FE0401 Accept key fails.		1. Repeat test. 2. Replace keyboard.
Failure: Wrong key pressed or key not pressed within 15 s.	FE0402 Clear key fails.		1. Repeat test. 2. Replace keyboard.
Failure: Wrong key pressed or key not pressed within 15 s.	FE0403 Insp. Pause key fails.		1. Repeat test. 2. Replace keyboard.
Failure: Wrong key pressed or key not pressed within 15 s.	FE0404 Exp. Pause key fails.		1. Repeat test. 2. Replace keyboard.
Failure: Wrong key pressed or key not pressed within 15 s.	FE0405 Man Insp fails.		1. Repeat test. 2. Replace keyboard.
Failure: Wrong key pressed or key not pressed within 15 s.	FE0406 100% O_2 / CAL key fails.		1. Repeat test. 2. Replace keyboard.
Failure: Wrong key pressed or key not pressed within 15 s.	FE0407 Info key fails.		1. Repeat test. 2. Replace keyboard.

Table 6-10: EST test sequence (continued)

Description	Code and message	Display	Corrective actions
Failure: Wrong key pressed or key not pressed within 15 s.	FE0408 Alarm Reset key fails.		1. Repeat test. 2. Replace keyboard.
Failure: Wrong key pressed or key not pressed within 15 s.	FE0409 Alarm Silence key fails.		1. Repeat test. 2. Replace keyboard.
Failure: Wrong key pressed or key not pressed within 15 s.	FE0410 Alarm Volume key fails.		1. Repeat test. 2. Replace keyboard.
Failure: Wrong key pressed or key not pressed within 15 s.	FE0411 Screen brightness fails.		1. Repeat test. 2. Replace keyboard.
Failure: Wrong key pressed or key not pressed within 15 s.	FE0412 Screen contrast key fails.		1. Repeat test. 2. Replace keyboard.
Failure: Wrong key pressed or key not pressed within 15 s.	FE0413 Screen lock key fails.		1. Repeat test. 2. Replace keyboard.
EST GUI Knob Test			
Test: Prompts user to turn knob counterclockwise and clockwise.			
Failure: Knob was not turned in direction as prompted within 15 s.	FE0501 Bad knob		1. Repeat test. 2. Replace keyboard.
GUI Lamp Test			
Test: Prompts user to acknowledge that LED is on.			
Failure: CLEAR key pressed to indicate LED not on.	AE0601 GUI High Alarm LED fails.		1. Check/replace interconnect cable between the GUI LED PCB and the GUI CPU PCB. 2. Replace the GUI LED PCB.
Failure: CLEAR key pressed to indicate LED not on.	AE0602 GUI Medium Alarm LED fails.		1. Check/replace interconnect cable between the GUI LED PCB and the GUI CPU PCB. 2. Replace the GUI LED PCB.
Failure: CLEAR key pressed to indicate LED not on.	AE0603 GUI Low Alarm LED fails.		1. Check/replace interconnect cable between the GUI LED PCB and the GUI CPU PCB. 2. Replace the GUI LED PCB.
Failure: CLEAR key pressed to indicate LED not on.	AE0604 GUI Normal LED fails.		1. Check/replace interconnect cable between the GUI LED PCB and the GUI CPU PCB. 2. Replace the GUI LED PCB.

Table 6-10: EST test sequence (continued)

Description	Code and message	Display	Corrective actions
Failure: CLEAR key pressed to indicate LED not on.	AE0605 GUI Batt Backup LED fails.		1. Check/replace interconnect cable between the GUI LED PCB and the GUI CPU PCB. 2. Replace the GUI LED PCB.
Failure: CLEAR key pressed to indicate LED not on.	AE0606 GUI On Batt Pwr LED fails.		1. Check/replace interconnect cable between the GUI LED PCB and the GUI CPU PCB. 2. Replace the GUI LED PCB.
Failure: CLEAR key pressed to indicate LED not on.	AE0607 GUI Compressor Ready LED fails.		1. Check/replace interconnect cable between the GUI LED PCB and the GUI CPU PCB. 2. Replace the GUI LED PCB.
Failure: CLEAR key pressed to indicate LED not on.	AE0608 GUI Compressor Operating LED fails.		1. Check/replace interconnect cable between the GUI LED PCB and the GUI CPU PCB. 2. Replace the GUI LED PCB.
Failure: CLEAR key pressed to indicate LED not on.	AE0609 GUI 100% O_2 LED fails.		1. Check/replace interconnect cable between the GUI LED PCB and the GUI CPU PCB. 2. Replace keyboard.
Failure: CLEAR key pressed to indicate LED not on.	AE0610 GUI Alarm Silence LED fails.		1. Check/replace interconnect cable between the GUI LED PCB and the GUI CPU PCB. 2. Replace keyboard.
Failure: CLEAR key pressed to indicate LED not on.	AE0611 GUI Screen Lock LED fails.		1. Check/replace interconnect cable between the GUI LED PCB and the GUI CPU PCB. 2. Replace keyboard.
BD Lamp Test			
Test: Prompts user to acknowledge that LEDs are on. **Failure:** CLEAR key pressed to indicate one or both ventilator inoperative LEDs not on.	AE0702 Bad Vent inop LED		Replace BDU LED PCB.
Test: Prompts user to acknowledge that LEDs are on. **Failure:** CLEAR key pressed to indicate one or both SVO LEDs not on.	AE0703 Bad SVO LED		Replace BDU LED PCB.
Test: Prompts user to acknowledge that LED is on. **Failure:** CLEAR key pressed to indicate LED not on.	AE0704 Bad Loss of GUI LED		Replace BDU LED PCB.

Table 6-10: EST test sequence (continued)

Description	Code and message	Display	Corrective actions
GUI Audio Test			
Test: Activates GUI high-urgency alarm sound and prompts user to verify that GUI alarm sounds. **Failure:** CLEAR key pressed to indicate GUI audio diagnostic failed.	FE0801 SAAS *(Safety Audible Alarm System)* test failed		1. Verify the GUI alarm cable connection to the GUI CPU PCB. 2. Replace GUI alarm assembly. 3. Replace GUI CPU PCB.
GUI Nurse Call Test			
Prompts user to acknowledge whether test is to be performed.			
Test: Prompts user to indicate if nurse's call (remote alarm) is off. **Failure:** CLEAR key pressed to indicate relay is stuck on when it should be off.	FE2301 Nurse call stuck on		1. Make sure test equipment is connected properly to remote alarm port. 2. Replace GUI CPU PCB.
Test: Activates nurse's call (remote alarm) relay, then prompts user to indicate if nurse's call is on. **Failure:** CLEAR key pressed to indicate relay is stuck off when it should be on.	FE2302 Nurse call stuck off		1. Make sure test equipment is connected properly to remote alarm port. 2. Replace GUI CPU PCB.
Deactivates nurse's call port.			
BD Audio Test			
Test: Checks alarm cable voltage. **Failure:** Voltage out of range (< 3.5 or > 5.05 V).	FE0901 Bad alarm cable	Alarm cable voltage	1. Make sure BD alarm cable is connected. 2. Replace BD alarm. 3. Replace AI PCB. 4. Replace BD alarm cable.
Test: Checks initial power failure capacitor voltage. **Failure:** Voltage out of range (< 4.5 or > 5.05 V).	FE0902 Bad power fail cap	Initial power failure capacitor voltage	1. Make sure BD alarm cable is connected. 2. Replace BD alarm. 3. Replace AI PCB. 4. Replace BD alarm cable. 5. Replace Motherboard PCB.

Table 6-10: EST test sequence (continued)

Description	Code and message	Display	Corrective actions
Test: Sounds BD alarm. Prompts user to acknowledge audible alarm. **Failure:** CLEAR key pressed to indicate user did not hear alarm, although alarm was active.	FE0904 Bad BD audio		1. Make sure BD alarm cable is connected. 2. Replace BD alarm. 3. Replace AI PCB. 4. Replace BD alarm cable.
Test: Measures and compares power fail capacitor voltages before and after alarm is sounded. **Failure:** Final capacitor voltage higher than initial voltage.	FE0903 Bad power fail cap		1. Make sure BD alarm cable is connected. 2. Replace BD alarm. 3. Replace AI PCB.
Test: Calculate and check RC constant. **Failure:** RC constant < 60 s.	FE0903 Bad power fail cap	RC constant for power fail capacitor	1. Make sure BD alarm cable is connected. 2. Replace BD alarm. 3. Replace AI PCB.
PSOL Loopback Test			
Test: Reads air PSOL (PSOL2) loopback current at various drive currents. Verifies that PSOL2 loopback current is within range of drive current. **Failure:** PSOL2 loopback current out of range (OOR) of drive current.	AE1001 Air PSOL loopback current OOR	PSOL2 loopback current at various drive currents	1. Verify that the air supply is good. 2. Verify air regulator pressure set to between 9 and 12 psi. 3. Switch PSOLs to see if failure transfers to the other gas side. If yes, return oxygen PSOL (PSOL1) to its original position and replace PSOL2. 4. Switch Q1 and Q2, run a flow sensor calibration and rerun test. If the problem transfers to the other gas side, return Q1 to its original position and replace Q2. 5. Replace the AI PCB. 6. Replace the Inspiratory Electronics PCB.

Table 6-10: EST test sequence (continued)

Description	Code and message	Display	Corrective actions
Test: Reads oxygen PSOL (PSOL1) loopback current at various drive currents. Verifies that PSOL1 loopback current is within range of drive current.		PSOL1 loopback current at various drive currents	
Failure: PSOL1 loopback current out of range (OOR) of drive current.	AE1002 O_2 PSOL loopback current OOR		1. Verify that the oxygen supply is good. 2. Verify oxygen regulator pressure set to between 9 and 12 psi. 3. Switch PSOLs to see if failure transfers to the other gas side. If yes, return the air PSOL to its original position and replace PSOL1. 4. Switch Q1 and Q2, run a flow sensor calibration and rerun test. If the problem transfers to the other gas side, return Q2 to its original position and replace Q1. 5. Replace the AI PCB. 6. Replace the Inspiratory Electronics PCB.
Safety System Test			
Test: Establishes an air flow of 60 L/min.			
Failure: Flow controller unable to establish and control gas flow at 60 L/min.	FE1105 Unable to establish flow		1. Make sure air supply is connected and unrestricted. 2. Check air regulator pressure. 3. Run flow sensor calibration. 4. Switch PSOLs to see if test passes. If it does, return PSOL1 to its original position and replace PSOL2. 5. Replace Q2.
Test: Reads inspiratory pressure (safety valve back pressure) and verifies that it is ≤ 1.0 cmH_2O.		Inspiratory pressure (safety valve back pressure)	
Failure: Excessive safety valve back pressure when safety valve is open.	FE1101 Safety valve occluded		Replace safety valve.
Test: Reads loopback current (safety valve open and closed; during low and high current conditions) and verifies it is in range.		Safety valve loopback current	
Failure: Safety valve loopback current out of range.	FE1102 Bad safety valve driver or loopback		1. Replace safety valve. 2. Replace AI PCB. 3. Replace Inspiratory Electronics PCB.

Table 6-10: EST test sequence (continued)

Description	Code and message	Display	Corrective actions
Test: Performs a reverse-flow check of inspiratory check valve. Establishes a pressure of 95 cmH_2O with air flow of 5 L/min. Reads inspiratory pressure. Then stops flow and opens safety valve. Determines time it takes for pressure to drop from 85 to 5 cmH_2O. Verifies time is within range.		Elapsed time for pressure to drop from 85 to 5 cmH_2O	
Failure: It took too long to relieve excess pressure through open safety valve, indicating inspiratory check valve (CV3) is occluded or test circuit is too large.	FE1103 Insp check valve test failed		1. Make sure proper test circuit is used. 2. Make sure CV3 is not installed backward. 3. Replace CV3. 4. Replace Safety Valve (SV).
Failure: It took too little time to relieve excess pressure through open safety valve, indicating inspiratory check valve (CV3) may be damaged or incorrectly mounted.	AE1104 Insp check valve test failed		1. Make sure test circuit is connected. 2. Make sure CV3 is not installed backward. 3. Replace CV3.
Exp Valve Loopback Test			
Test: Reads exhalation valve loopback current and compares it to drive current for several size openings.		Exhalation valve loopback current	
Failure: Exhalation valve loopback current is out of range (OOR) of drive current.	AE1201 Exp valve loopback current OOR		1. Verify that the system has no leaks or occlusions by running the leak test in EST. 2. Clean exhalation valve diaphragm. 3. Calibrate the exhalation valve. 4. Clean/replace the exhalation valve. 5. Replace the AI PCB.
Exp Valve Seal Test			
Test: Verifies that exhalation valve calibration table checksum is valid and that last calibration performed was completed successfully (i.e., flag set in BD NOVRAM).			
Failure: Exhalation valve table checksum invalid or last calibration performed was not completed successfully.	FE1304 Exp valve not calibrated		1. Check for leaks or occlusions. Correct and then run the exhalation valve calibration. 2. Replace the exhalation valve. 3. Replace the AI PCB. 4. Replace Q3. 5. Replace Q2.

Table 6-10: EST test sequence (continued)

Description	Code and message	Display	Corrective actions
Test: Verifies that exhalation valve magnet temperature is in range. **Failure:** Exhalation valve magnet temperature out of range (OOR) (10 to 100 °C).	FE1302 Exp valve temp OOR		1. Ensure the unit has been warmed up at ambient temperature for at least 10 minutes. 2. Calibrate the exhalation valve (EV). 3. Replace exhalation valve (EV). 4. Replace AI PCB.
Test: Using exhalation valve calibration table, commands valve to generate system pressure of 45 cmH_2O. Establishes air flow of 5 L/min and waits a short interval for flow to stabilize. **Failure:** Flow controller unable to establish and control air flow measured by exhalation flow sensor (Q3).	FE1303 Unable to establish exp flow		1. Make sure proper test circuit it used and that there are no leaks or occlusions. 2. Make sure air supply is still con-nected. 3. Run flow sensor calibration. 4. Replace Q3. 5. Replace Q2. 6. Replace the exhalation valve.
Test: Reads exhaled flow (for 5 L/min) from Q3. Reduces flow, then reads expiratory flow (for 0.3 L/min). Verifies that test Δ pressure is acceptable. **Failure:** Seal test Δ pressure is above failure level. **Failure:** Seal test Δ pressure is above alert level but below failure level.	FE1301 Seal test failed AE1305 Seal test failed		1. Clean exhalation valve. 2. Calibrate exhalation valve. 3. Run flow sensor calibration. 4. Replace exhalation valve. 5. Replace AI PCB. 6. Replace PE. 1. Verify that the system has no leaks or occlusions by running the leak test in EST. 2. Clean the exhalation valve. 3. Calibrate exhalation valve. 4. Replace the exhalation valve. 5. Replace the AI PCB.

Table 6-10: EST test sequence (continued)

Description	Code and message	Display	Corrective actions
Exp Valve Test			
Test: Verifies that exhalation valve calibration table checksum is valid and that last calibration performed was completed successfully (i.e., flag set in BD NOVRAM). **Failure:** Exhalation valve table checksum invalid or last calibration performed was not completed successfully.	FE1402 Exp valve not calibrated		1. Check for leaks or occlusions. Correct and then run the exhalation valve calibration. 2. Replace the exhalation valve. 3. Replace the AI PCB. 4. Replace Q3. 5. Replace Q2.
Test: Establishes 5 L/min expiratory-controlled air flow. Commands exhalation valve gain port to 0.5 V. Using expiratory valve calibration table, commands exhalation valve to open as required to maintain system pressure of 10 cmH_2O. **Failure:** Flow controller unable to establish and control air flow measured by exhalation flow sensor (Q3).	FE1403 Unable to establish exp flow		1. Make sure air supply is connected. 2. Make sure proper test circuit is used.
Test: Reads expiratory pressure for several test points, and verifies it is within range. **Failure:** Measured system pressure at one or more test points is out of range.	FE1401 Bad calibration	Expiratory pressure	1. Calibrate exhalation valve. 2. Replace exhalation valve. 3. Replace AI PCB. 4. Replace the Exhalation Pressure Transducer PCB.
EV Velocity Transducer Test			
Test: Calculates Δ P for expiratory pressures made with exhalation valve commanded with high and zero damping gains. **Failure:** Expiratory Δ P too low, indicating velocity transducer not responding properly.	FE2201 Low exp ΔP		1. Calibrate exhalation valve and retest. 2. Replace exhalation valve.
Exp Heater Test			
Test: Establishes 60 L/min inspiratory-controlled air flow. **Failure:** Flow controller unable to establish and control 60 L/min flow.	FE1501 Unable to establish air flow		Make sure air supply is connected.

Table 6-10: EST test sequence (continued)

Description	Code and message	Display	Corrective actions
Test: Turns on exhalation heater. Reads heater-on temperature periodically over an interval, checking for a temperature rise of ≥ 3 °C. Displays heater-on temperature as soon as it rises ≥3 °C.		Heater-on temperature (displayed as soon as it rises ≥ 3 °C above initial temperature)	
Failure: Heater temperature did not rise sufficiently during an interval after heater was turned on.	FE1502 Bad exp heater		1. Replace exhalation heater. 2. Replace AI PCB.
Test: Turns off exhalation heater. Reads heater-off temperature periodically over an interval, checking for a temperature drop of ≥ 2 °C from heater-on temperature.		Heater-off temperature (displayed as soon as it drops ≥ 3 °C below heater-on temperature)	
Failure: Heater temperature did not drop sufficiently during an interval after heater was turned off.	FE1503 Bad exp heater		1. Replace exhalation heater. 2. Replace AI PCB.
Compressor Test			
Checks that compressor is installed.			
Test: Checks whether unit is running on ac. If unit is running on ac (BPS is not installed or BPS is installed but battery power is not being used), prompts user to connect ac.			
Failure: System is still running on battery power (i.e., when polled, either BPS charged or BPS charging line is active). Compressor can only run on ac (facility) power.	AE1602 ac power not connected		1. Plug in ventilator power cord and check the cord connection at the ventilator. 2. Check ac. 3. Disconnect BPS to isolate problem. 4. Replace power supply.
Test: Checks whether wall air is connected (air pressure switch (PS2) closed). If so, prompts user to disconnect it so compressor can be tested. Verifies that PS2 is now open.			
Failure: PS2 is closed when it should be open.	AE1601 Wall air pressure detected		1. Make sure air supply is disconnected. 2. Disconnect PS2 and rerun test. If test passes, replace PS2.

Table 6-10: EST test sequence (continued)

Description	Code and message	Display	Corrective actions
Test: Reads initial compressor time, waits 15 s, reads final compressor time, then calculates compressor run elapsed time. **Failure:** Calculated run time not within range, perhaps because compressor timer is not running while compressor motor is on.	AE1604 Run mode time OOR		Listen for motor. If motor is on, replace compressor PCB. Otherwise, replace compressor.
Test: Reads compressor pressure transducer (PC) and verifies that there is compressor pressure. **Failure:** PC indicates that compressor air is not present, although compressor motor is on.	AE1603 Compressor pressure not detected		1. If compressor system is an 804 model, replace with the 806 model. 2. Run compressor leak test to check for leaks. a. Use leak detector to check for leaks at the accumulator fittings and other tubing connections. b. Verify no leaks at CV2 within the ventilator by plugging the air inlet fitting. 3. Replace compressor PCB.
Test: Disables compressor control and commands compressor to disabled mode. Reads compressor pressure transducer (PC) and verifies that compressor air is not present. **Failure:** PC indicates that compressor air is present after compressor motor is disabled and accumulator drained.	AE1606 Compressor pressure detected		Replace compressor PCB.
Test: Reads initial compressor time, waits 15 s, reads final compressor time, then calculates compressor disabled elapsed time. **Failure:** Calculated disabled time not within range, perhaps because compressor timer is running while compressor motor is off.	AE1607 Disabled mode time OOR		Replace compressor PCB.
Test: Checks that compressor timer was verified to be functional during previous compressor run and disabled tests. **Failure:** Compressor standby mode check cannot be run, because of inability to verify timer functionality.	AE1608 Unable to test standby mode		1. Troubleshoot code AE1604 or AE1607, if present. 2. Replace compressor PCB.

Table 6-10: EST test sequence (continued)

Description	Code and message	Display	Corrective actions
Test: Reads initial compressor time, waits 15 s, reads final compressor time, then calculates compressor standby mode elapsed time. **Failure:** Calculated standby mode time not within range, perhaps because compressor motor is still running. During standby mode test phase, compressor motor should eventually turn off.	AE1609 Standby mode time OOR		Replace compressor PCB.
Test: Re-enables compressor control. Checks that compressor pressure transducer (PC) was verified to be functional during previous compressor run and disabled tests. **Failure:** Compressor load test cannot be run, because of inability to verify PC functionality.	AE1610 Unable to perform compressor load test		Troubleshoot code AE1603 or AE1606.
Test: Commands expiratory valve damping gain DAC and expiratory valve DAC to values corresponding to 45 cmH_2O. Performs 1 cycle of worst-case breath delivery waveform (200 lpm). Stops flow control and verifies that compressor air is present, as indicated by compressor pressure switch (PC). **Failure:** PC reading indicates compressor unable to maintain minimum pressure under worst-case breath delivery waveform.	AE1611 Compressor load test failed		1. Run compressor leak test to check for compressor leak. a. Use leak detector to check for leaks at the accumulator fittings and other tubing connections. b. Verify no leaks at CV2 within the ventilator by plugging the air inlet fitting. 2. Replace compressor. 3. Replace compressor PCB.
Compressor Leak Test			
Checks that compressor is installed.			
Test: Verifies that compressor timer tests passed during Compressor Test. **Failure:** Compressor leak test cannot be run, because of inability to verify timer functionality.	AE1701 Unable to perform compressor leak test		1. Troubleshoot accompanying code AE1604 or AE1607. 2. Replace compressor PCB.

Table 6-10: EST test sequence (continued)

Description	Code and message	Display	Corrective actions
Test: Disables compressor control and commands compressor to disabled mode. If wall air is connected (pressure switch PS2 closed), prompts user to disconnect wall air, then verifies that PS2 is open. **Failure:** PS2 is closed, but it should be open. Compressor control is restored.	AE1702 Wall air pressure detected		1. Make sure air supply is disconnected. 2. Disconnect PS2 and rerun test. If test passes, replace PS2.
Test: Prompts user to reconnect wall air, then verifies that wall air pressure switch (PS2) is closed. **Failure:** PS2 is open, but it should be closed. Compressor control is restored.	AE1703 Wall air pressure not detected		1. Make sure air supply is connected. 2. Run Gas Supply/SV Test.
Test: Commands compressor to standby mode, then lets compressor recharge. Checks compressor pressure periodically over a 1-minute interval. **Failure:** Compressor pressure transducer (PC) indicates loss of compressor pressure, pointing to a leak.	AE1704 Compressor leak detected		Troubleshoot compressor compartment or inspiratory module for leaks.
Test: Determines compressor elapsed time with compressor in standby mode. **Failure:** Compressor elapsed time > 1 s. This indicates compressor has been on when it should not have been, pointing to a possible leak.	AE1704 Compressor leak detected	Elapsed time	Troubleshoot compressor compartment or inspiratory module for leaks.
Analog Data Display			
Reads analog data channels.		All analog data channel measurements	
GUI Touch Test			
Test: Reads touchscreen error report buffer. **Failure:** Touchscreen error occurred (e.g., blocked beam or low-level error), buffer cannot be read, or report is invalid.	AE1901 GUI touch: Error		1. Clean touchscreen, removing any obstructions. 2. Replace touchframe PCB. 3. Replace GUI CPU PCB.

Table 6-10: EST test sequence (continued)

Description	Code and message	Display	Corrective actions
GUI Serial Port Test			
Test: Activates GUI serial port loopback mode. Transmits a character string. Verifies that received string is identical to transmitted string. **Failure:** Received message not identical to transmitted message.	AE2001 Bad GUI serial port		Replace GUI CPU PCB.
Battery Test			
Verifies that BPS is installed (by reading BPS model line).			
Test: Verifies that BPS is charged (BPS charged bit off and BPS charging bit on). **Failure:** BPS not fully charged.	AE2101 Battery not charged		1. Allow BPS to fully charge, then repeat test. 2. Replace BPS PCB. 3. Replace battery pack. 4. Replace BD CPU PCB.
Prompts user to disconnect ac.			
Test: Loads BPS with known load. Verifies that system is running on BPS (BPS charged bit on and BPS charging bit on). **Failure:** BPS not discharging.	AE2102 Battery not discharging		1. Verify ac power is disconnected when prompted. 2. Replace BPS PCB. 3. Replace battery pack. 4. Replace BD CPU PCB.
Test: Makes several BPS voltage readings while BPS discharges and verifies that voltages are within range. **Failure:** BPS voltage dropped below accepted level or dropped too quickly.	AE2103 Bad Backup Power Supply	BPS voltage	1. Ensure that the battery pack is fully charged by checking that the green LED on the BPS is lit prior to initiating an EST. If the amber LED is lit, allow the unit to charge the batteries prior to rerunning EST. 2. Replace the battery pack. 3. Replace the BPS PCB. 4. Replace the AI PCB. 5. Replace the power supply.

Table 6-10: EST test sequence (continued)

Description	Code and message	Display	Corrective actions
Test: Prompts user to reconnect ac. Verifies that BPS is now charging (BPS charged bit on and BPS charging bit off). **Failure:** BPS not charging after ac power was reconnected.	AE2104 Battery not charging		1. Verify that ac power is reconnected when prompted and that ac is good. 2. Replace BPS PCB. 3. Replace the battery pack. 4. Replace the power supply. 5. Replace the BD CPU. 6. Replace the AI PCB.

6.10.1 How to troubleshoot LCD inverter PCB faults (UT0002)

For all UT00002 errors, check the System Diagnostic Log for the indicators of a VGA controller fault. Check the three digits of the Fault Address (FA) that immediately follow “0x”. (Refer to example below.)

TIME	TEST/EVENT	CODE	TYPE	NOTES
12:55:59 08 Aug 03	**Bus Error/Access Fault**	**UT0002**	**FAILURE**	**PC: 0xFF77B7FeTID'21 FA: 0x02F0 0000**

The NOTES column in the log contains the UT0002 Fault Address (FA). Using the FA, you can determine if there is a problem with an VGA controller, and identify whether it is the upper LCD PCB or the lower LCD PCB. If you cannot locate a fault code in Table 6-1 that matches the three digits of the reported fault code then replace the GUI CPU PCB.

Table 6-11: UT0002 Fault Addresses for LCD inverter PCB errors

LCD inverter PCB	Fault Address (FA)
Lower	0x020X XXXX 0x021x XXXX 0x022x XXXX 0x023x XXXX 0x024x XXXX 0x025x XXXX 0x026x XXXX 0x027x XXXX
Upper	0x028X XXXX 0x029X XXXX 0x02AX XXXX 0x02BX XXXX 0x02CX XXXX 0x02DX XXXX 0x02EX XXXX 0x02FX XXXX

The example given indicates that the upper VGA Controller PCB should be replaced.

Alarm handling

This section describes how to respond to ventilator alarms. It also lists, in alphabetic order, messages displayed by the ventilator when it detects alarm conditions.

7.1 Alarm classifications

Alarms in the *840* Ventilator are classified by urgency level; this classification determines how the ventilator responds (Table 7-1). Some alarms are triggered by a ventilator setting or patient condition, and they can occur in the usual course of patient care. Others are triggered by the ventilator's built-in background checks and may indicate that the ventilator requires service; some of these are called DEVICE ALERTs. When the ventilator declares a DEVICE ALERT, it not only displays a message and writes to the alarm log, but it also places an associated diagnostic code into the System Diagnostic Log.

Table 7-1: How the ventilator responds to alarm conditions

Urgency	Meaning	Displays	Audible alarm	Notes
High	Requires immediate attention to ensure patient safety	Red high-urgency ! ! ! indicator flashes rapidly. Alarm message flashes at top of upper screen.	Sequence of 5 tones that repeats twice, pauses, then repeats again	If a high-urgency alarm goes away spontaneously (autoresets), its indicator remains lit (not flashing) until you press the alarm reset key.
Medium	Requires prompt attention	Yellow medium-urgency ! ! indicator flashes slowly. Alarm message flashes at top of upper screen.	Repeating sequence of 3 tones	
Low	There has been a change in the patient-ventilator system	Yellow low-urgency ! indicator lights. Alarm message flashes at top of upper screen.	1 tone, non-repeating	

7.2 Responding to alarms

1 Silence the audible alarm for 2 minutes (where possible) by pressing the alarm silence key.

2 Read the alarm message from the top screen (Figure 7-1).

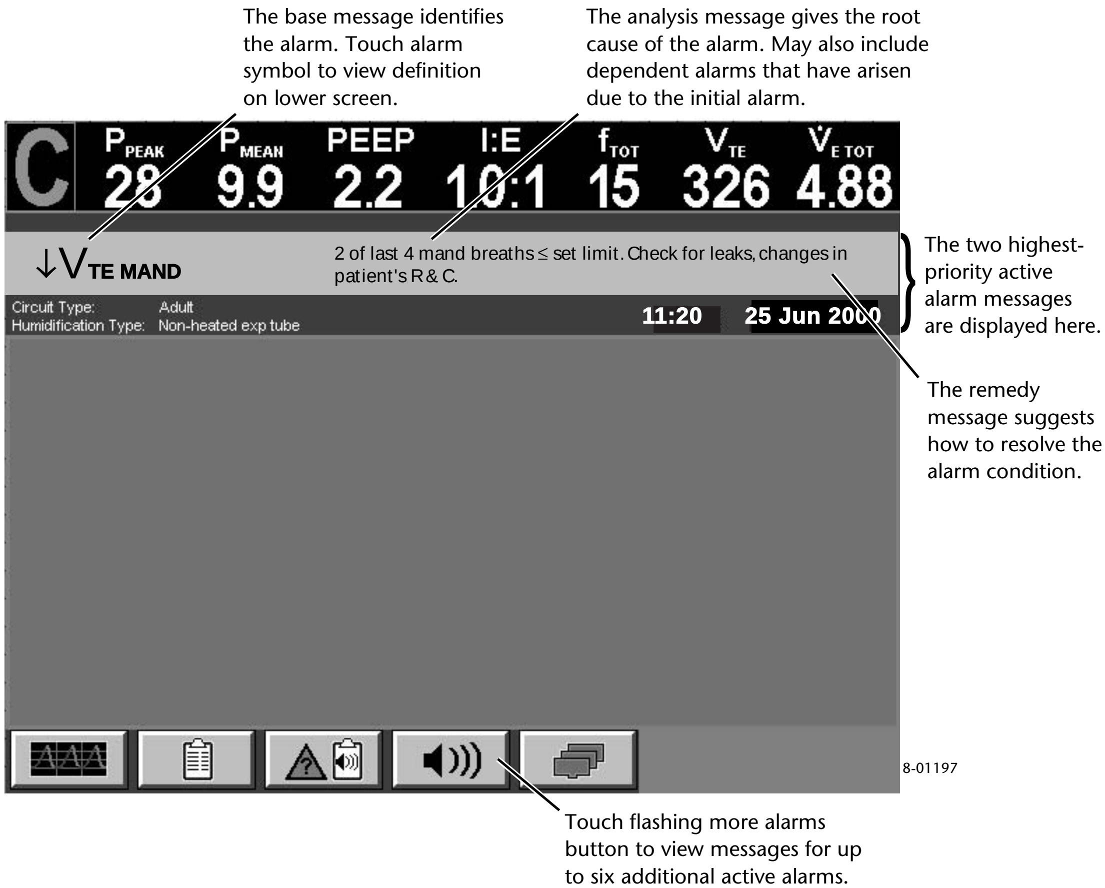


Figure 7-1. Alarm message format

3 Correct the condition, if necessary, referring to Table 7-2. You can check the alarm log (Figure 7-2). You may want to check the contents of the System Diagnostic Log (accessible through the service menu, Section 4) for related diagnostic codes. The troubleshooting procedures listed are sequenced to correct the most probable malfunction or to present the most efficient corrective action first. The proposed fixes listed, however, may not always correct the particular problem.

NOTE:
- You can change alarm settings even when alarms are active.
- Completing a new patient setup or running EST clears the alarm log.
- When more than one alarm is active and their alarm messages vary in their degree of seriousness, you should assume that the most serious message is applicable.

4 If necessary, clear the message or reset the alarm by pressing the alarm reset key.

For specifics about alarm operation, see the *840 Ventilator System Operator's and Technical Reference Manual*.

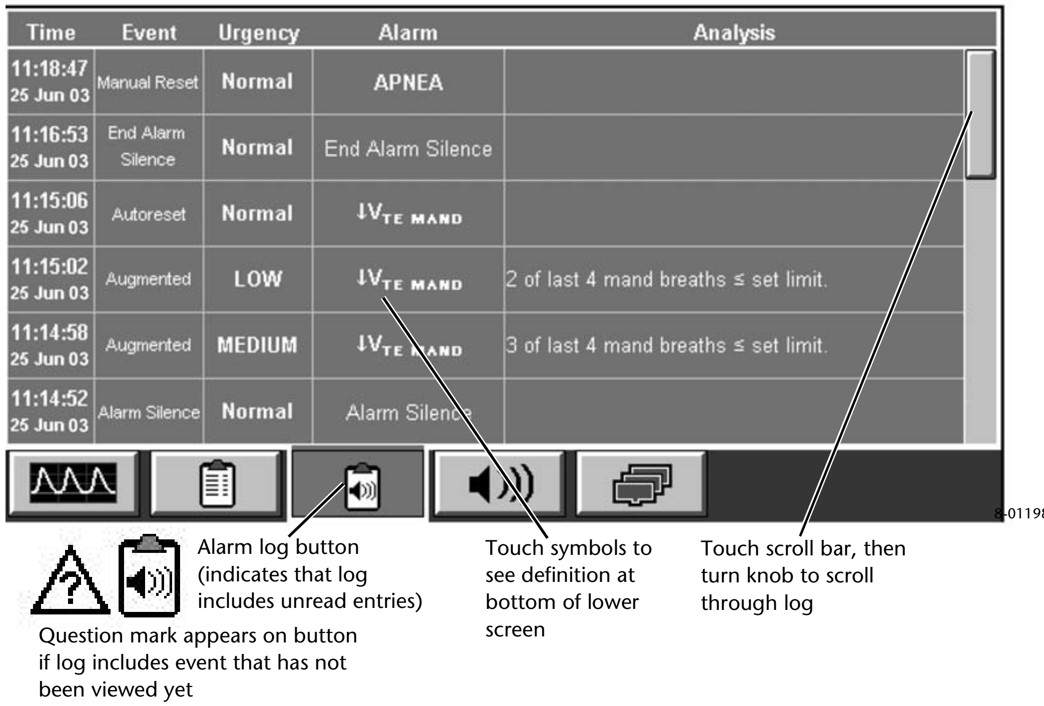


Figure 7-2. Alarm log

"Lockable" alarms include all PATIENT DATA and CIRCUIT DISCONNECT alarms and can be silenced for two minutes by pressing the alarm silence key. A new, high-urgency alarm cancels the silence. Each time you press the alarm silence key, the silence period resets to two minutes. Each time you press the alarm silence key (whether or not there is an active alarm), the keypress is recorded in the alarm log.

Table 7-2: Alarm messages

Base message	Analysis message	Remedy message	Description	Corrective action
AC POWER LOSS	Operating on battery.		Power switch is on, and ac is not available, so ventilator is operating on BPS. (BPS operating indicator is on and power indicator is off.) Resets when ac power is restored.	1. Check integrity of ac power source. 2. Replace power supply.
	Operational time < 2 minutes.	Prepare for power loss.	Two minutes of battery power remain.	
APNEA (lockable)			The set apnea interval has elapsed without the ventilator, patient, or operator triggering a breath. Resets when patient initiates 2 consecutive breaths.	Check patient and settings.

Table 7-2: Alarm messages (continued)

Base message	Analysis message	Remedy message	Description	Corrective action
CIRCUIT DISCONNECT (lockable)	No ventilation.	Check patient/ ventilator status.	Ventilator has recovered from unintended power loss, detects circuit disconnect, and switches to idle mode; upper screen displays elapsed time without ventilator support. Resets when ventilator senses reconnection.	1. Check patient circuit connections. 2. Run EST.
		Check patient. Reconnect circuit.	Ventilator detects circuit disconnect and switches to idle mode; upper screen displays elapsed time without ventilator support. Resets when ventilator senses reconnection.	1. Check patient circuit connections. 2. Run EST.
COMPLIANCE LIMITED V_T (lockable)			Compliance volume required to compensate delivery of a volume controlled breath exceeds the maximum allowed for 3 of the last 4 breaths.	1. Check patient circuit connections. 2. Run SST.
COMPRESSOR INOPERATIVE			Compressor is not operating due to low ac. Resets when full ac is restored.	1. Check integrity of ac power source. 2. Check mains circuit breaker. 3. Run EST.
DEVICE ALERT			A background check or POST has detected a problem. Resets when ventilator passes EST or POST.	Check System Diagnostic Log for any associated error codes. Rerun POST/EST.
↑O_2%			The O_2% measured during any phase of a breath cycle is 7% (12% during the first hour of operation) or more above the O_2% setting for at least 30 s. (These percentages increase by 5% for 4 minutes following a decrease in the O_2% setting.) Alarm updated at 1-s intervals.	Calibrate oxygen sensor.

Table 7-2: Alarm messages (continued)

Base message	Analysis message	Remedy message	Description	Corrective action
↑P_{COMP} (lockable)	↑P_{PEAK} detected but not ↑P_{COMP}	Check for leaks, tube type/I.D. setting	Target pressure ≥ (↑P_{PEAK} - 5 cmH_2O)	1. Check for leaks. 2. Check for correct tube type and I.D. settings.
	Last spont breath ≥ set ↑P_{PEAK} limit			
	Last 3 spont breaths ≥ set ↑P_{PEAK} limit			
	Last 4 or more spont breaths ≥ set ↑P_{PEAK} limit			
	↓$V_{TE\ SPONT}$	Check patient & settings	Exhaled spontaneous tidal volume ≤ set limit	
	↓$\dot{V}_{E\ TOT}$	Check patient & settings	Total minute volume ≤ set limit	
	↑f_{TOT}	Check patient & settings	Total respiratory rate ≥ set limit.	
↑P_{MEAN} (lockable)			Measured airway pressure ≥ set limit. Ventilator truncates current breath unless already in exhalation.	1. Run SST. 2. Run EST.
↑P_{PEAK} (lockable)		Check patient, circuit, & ET tube.	↑P_{PEAK} detected and NOT ↑P_{COMP}.	
↑P_{VENT} (lockable)			Inspiratory pressure > 100 cmH_2O and mandatory type = VC. Ventilator truncates current breath unless already in exhalation.	1. Run SST. 2. Run EST.
↑V_{TE} (lockable)			Exhaled tidal volume ≥ set limit. Alarm updated whenever exhaled tidal volume is recalculated.	1. Run SST. 2. Run EST.
↑$\dot{V}_{E\ TOT}$ (lockable)			Expiratory minute volume ≥ set limit. Alarm updated whenever an exhaled minute volume is recalculated.	1. Run SST. 2. Run EST.
↑$V_{TI\ MAND}$ (lockable)			Delivered inspiratory volume ≥ high inspiratory volume limit (breath type = VC+)	Check patient and settings.

Table 7-2: Alarm messages (continued)

Base message	Analysis message	Remedy message	Description	Corrective action
↑$V_{TI\ SPONT}$ (lockable)			Delivered inspiratory volume ≥ high inspiratory volume limit (breath type = TC or VS)	1. For TC: Check for leaks, tube type/I.D. setting. 2. For VS: Check patient and settings.
↑f_{TOT} (lockable)			Total respiratory rate ≥ set limit. Alarm updated at the beginning of each inspiration. Reset when measured respiratory rate falls below the alarm limit.	1. Run SST. 2. Run EST.
INOPERATIVE BATTERY			BPS installed but not functioning. Resets when BPS is functional.	Run EST.
INSPIRATION TOO LONG (lockable)			Inspiratory time for spontaneous breath ≥ IBW-based limit. Ventilator transitions to exhalation. Resets when T_I falls below IBW-based limit.	1. Run SST. 2. Run EST.
LOSS OF POWER			Power switch is on, but there is insufficient ac and BPS power. There may not be a visual indicator for this alarm, but an independent audio alarm sounds for at least 120 s.	Turn power switch off to reset alarm. Restore ac power.
LOW AC POWER	Ventilator currently not affected.	Power interrupt possible.	Mains (ac) power has dropped below 80% of nominal for 1 s. Ventilator continues operation as close to settings as possible. Resets when there is no low ac power signal for 1 s. **NOTE:** Compressor operation may be disrupted during low ac events.	1. Check integrity of ac power source. 2. If ventilator software was recently downloaded or if ventilator was moved between locations with different voltages, check Service Mode Setup configuration. 3. Check connections of ac power distribution components.
LOW BATTERY	Operational time < 2 minutes.	Replace or allow recharge.	Resets when BPS has more than approximately 2 min of operational time remaining.	1. Check integrity of ac power source. 2. Check connections of ac power distribution components.
LOW INSP PRESSURE (lockable)			Inspiratory target pressure < (PEEP + 5cmH_2O) when mandatory type is VC+	1. Check patient. 2. Check target volume.

Table 7-2: Alarm messages (continued)

Base message	Analysis message	Remedy message	Description	Corrective action
↓O_2%	Measured O_2% < set O_2%.	Check patient, gas sources, O_2 analyzer & ventilator.	The O_2% measured during any phase of a breath cycle is 7% (12% during the first hour of operation) or more below the O_2% setting for at least 30 s, or below 18%. (These percentages increase by 5% for 4 minutes following an increase in the O_2% setting.) Alarm updated at 1-s intervals.	1. Calibrate oxygen sensor. 2. Run EST. 3. Replace oxygen sensor. 4. Inspect oxygen PSOL (PSOL1).
↓$V_{TE\ MAND}$ (lockable)	2 of last 4 mand. breaths ≤ set limit.	Check for leaks, changes in patient's R_{STAT} & C_{STAT}.	Exhaled mandatory tidal volume ≤ set limit. Alarm updated whenever exhaled mandatory tidal volume is recalculated.	Run SST.
	3 of last 4 mand. breaths ≤ set limit.	Check for leaks, changes in patient's R_{STAT} & C_{STAT}.		
	4 of last 4 mand. breaths ≤ set limit.	Check for leaks, changes in patient's R_{STAT} & C_{STAT}.		
↓$V_{TE\ SPONT}$ (lockable)			Exhaled spontaneous tidal volume ≤ set limit. Alarm updated whenever exhaled spontaneous tidal volume is recalculated.	Run SST.
↓$\dot{V}_{E\ TOT}$ (lockable)	$\dot{V}_{E\ TOT}$ ≤ set limit for ≤ 20s.	Check patient & settings.	Total minute volume ≤ set limit. Alarm updated whenever exhaled minute volume is recalculated.	Run SST.
	$\dot{V}_{E\ TOT}$ ≤ set limit for > 20s.	Check patient & settings.		
	$\dot{V}_{E\ TOT}$ ≤ set limit for > 40s.	Check patient & settings.		

Table 7-2: Alarm messages (continued)

Base message	Analysis message	Remedy message	Description	Corrective action
NO AIR SUPPLY	Ventilation continues as set. Only O_2 available.	Check air source.	Ventilator delivers 100% oxygen. Resets if air supply connected.	1. Check air inlet filter. 2. Check pressure switch connections. 3. Run EST.
	Compressor inoperative. Ventilation continues as set. Only O_2 available.	Check air source.	Ventilator delivers 100% oxygen. Resets if air supply connected.	1. Check air inlet filter. 2. Check pressure switch connections. 3. Run EST.
	Ventilation continues as set except O_2% = 100	Check patient & air source.	Ventilator delivers 100% oxygen instead of set O_2%. Resets if air supply connected.	1. Check air inlet filter. 2. Check pressure switch connections. 3. Run EST.
	Compressor inoperative. Ventilation continues as set, except O_2% = 100.	Check patient & air source.	Ventilator delivers 100% oxygen instead of set O_2%. Resets if air supply connected.	1. Check air inlet filter. 2. Check pressure switch connections. 3. Run EST.
	No ventilation. Safety Valve Open.	Provide alternate ventilation. Check both gas sources.	Safety valve open indicator lights. Upper screen displays elapsed time without ventilator support. Resets if air and oxygen supplies are connected.	1. Check inlet filters. 2. Check pressure switch connections. 3. Run EST.
NO O_2 SUPPLY	Ventilation continues as set. Only air available.	Check patient and O_2 source.	Resets if oxygen supply connected.	1. Check oxygen inlet filter. 2. Check pressure switch connections. 3. Run EST.
	Ventilation continues as set, except O_2% = 21.	Check patient & O_2 source	Ventilator delivers 21% oxygen instead of set O_2%. Resets if oxygen supply connected.	1. Check oxygen inlet filter. 2. Check pressure switch connections. 3. Run EST.
	No ventilation. Safety Valve Open.	Provide alternate ventilation. Check both gas sources.	Safety valve open indicator lights. Upper screen displays elapsed time without ventilator support. Resets if air and oxygen supplies are connected.	1. Check inlet filters. 2. Check pressure switch connections. 3. Run EST.
O2 SENSOR		O_2 sensor out of calibration/ failure. Press 100% O2 CAL, replace, or disable.	Oxygen sensor requires calibration or replacement. Ventilation is unaffected. User may also disable FIO_2 monitor.	1. Calibrate O_2 sensor. 2. Replace and calibrate O_2 sensor. 3. Disable O_2 sensor.
PROCEDURE ERROR	Patient connected before setup complete.	Provide alternate ventilation. Complete setup process.	Ventilator begins safety ventilation. Resets when ventilator startup procedure is complete.	Complete patient setup.

Table 7-2: Alarm messages (continued)

Base message	Analysis message	Remedy message	Description	Corrective action
SCREEN BLOCK	Possible blocked beam or touch screen block.	Remove obstruction or service ventilator.	Possible blocked beam (GUI) or touch screen fault.	1. Remove obstruction. 2. Service ventilator.
SEVERE OCCLUSION	Little/no ventilation.	Check patient. Provide alternate ventilation. Clear occlusions; drain circuit.	Ventilator enters occlusion status cycling (OSC) and upper screen displays elapsed time without ventilator support.	Run EST.
VOLUME NOT DELIVERED (This alarm applies to VC+ and VS breaths.)	Last 2 mand breaths, pressure > max allowable level Last 10 or more mand breaths, pressure > max allowable level	Check patient and setting for ↑P_{PEAK}.	Ventilator cannot deliver target volume.	Check patient and settings.

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SECTION

8

Service and repair

8.1 How to use this section

This section describes how to repair the major ventilator subassemblies and their components. These repair procedures include removal, installation, and adjustment, as applicable. This section does not provide complete breakdowns of all assemblies and complete disassembly information. Repair procedures are provided mostly for major components. For a complete illustrated parts breakdown (IPB), refer to Section 9. Do not rely exclusively on Section 9 for removal and installation of parts.

8.2 General repair safety

- When servicing the ventilator, be sure to familiarize yourself with, and adhere to all posted and stated safety warning and caution labels on the ventilator and its components, and on any service equipment and materials used. Failure to adhere to such warnings and cautions at all times may result in injury or property damage.
- To prevent patient injury, do not use a ventilator if it requires repair.
- To prevent personal injury or death, do not attempt any ventilator service while a patient, or other person, is connected to the ventilator.
- Use personal protective equipment whenever exposure to toxic fumes, vapor, dust particles, blood pathogens, and other transmittable diseases and hazardous material can be expected. If in doubt, consult an environmental, health, and safety specialist or an industrial hygienist before servicing the ventilator.
- To prevent electrical shock hazard and possible personal injury, always disconnect electrical power sources before servicing the ventilator. Follow accepted safety practices for electrical equipment when testing or making equipment, adjustment, or repairs.
- To prevent possible personal injury, always disconnect air and oxygen sources from the ventilator before service.
- To prevent possible personal injury, never attempt to push or pull a ventilator that is installed on a cart, while the brakes are set on the casters.
- To prevent possible personal injury and equipment damage, make sure the brakes on the casters are set to prevent inadvertent movement of the ventilator during service.
- To prevent possible personal injury and equipment damage, have someone assist you when lifting the ventilator or any of its major components.
- Chemicals from a broken LCD panel are toxic when ingested. Use caution when handling a GUI with a broken display panel.
- Replacing some ventilator parts requires the use of leak detector fluid to ensure a good gas seal. Use extreme caution when using leak detector in the vicinity of electronics. Thoroughly dry all components following use of leak detector.

8.3 General repair guidelines

Follow these general guidelines when servicing the ventilator.

- To prevent damage to electrostatic discharge (ESD) sensitive components, always follow ESD guidelines when servicing the ventilator. Adhere to ESD control techniques when repairing ESD sensitive components.
- Damage to components may occur due to overtightening of screws. Care should be taken during reassembly not to overtighten screws where instructed.
- Use only recommended tools, test equipment, and service materials when servicing the ventilator (Section 1).
- As you repair the ventilator, perform any applicable cleaning and inspection procedures listed below.
- Visually inspect any removed ventilator parts, including those removed to gain access to a suspected faulty part. Inspect the exposed area behind the removed parts as well. Clean removed parts to facilitate further inspection as necessary.
- Investigate and determine the cause of any detected abnormality. Repair the unit or contact Puritan Bennett Technical Support for help in diagnosing unresolved symptoms.
- Replace or repair all parts that are worn, missing, damaged, cracked, corroded, burnt, warped, bent, disfigured, or broken. Consult Section 9 for parts availability.
- Leak-test pneumatic parts where indicated, following procedures in Section 8.7.
- Puritan Bennett recommends that customers or technical services personnel follow local governing ordinances and recycling instructions regarding disposal or recycling of battery or other device components.
- The repair sections assume the patient system, flex arm, oxygen, and humidifier are already removed from the ventilator.

8.4 Repair-related cleaning

The following cleaning guidelines pertain to parts that require cleaning while servicing the ventilator. For procedures on periodic cleaning and sterilization of the ventilator and accessories, refer to the 840 Ventilator System Operator's and Technical Reference Manual. For periodic cleaning and inspection procedures that are required during a ventilator's performance verification, refer to Section 5 in this manual. Replace all parts that cannot be cleaned.

- Clean ventilator exterior surfaces before disassembly. Table 1-5 in Section 1 of this manual lists acceptable cleaning and disinfecting agents. Use a clean, lint-free cotton cloth. Allow cleaned ventilator parts and surfaces to air-dry.
- Vacuum ventilator interior using ESD safe equipment. *Do not* clean the ventilator interior or exterior surface with high-pressure air.
- Clean or polish electrical contacts with a very fine abrasive paper or with a special tool designed for such purposes. Do not bend contacts.

8.5 Electrical cables and pneumatic tubing

- To ensure proper reassembly, note or label wire and tube positions before disconnecting parts.
- To avoid shredding a silicone tube when removing from a fitting, gently pull the tube while turning. Do not attempt to remove silicone tubing from barbed fittings in inspiratory module. Removal of tubing from non-barbed fittings only is permissible.
- Make sure all tubes, and harnesses or cables, are installed using tie wraps, as specified. Make sure wiring does not interfere with, and cannot be damaged by, hinged or moving ventilator parts.

8.6 Adhesive use

- For lubricants and resin-based adhesives, always verify the shelf-life expiration date has not passed.
- When installing a part to be attached with adhesive, first remove the adhesive residue using a suitable scraping tool that won't scratch the ventilator surface. Clean scraped surfaces thoroughly with isopropyl alcohol. Be sure the application area is free of dust and grease; then apply pressure, ensuring adhesive contact and bonding. Eliminate any trapped air bubbles.
- Be careful when using any cleaners and solvents, as these may cause personal injury or damage to ventilator surfaces. Use in a well-ventilated area.
- Replace any damaged warning and caution labels using the removal and installation techniques described above.

Warning

The failure to replace damaged warning, caution, and identification labels may result in personal injury or equipment/property damage.

8.7 Leak testing

Caution

Replacing some ventilator components requires the use of leak detector fluid to ensure a good gas seal. Use extreme caution when using leak detector in the vicinity of electronics. Thoroughly dry all components following use of leak detector.

1. Connect compressed gas sources to ventilator.
2. Using small brush, apply leak detector fluid (P/N 4-004489-00) to pneumatic connections.
3. If a connection leaks, repair and retest module.
4. Dry all leak detector fluid from chassis.

8.8 Electrostatic discharge control

It is important to follow ESD control procedures whenever the ventilator is repaired.

Electrostatic discharge can permanently damage ESD sensitive microelectronic components or assemblies when they are handled, and even when no direct contact is made with the component or assembly. ESD damage may not be immediately detectable; however, ESD damage will show up at a later time. It can manifest as a premature catastrophic failure of a component or assembly, or as an intermittent failure, all of which can be difficult and costly to locate.

8.8.1 ESD procedures and precautions

Follow these procedures and precautions to prevent ESD damage to the ESD-sensitive microelectronic components and assemblies in the *840* Ventilator System.

- Use a personnel-grounding system. Before opening the ventilator lid or removing its enclosure panels, ensure that a personnel grounding system such as P/N 4-018049-00 (wrist strap, static-dissipate mat, and ground cord) is worn correctly and is properly connected to a reliable ground.
- Follow correct procedures when using an antistatic mat. Place tools, test equipment, and the ESD sensitive device on the mat before starting repairs. Conduct all work on the mat. Never place nonconducting items, i.e. foam cups, on the mat.
- Handle ESD sensitive components properly. *Do not* handle ESD sensitive component connection points, connector pins, leads, or terminals.
- Keep nonconducting materials away from the work area. Static charges from nonconducting material, (i.e. plastic containers, foam cups, synthetic clothing, cellophane tape, etc.) cannot be removed by grounding. These items must be kept away from the work area when handling ESD sensitive devices.
- Follow correct procedures for use of static-shielding bags. Store and transport all ESD sensitive devices in static-shielding bags at all times, except when being worked on. Never place more than one ESD sensitive device in a static-shielding bag. Never place static-generating nonconducting material inside a static-shielding bag with an ESD sensitive device. Place any faulty ESD-sensitive device in a static-shielding bag immediately after removal, to prevent additional damage. Close the bag to ensure that the shield is effective.

8.9 Replacement part ordering

Ordering correct parts requires that you properly identify the ventilator version and part. To replace a part that is not stocked or that is unavailable, order the next higher assembly. Retain the part to be replaced until the replacement part is obtained, and compare the two for compatibility, if possible.

8.10 Testing, calibration, and other post-service procedures

After you complete the ventilator repair, do the following before placing the ventilator on a patient:

- Visually verify that all pneumatic and electrical parts are properly connected and that all parts are properly installed. Then, with a light tug, verify that connections are secure and that parts are securely attached. Listen for any uncharacteristic sounds (pneumatic leaking, vibrations, grinding, squeaking, or others).
- Perform the additional service, testing, and calibration activities listed in Table 8-1. The numbers in the columns indicate the sequence in which to perform these activities.
- Keep a maintenance log of all repairs. Make sure service records and other documentation are completed.

Table 8-1: Testing and calibration requirements

Type of service / Test or calibration	Ventilator warm-up cycle[1]	Software Download	Flow sensor calibration	Expiratory valve calibration	Atmospheric pressure transducer calibration	Extended self test (EST)	Vent inop test	Short self test (SST)	Oxygen sensor (OS) calibration	Performance verification testing (PVT)
Ventilator installation	1	--	2	3	4	5	6	7	8	9[2]
Software update or software option installation	1	2	3	4	5	6	7	8	9	--[3]
10,000-hour preventive maintenance (ventilator or compressor)	1	--	2	3	4	5	6	7	8	9
Oxygen sensor								2	1	
PSOL1, PSOL2, flow sensors, expiratory valve, safety valve, SOL1, SOL2, AI PCB, inspiratory electronics PCB, exhalation transducer PCB, regulators‘, power supply, BPS PCB, battery pack, alarms, motherboard, all blindmate cables, BDU and GUI LED PCBs, touchframe PCB, LCD panels, backlight inverters, keyboard, knob	1	--	2	3	4	5	6	7	8	9
Compressor 15,000 hour preventative maintenance						1				2[4]
Compressor, compressor PCB, keyboard assembly, LED panel, VGA controller PCB, backlight inverter PCB	--	--	--	--	--	1	--	--	--	--
BD CPU PCB or GUI CPU PCB replacement	1	2	3	4	5	6	7	8	9	10
6 month ventilator check	1	--	--	--	--	2	--	--	--	--
Yearly ventilator check	1	--	2	3	4	5	6	7	8	--

1. Warm-up **must** be done in the service mode.
2. Perform the electrical safety test only.
3. Performance verification testing (PVT) is *not* required for simple software updates, provided **all** of the following conditions exist:
   The ventilator passes the Extended Self Test *before* the software is updated.
   The reason for service is software update or software option installation *only*.
   There are no events or entries in the ventilator’s diagnostic logs that indicate a need for hardware repair.
   No functional hardware repairs are conducted or required during the software update service call.
   Unless the ventilator meets *all* of these requirements, PVT **must** be performed following the repair.
4. Perform EST and electrical safety testing only.

8.11 Patient system and accessories

To service the patient system and accessories, consult the *840 Ventilator System Operator's and Technical Reference Manual* or applicable accessory manuals.

Warning

Connectors and tubes with the proprietary Bennett barbed cuff fittings are intended for use only with like fittings. They are not interchangeable with ISO-standard cone and socket fittings. A leak-tight connection cannot be ensured if these two fitting types are combined. Adapters may be used to connect Bennett barbed cuff fittings to ISO-standard cone and socket fittings.

8.12 Graphic user interface (GUI)

Caution

Chemicals from a broken LCD panel are toxic when ingested. Use caution when handling a GUI with a broken display panel.

There are two configurations of the GUI in the field: the older 9.4-inch GUI and the newer 10.4-inch GUI. The table below lists the major differences between the two versions.

Table 8-2: Differences between 9.4-inch and 10.4-inch GUI

Feature	Original Color GUI	New Color GUI
Screen size	9.4 inch	10.4 inch
Communication Ports	Single null port	Single null port and two serial ports
GUI Status LEDs visible?	No	Yes
Configurable keyboard?	No	Yes
Minimum software level required?	No	Yes; H or higher
EST changes?	No	Yes, port test
Print Screen function?	Yes; S/W revision H (US only or equivalent) and higher	Yes; S/W revision H (US only or equivalent) and higher

The GUI, shown in Figure 8-1, is a detachable module that can be mounted on the optional cart or shelf. When the ventilator is mounted on a shelf, an optional cable allows you to place the GUI up to 10 ft from the BDU.

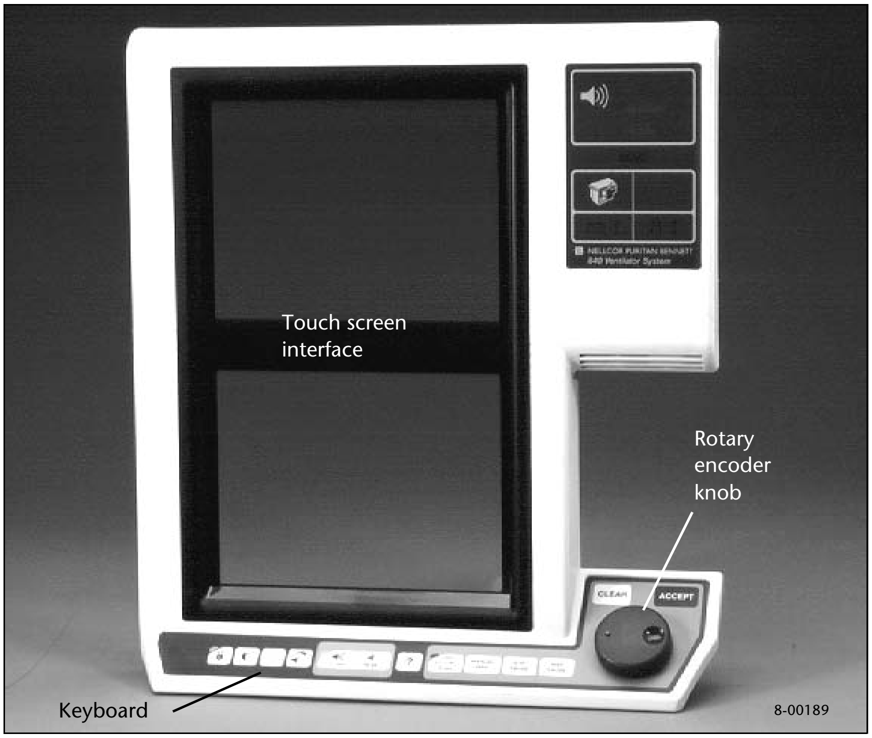


Figure 8-1. GUI

Table 8-3: GUI part replacement chart

GUI replacement part	GUI mounted	GUI detached	GUI rear housing removed
Bezel and gasket (9.4-inch)	X		
Window and gasket (9.4-inch)	X		
Alarm assembly		X	X
GUI LED PCB		X	X
Backlight inverter PCB		X	X
Video controller PCBs		X	X
GUI CPU PCB		X	X
Touchframe PCB		X	X
Liquid crystal display (LCD) panels		X	X
Backlight tube (9.4-inch)		X	X
Keyboard assembly	X		
Cooling vent filters (9.4-inch)		X	X
Rotor housing assembly		X	

The service and repair procedures that follow are organized into procedures for the 10.4-inch GUI, followed by procedures for the 9.4-inch GUI.

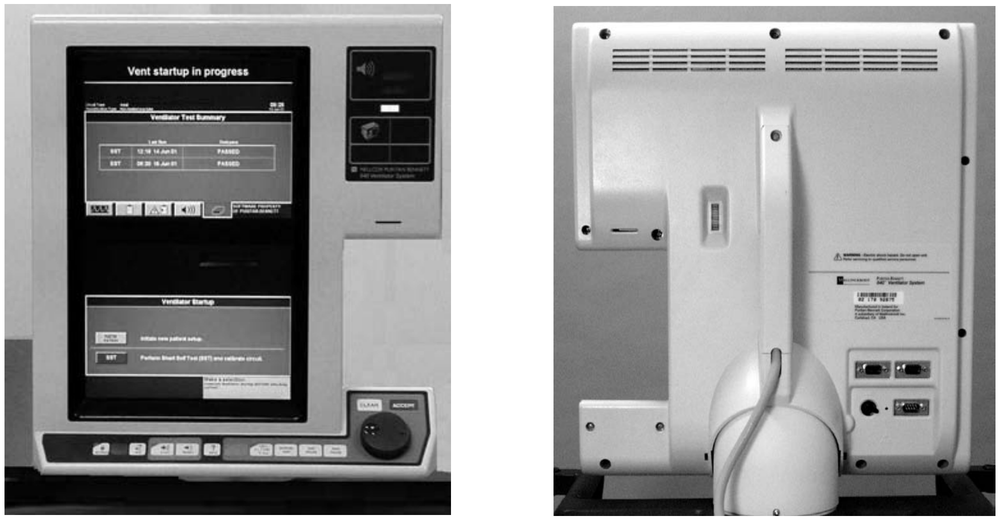


Figure 8-2. 10.4-inch GUI front and back

8.13 Repairing the 10.4-inch GUI

8.13.1 Removing or installing the 10.4-inch GUI

1 Disconnect GUI interface cable from side of BDU (Figure 8-3).

2 If GUI is mounted to optional cart, detach cable from cable guide at rear of cart.

3 Remove GUI from its mount:

a. Grasp handle at back of GUI.

b. Push GUI release knob to right to disengage rotor housing from mounting platform.

c. While holding knob to right, lift module up and away from mounting platform.

d. Release knob and it will snap back to left, locked position.

4 Place GUI face down on flat ESD-protected work surface.

5 To install GUI, position it over GUI mount. Push GUI release knob to right to disengage rotor housing from mounting platform; then push knob to left to engage housing.

6 Connect GUI cable to the side of BDU.

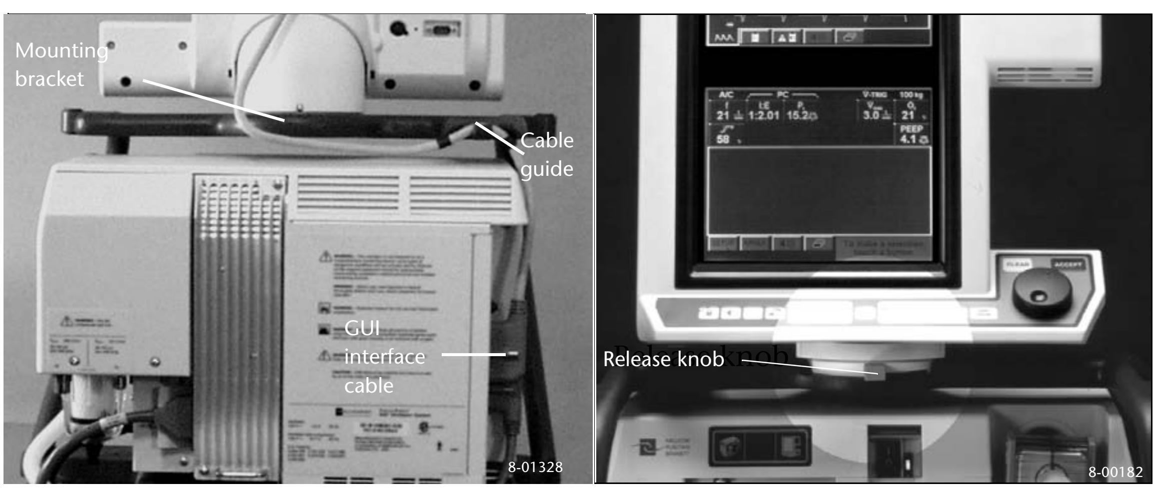


Figure 8-3. 10.4-inch GUI mounting platform

8.13.2 Removing the 10.4-inch GUI cable assembly

1. Using a Phillips screwdriver, remove the screw securing the outer handle. (Refer to Figure 8-4.)
2. Remove the top handle and set aside.
3. Using a small flat blade screwdriver, unscrew the captive screws securing the GUI cable. Gently remove the GUI cable and set it aside.

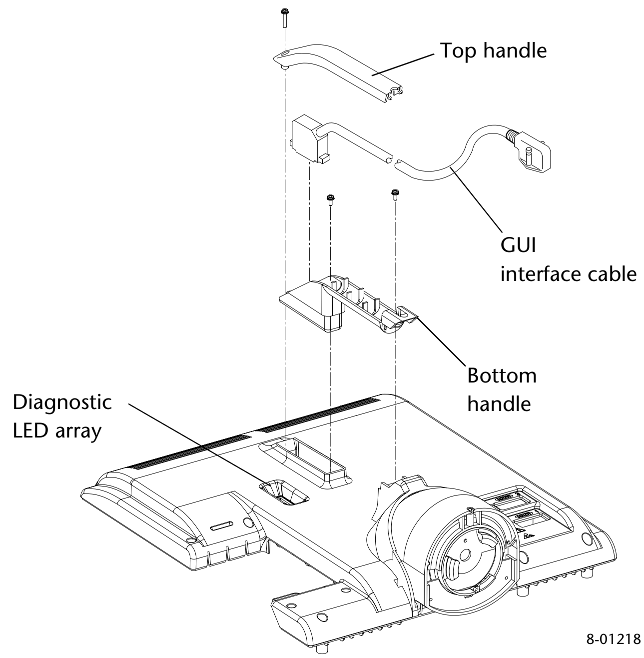


Figure 8-4. Removing and replacing 10.4-inch GUI cable assembly

8.13.3 Replacing the 10.4-inch GUI cable assembly

1. Align the GUI PCB cable end with the connector on the rear of the GUI. Press firmly into place and tighten the captive screws with a small straight blade screwdriver.

Caution

Use care not to overtighten captive screws.

2. Align the tabs on the top handle into the slots in the bottom handle. Press handle into place.
3. Insert screw and gently tighten until snug.

8.13.4 Removing 10.4-inch GUI rear housing

1. Remove the two Phillips screws that secure the bottom handle to the rear housing (Figure 8-5.)
2. Remove the lower handle and set aside with the two screws.
3. Remove the remaining 12 screws that secure the rear panel to the GUI and set them aside.

4 Gently separate the rear panel from the front housing and set aside. If necessary, a small flat-bladed screwdriver may be used to separate the GUI rear panel from the front.

Caution

If you use a small flat-blade screwdriver to separate the rear and front housings, take care not to damage the GUI front and rear panels.

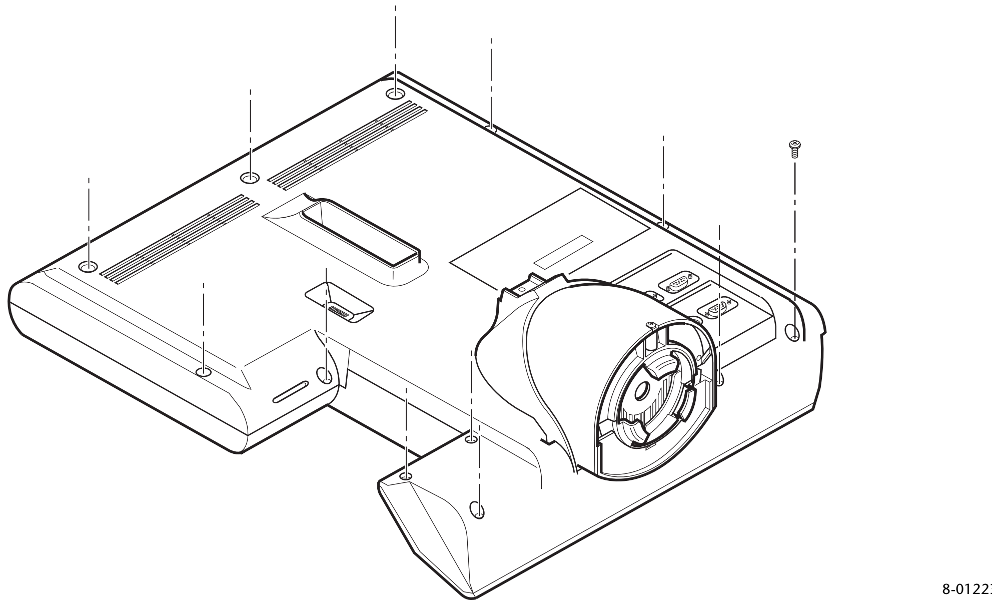


Figure 8-5. Removing 10.4-inch GUI rear housing

8.13.5 Replacing 10.4-inch GUI rear housing

1. Follow the instructions for removing the handle, cable, and rear housing from the GUI.
2. Remove the rear panel warning label from the old rear housing by gently peeling it from the housing to expose the serial number tag.
3. Carefully peel the serial number tag from the housing and set aside.
4. Install the new GUI rear housing.
5. Position the old serial number tag on the rear housing and apply a new rear panel warning label over it.

   The serial number should be visible through the clear window in the label.

Figure 8-6. 10.4-inch GUI rear warning label and serial number tag

8.13.6 Removing the 10.4-inch CPU shield

1 Using a Phillips screw driver, remove the 11 screws that secure the CPU shield to the LCD/GUI bracket (Figure 8-7).

NOTE:

Remove only those screws that go through the shield and not those located in a cutout.

2 Lift the shield from the bottom and tilt up.

3 Gently remove the shield from the GUI assembly and set aside.

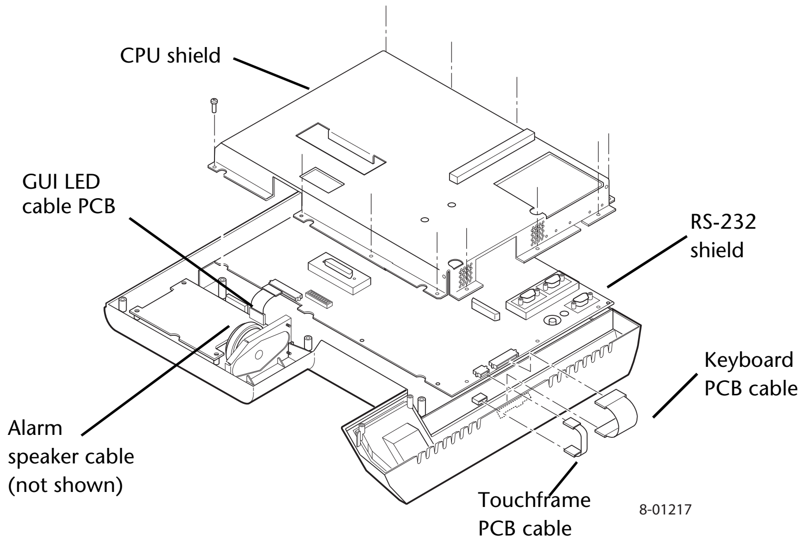


Figure 8-7. Removing the 10.4-inch CPU shield and GUI PCB

8.13.7 Removing the 10.4-inch GUI backlight inverter PCBs

1 Remove the rear housing panel (Section 8.13.5).

2 Remove the GUI protective shield (Section 8.13.6).

3 Using a small Phillips screwdriver, remove the two nylon screws and washers securing each of the two backlight inverter PCBs to the GUI CPU.

Caution

To maintain an isolated ground system, ensure the nylon washer is placed between the inverter PCB and the standoff on the GUI CPU PCB when mounting the backlight inverter PCBs on the GUI CPU PCB.

4 For each of the backlight inverter PCBs, disconnect the harness that connects the LCD to the backlight inverter and the cable from the backlight inverter to the GUI CPU PCB (Figure 8-8).

5 Remove each of the PCBs and place into a conductive bag.

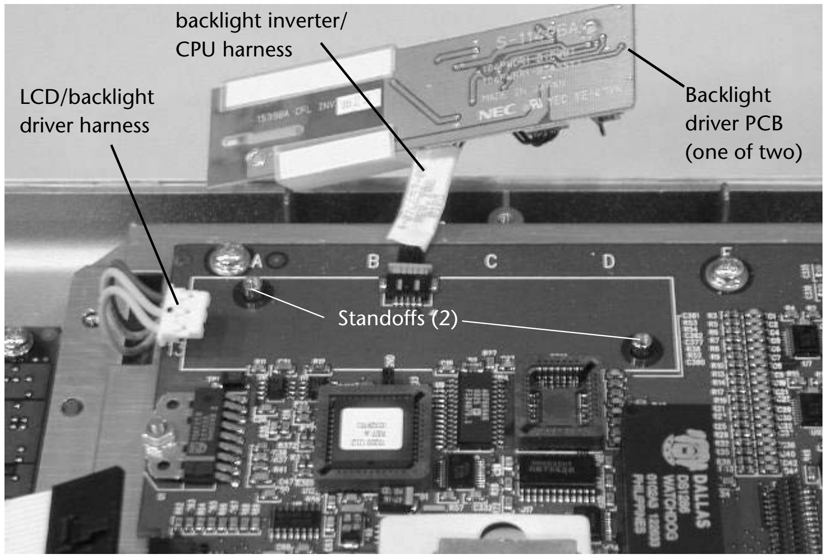


Figure 8-8. Removal of a 10.4-inch backlight inverter PCB

8.13.8 Removing the 10.4-inch GUI CPU PCB

1 Disconnect the following cables from the CPU PCB (Figure 8-7):
   - keyboard PCB cable (J20)
   - touchframe PCB cable (J19)
   - alarm speaker cable (J7)
   - GUI LED PCB cable (J3)
2 Using a 3/16" nut driver, remove the four female screw-lock screws that secure the RS-232 shield (Figure 8-9).
3 Remove RS-232 shield and set aside. Gently remove the RS-232 flex circuit cable and set aside.

Caution

Handle the flex circuit cable with extreme care to prevent damage to the flex circuit connectors.

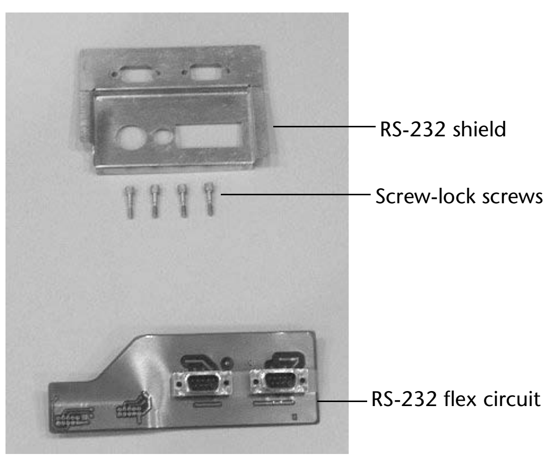


Figure 8-9. RS-232 shield and flex circuit

4 Using a Phillips screwdriver, remove the 10 screws securing the PCB to the GUI housing.

5 Gently tilt the GUI CPU PCB to the right and disconnect the LCD panel flex cables (2) from the board (J2, J11).

6 Remove the GUI CPU PCB and place into a conductive bag. Set the PCB aside.

NOTE:

If installing a new 10.4-inch CPU PCB, ensure the touch panel jumpers are set to the 10.4-inch touchframe style, “MKG TOUCH.” The five jumpers are located on the lower left side of the PCB (Figure 8-10).

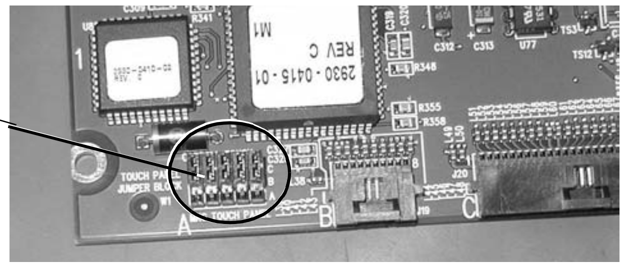


Figure 8-10. GUI CPU PCB touch panel jumpers

8.13.9 10.4-inch GUI support bracket

The GUI support bracket secures the GUI CPU PCB on one side and the LCD panels on the other. The bracket must be removed to access the LCD panels, the touchframe PCB, and the inside front of the GUI housing. Refer to Figure 8-11 for parts identification.

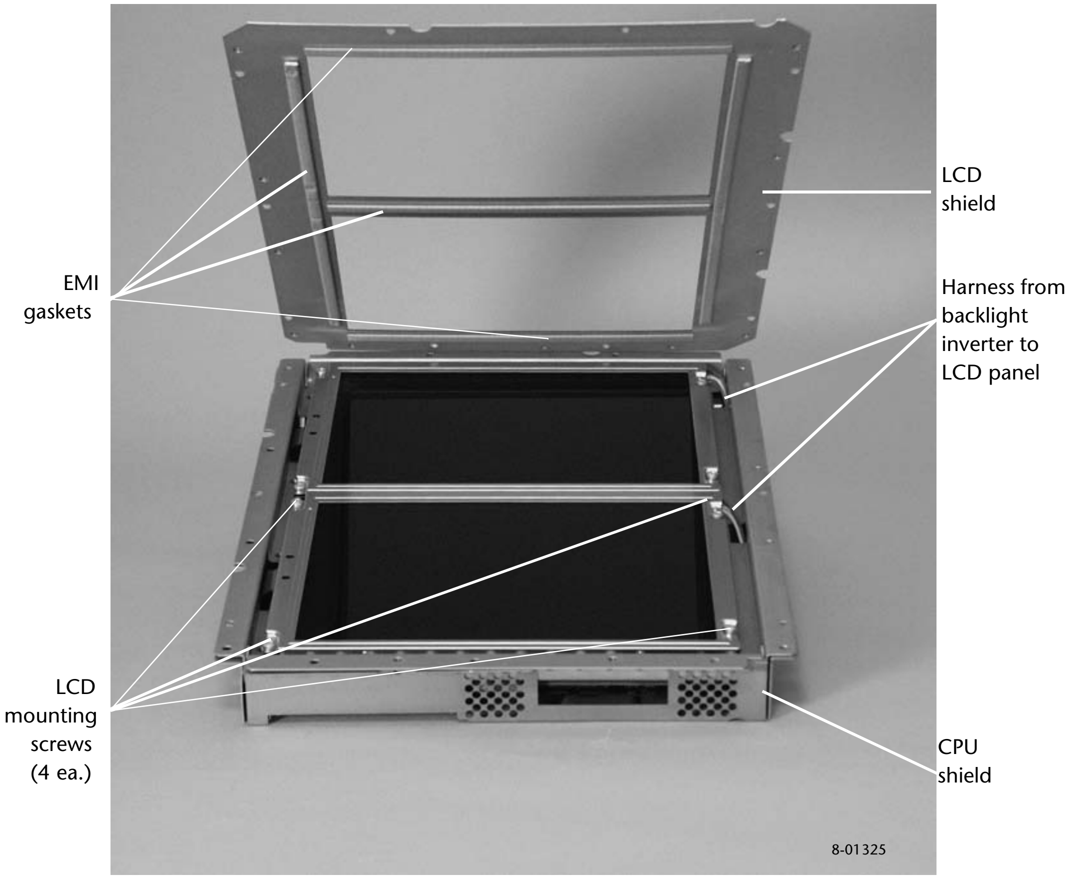


Figure 8-11. 10.4-inch LCD panels and LCD shield

8.13.9.1 Removing the 10.4-inch GUI support bracket

1 Remove the six remaining screws that secure the support bracket to the front housing.

2 Remove the bracket from the GUI housing and place upon a protected work surface with the LCD panels facing up.

3 Using a Phillips screwdriver, remove the four (4) screws that secure the LCD shield in place.

4 Set the shield and screws aside.

8.13.10 10.4-inch LCD panels

Caution

- The LCD panels are easily soiled or damaged. Use caution not to touch the surface of the LCD panel or the inside of the GUI window as fingerprints will result.
- Do not allow the LCD panels to be exposed to the ambient environment any longer than necessary as dirt and debris will be deposited on the LCD panels. Should this occur, use an ESD-protected air source to gently blow away any dust or debris.

8.13.10.1 Removing the 10.4-inch LCD panels

1. With the LCD panels exposed, remove the four screws that secure the each of the two LCD panel in place. Set screws aside (Figure 8-11).
2. Gently lift each LCD panel while routing the cables through the panel.

8.13.11 10.4-inch touchframe PCB (MKG Touch)

Caution

The touchframe PCB should not be flexed or bent as damage will occur. Use caution when handling and avoid touching emitters or receptors mounted on the board.

8.13.11.1 Removing the 10.4-inch touchframe PCB

1. Disconnect the touchframe cable and set aside (Figure 8-12).
2. Using small pliers or thumbnail pressure to remove the eleven (11) plastic rivets that secure the touchframe PCB to the front housing. Set plastic rivets aside.
3. Remove the touchframe PCB and place into a conductive bag. Set PCB aside.

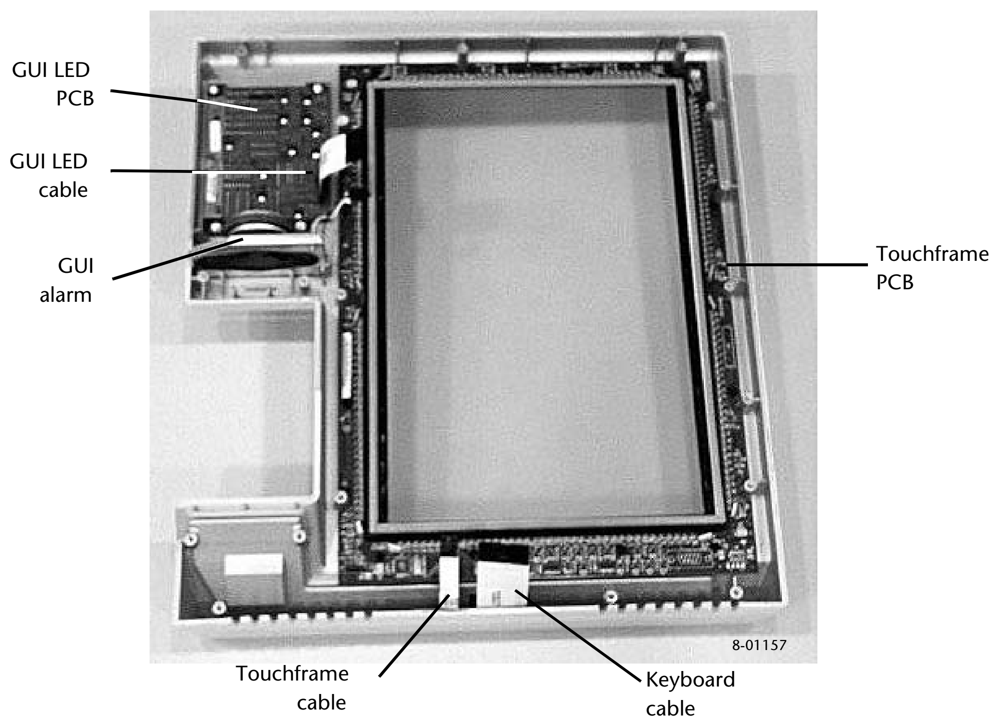


Figure 8-12. 10.4-inch GUI touchframe PCB and GUI LED PCB locations

8.13.12 Replacing the 10.4-inch touchframe PCB

1. Orient the touchframe PCB with the cable connector facing the bottom inside of the front GUI housing.
2. Align the rivet holes of the touchframe over the standoffs located on the inside of the front housing.
3. Insert the eleven (11) plastic rivets through the mounting holes in the touchframe PCB and lock into place.
4. Ensure that the rivets are fully seated.
5. Connect the touchframe PCB cable

8.13.13 10.4-inch GUI LED PCB

8.13.13.1 Removing the 10.4-inch GUI LED PCB

1. Disconnect the GUI LED cable from the GUI LED PCB (J3) (Figure 8-12).
2. Using a small Phillips screwdriver, remove the four screws that secure the GUI LED PCB to the front housing (Figure 8-13). Set screws aside.
3. Remove the GUI LED PCB and place into a conductive bag. Set PCB aside.

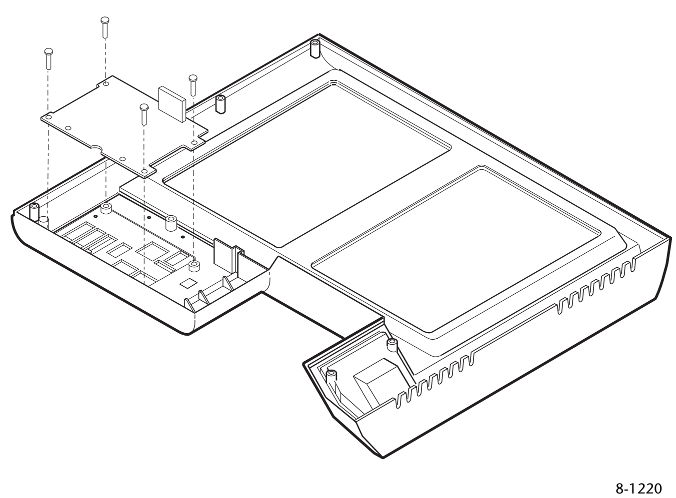


Figure 8-13. Removal of the 10.4" GUI LED PCB

8.13.13.2 Replacing the 10.4-inch GUI LED PCB

1. Align the GUI LED PCB on the four standoffs inside the GUI front housing.
2. Use the four screws to secure the GUI LED PCB to the front housing (Figure 8-13).
3. Connect the GUI LED cable to the GUI LED PCB.

8.13.14 10.4-inch GUI alarm assembly

The GUI alarm is located behind the GUI front panel and can only be accessed by removing the rear GUI housing.

Caution

When handling the GUI alarm assembly, be careful not to damage the speaker element.

8.13.14.1 Removing the 10.4-inch GUI alarm assembly

1. Remove the GUI rear housing as described above.
2. Disconnect the alarm harness from the GUI CPU PCB (J7).
3. Grasp the alarm assembly by the sides and pull up on the alarm body to remove it from the slots in the GUI front housing (Figure 8-14).

8.13.14.2 Replacing the 10.4-inch GUI alarm assembly

1. Grasp the alarm assembly by the sides and align it with the slots in the GUI front housing.

   The speaker element should be facing the bottom of the front housing (Figure 8-14).
2. Gently push the alarm assembly into position.
3. Connect the alarm harness to the GUI CPU PCB (J7).

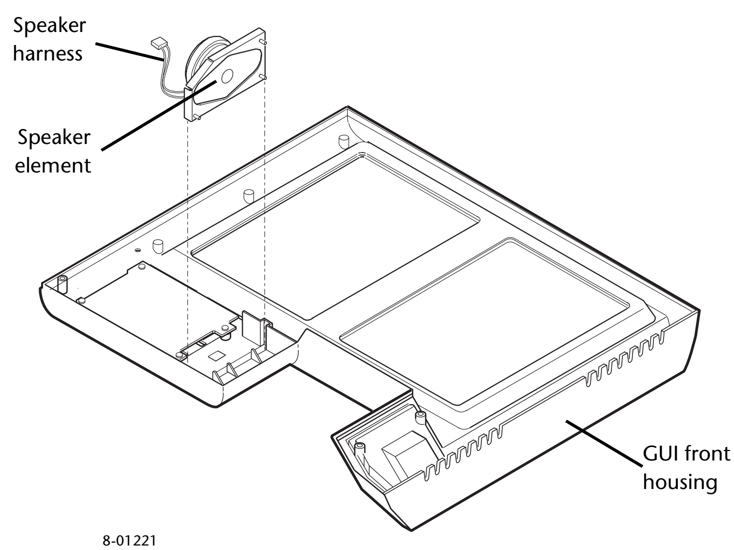


Figure 8-14. Removing the 10.4-inch GUI alarm

8.13.15 10.4-inch GUI keyboard assembly

The 10.4-inch GUI keyboard assembly can be replaced without accessing the GUI CPU PCB and without opening the GUI housing.

8.13.15.1 Replacing the 10.4-inch GUI keyboard assembly

1. Orient the front housing assembly so that the keyboard is facing up.
2. Slide a flat tool under one edge of the keyboard and gently lift to break the adhesive bond with the front housing.
3. Once the adhesive has been broken, disconnect the keyboard cable from the keyboard. Remove the keyboard.
4. Clean the surface of the GUI housing with alcohol to remove any adhesive residue.
5. Prepare the new keyboard for installation by connecting the ribbon cable to the keyboard and removing the adhesive cover strip.

   Verify that the ribbon cable is in the upper row of the connector and is firmly latched into place.
6. Align the keyboard with the opening, sliding the PCB as far up as possible on the front housing. Press firmly into place.

8.13.16 10.4-inch GUI front housing

The window, bezel, and front housing are all laminated together to form one part.

Caution

Do not touch the inside (coated side) of the GUI window. If necessary, use finger cots or protective gloves. The window is treated for glare resistance and touching it creates smudges, which cannot be removed without damaging the window.

8.13.16.1 Replacing the 10.4-inch front housing

1. Follow the preceding procedures to disassemble the GUI to the touchframe PCB.
2. Remove the touchframe PCB.
3. Remove the GUI LED PCB.
4. Remove the GUI alarm assembly.
5. Remove the keyboard using care not to damage the adhesive.
6. Install a new front housing.
7. Reinstall or replace the keyboard assembly.
8. Reinstall the GUI LED PCB, the alarm assembly and the touchframe PCB.
9. Continue reinstalling the GUI components that were removed to access the front housing.
10. Install the GUI alarm graphics label.

8.13.17 10.4-inch rotor housing

The rotor housing is easily replaced without disassembling the GUI housing.

8.13.17.1 Replacing the 10.4-inch rotor housing

1 Remove the GUI from the cart.

2 Using a Phillips screwdriver, remove the two screws that secure the fascia panel in place. Set the bezel and the screws aside.

3 Using pliers, carefully pull the spring away from the rotor brake shoes. Let the spring hang from the base.

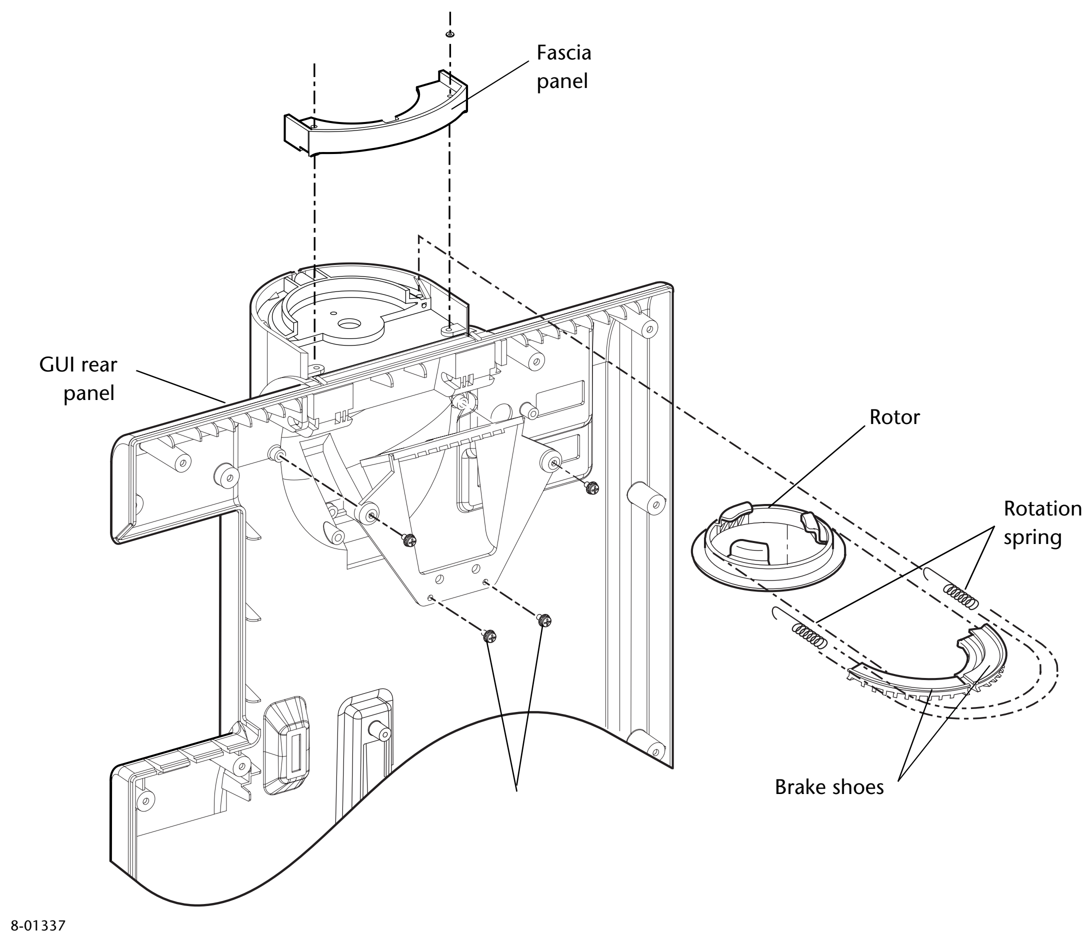


Figure 8-15. 10.4-inch GUI rotor housing

4 Remove the brake shoes from the rotor.

5 Remove the rotor and discard.

6 Install the new rotor into the groove and slide into place.

7 Install the two brake shoes and align the spring to fit in the brake shoe groove.

8 Align the fascia panel over the rotor and secure with the two screws. Tighten until snug.

9 Reinstall the GUI onto the cart.

8.14 Repairing the 9.4-inch GUI

The following repair and installation instructions are specific to the 9.4-inch color GUI.

8.14.1 Removing the 9.4-inch GUI touch screen bezel

The bezel surrounds the GUI window and holds it in place. To replace the window, you must first remove the bezel.

1. Disconnect GUI cable from side of BDU (Figure 8-19). If ventilator is mounted on optional cart, detach cable from cable guide at rear of cart.
2. At top left corner of touch screen, position blade of a small flat-bladed screwdriver (pointing up) between bezel and window (Figure 8-16). Gently wedge blade (do not twist) between bezel and window.
3. Without placing blade in direct contact with window, carefully apply negative pressure to bezel to dislodge from GUI housing.
4. Gently pull each side of bezel (do not twist) until it snaps out of housing. Remove gasket.
5. Inspect bezel. Replace if heavily scratched or if tabs are broken.

Caution

Be careful not to touch the inside (coated side) of the window. If necessary, use finger cots or protective gloves. The window is treated for glare resistance and touching it creates smudges which cannot be removed without damaging the window.

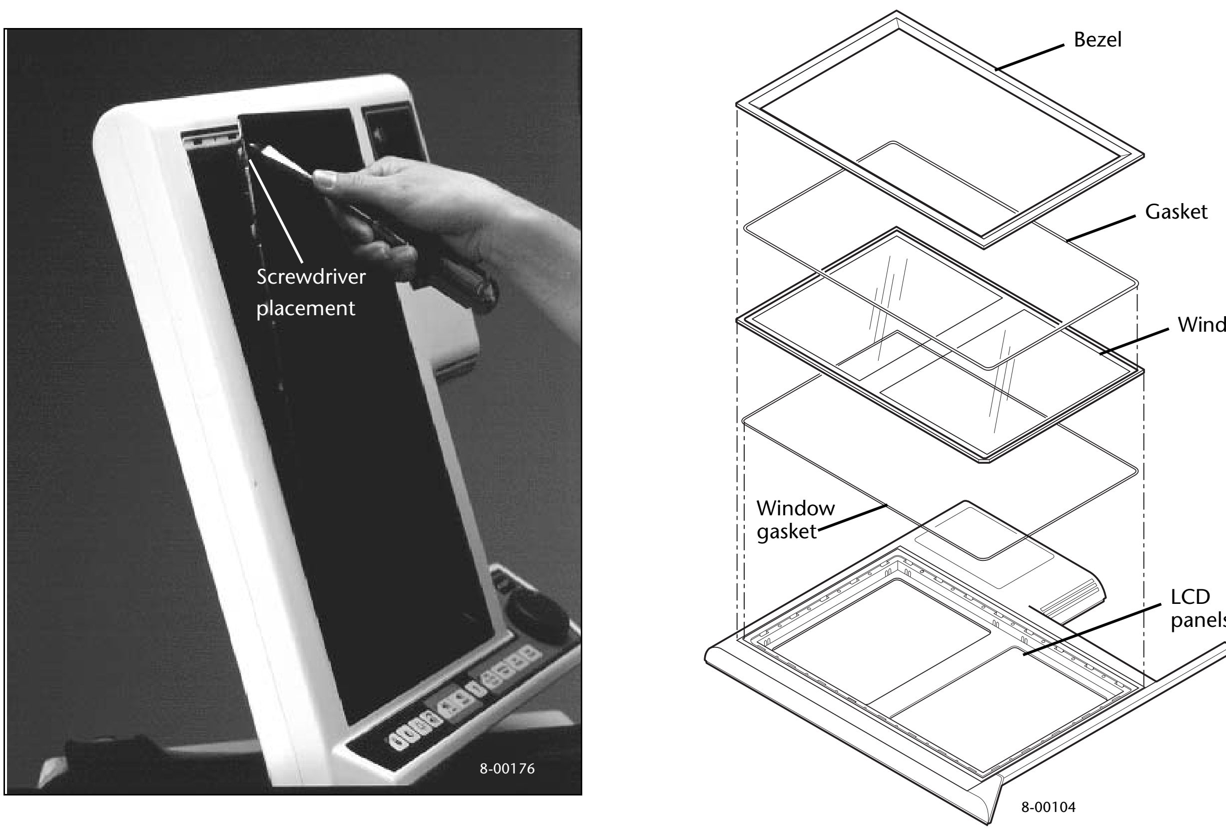


Figure 8-16. 9.4-inch touch screen bezel and window

8.14.2 9.4-inch GUI window

Caution

- Be careful not to touch the inside (coated side) of the window. If necessary, use finger cots or protective gloves. The window is treated for glare resistance and touching it creates smudges which cannot be removed without damaging the window.
- Avoid cleaning the coated side of the window. If necessary, gently blow off dust or debris using compressed air.

The window serves as the GUI touch screen; it is held in place by the bezel.

8.14.2.0.1 Removing 9.4-inch GUI window

1. Carefully slide blade of a small, flat-bladed screwdriver under window at lower left and/ or right corners (Figure 8-16).
2. Gently apply negative pressure to unseat bottom of window.
3. Carefully remove window and its gasket.
4. Place window on flat surface with coated side facing up.

8.14.2.0.2 Installing 9.4-inch GUI window

Caution

Be careful not to touch the inside (coated side) of the window. If necessary, use finger cots or protective gloves. The window is treated for glare resistance and touching it creates smudges which cannot be removed without damaging the window.

NOTE:

When installing the window, be sure the coated-side (with the painted black strip) is facing to the inside of the unit.

1. Tilt GUI to its rear-most position (Figure 8-17).
2. Making sure gasket is in place and coated side of window is facing GUI, carefully set window into window frame (Figure 8-16).
3. Carefully insert window gasket into groove around uncoated (front) side of window.
4. Gently press edges of window until it fully seats into front housing.

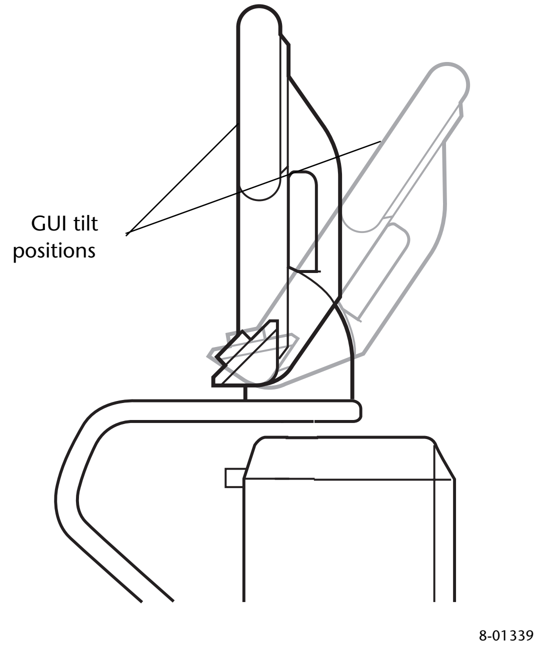


Figure 8-17. 9.4-inch GUI tilt positions

8.14.3 Installing the 9.4-inch bezel

NOTE: The top of the bezel is narrower than the bottom. When replacing the bezel, position the narrower end at the top.

1. Make sure window gasket is in place (Figure 8-16).
2. Carefully insert bezel gasket into groove around bezel frame.
3. With narrow side of bezel on top, carefully place bezel into bezel frame.
4. Make sure gasket is not exposed or pinched; then starting at top, press edges of bezel until it is fully inserted and securely seated in frame.

8.14.4 The 9.4-inch keyboard assembly

The keyboard assembly is a field-replaceable unit (FRU), consisting of a keyboard laminate, a keyboard PCB, and a rotary encoder. The keyboard can be removed with the GUI mounted on the ventilator.

8.14.4.1 Removing 9.4-inch keyboard assembly

1. Orient front housing assembly so keyboard laminate is facing up (Figure 8-18).

Caution

Carefully remove the keyboard assembly to avoid damaging the GUI front housing.

2. Slide a flat tool under one edge of keyboard laminate and pull up to break keyboard's adhesive bond to front housing.
3. Once the adhesive has been broken, disconnect ribbon cable from keyboard.
4. Continue to pull keyboard assembly away from front housing. Remove entire assembly including keyboard laminate, keyboard PCB, and rotary encoder.

5 Gently remove keyboard assembly and place in conductive bag or on ESD-protected mat.

6 Using alcohol, clean any remaining adhesive from front housing, being careful not to let debris fall into the GUI housing.

NOTE: Do not attempt to reuse the 9.4-inch keyboard assembly after removal.

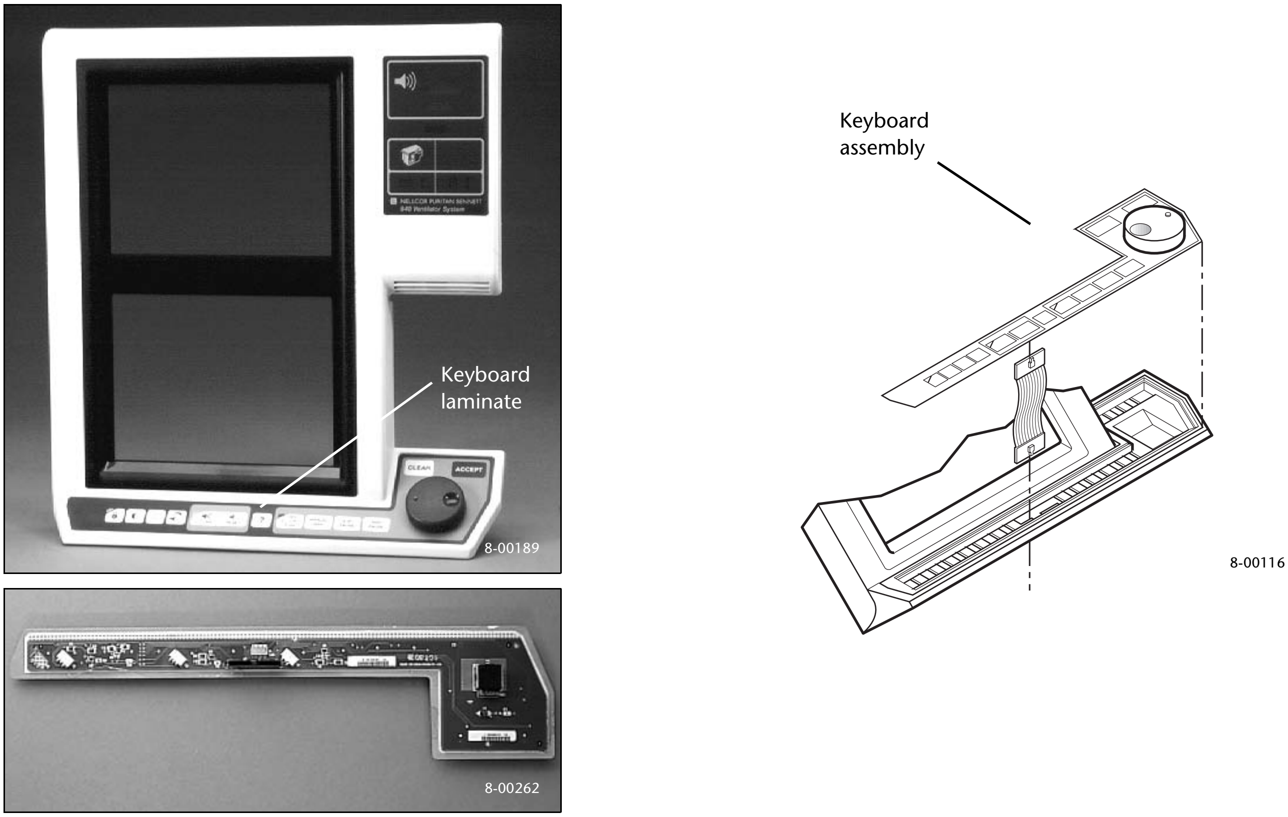


Figure 8-18. Replacing the 9.4-inch keyboard assembly

8.14.4.2 Installing the 9.4-inch keyboard assembly

Caution

The keyboard assembly is held in place by a quick bonding adhesive that surrounds the inside perimeter of the keyboard laminate. Once the adhesive is exposed, it immediately bonds to anything it touches. Therefore, use extreme care when removing the protective strip concealing the adhesive, and while aligning the keyboard laminate to the GUI's front panel.

1. Align keyboard over housing and connect keyboard PCB ribbon cable (dark stripe goes to pin 1 of GUI CPU PCB J20) (Figure 8-18). Verify that cable is positively locked into place.
2. On inside of keyboard laminate, carefully peel back protective strip that conceals adhesive.
3. Taking care not to touch keyboard assembly to GUI front housing, align keyboard laminate (starting with side containing rotary encoder) with keyboard inset on front housing.
4. Carefully press keyboard in place by applying pressure to perimeter of laminate; then, check keyboard perimeter to ensure it is securely bonded to GUI housing.

8.14.5 Removing or installing the 9.4-inch GUI

1. Disconnect GUI interface cable from side of BDU (Figure 8-19).
2. If GUI is mounted to optional cart, detach cable from cable guide at rear of cart.
3. Remove GUI from its mount:
   a. Grasp handle at back of GUI.
   b. Push GUI release knob to right to disengage rotor housing from mounting platform.
   c. While holding knob to right, lift module up and away from mounting platform.
   d. Release knob and it will snap back to left, locked position.
4. Place GUI face down on flat ESD-protected work surface.
5. To install the GUI:
   a. Position the GUI over the GUI mount.
   b. Push GUI release knob to right to disengage rotor housing from mounting platform.
   c. Push knob to left to engage housing.
   d. Connect GUI cable from side of BDU.

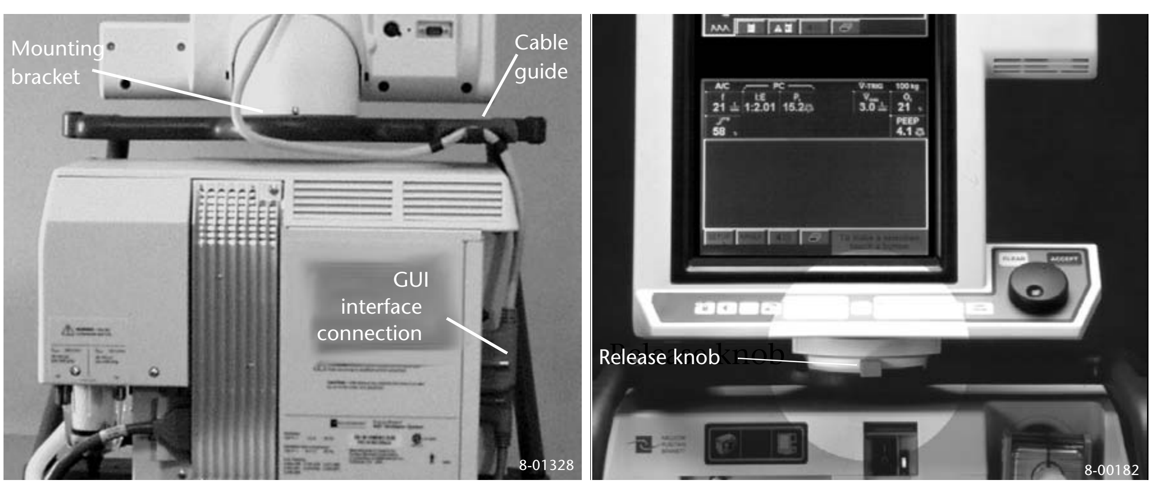


Figure 8-19. 9.4-inch GUI mounting platform

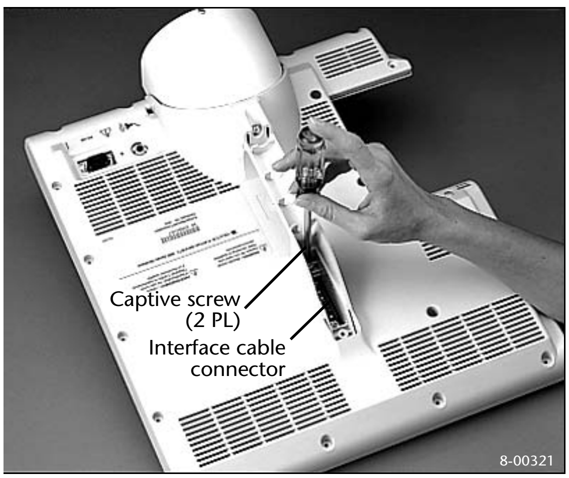
8.14.6 9.4-inch GUI rear housing

Caution

To prevent damage to ESD-sensitive components, always follow ESD guidelines when disassembling the GUI.

8.14.6.1 Removing 9.4-inch GUI rear housing

1. Remove GUI (Section 8.14.5).
2. With GUI face down, remove screw that holds top portion of handle assembly to GUI rear housing (Figure 8-20). Remove top handle and set aside.
3. Loosen two captive screws that secure interface cable connector to GUI CPU PCB. Disconnect interface cable and set aside.
4. Remove the two screws that secure bottom handle to GUI rear housing and set aside.



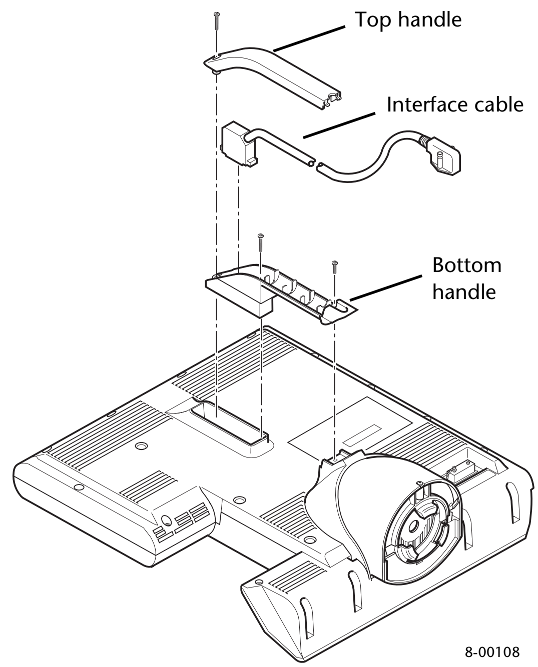


Figure 8-20. Removing 9.4-inch GUI handle assembly and interface cable

5. Loosen the two captive screws that retain RS-232 port cover; remove cover.
6. Unplug nurse's call port cover.
7. Remove 19 screws from GUI rear housing (Figure 8-21) and set aside.
8. Gently separate GUI rear and front housing. If necessary, use a small flat-bladed screwdriver to separate the GUI rear panel from the front.

Caution

If you do use a small flat-blade screwdriver to separate the GUI rear and front housings, use care not to damage the GUI front or rear housing.

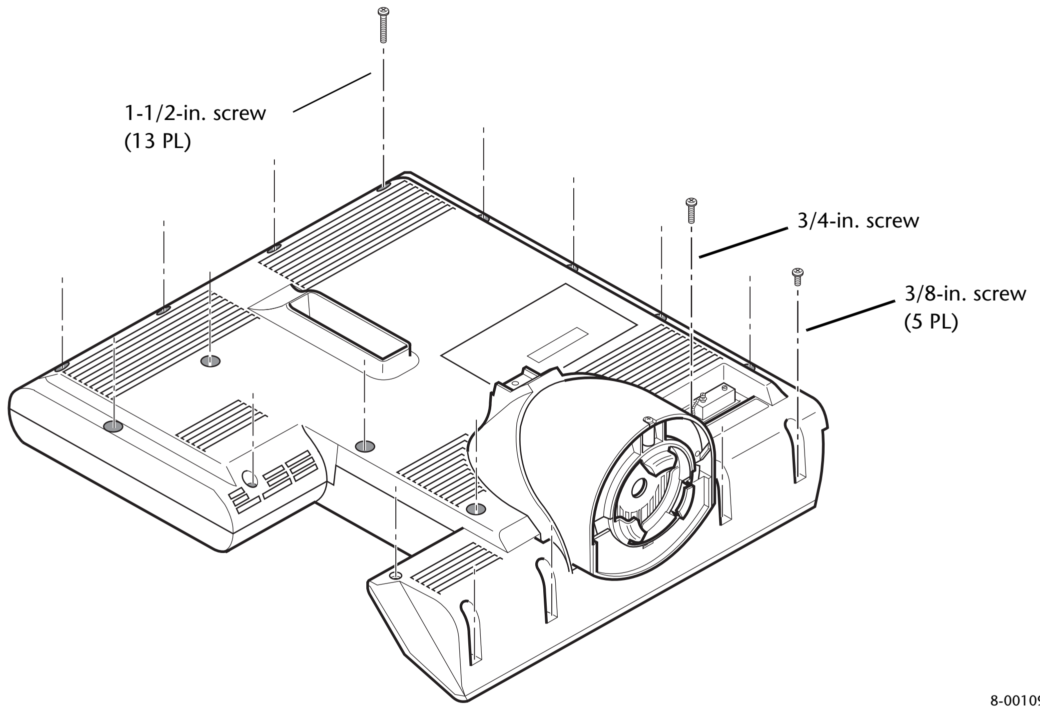


Figure 8-21. Replacing 9.4-inch GUI rear housing

8.14.6.2 Installing 9.4-inch GUI rear housing

NOTE:

The screws that secure the GUI rear housing to the front housing come in three lengths. Refer to Figure 8-21 for correct lengths.

1 With GUI front housing face down, align rear and front housings.
2 Feed remote alarm cover through rear housing.
3 Check perimeter of housing to make sure cables are not being pinched.
4 Gently press rear housing into front housing until two enclosures fully seat.
5 Install GUI rear housing (Section 8.14.6.1).

Caution

Ensure cables are not pinched between the front and rear housings. Otherwise, damage to the cables may result.

6 Install and hand-tighten 19 screws; then, using a screwdriver, tighten until snug. **Do not overtighten.**
7 Insert the bottom handle into handle seating on rear housing (Figure 8-20). Install and hand-tighten two screws; then, using a screwdriver, tighten until snug. **Do not overtighten.**
8 Connect female end of GUI interface cable to GUI CPU PCB connector located inside bottom handle. Tighten two interface cable captive screws to GUI CPU PCB until snug. **Do not overtighten.**
9 Position the interface cable into the handle slots.
10 Snap top handle into place. Install screw and tighten until snug. **Do not overtighten.**
11 Install GUI (Section 8.14.5).

8.14.7 9.4-inch GUI alarm assembly

The GUI alarm assembly is located behind the GUI front panel.

8.14.7.1 Removing 9.4-inch GUI alarm assembly

1 Remove GUI rear housing (Section 8.14.6).
2 Disconnect alarm harness from GUI CPU PCB J9 (Figure 8-22).
3 Grasp assembly at sides and pull up on alarm body; it will slide out of slots in GUI housing (Figure 8-23).

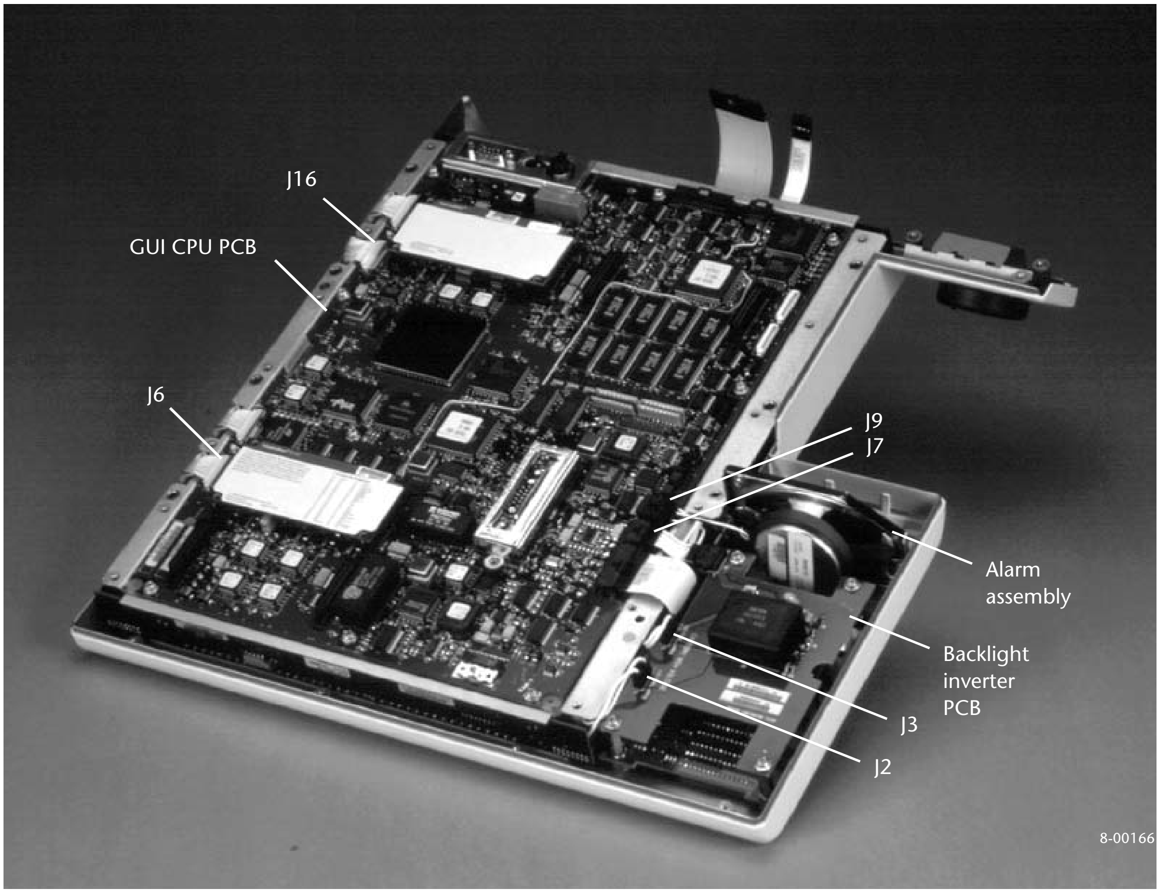


Figure 8-22. 9.4" GUI interior

8.14.7.2 Installing 9.4-inch GUI alarm assembly

1. Orient alarm assembly with harness toward GUI CPU PCB and speaker away from backlight inverter PCB (Figure 8-23).
2. Slide alarm side brackets into slots on GUI housing. Make sure bracket is fully seated in slots.
3. Connect alarm harness to GUI CPU PCB J9 (Figure 8-22).
4. Install GUI rear housing (Section 8.14.6.2).

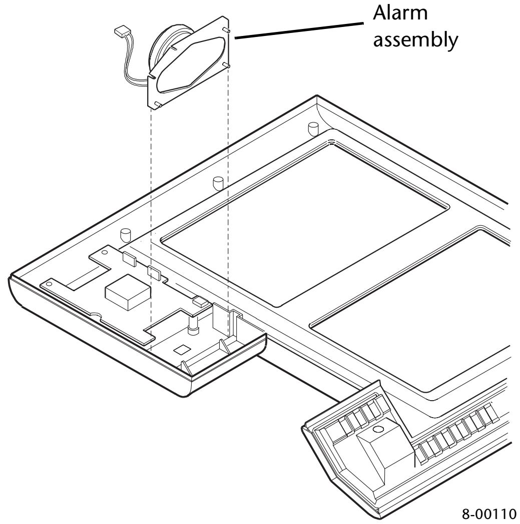


Figure 8-23. Replacing the 9.4-inch GUI alarm assembly

8.14.8 9.4-inch GUI backlight inverter PCB and GUI LED PCB

The backlight inverter PCB, which is part of the LCD backlight control circuit, controls the brightness of both LCD panels.

The GUI LED PCB interface lets the GUI microprocessor control the discrete diagnostic LEDs on the LED PCB.

8.14.8.1 Removing 9.4-inch GUI backlight inverter PCB

1. Remove GUI rear housing (Section 8.14.6).
2. Disconnect backlight inverter PCB ribbon cable from GUI CPU connector J7 (Figure 8-22).
3. Disconnect two LCD harnesses from backlight inverter PCB connectors J2 and J3.
4. Remove four screws that secure backlight inverter PCB to standoffs (Figure 8-24).
5. Lift backlight inverter PCB off standoffs and place into conductive bag or on ESD-protected mat. If you are installing a new backlight inverter PCB, remove backlight inverter PCB/GUI CPU PCB ribbon cable and save for reinstallation.

8.14.8.2 Installing 9.4-inch GUI backlight inverter PCB

1 If applicable, install backlight inverter PCB/GUI CPU PCB ribbon cable to backlight inverter PCB connector J1.

2 With ribbon cable facing GUI CPU PCB and components facing up, align backlight inverter PCB to four standoffs (Figure 8-24).

3 Manually install and tighten four screws; then, using a screwdriver, tighten until snug. **Do not overtighten.**

4 Connect backlight inverter PCB/GUI CPU PCB ribbon cable to GUI CPU PCB connector J7 (Figure 8-22).

5 Connect two LCD panel cables to backlight inverter PCB connectors J2 and J3.

6 Install GUI rear housing (Section 8.14.6.2).

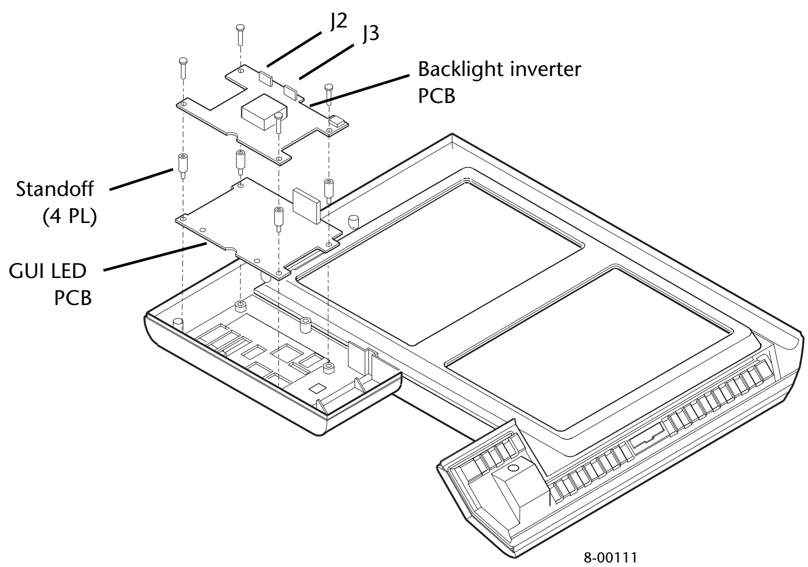


Figure 8-24. Replacing 9.4-inch backlight inverter and GUI LED PCBs

8.14.8.3 Removing 9.4-inch GUI LED PCB

1 Remove backlight inverter PCB (Section 8.14.8.1).

2 Disconnect GUI LED PCB ribbon cable from GUI CPU PCB connector J3 (Figure 8-22).

3 Using 1/4-in. nutdriver, remove four standoffs that secure GUI LED PCB to front housing (Figure 8-24).

4 Remove GUI LED PCB and place into conductive bag or on ESD-protected mat. If you are installing new GUI LED PCB, remove GUI LED PCB/GUI CPU PCB ribbon cable and save for reinstallation.

8.14.8.4 Installing 9.4-inch GUI LED PCB

1 If applicable, install GUI LED PCB/GUI CPU PCB ribbon cable to GUI LED PCB.

2 With ribbon cable facing GUI CPU PCB, align GUI LED PCB to four standoff screwholes (Figure 8-24).

3 Manually install and tighten four standoffs; then using a 1/4-in. nutdriver, tighten until snug. **Do not overtighten.**

4 Connect GUI LED PCB ribbon cable to GUI CPU PCB connector J3 (Figure 8-22).

5 Install backlight inverter PCB. Section 8.14.8.2

8.14.9 GUI EMI shield

8.14.9.1 Removing the GUI EMI shield

1. Remove the 11 screws from the rear of the GUI EMI shield and set aside (Figure 8-25).
2. Disconnect the touch frame PCB cable (J19) and keyboard cable (J20).
3. Remove the GUI EMI shield and set aside.

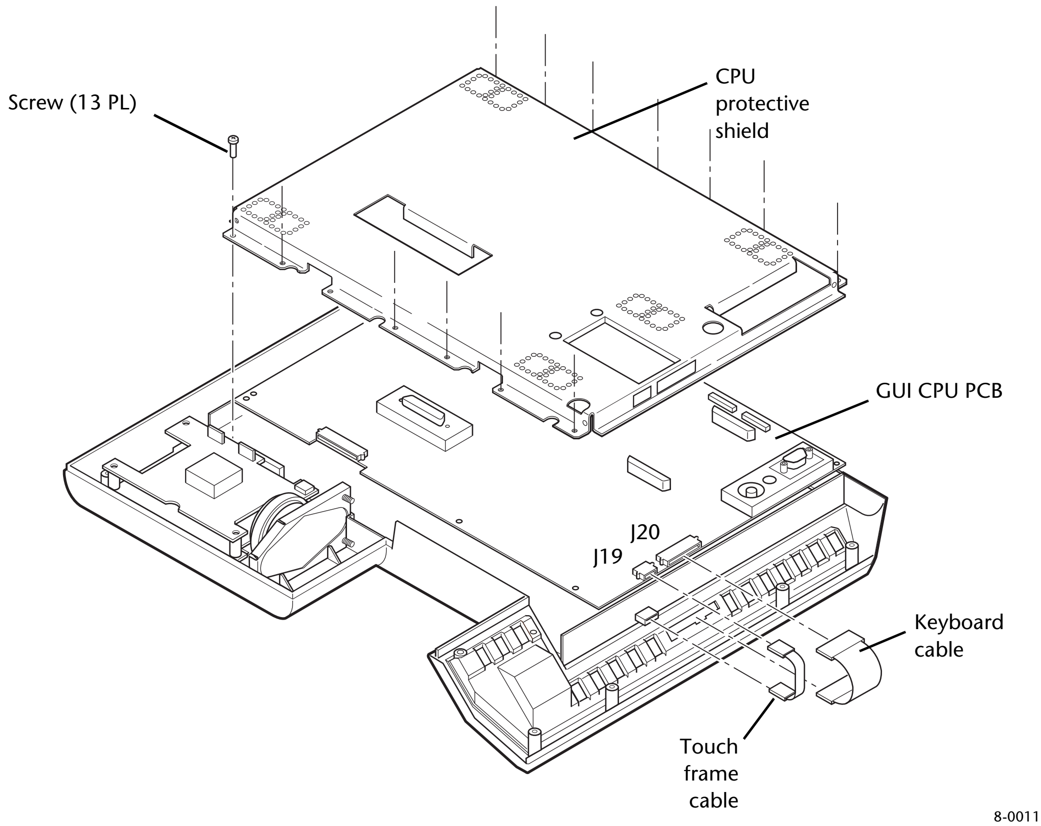


Figure 8-25. Removing 9.4-inch GUI EMI shield

8.14.9.2 Installing the 9.4-inch GUI EMI shield

1. Align GUI EMI shield to 13 screwholes on CPU bracket (Figure 8-25). Install and hand-tighten 13 screws; then, using a screwdriver, tighten until snug. **Do not overtighten.**
2. Connect these cables to bottom of GUI (Figure 8-21):
   - Touchframe PCB ribbon cable to GUI CPU PCB connector J19
   - Keyboard ribbon cable to GUI CPU PCB connector J20

8.14.10 9.4-inch video controller and VGA LCD controller PCBs

Later versions of the 9.4-inch GUIs use a CPU PCB that is common to both 9.4-inch and 10.4-inch GUIs. This later PCB design includes two built-in VGA controllers that interface with the LCD panels. If replacing an older GUI CPU PCB in a 9.4-inch GUI with the newer PCB, discard the VGA controllers.

8.14.10.1 Removing 9.4-inch VGA LCD controller PCBs (older CPU PCB)

1. Remove GUI rear housing (Section 8.14.6).
2. Remove CPU EMI shield (Section 8.14.9.1).
3. Grasp sides of desired VGA LCD controller PCB and pull up to disengage pins from GUI CPU PCB connectors (Figure 8-26). Place in conductive bag or on ESD-protected mat.

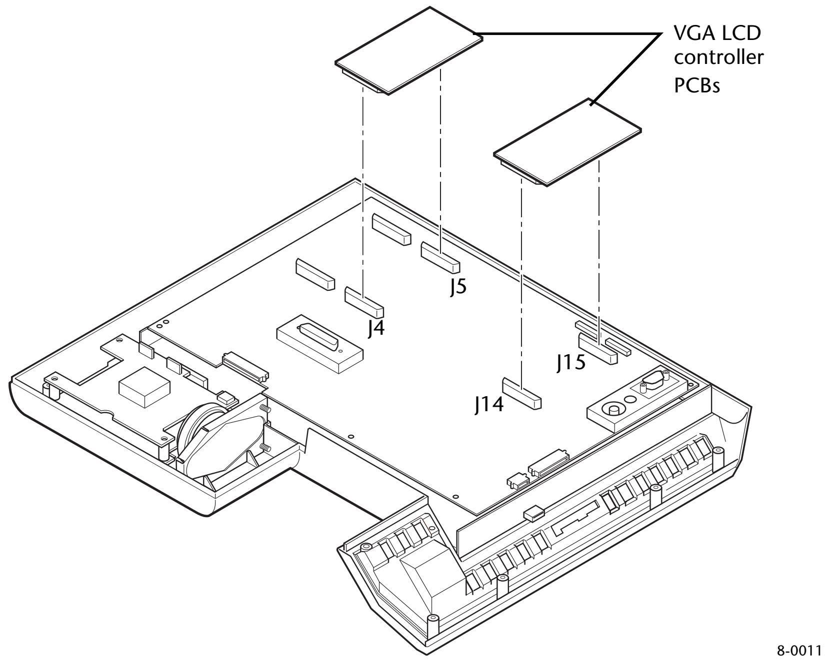


Figure 8-26. Removing 9.4-inch video controller PCBs

8.14.10.2 Installing 9.4-inch VGA LCD controller PCBs (older CPU PCB)

NOTE:

The two plug-in IP interface VGA LCD controller PCBs are identical and can be mounted at either GUI CPU PCB location (J14/J15 or J4/J5). The pin sets at each end of the video controller PCBs are different, preventing the video controller PCBs from being mounted backward on the GUI CPU PCB.

1. Orient pins on video controller PCB so they align with corresponding connectors on GUI CPU PCB (Figure 8-26).
2. Gently press video controller PCB until fully seated.
3. Install GUI EMI shield (Section 8.14.9.2).
4. Install GUI rear housing (Section 8.14.6.2).

8.14.11 9.4-inch GUI CPU PCB

8.14.11.1 Removing the 9.4-inch GUI CPU PCB

1. Remove GUI rear housing. (Section 8.14.6.1).
2. Remove the GUI EMI shield (Section 8.14.9.1).
3. Disconnect these cables from GUI CPU PCB (Figure 8-22):
   - Two LCD harnesses from J6/J8 and J16/J18
   - Backlight inverter PCB ribbon cable from J7
   - GUI LED PCB ribbon cable from J3
   - GUI alarm harness from J9
4. Disconnect the backlight extender cable assemblies from the backlight inverter PCB connectors J2 and J3.
5. Disconnect these cables from bottom of GUI (Figure 8-22):
   - Touchframe PCB ribbon cable to GUI CPU PCB connector J19
   - Keyboard ribbon cable to GUI CPU PCB connector J20
6. Remove the eleven (11) screws that secure GUI CPU PCB/bracket assembly to the standoffs in front housing.
7. Lift the CPU bracket assembly off standoffs.

Caution

When removing the GUI CPU PCB, be careful not to damage surface components. **Do not flex the PCB.**

8.14.11.2 Installing the 9.4-inch GUI CPU PCB

When installing a later generation CPU PCB in a 9.4-inch GUI, be sure to set the five touch panel jumpers on the lower left side of the GUI CPU PCB TO “Carroll Touch.”

Jumpers

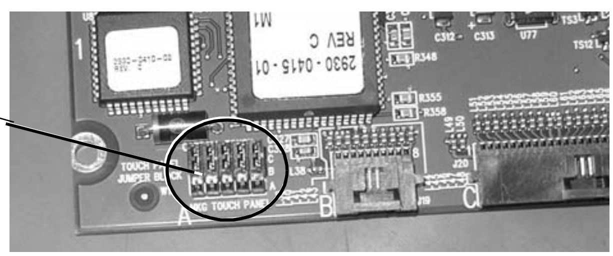


Figure 8-27. GUI CPU PCB touch panel jumpers

1. Align GUI CPU PCB to eleven (11) screwholes in mounting bracket (Figure 8-22). Install and hand-tighten 11 screws. Then use a screwdriver to tighten the screws until snug. **Do not overtighten.**
2. Connect the backlight extender cable assemblies from the backlight inverter PCB connectors J2 and J3.

3 Connect these cables to GUI CPU PCB:
- LCD harnesses (2) to J6 and J16
- Backlight inverter PCB ribbon cable to J7
- GUI LED PCB ribbon cable to J3
- GUI alarm harness to J9

4 Align CPU EMI shield to 13 screwholes on CPU bracket (Figure 8-25). Install and hand-tighten 13 screws. Then, use a screwdriver to tighten the screws until snug. **Do not overtighten.**

5 Connect these cables to bottom of GUI (Figure 8-22):
- Touchframe PCB ribbon cable to GUI CPU PCB connector J19
- Keyboard ribbon cable to GUI CPU PCB connector J20

6 Install GUI rear housing (Section 8.14.6.2).

8.14.12 9.4-inch touchframe PCB (Carroll Touch)

Caution

- Handle the touchframe PCB with care: do not flex the assembly, damage any of the surface components, or touch emitters or receivers.
- Take care when disconnecting the LCD harnesses; do not pull on wires. These harnesses are delicate.

8.14.12.1 Removing the 9.4-inch touchframe PCB

1 Remove GUI rear housing (Section 8.14.6.1).

2 Remove the GUI EMI shield (Section 8.14.9.1).

3 Remove the GUI CPU PCB/bracket assembly (Section 8.14.11.1):

4 Turn the CPU bracket assembly (LCD panels up) and place on an ESD-protected mat.

5 Remove the two screws that secure touchframe PCB to CPU bracket (Figure 8-28).

6 Gently lift off touchframe PCB and place in conductive bag or on ESD-protected mat.

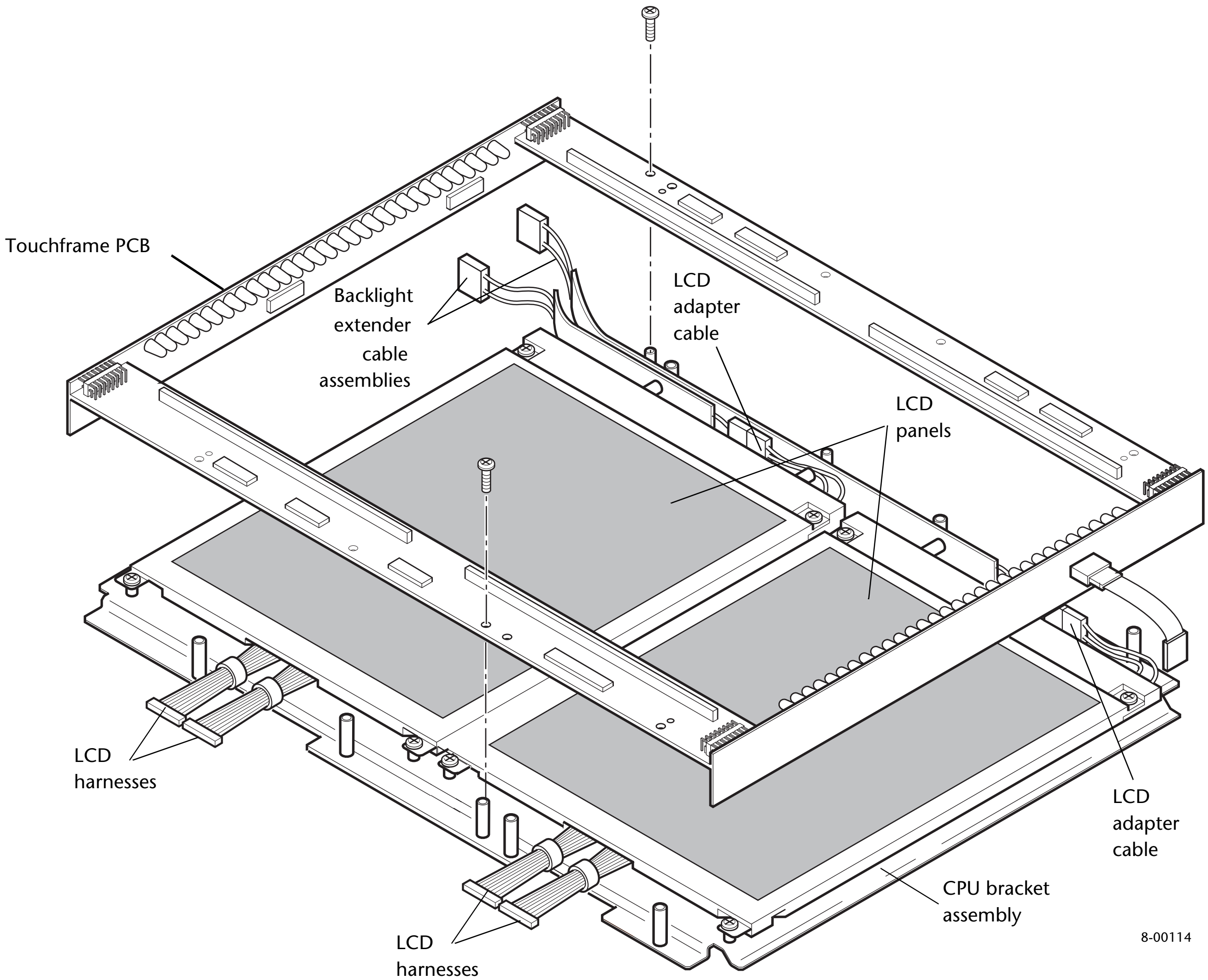


Figure 8-28. Replacing the 9.4-inch touchframe PCB and LCD panel assembly

8.14.12.2 Reinstalling the 9.4-inch touchframe PCB

1. Align the touchframe PCB to two screwholes on CPU bracket (Figure 8-28).
2. Turn the CPU bracket assembly over (LCD panels down) and place on an ESD-protected mat.
3. Route the backlight extender cable assemblies as shown in Figure 8-29. Ensure that the foam side of the cable assemblies are facing away from the LCD panels.

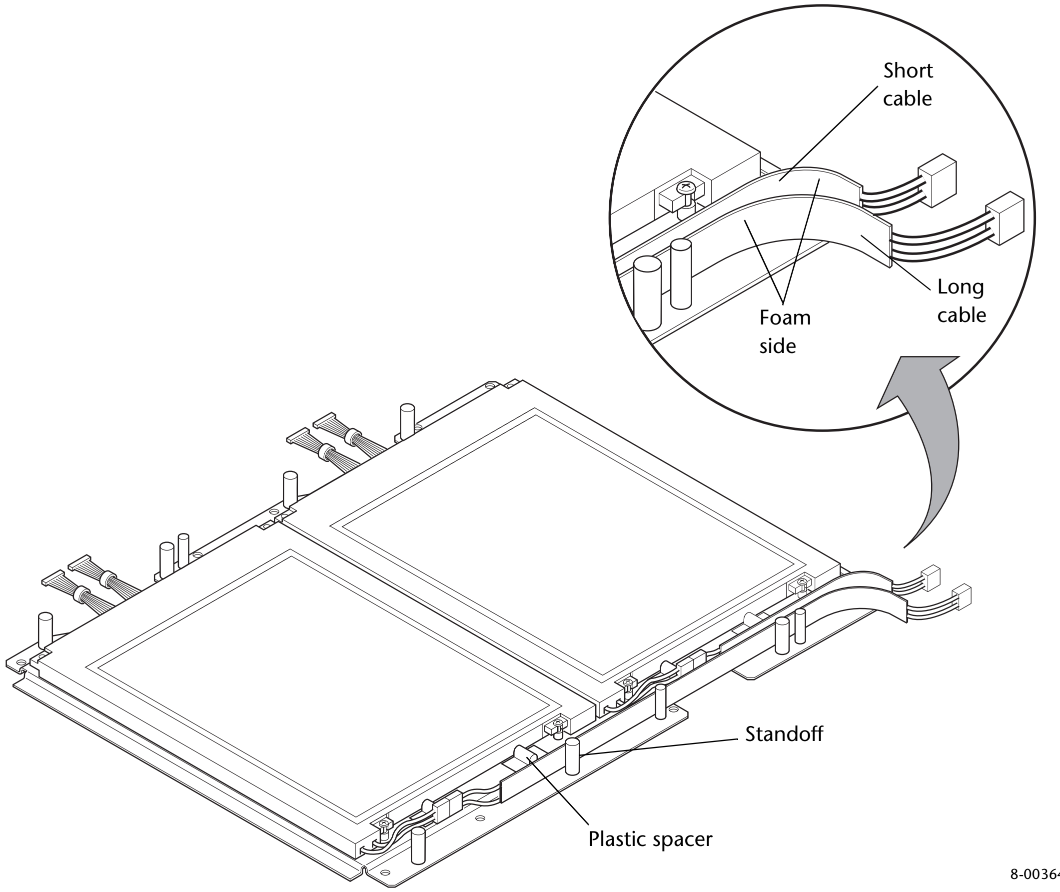


Figure 8-29. Routing the backlight extender cable assemblies

4 Install GUI CPU PCB/bracket assembly (Section 8.14.11.2).

5 Install GUI EMI shield (Section 8.14.9.2).

6 Install GUI rear housing (Section 8.14.6.2).

8.14.13 9.4-inch backlight panels and LCD panels

The 10,000 hour preventative maintenance kit for the monochrome LCD is no longer available. The unit must be upgraded to the 9.4-inch color display.

Caution

- Avoid touching the front of the LCD panels. Smudges are difficult to remove.
- Use care not to scratch the front of LCD panels.

8.14.13.1 Removing a 9.4-inch backlight panel and LCD pane

1 Remove GUI rear housing (Section 8.14.6).

2 Remove the GUI EMI shield (Section 8.14.9.1).

3 Remove GUI CPU PCB (Section 8.14.11.1).

4 Remove touchframe PCB (Section 8.14.12.1).

5 Disconnect the adapter cable from one LCD (Figure 8-28). Leave the cable in place.

6 Remove the four screws that secure the LCD panel to the CPU bracket assembly.

NOTE:

LCD panels are not interchangeable due to backlight wire lengths. Do not reverse displays. Complete the backlight replacement for one LCD panel first, then complete the second backlight replacement.

7 Gently lift the LCD panel from the bracket and place the panel face down on an ESD-protected mat.

8 Remove the LCD interface PCB (with LCD harnesses attached) from the rear of the LCD panel and set aside (Figure 8-30).

9 Remove the backlight panel (Figure 8-30):

a. Using a small flat-bladed screwdriver, straighten the small metal tabs around the perimeter of the LCD panel.

b. Carefully remove the backlight panel.

c. Discard if replacing the panel.

8.14.13.2 Reinstalling a backlight panel and LCD panel

1 Remove the replacement backlight panel from the ESD bag. Place it over the LCD panel.

2 Gently press the backlight panel into position. Using a flat-blade screwdriver, bend the small metal tabs around the perimeter of the panel to hold it in place.

3 Reattach the LCD interface PCB (with cables attached) to the LCD panel.

4 Align the LCD panel (face up) with the four screw holes in the mounting bracket (Figure 8-30).

5 Reattach the backlight extender cable assembly, then verify that it is properly connected.

6 Install and hand-tighten the four screws. Then, using a screwdriver, tighten the screws until they are snug. **Do not overtighten.**

7 Verify backlight extender cable assembly is firmly connected.

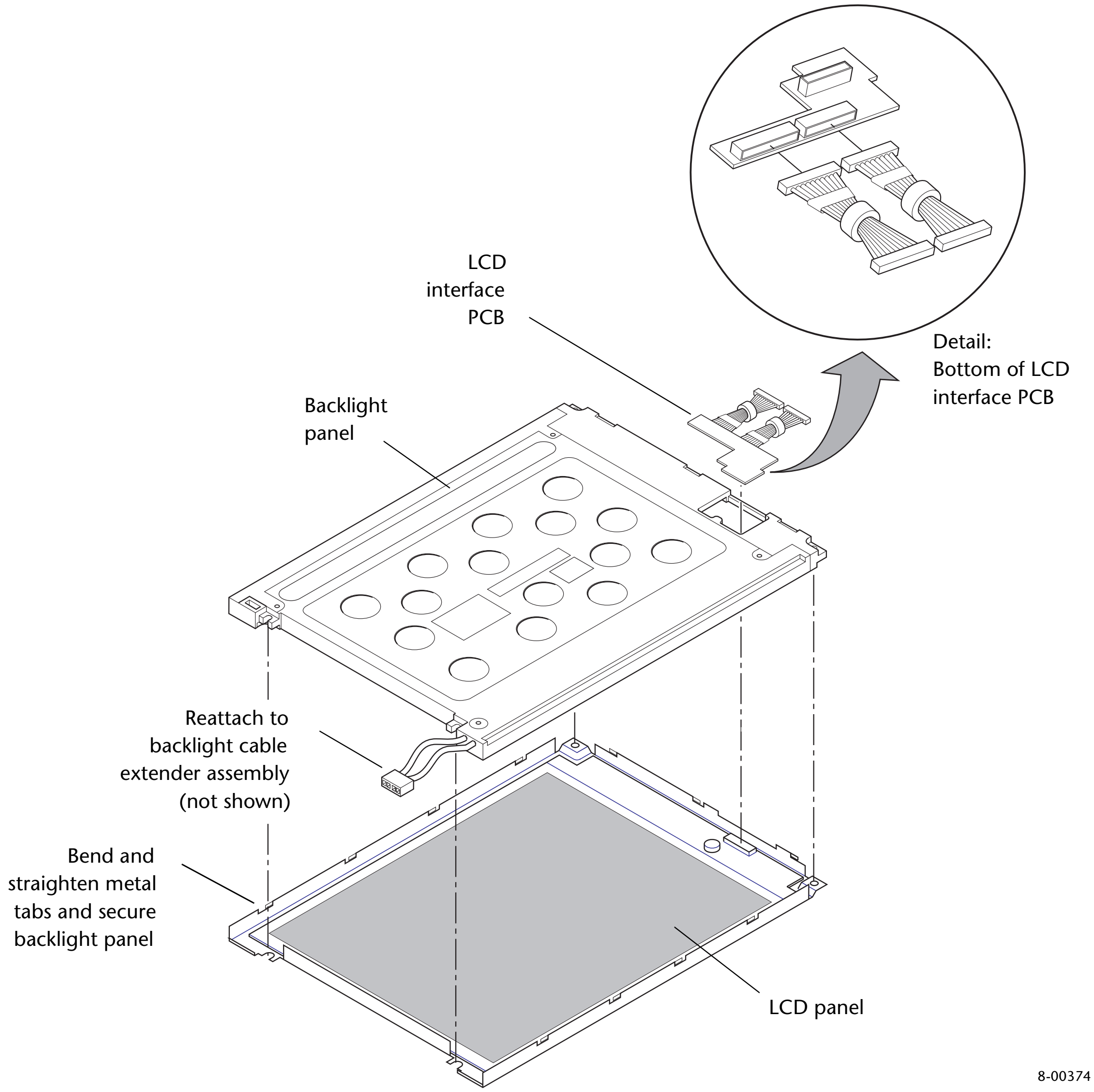


Figure 8-30. LCD panel and backlight panel assembly

8.14.14 9.4-inch GUI cooling vent filters

The GUI rear housing cooling vents are covered with foam filters as shown in Figure 8-31. These filters collect debris that enter through the GUI cooling vents and must be replaced when dirty.

Caution

To prevent damage to filter-retaining studs, do not attempt to remove the pushnuts that hold the foam filters in place.

1. Remove GUI rear housing (Section 8.14.6.1).
2. Remove dirty filter by tearing all remnants of foam away from retaining posts and vent. *Do not remove existing pushnuts; you will install the new foam and pushnuts directly over the existing pushnuts* (Figure 8-31).
3. Vacuum vent area to remove any remaining filter debris.
4. Align new foam filter over vent and press onto posts. Secure foam filter with new pushnuts, making sure each pushnut is fully seated.
5. Repeat steps for each foam filter.
6. After all filters are replaced, gently blow dry, compressed air over inside of rear housing to remove any foam residue.
7. Install GUI rear housing (Section 8.14.6.2).

Caution

Ensure cables are not pinched between the front and rear housings as you reassemble the GUI unit. Otherwise, damage to the cables may result.

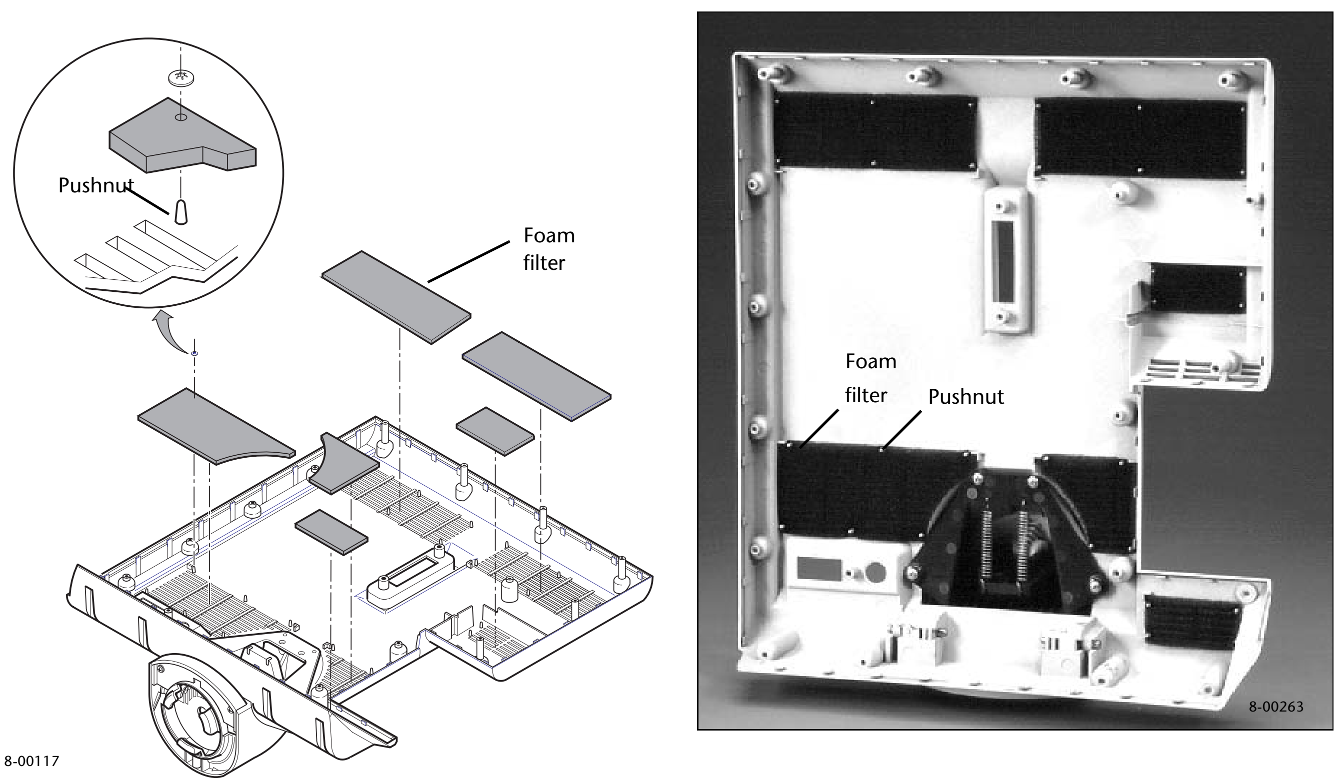


Figure 8-31. Replacing the 9.4-inch GUI cooling vent filters

8.14.15 9.4-inch rotor housing

The blue rotor housing supports the GUI. When the GUI's release knob is slid to the right, the rotor housing opens and the module is released.

8.14.15.1 Removing the 9.4-inch rotor housing

1. Remove GUI from mounting platform (Section 8.14.5).
2. Remove two screws that secure fascia panel to rotation assembly (Figure 8-32). Remove fascia panel.
3. Pull retaining spring out of groove and lift off brake shoes; release spring.
4. Slide out rotor housing.

8.14.15.2 Installing the 9.4-inch rotor housing

1. Slide blue rotor housing into place in base of GUI rear housing (Figure 8-32). Position it so that one of the three projections faces forward.
2. Slip on two brake shoes as shown. Secure by positioning spring into brake shoes' groove.
3. Position fascia panel; then install and hand-tighten two screws. Using a screwdriver, tighten until snug. **Do not overtighten.**
4. Install GUI (Section 8.14.5).

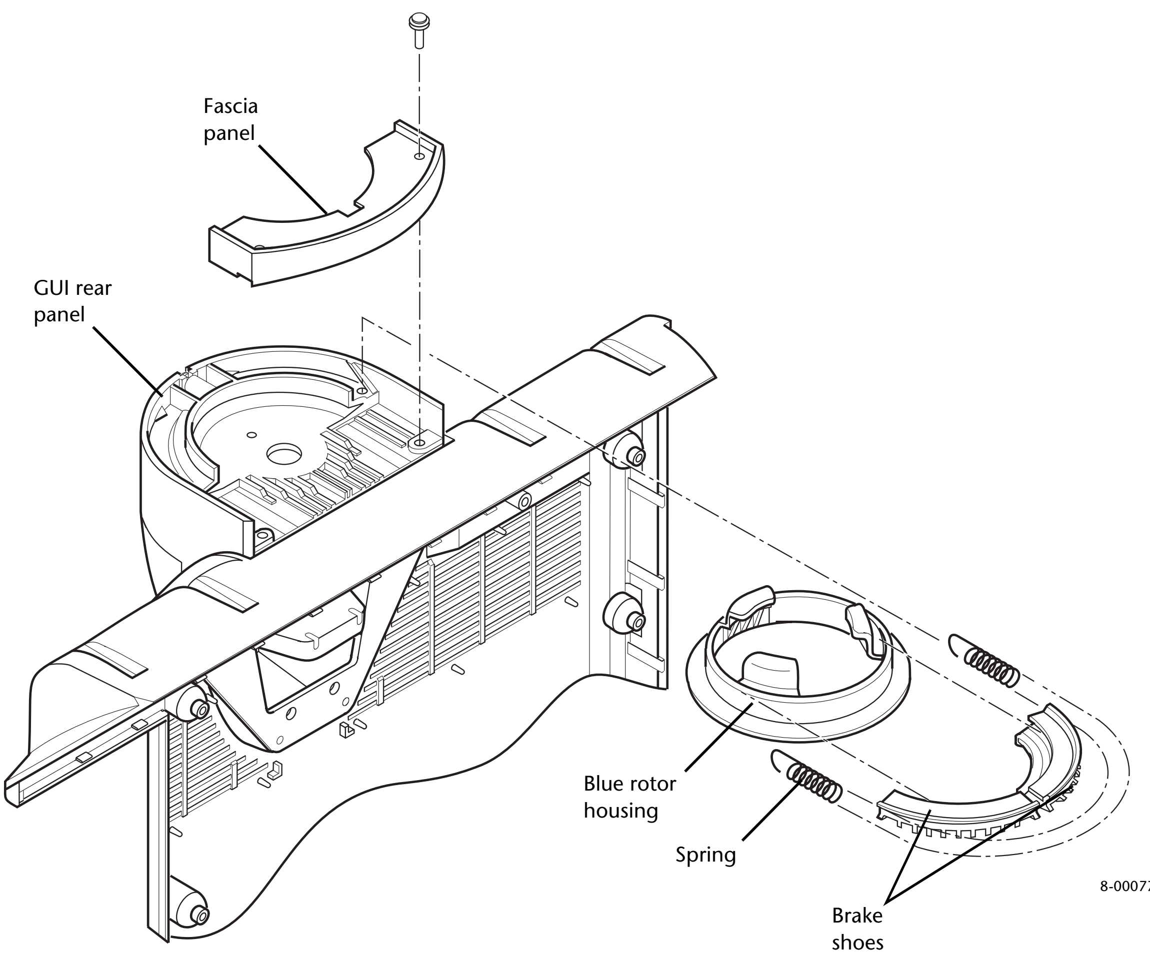


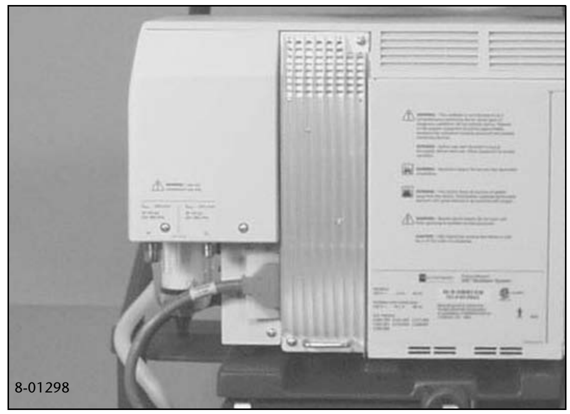
Figure 8-32. 9.4-inch rotor housing assembly

8.15 Breath delivery unit (BDU)

The BDU, shown in Figure 8-33, includes the following major assemblies:

- Inspiratory module
- Exhalation module
- Power supply
- ac panel
- BDU alarm
- AI and BD CPU PCBs with corresponding cabling and interconnect devices

Front view



Rear view

Figure 8-33. BDU

The BDU is a removable unit that can be mounted to the optional cart or shelf (using the shelf-mount kit).

Many BDU parts can be replaced without removing the unit from its mounting platform. Table 8-4 indicates the level of disassembly required for all BDU field-replaceable units (FRUs).

As you conduct the following replacement and installation procedures for the BDU, you may find it useful to refer to Table 2-2, and Figure 2-11 in Section 2 of this manual.

Caution

To prevent damage to ESD-sensitive components, always follow ESD guidelines when servicing the BDU.

Table 8-4: BDU part replacement chart

BDU replacement part	Modules removed						
	BDU	Power supply	BPS	Inspiratory module	Exhalation module	BDU housing	Card cage PCBs
Card cage replacement parts							
AI PCB							X
BD CPU PCB							X
Power replacement parts							
Power supply assembly		X					
Power switch (S1)		X					
Power indicator	X	X	X	X	X	X	X
Inspiratory module replacement parts							
Air inlet filter (F2)							
Oxygen filters (F1/ F3)							
Pressure switches (PS1/PS2)							
PSOL cartridges (PSOL1/PSOL2)				X			
Inspiratory electronics PCB				X			
Oxygen sensor				X			
Flow sensors (Q1/ Q2)				X			
Safety valve				X			
Inspiratory check valve (CV3)				X			
Regulators (REG1/ REG2)				X			
Inspiratory pressure transducer autozero solenoid (SOL1)				X			
Exhalation module replacement parts							
Exhalation valve (EV)							
Exhalation flow sensor (Q3)							

Table 8-4: BDU part replacement chart (continued)

BDU replacement part	Modules removed						
	BDU	Power supply	BPS	Inspiratory module	Exhalation module	BDU housing	Card cage PCBs
Exhalation transducer PCB					X		
Filter seal							
Expiratory pressure transducer autozero solenoid (SOL2)					X		
Exhalation heater					X		
Exhalation check valve (CV5)					X		
Sample port					X		
Other replacement parts							
Motherboard PCB	X	X	X	X	X	X	X
BDU alarm assembly	X	X	X	X	X	X	
Alarm blindmate cable	X	X	X	X	X	X	X
Inspiratory blindmate cable	X	X	X	X	X	X	X
dc power supply blindmate cable	X	X	X	X	X	X	X
ac power supply blindmate cable	X	X	X	X	X	X	X
ac panel	X						
Humidifier receptacle		X					

8.15.1 Removing BDU

Warning

To prevent personal injury, take appropriate measures when removing the BDU from its mounting platform as the unit weighs 18.2 kg (40.1 lb) when fully loaded.

1 Make these disconnections (Figure 8-34):

a. Ventilator power cord from facility power (Section 8.15.2.)

b. Ventilator from pressurized gas source

c. Compressor unit power cord from BDU, if applicable

d. Compressor unit data cable from BDU, if applicable

e. GUI cable from BDU

f. BPS cable from BDU [use 1/8-in. (3-mm) flat-bladed screwdriver to loosen captive screws]

Caution

Use extreme care when moving the BDU. Do not jar or drop the unit.

2 Pull out BDU release handle (Figure 8-36) to disengage BDU locking bracket; while holding handle out, slide BDU off bracket while resting it on edge of mounting platform. Release handle.

3 Carefully lift BDU off platform from rear of ventilator, and place on a firm, clean surface.

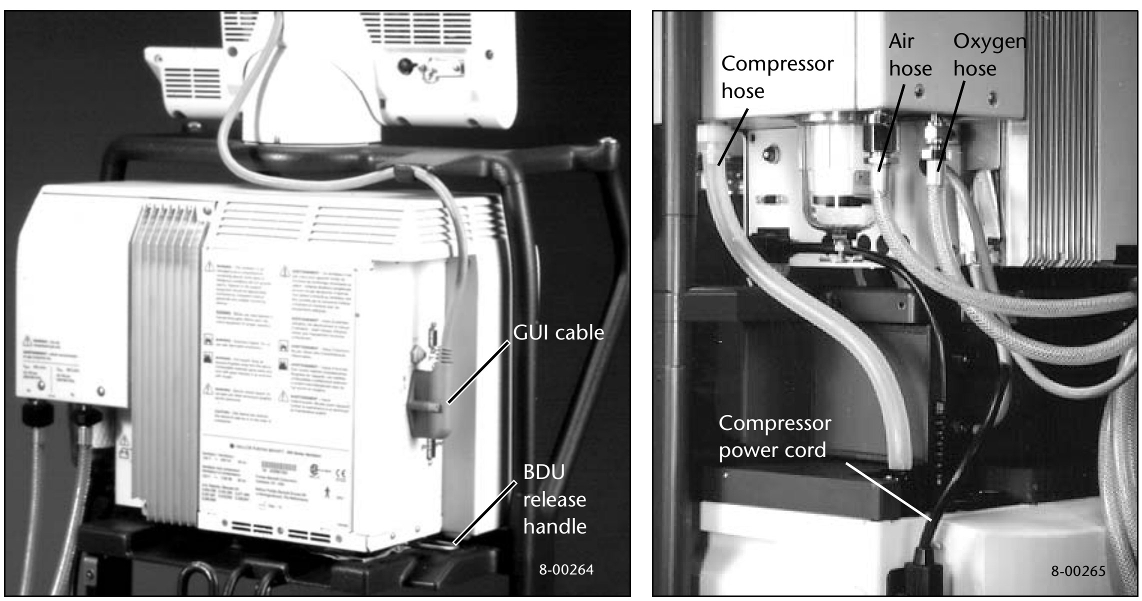


Figure 8-34. BDU connections

8.15.2 BDU power cord and retainer

There are two styles of the BDU power cord and retainer combination. The later version uses the cord and the retainer together to positively lock the power cord to the ventilator. Parts are not interchangeable between the old and the new power cords and retainers.

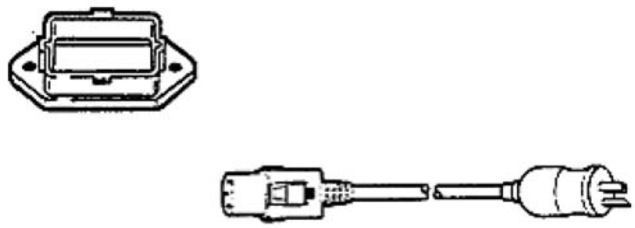


Figure 8-35. Sure-Lock™ retainer and power cord

Older field units can be retrofitted with this new combination, using a FRU kit version. (Refer to Section 9 for part numbers.)

1. Remove the two screws securing the current bracket to ac receptacle of the BDU.
2. Install the Sure-Lock retainer over the receptacle and secure with the two screws provided.
3. Insert the power cord and ensure that it clicks firmly into place.

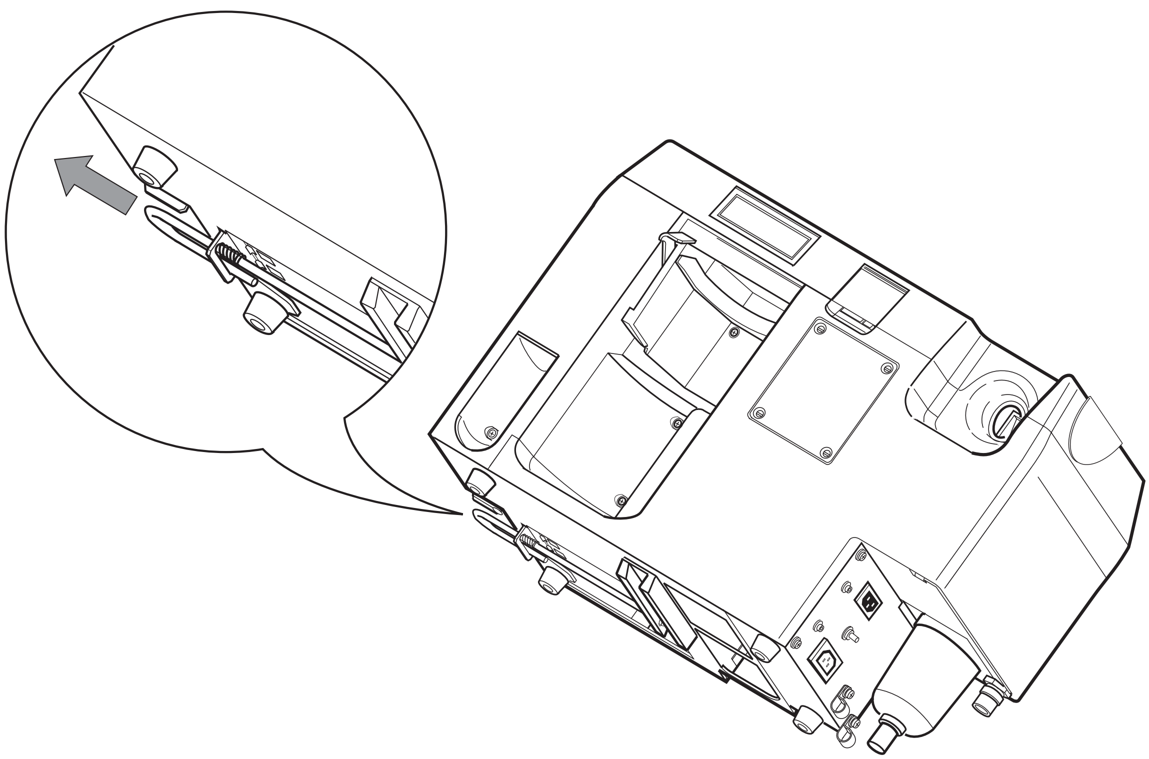


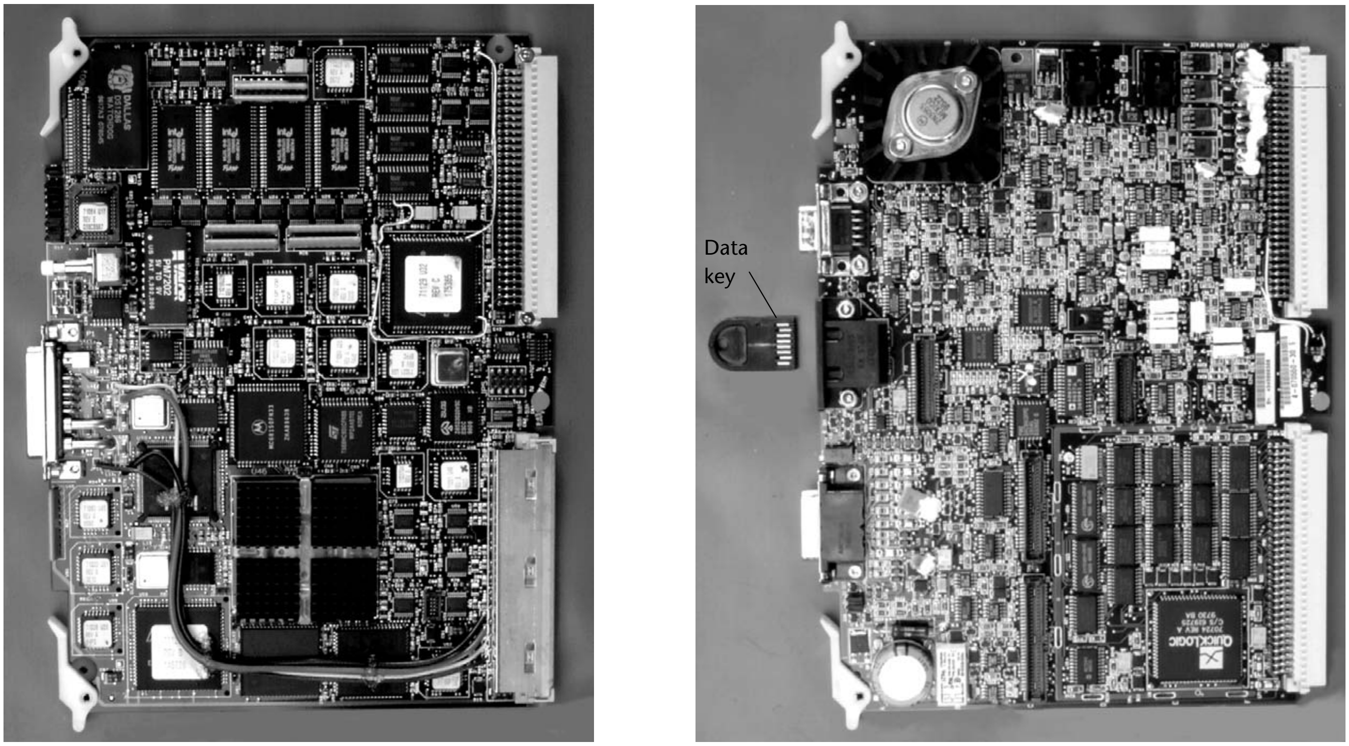
Figure 8-36. BDU release handle

8.15.3 Installing BDU

1. Lifting BDU from rear, rest front of BDU on edge of BDU mounting platform.
2. Slide BDU onto mounting bracket.
3. Make sure BDU is locked in place by pushing and pulling it on slide.
4. Connect cables to GUI, BPS, compressor, and ac power, as required (Figure 8-34).

8.15.4 Analog interface (AI) PCB and breath delivery (BD) CPU PCB

The AI and the BD CPU PCBs (Figure 8-37) reside in the card cage of the BDU.



BD CPU PCB **AI PCB**

Figure 8-37. BD CPU PCB and AI PCB

Looking into the card cage, the AI PCB sits in the far right slot (toward the front of the ventilator), and the BD CPU PCB sits in second slot from the right (behind the AI PCB). Refer to Figure 8-37.

Caution

The data key is matched to each ventilator. Ventilator is inoperable without the correct data key installed. *Do not lose the data key.*

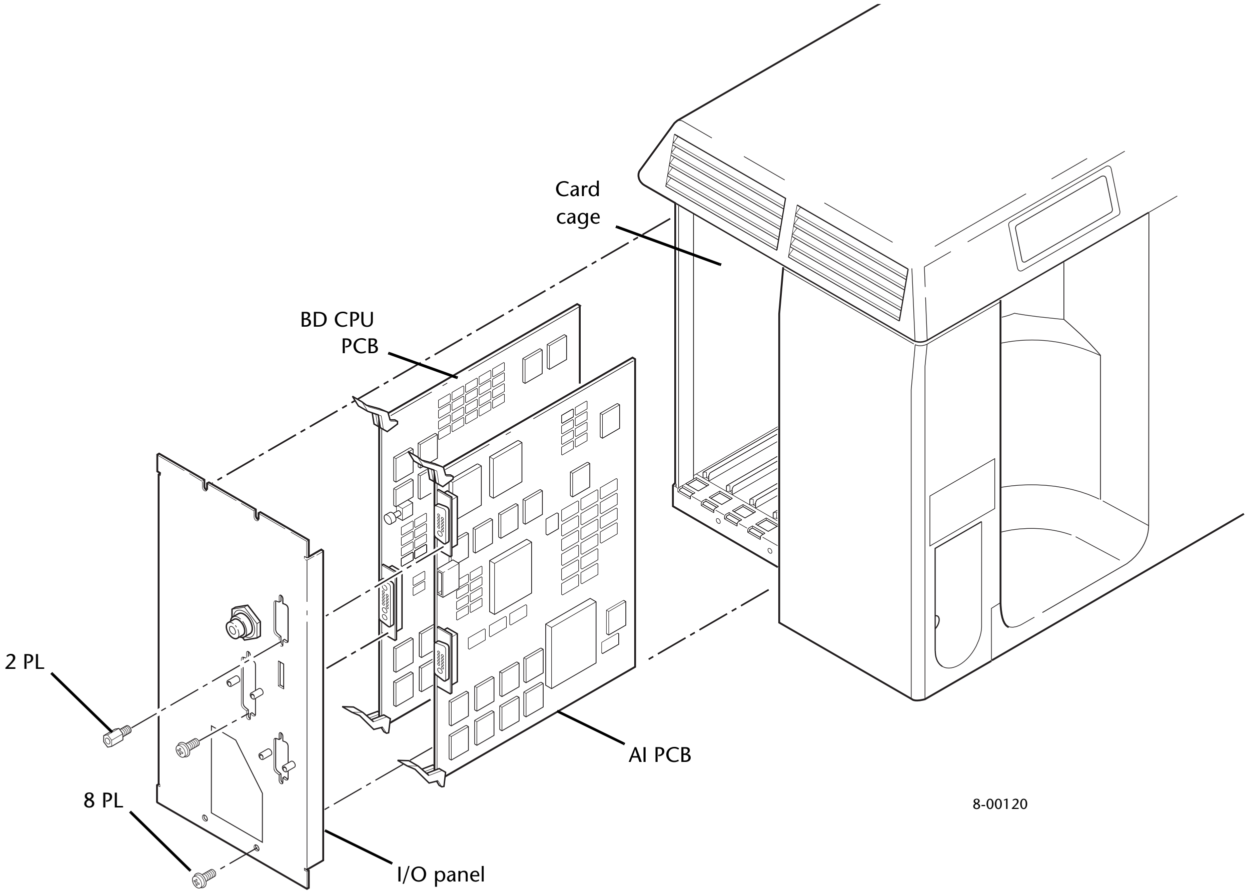


Figure 8-38. BD card cage and PCBs

8.15.4.1 Removing AI PCB or BD CPU PCB

1. Remove two screws that retain data key cover; remove cover. Remove data key.
2. Disconnect cables attached to card cage I/O panel (Figure 8-39).
3. Using 3/16-in. nutdriver, remove two latching post screws that secure panel to *PTS 2000* connector (Figure 8-38).
4. Using #0 Phillips screwdriver, loosen eight screws that secure panel to BDU chassis and to GUI and compressor data connectors. Remove panel.
5. Place your thumbs on backside of upper and lower ejector clips of PCB being installed. Simultaneously apply negative pressure to disengage clips. (When the clips snap open, the PCB is released.)
6. Gently pull PCB out of card cage, detaching it from motherboard PCB. Place PCB in a conductive bag or on ESD-protected mat.

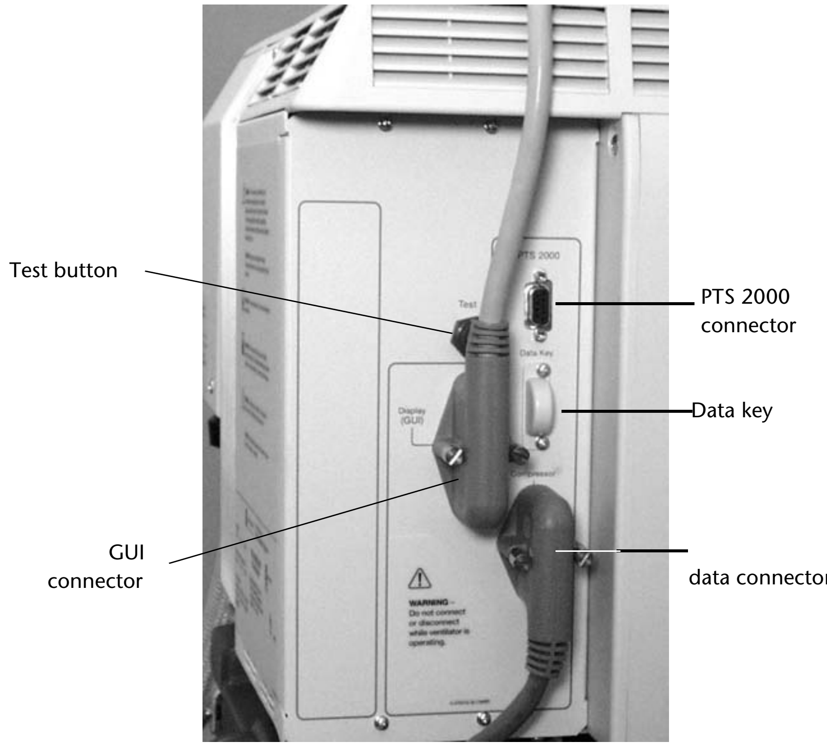


Figure 8-39. BDU I/O panel connections

8.15.4.2 Installing AI PCB or BD CPU PCB

1. Orient PCB (Figure 8-38) with component side toward front of ventilator.
2. Align PCB to upper and lower card guides and gently slide PCB along guides into card cage.
3. Gently press PCB into card cage until it seats to motherboard PCB connector at back; then, simultaneously press ejector clips closed until they latch.
4. Using #0 Phillips screwdriver, install eight screws that secure card cage I/O panel to BDU chassis and to GUI and compressor data connections. Tighten screws until snug. **Do not overtighten.**

Caution

Grounding of the BDU can be compromised is the I/O panel is incorrectly installed.

5. Using a 3/16-in. nutdriver, install two latching post screws that secure panel to *PTS 2000* connector, and tighten until snug. **Do not overtighten.**
6. Insert data key, install data key cover, and connect cables to panel.

8.15.5 Power supply assembly

Caution

To prevent electrical shock hazard, always unplug the power cord from facility power and disconnect the BPS cable from the power supply before servicing the power supply.

8.15.5.1 Removing power supply assembly

1. Disconnect BPS cable by first opening spring-loaded cover that shields power supply connector, then loosening connector’s two captive screws with 1/8-in. (3-mm) flat-bladed screwdriver.
2. Remove two screws that secure power supply assembly to BDU chassis. Gently pull out power supply assembly, unseating it from connectors (Figure 8-40). Set assembly on firm surface.

Figure 8-40. Replacing power supply assembly

8.15.5.2 Installing power supply assembly

1. Orient power supply assembly with slanted heatsink portion at top (Figure 8-40).
2. Gently slide power supply assembly into BDU chassis until it is fully inserted.
3. Install two screws, and tighten until snug.
4. Connect BPS cable to power supply by opening spring-loaded cover that shields power supply connector, connecting cable, and using 1/8-in. (3-mm) flat-bladed screwdriver to tighten connector's two captive screws until snug. **Do not overtighten.**

8.15.6 Power switch (S1)

Warning

To prevent electrical shock hazard, always unplug the power cord from facility power and disconnect the BPS cable from the power supply assembly before servicing ac components.

8.15.6.1 Removing power switch (S1)

1. Remove power supply assembly (Section 8.15.5.1).
2. Reaching into power supply compartment from rear, disconnect harness from power switch (Figure 8-41).
3. If you are installing a new power switch, remove actuator and save for reinstallation.

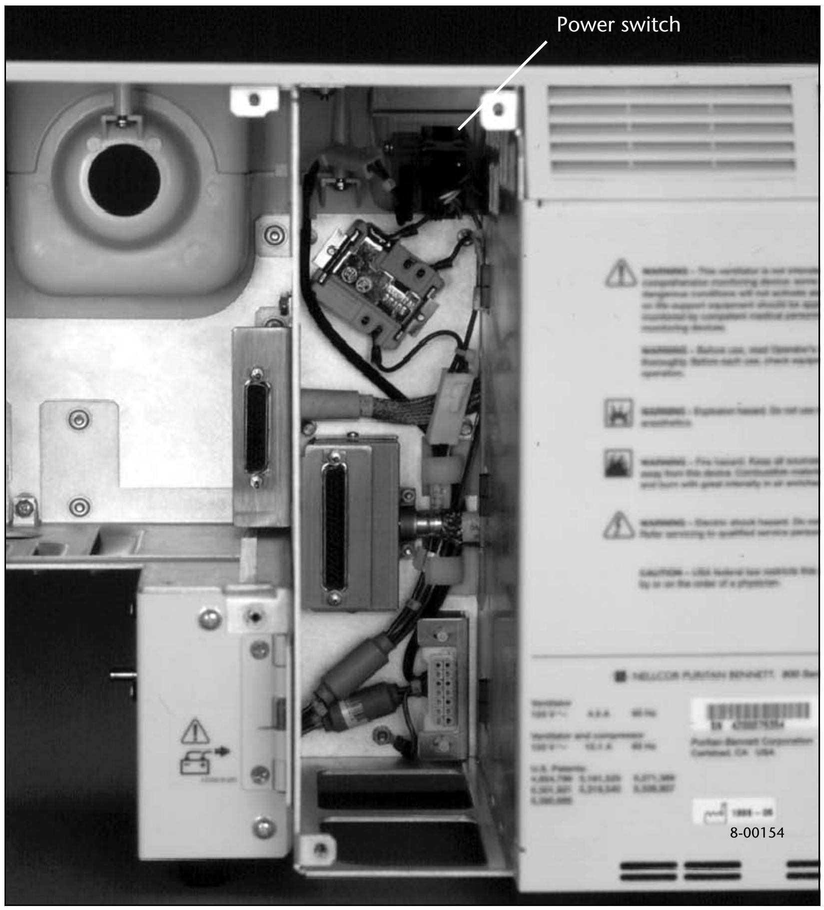


Figure 8-41. Replacing power switch (S1)

8.15.6.2 Installing power switch (S1)

1. If you are installing a new power switch, snap on actuator, orienting it so that **I** is at top.
2. From front of BDU, orient power switch so that **I** is at top of switch, and slide switch into slot.
3. From inside power supply compartment, connect harness to power switch (Figure 8-41).
4. Install power supply (Section 8.15.5.2).

8.15.7 Humidifier receptacle (100 – 120 V models only)

8.15.7.1 Removing humidifier receptacle

1 Remove power supply assembly (Section 8.15.5.1).

2 Reaching into power supply compartment from rear, disconnect harness from receptacle (Figure 8-42).

3 If humidifier receptacle cover is attached to front of ventilator, remove four flat-head screws that hold cover in place.

4 From front of ventilator, remove two flat-head screws that secure humidifier receptacle to chassis. Feed receptacle through power supply cavity. Remove receptacle assembly from chassis.

Figure 8-42. Replacing humidifier receptacle

8.15.7.2 Installing humidifier receptacle

1 From inside power supply compartment, align receptacle to two screw locations on front of chassis (Figure 8-42). When facing front of ventilator, the ground socket should be on your left. Install two flat-head screws.

2 From inside power supply compartment, connect harness to receptacle.

Caution

Route the humidifier cables so they do not obstruct the ac power supply harness and blindmate bracket, located at the bottom rear of the power supply compartment.

3 If desired, install humidifier receptacle cover with four flat-head screws.

4 Install power supply assembly (Section 8.15.5.2).

NOTE:

Consult this manual or the humidifier vendor for the appropriate bracket model when mounting a humidifier to the ventilator.

8.15.7.3 ac panel

8.15.7.3.1 Removing ac panel

1. Remove inspiratory module (Section 8.15.8.8). This is necessary to provide access to the panel.
2. If connected, disconnect ventilator and compressor (if installed) power cords from ac panel, and BPS cable from BDU.
3. Remove six screws that secure panel (Figure 8-43) to BDU chassis. (Two screws also secure BPS connector cover to panel.)
4. Taking care not to disturb electrical connections on inside of ac panel, gently separate panel from chassis.
5. To provide better access to component connections, cut tie wrap that secures wires to wall of ac power distribution compartment.
6. Using needlenose pliers, disconnect the wires from the ac panel components:
   - red wire from terminal 10 of relay
   - black wire from terminal 12 of relay
   - blue wire from top left-hand terminal of ac filter PCB
   - brown wire from top right-hand terminal of ac filter PCB
   - brown wire from middle left-hand terminal of compressor ac receptacle
   - blue wire from middle right-hand terminal of compressor ac receptacle
7. Using 5/16-in. nutdriver, disconnect ground wires from ground stud of ac panel.
8. Remove ac panel.

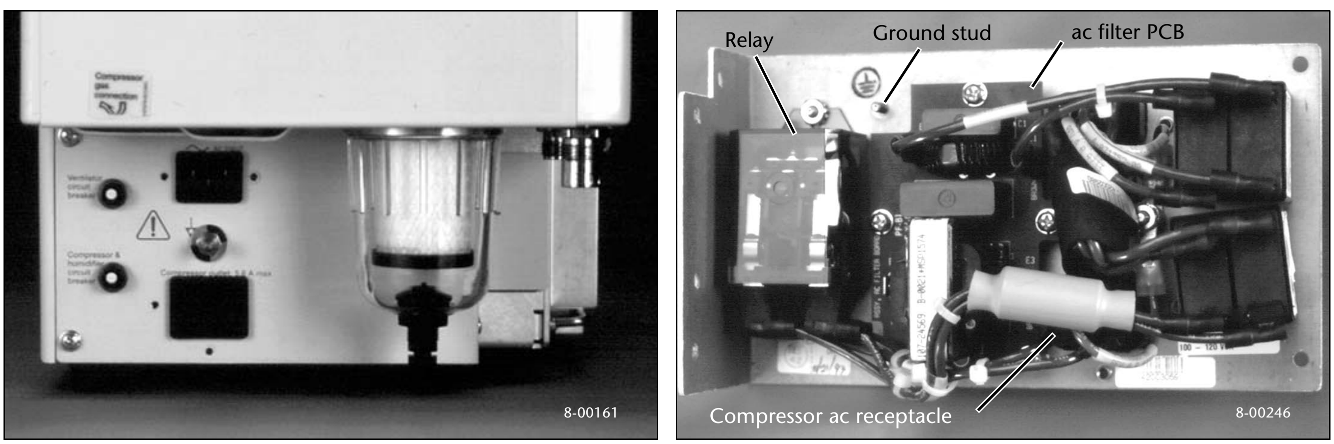


Figure 8-43. ac panel

8.15.7.3.2 Installing ac panel

1 Using needlenose pliers, connect wires to ac panel components (Figure 8-43):
- red wire to terminal 10 of relay
- black wire to terminal 12 of relay
- blue wire to top left-hand terminal of ac filter PCB
- brown wire to top right-hand terminal of ac filter PCB
- brown wire to middle left-hand terminal of compressor ac receptacle
- blue wire to middle right-hand terminal of compressor ac receptacle

2 Using 5/16-in. nutdriver, connect the two green ground wires to top left-hand ground stud of ac panel.

3 Secure wires to wall of ac power distribution compartment using small tie wrap.

4 Install panel to BDU chassis using six screws. (Two screws also secure BPS connector cover to panel.) *Take care not to pinch wires between panel and chassis.*

5 Connect ventilator and compressor power cords to ac panel, and BPS cable to BDU.

6 Install inspiratory module (Section 8.15.8.10).

8.15.8 Inspiratory module

Warning

Replacing key inspiratory module components requires the use of leak detector fluid to ensure a good gas seal. Use extreme caution when using leak detector in the vicinity of electronics. Thoroughly dry all components following use of leak detector.

8.15.8.1 Inspiratory module modifications

Earlier inspiratory modules used threaded air and oxygen inlets. Later versions use a common manifold that allows the module to be easily configured for each style of connection.

When ordering a replacement inspiratory module, you must order two additional parts: the inlets (air and oxygen), and the mounting brackets. There are five unique configurations available to support the needs of various countries. Refer to Section 9 of this manual for part numbers.

If replacing the inlet manifold only on an original module, refer to Section 9 to determine the replacement parts required.

8.15.8.2 Additional noise suppression (ferrite cores)

Additional noise suppression has been added to the 840 ventilator, in form of three ferrite cores on the air flow transducer harnesses. The cores are now standard on new ventilators. When configuring a field unit for the NeoMode option, you must add these ferrite cores to the unit.

Add the ferrites to the inspiratory module in accordance with the following instructions.

1 Remove the inspiratory module fascia panel. (Section 8.15.8.5.1)

2 Place the first of two latching ferrite cores around the lower third of the air flow transducer harness (Figure 8-44).

3 Place the second latching ferrite core around the upper third of the air flow transducer harness, allowing a minimum of 0.75 inches distance between the two cores.

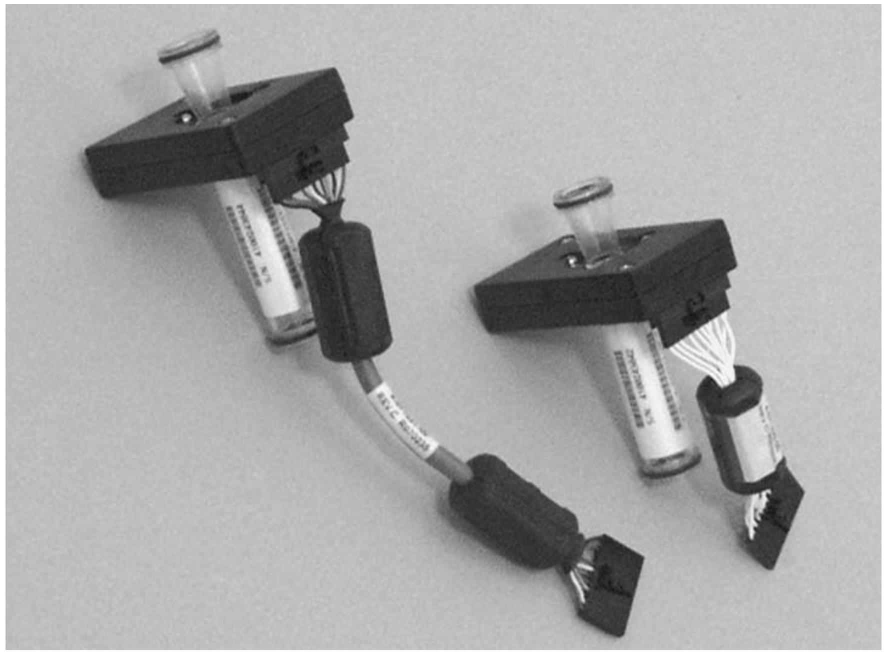


Figure 8-44. Adding ferrites to air and oxygen transducer harnesses

4 Place the third core in the middle of the oxygen transducer harness, using care not to pinch or damage the wires.

5 Visually inspect the cables and ensure that both of the latches are secure and that no stress is being placed on any discrete wires.

6 Reinstall the fascia panel. (Section 8.15.8.5.2)

8.15.8.3 Inspiratory module O-rings

Caution

When replacing damaged O-rings, carefully remove and install to prevent damage to the manifold ports.

Check for damaged O-rings as you disassemble the inspiratory module. If O-rings are damaged, pry them off of the ports. Lubricate replacement O-rings with Krytox grease, then gently stretch O-ring over base of the port and position in place.

Allow replaced O-rings to settle in place; then verify their integrity.

8.15.8.4 Air inlet filter (F2)

NOTE:

Replace the air inlet filter (F2) and O-ring every 10,000 hours. They are part of the 10,000-hour preventive maintenance kit.

8.15.8.4.1 Removing F2

1 Make sure air source is disconnected from ventilator.

2 Drain any condensate from air inlet filter bowl by unscrewing captive drain plug at bottom (Figure 8-45). Tighten plug.

3 Unscrew bowl.

4 Unscrew filter.

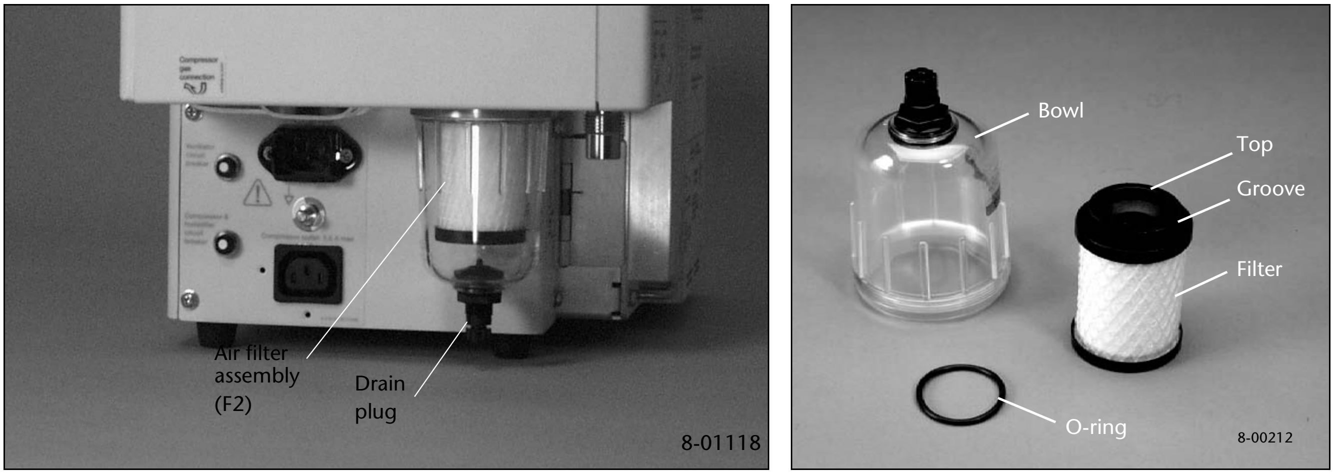


Figure 8-45. Replacing F2

8.15.8.4.2 Installing F2

1. Make sure O-ring is seated in unthreaded groove atop F2 (Figure 8-45).
2. Screw filter in place until snug. Make sure O-ring makes contact with BDU chassis.
3. Screw clear bowl in place over filter until snug.
4. Using leak detector fluid (P/N 4-004489-00), verify that bowl does not leak.

8.15.8.5 Fascia panel

8.15.8.5.1 Removing fascia panel

Remove the fascia panel that houses the inspiratory module by removing two screws (Figure 8-46).

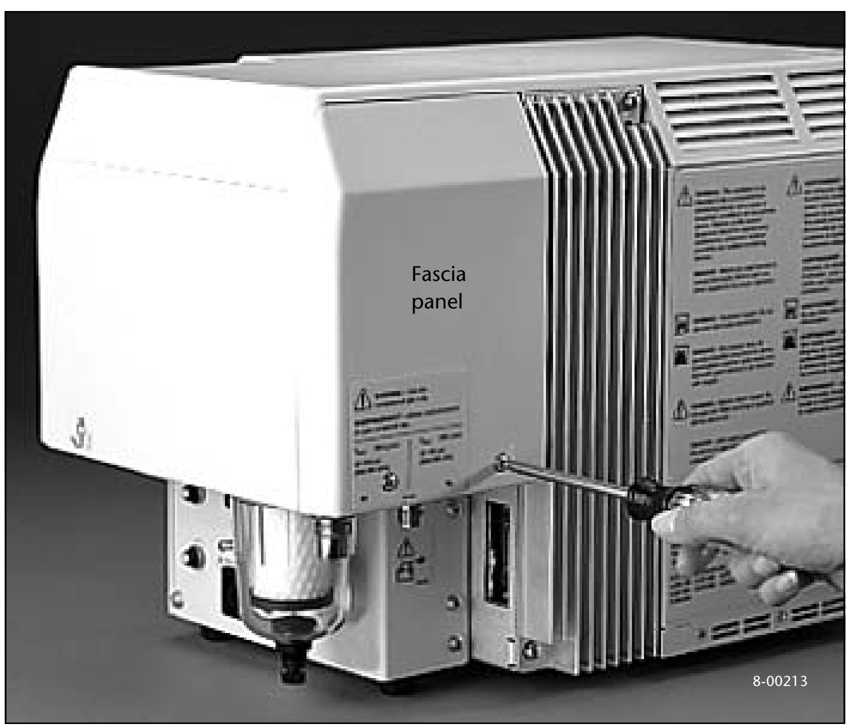


Figure 8-46. Removing inspiratory module fascia panel

8.15.8.5.2 Installing fascia panel

1 Insert lip, at top of fascia panel, under rim of BDU plastic housing and gently press fascia panel in place (Figure 8-46).

2 Install two screws that secure fascia panel to BDU chassis and tighten until snug. **Do not overtighten.**

NOTE:

Replace the oxygen impact filter (F1), oxygen inlet filter (F3) with a new O-ring and spring every 10,000 hours. (These items are part of the 10,000-hour preventive maintenance kit.)

8.15.8.5.3 Removing oxygen filter assembly

1 Remove fascia panel (Section 8.15.8.5.1).

2 Placing adjustable wrench on hexagonal part of clear filter bowl, loosen bowl (Figure 8-47). Finish unscrewing it by hand.

3 Unscrew oxygen inlet filter (F3) element.

4 Remove sintered metal oxygen impact filter (F1) and spring.

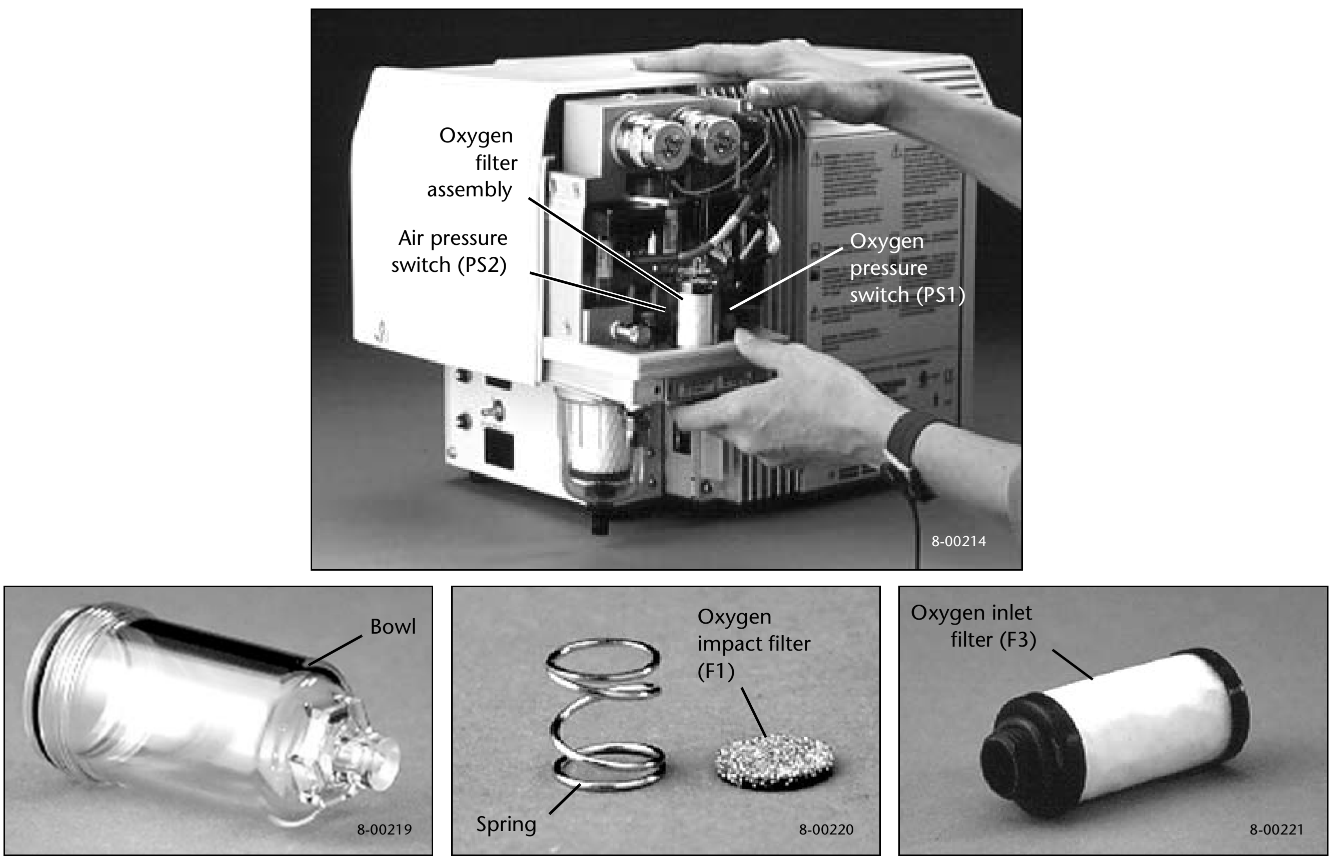


Figure 8-47. Oxygen filter assembly and pressure switches

8.15.8.5.4 Installing oxygen filter assembly

1. Install spring into threaded cavity (Figure 8-47).
2. With rough side down, place sintered metal filter (F1) over spring and make sure it is lying flat.
3. Insert threaded base of filter element over metal filter, and screw it into place until snug.
4. Make sure O-ring on threaded base of bowl is in place and fully seated into groove.
5. Place bowl over filter and screw into place until snug.
6. Using leak detector fluid (P/N 4-004489-00), verify that bowl does not leak.
7. Install fascia panel (Section 8.15.8.5.2).

8.15.8.6 Oxygen and air pressure switches (PS1 and PS2)

8.15.8.6.1 Removing PS1 and PS2

1. Remove fascia panel (Section 8.15.8.5.1).
2. Remove oxygen filter assembly (Section 8.15.8.5.3).
3. Disconnect harness from terminals at top of applicable switch (Figure 8-47).
4. Using 9/16-in. open-end wrench, loosen pressure switch (Figure 8-48). Remove.

Figure 8-48. Pressure switches

8.15.8.6.2 Installing pressure switches (PS1 and PS2)

The pressure switch located directly behind the oxygen filter must be installed first.

1. Make sure O-ring is properly seated at top of threaded base on pressure switch (Figure 8-48); then screw pressure switch into place (Figure 8-47).
2. Using 9/16-in. open-end wrench, tighten pressure switch until snug. **Do not overtighten.**
3. Connect harness to top of switch. Make sure connectors are tight and that they make contact with switch.
4. Install oxygen filter assembly (Section 8.15.8.5.4). Using leak detector fluid (P/N 4-004489-00), verify that bowl does not leak.
5. Install fascia panel (Section 8.15.8.5.2).

8.15.8.7 PSOL cartridge

8.15.8.7.1 Removing PSOL cartridge

1 Remove fascia panel (Section 8.15.8.5.1).

2 Pull inspiratory module out to access PSOLs:

a. Remove two screws that retain inspiratory module.

b. Firmly grasp bottom of inspiratory module, by air and oxygen inlet fittings. Pull module out of BDU chassis until nylon line atop PSOL manifold is visible (Figure 8-49).

3 At top of PSOL manifold, insert blade of small, flat-bladed screwdriver into etched notch adjacent to nylon line. Slide blade under nylon line and pull line up, creating a loop. Grasp loop and pull line completely out.

4 Disconnect appropriate PSOL harness from inspiratory electronics PCB. PSOL at your left is air PSOL (PSOL2); PSOL at your right is oxygen PSOL (PSOL1).

Caution

Place the PSOL cartridge on a clean work surface. Do not drop the assembly.

5 Carefully pull cartridge out of PSOL manifold and set on a clean work surface. Verify that all four O-rings are present and in good condition.

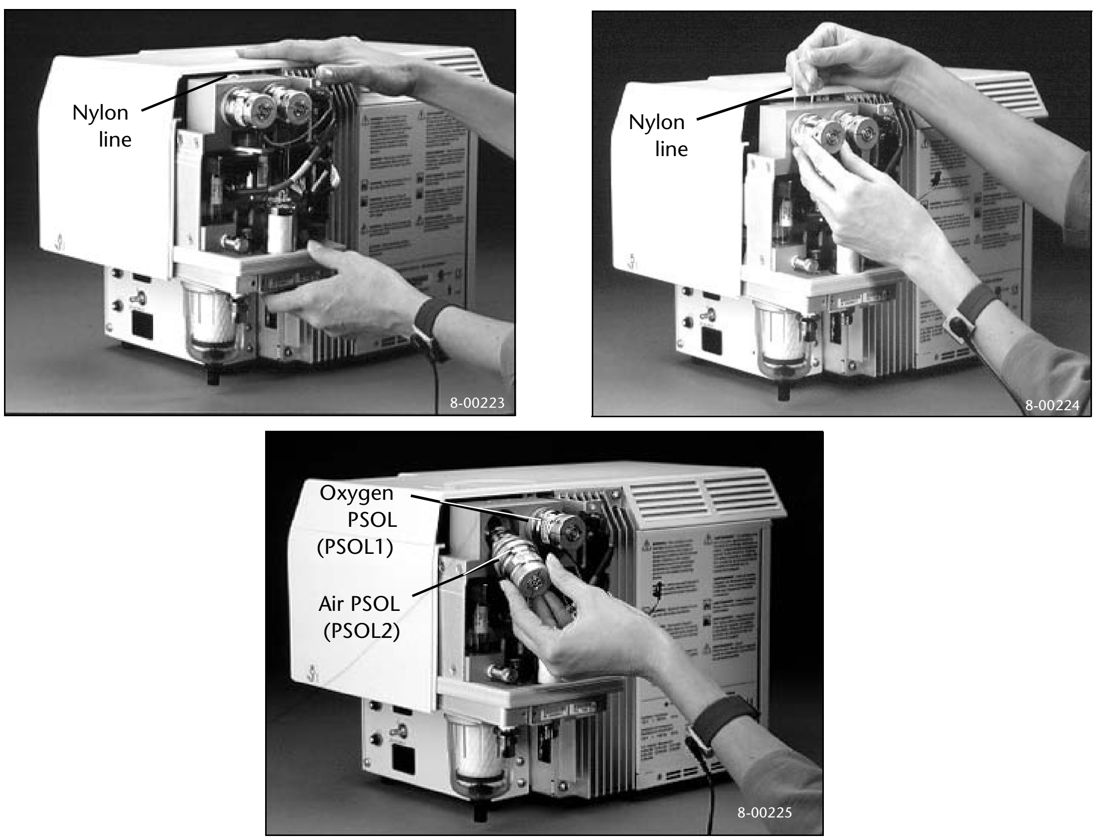


Figure 8-49. Replacing PSOL cartridge

8.15.8.7.2 Installing PSOL cartridge

If the PSOLs were difficult to remove, lubricate the o-rings with a very thin application of Krytox grease before reinstalling.

1 Orient body of PSOL cartridge (Figure 8-49) so that PSOL harness reaches inspiratory electronics PCB connector.
2 Insert cartridge into manifold base and gently press until cartridge is fully seated.
3 Connect PSOL harness to inspiratory electronics PCB connector (P5=oxygen, P6=air).
4 Insert both ends of nylon line into slots on top of manifold. Guide lines into manifold until one end reaches bottom of slot. Feed any remaining line into opposite slot.
5 Press nylon line into groove at top of slots until it is flush with PSOL manifold surface.
6 Slide inspiratory module back into BDU.
7 Install two mounting screws that secure module to BDU chassis. Tighten until snug.
8 Install fascia panel (Section 8.15.8.5.2).

8.15.8.8 Removing inspiratory module

1 Remove fascia panel (Section 8.15.8.5.1).
2 Remove two screws that secure inspiratory module (Figure 8-50) to BDU chassis.
3 Firmly grasp bottom of inspiratory module, by air and oxygen inlet fittings, and pull module out of BDU chassis. Place module on firm, ESD-protected, work surface.

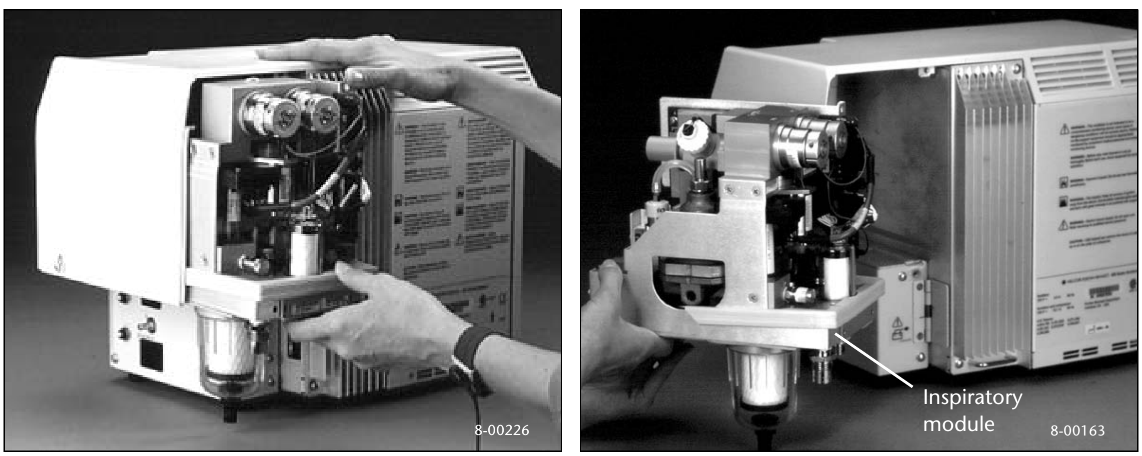


Figure 8-50. Removing inspiratory module

8.15.8.9 Leak testing inspiratory module

Before installing the inspiratory module, leak-test it as follows, referring to Figure 8-50.

1 Place inspiratory module on firm surface.
2 Connect compressed air and oxygen sources to inspiratory module.
3 Using small brush, apply leak detector fluid (P/N 4-004489-00) to these locations.
   - Base of air and oxygen flow sensors
   - Transfer tubes
   - Check valve assembly
   - Regulator inlet/outlet ports
   - Oxygen/air inlets

   If a connection leaks, repair and retest module.
4 Dry all leak detector fluid from chassis.

8.15.8.10 Installing inspiratory module

1 Leak-test inspiratory module (Section 8.15.8.9).

1 Firmly grasp bottom of inspiratory module, by air and oxygen inlet fittings and align inspiratory module with slots in inspiratory compartment (Figure 8-50).

2 Carefully slide module into inspiratory compartment and to back of BDU chassis.

3 Install two screws that secure inspiratory module to BDU chassis and tighten until snug. **Do not overtighten.**

4 Install fascia panel (Section 8.15.8.5.2).

8.15.8.11 Oxygen sensor (OS)

The oxygen sensor should be replaced every two years or as often as necessary.

Newer 840 BDU covers have an access port located on the top right edge of the BDU. This access port facilitates convenient access to the oxygen sensor for the purpose of replacement by medical staff. (Refer to Section 8.15.8.11.1 for replacement instructions.)

Replacement of the oxygen sensor on ventilators without this access port requires removal of the inspiratory module. (Refer to Section 8.15.8.11 for replacement instructions.)

8.15.8.11.1 Oxygen sensor replacement with access port

1 Locate the flexible oxygen sensor access cover on the top right edge of the BDU housing.

2 Firmly push the center of the lower flap of the access cover until the lower flap is dislodged from the housing.

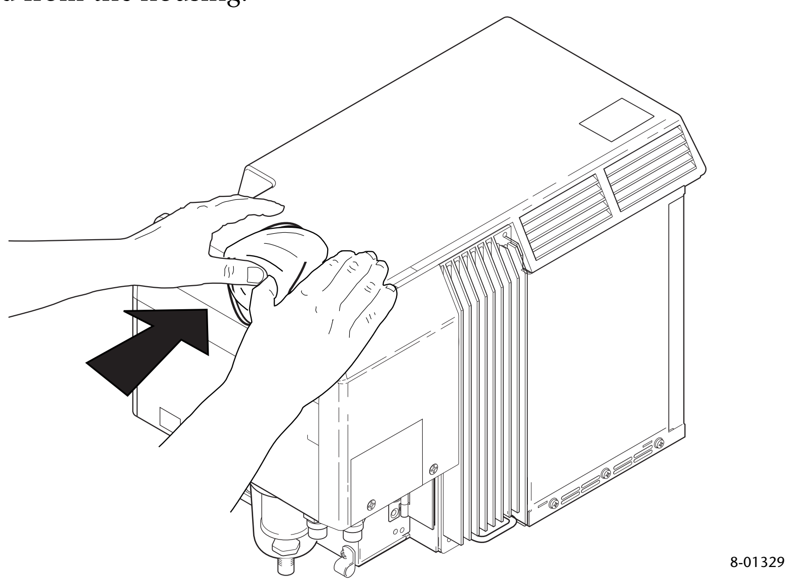


Figure 8-51. Opening oxygen sensor access port

3 Pinch the bottom and top flaps of the access cover firmly together and pull the access cover away from the housing to remove.

NOTE:

The access cover is permanently attached to the instrument by an retaining strap.

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4 Press wire retainer tab away from the connector to release the sensor cable connector. and gently remove the connector from the oxygen sensor.

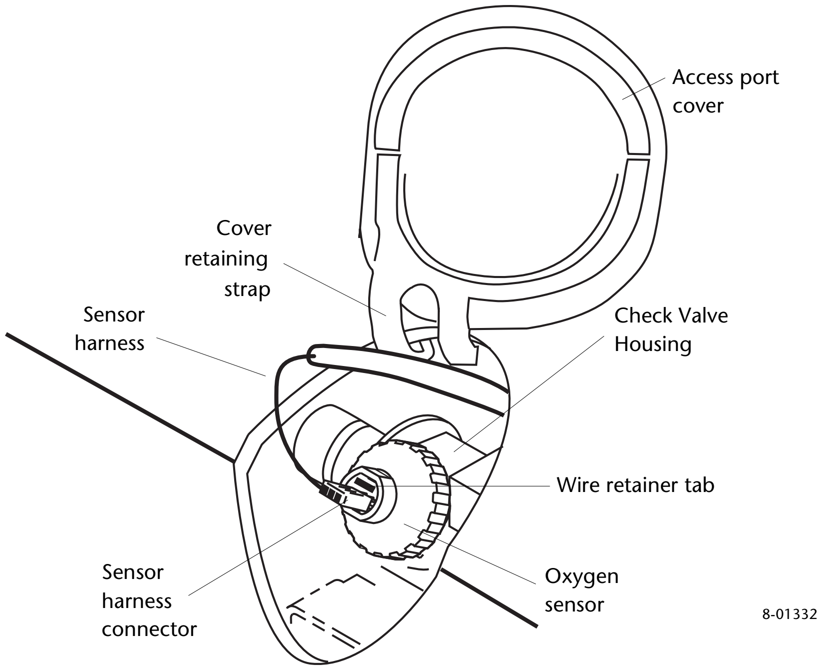


Figure 8-52. Detail of oxygen sensor

5 Remove the oxygen sensor from check valve housing.

6 Slide the new O-ring onto the threaded end of the replacement oxygen sensor. Seat the O-ring snugly against the sensor base above the threads.

Caution

Ensure that the oxygen sensor O-ring is properly seated on the sensor before installing in the ventilator. Failure to properly seat the O-ring may result in leaks.

7 Insert the threaded end of the oxygen sensor into the cavity on the check valve housing and finger-tighten the sensor without using excessive force. As the sensor is installed, ensure that it is not cross-threaded.

Caution

To prevent cracking of the sensor body, do not overtighten as you screw it into place on the check valve housing.

8 Connect the sensor harness connector to the oxygen sensor with the ridge on the cable connector oriented towards the wire retainer tab on the oxygen sensor.

9 Replace the access port cover by first sliding its top flap into the opening on the top of the BDU housing.

10 Using both thumbs, seat the port cover in the port by press the two outside corners of the lower flap at the juncture of the housing edge, fitting the into the housing opening.

11 Continue using both thumbs and firmly press the lower flap into place, working around the flap from the outside corners to the bottom center to seal the access cover. Be sure that the cover properly seals the housing opening.

12 Calibrate oxygen sensor by pressing 100% O_2/CAL 2 min key. Verify that the calibration passes.

13 Run an SST to check the system before placing the ventilator in service.

8.15.8.11.2 Removing oxygen sensor (no access port)

If your BDU unit does not have an access port on the top right edge of the housing, use the following instructions to replace the oxygen sensor.

1 Remove inspiratory module (Section 8.15.8.8).

2 Disconnect oxygen sensor harness from the sensor (Figure 8-53). Be sure to press the wire retainer tab inside the recess of the oxygen sensor to release the connector.

3 Unscrew oxygen sensor from PSOL manifold.

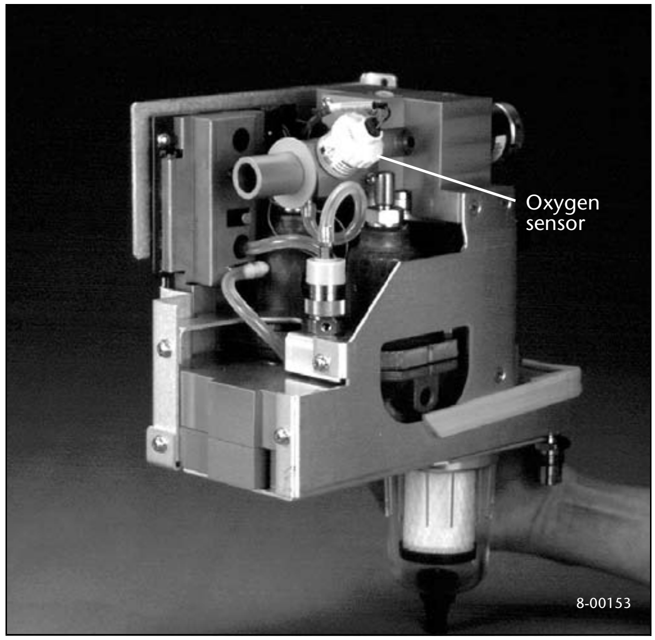


Figure 8-53. Replacing oxygen sensor

8.15.8.11.3 Installing oxygen sensor (OS)

1 Make sure O-ring is properly seated at top of threaded base on oxygen sensor (Figure 8-53).

Caution

Ensure that the oxygen sensor O-ring is properly seated on the sensor before installing in the ventilator. Failure to properly seat the O-ring may result in leaks.

2 Insert the threaded end of the oxygen sensor into the cavity on the check valve housing and finger-tighten the sensor without using excessive force. As the sensor is installed, ensure that it is not cross-threaded.

Caution

To prevent cracking of the sensor body, do not overtighten as you screw it into place on the check valve housing.

3 Connect oxygen sensor harness to sensor.

4 Install inspiratory module, as needed. (Section 8.15.8.10).

5 Calibrate oxygen sensor by pressing 100% O_2/CAL 2 min key.

6 Run an SST to check the system before placing vent in service.

8.15.8.12 Inspiratory check valve (CV3)

8.15.8.12.1 Removing inspiratory check valve

1. Remove inspiratory module (Section 8.15.8.8).
2. Disconnect harness from oxygen sensor.
3. Remove check valve housing (Figure 8-54) from PSOL manifold by removing four screws. Remove CV3 flap and seal.

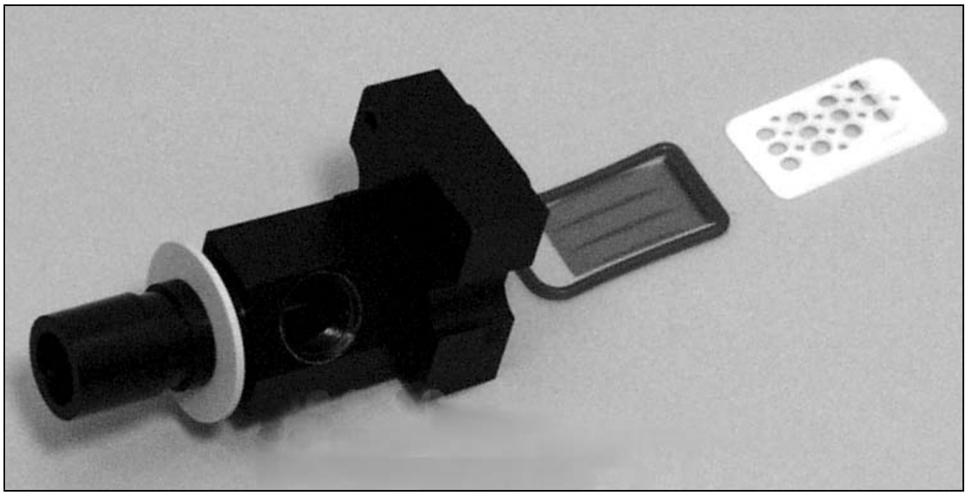


Figure 8-54. Inspiratory check valve (CV3) assembly

8.15.8.12.2 Installing inspiratory check valve

NOTE:

If replacing an earlier version of the inspiratory check valve assembly (silver) with a newer version (black), ensure the proper fit of the inspiratory filter. Otherwise, the patient circuit may leak.

---

1. Reassemble CV3 into housing, referring to Figure 8-54.
2. Install CV3 housing to PSOL manifold with four screws.
3. Connect harness to oxygen sensor.
4. Install inspiratory module, as needed (Section 8.15.8.10).

8.15.8.13 Right-side plate

This is the plate with the inspiratory electronics PCB attached.

8.15.8.13.1 Removing right-side plate

1 Remove inspiratory module (Section 8.15.8.8).

2 Disconnect these from inspiratory electronics PCB:

- Air PSOL (PSOL2) harness from P6
- Air flow sensor (Q2) harness from P4
- Pressure switch harness from P7
- Oxygen flow sensor (Q1) harness from P3
- Oxygen PSOL (PSOL1) harness from P5
- Oxygen sensor harness from P1
- Safety valve harness from P9 (adjacent to P1)
- Inspiratory pressure transducer autozero solenoid (SOL1) harness from P10
- Tube from inspiratory pressure transducer (PI) port

3 Orient inspiratory module with right-side plate on top.

4 Remove six screws that secure right-side plate to chassis (Figure 8-55):

- Three flat-head screws on flat side of plate
- One screw at front of plate
- Two screws at rear of plate

5 Remove right-side plate, with inspiratory electronics PCB attached, and place on ESD-protected mat.

Figure 8-55. Removing inspiratory module right-side plate

8.15.8.13.2 Installing right-side plate

1. Align plate to right side of inspiratory module and press into place (Figure 8-55).
2. Install three flat-head screws on side, one pan-head screw on front, and two pan-head screws on back.
3. Connect these to inspiratory electronics PCB:
   - Tube from side of inspiratory pressure transducer autozero solenoid (SOL1) to pressure transducer port (port farthest from PCB edge)
   - SOL1 harness to P10
   - Safety valve harness to P9 (adjacent to P1)
   - Oxygen sensor harness to P1
   - Oxygen PSOL (PSOL1) harness to P5
   - Oxygen flow sensor (Q1) harness to P3
   - Pressure switch harness to P7
   - Air flow sensor (Q2) harness to P4
   - Air PSOL (PSOL2) harness to P6
4. Install inspiratory module (Section 8.15.8.10).

8.15.8.14 Inspiratory electronics PCB

The inspiratory electronics PCB is mounted to the right-side plate.

8.15.8.14.1 Removing inspiratory electronics PCB

1. Remove right-side plate (Section 8.15.8.13.1).
2. Remove six screws that secure inspiratory electronics PCB to right-side plate.
3. Carefully lift inspiratory electronics PCB off plate. Place PCB in a conductive bag or on ESD-protected mat.

8.15.8.14.2 Installing inspiratory electronics PCB

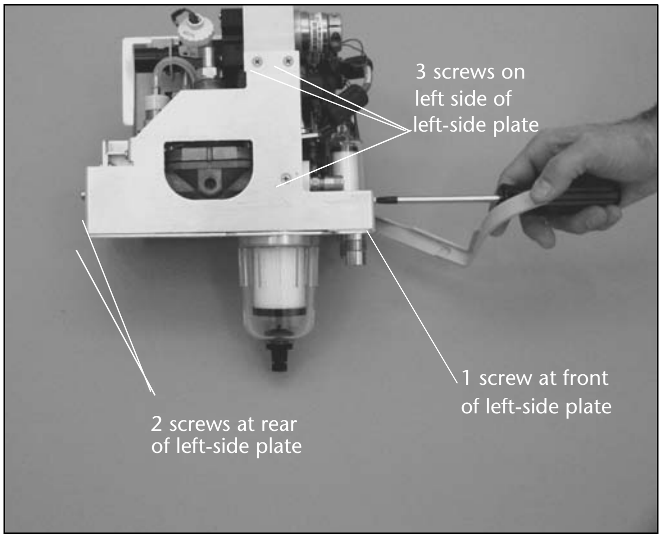
1. Align inspiratory electronics PCB six screw locations to right-side plate. Install six screws that secure PCB to right-side plate.
2. Install right-side plate (Section 8.15.8.13.2).

8.15.8.15 Left-side plate

The left-side plate is opposite the inspiratory electronics PCB mounting plate.

8.15.8.15.1 Removing left-side plate

1. Remove inspiratory module (Section 8.15.8.8).
2. Remove three flat-head screws from side of left-side plate (Figure 8-56).
3. Taking care not to contaminate seal adhesive, carefully peel seal away from left-side plate. If seal is damaged, refer to Section 9 for replacement adhesive tape.
4. Remove one screw from rear of plate.
5. Remove two screws from front of plate. One screw is under seal.
6. Carefully lift left-side plate off inspiratory module.



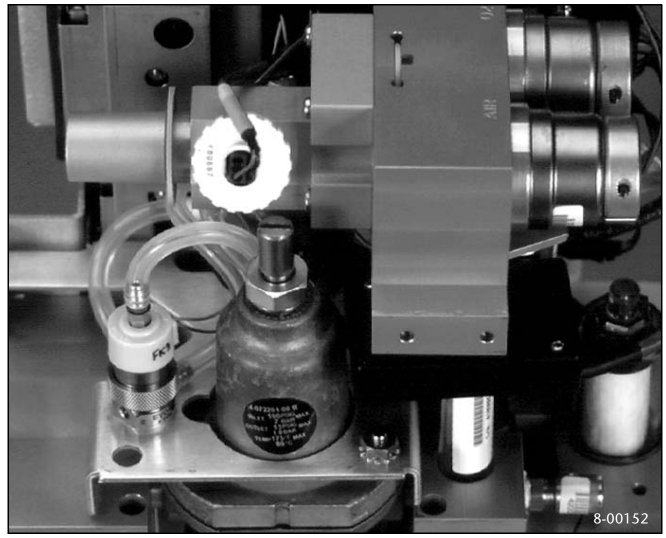


Figure 8-56. Replacing inspiratory module left-side plate

8.15.8.15.2 Installing left-side plate

1. Align plate (Figure 8-56) to left side of inspiratory module and press into place.
2. Install and slightly tighten two pan-head screws on front, one pan-head screw on rear, and three flat-head screws on side. Tighten all screws until snug. **Do not overtighten.**
3. Reinstall adhesive seal where it was peeled back.

NOTE:

If seal is damaged, refer to Section 9 for replacement adhesive tape.

---

4. Install inspiratory module (Section 8.15.8.10).

8.15.8.16 PSOL manifold

8.15.8.16.1 Removing PSOL manifold

1. Remove inspiratory module (Section 8.15.8.8).
2. Remove four flat-head screws that retain PSOL manifold, from both right- and left-side plates (Figure 8-57).
3. Disconnect harnesses from inspiratory electronics PCB, as required.
4. Disconnect SOL1/PSOL manifold interconnect tube from PSOL manifold.
5. Gently pull manifold away from inspiratory module. The flow sensors should be attached to the manifold.
6. Place manifold on clean work surface.

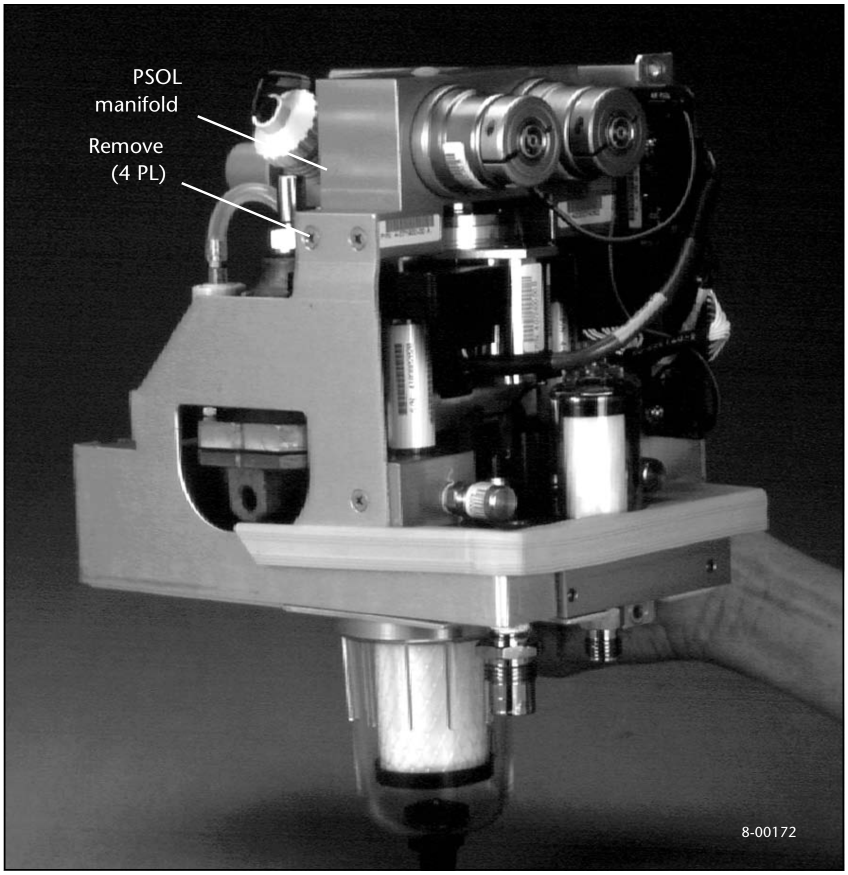


Figure 8-57. PSOL manifold ready for removal

8.15.8.16.2 Installing PSOL manifold

NOTE:

The PSOL manifold slides between the left- and right-side plates. If the fit is too tight, loosen the flat-head screw on the left side plate, allowing the plate to be lifted slightly to provide sufficient clearance for the manifold.

1. Align flow sensor tubes on PSOL manifold to vents on air sensor manifold and gently press manifold until tubes fully seat into vents.
2. Install four flat-head screws that secure PSOL manifold to right- and left-side plates (Figure 8-57). Tighten screws. **Do not overtighten.**
3. If third flat-head screw on left-side plate was loosened to install PSOL manifold, tighten until snug.
4. Connect tube attached to top of SOL1 to beneath PSOL manifold body.

5 Make these connections to inspiratory electronics PCB:

- Safety valve harness to P9 (this connector is located between P1 and P10)
- Oxygen sensor harness to P1
- Air PSOL (PSOL2) harness to P6
- Air flow sensor (Q2) harness to P4
- Pressure switch (PS1 and PS2) harness to P7
- Oxygen flow sensor (Q1) harness to P3
- Oxygen PSOL (PSOL1) harness to P5

6 Install inspiratory module (Section 8.15.8.10).

8.15.8.17 Oxygen and air flow sensors (Q1 and Q2)

If you are installing a pair of new flow sensors, the sensors are interchangeable. However, if you are reinstalling a flow sensor, you must install it in its previous position (air or oxygen) to prevent contamination of the oxygen system. Always note which sensor is which before removing the pair.

The flow sensor with the longer harness and two ferrites is Q2.

8.15.8.17.1 Removing oxygen and air flow sensors

1 Remove PSOL manifold (Section 8.15.8.16.1).

2 Gently pull sensor from PSOL manifold (Figure 8-58). Place on a clean surface to prevent contamination.

3 If you are installing a new flow sensor, do the following:

a. Disconnect harness from existing sensor and transfer to new sensor.

b. Remove end caps from new sensor tube, and transfer to existing flow sensor tube.

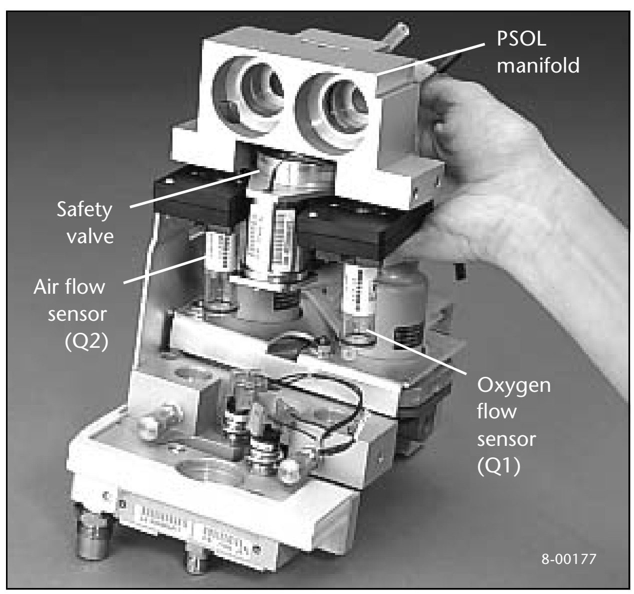


Figure 8-58. Replacing oxygen and air flow sensors (Q1 and Q2) and safety valve

8.15.8.17.2 Installing oxygen and air flow sensors

1 Make sure O-rings are properly seated at each end of flow sensor tube (Figure 8-59).
2 Orienting flow sensor body as shown in Figure 8-58, gently push sensor into PSOL manifold.
3 Install PSOL manifold (Section 8.15.8.16.2).
4 Applying leak detector fluid (P/N 4-004489-00) to bottom of flow sensor only, verify that sensor does not leak.

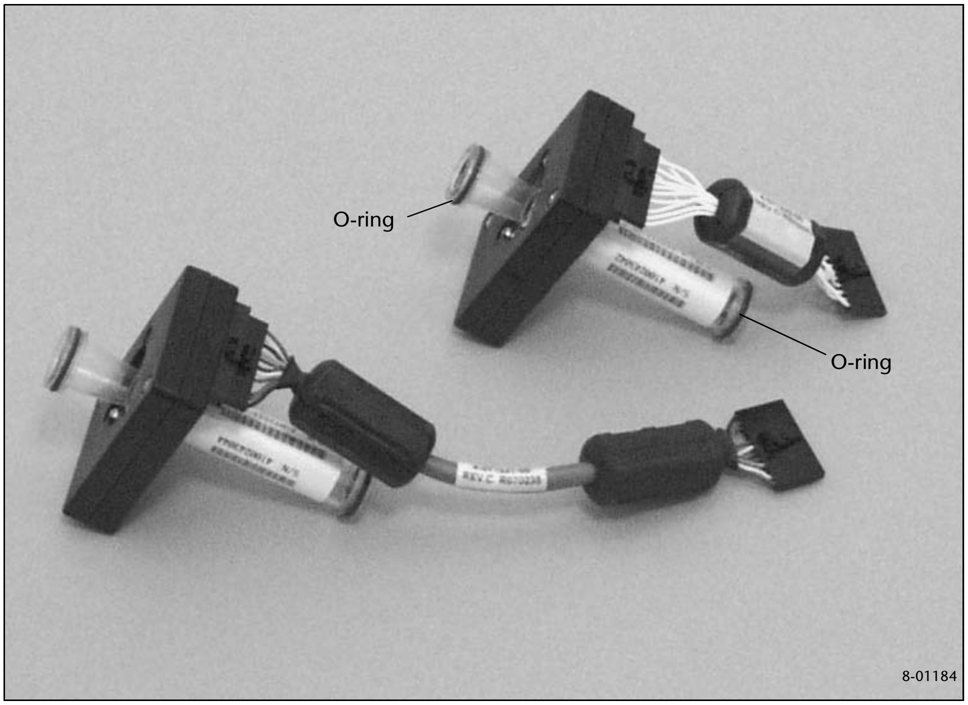


Figure 8-59. Oxygen and air flow sensors (Q1 and Q2)

8.15.8.18 Safety valve

8.15.8.18.1 Removing safety valve (SV)

1 Remove oxygen and air flow sensors (Section 8.15.8.17.1).
2 Remove two flat-head screws that secure safety valve (Figure 8-58) to PSOL manifold. Gently pull safety valve (Figure 8-60) out of manifold.

Figure 8-60. Safety valve

8.15.8.18.2 Installing safety valve

1. Make sure O-ring is properly seated in groove at base of safety valve (Figure 8-60).
2. Before inserting valve into manifold, route safety valve cable under plate that seats to manifold, toward oxygen sensor.
3. Align safety valve to two screw locations on PSOL manifold (Figure 8-58). Carefully press base of safety valve into manifold until fully seated. Make sure safety valve cable is not pinched between valve and manifold.
4. Install two flat-head screws that secure safety valve to PSOL manifold. Tighten until snug. **Do not overtighten.**
5. Install oxygen and air flow sensors (Section 8.15.8.17.2).

Caution

To prevent component damage when installing the safety valve, do not apply leak detector fluid.

8.15.8.19 Check valve assembly, regulator assembly, and flow sensor manifold

8.15.8.19.1 Removing check valve assembly, regulator assembly, and flow sensor manifold

1. Remove right-side plate (Section 8.15.8.13.1) and left-side plate (Section 8.15.8.15).
2. Remove PSOL manifold (Section 8.15.8.16.1).
3. Remove four inset screws that secure check valve assembly and flow sensor manifold to inspiratory floor (Figure 8-61).
4. Disconnect oxygen vent tube from inspiratory floor.
5. Pulling in direction of check valve assembly, remove flow sensor manifold/regulator assembly/check valve assembly from plate.
6. Pull flow sensor manifold/regulator assembly/check valve assembly apart into three pieces as shown.

8.15.8.19.2 Installing check valve assembly, regulator assembly, and flow sensor manifold

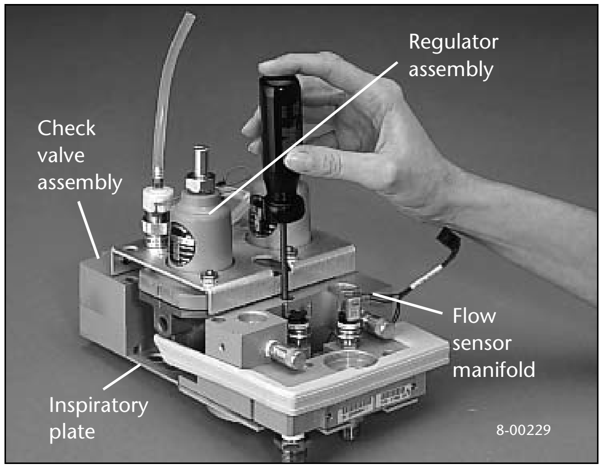
1. Make sure four O-rings on check valve assembly (Figure 8-61) are present and properly positioned (two O-rings on air and oxygen ports and two O-rings in transfer tube port cavities).
2. Align air and oxygen ports (on check valve assembly) to air and oxygen ports on regulator assembly.
3. Gently press check valve assembly against regulator assembly until it reaches stop post.

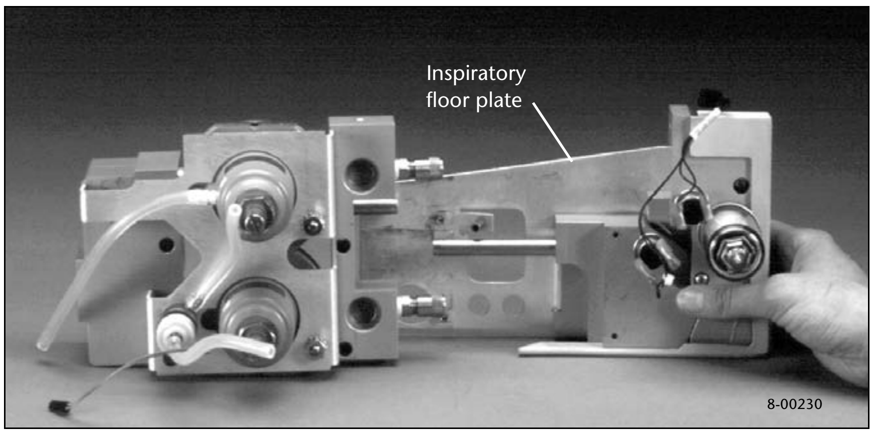
NOTE:

It may be necessary to flex the inspiratory floor plate down in order to seat the check valve assembly to the regulators.

---

4. Install two screws that secure check valve assembly to floor. Tighten screws until snug. **Do not overtighten.**
5. Install PSOL manifold (Section 8.15.8.16.2).
6. Install right-side plate (Section 8.15.8.13.2) and left-side plate (Section 8.15.8.15.2).





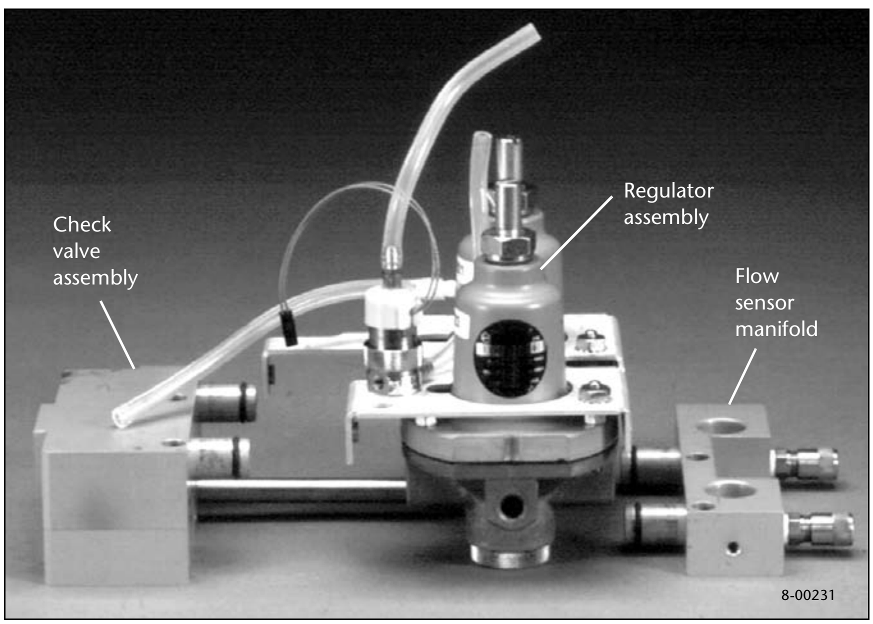
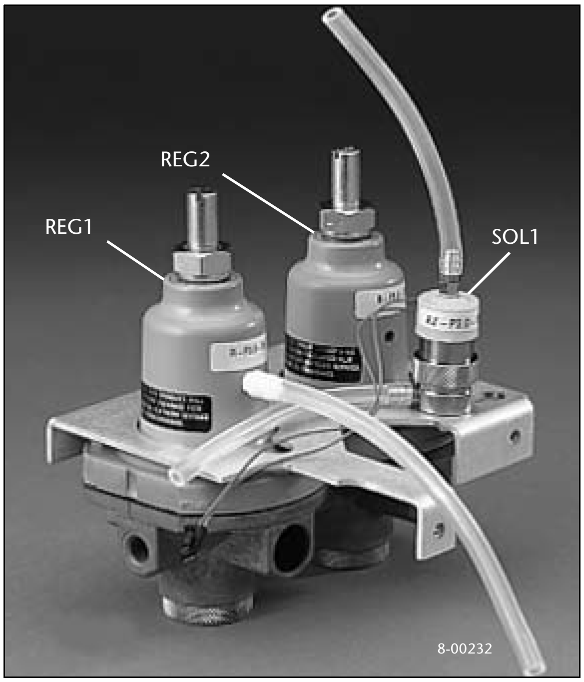


Figure 8-61. Disassembling flow sensor manifold/regulator assembly/check valve assembly

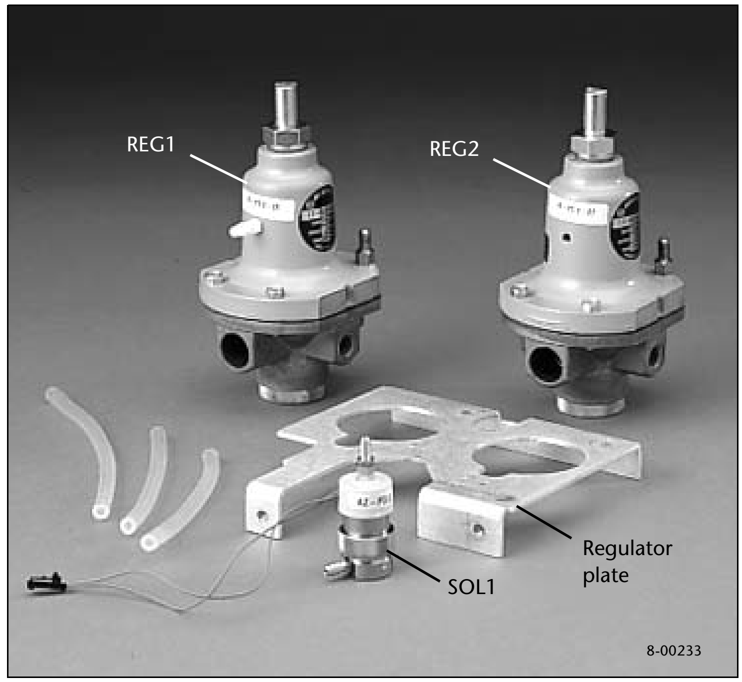
8.15.8.20 Oxygen and air regulators (REG1 and REG2)

8.15.8.20.1 Removing REG1 and REG2

1. Remove regulator assembly with plate (Section 8.15.8.19.1).
2. Using 7/16-in. socket or open-end wrench, remove retaining nut that secures applicable regulator (REG1 or REG2) to regulator plate (Figure 8-62). Remove regulator.
3. If you are removing REG1, disconnect vent tube from REG1 output port. Save for reinstallation.



Regulator assembly



Regulator assembly components

Figure 8-62. Removing REG1 and REG2

8.15.8.20.2 Installing REG1 and REG2

NOTE:

REG1 and REG2 are not interchangeable and must be installed in their appropriate locations. REG1 has an output port, which distinguishes it from REG2.

1. Insert regulator in appropriate cutout in regulator plate, and align mounting screw to plate (Figure 8-62). Using 7/16-in. socket or open-end wrench, install retaining nut and tighten until snug.
2. If you are installing REG1, connect vent tube to REG1 output port, at bottom of inspiratory floor plate.
3. Install regulator assembly with plate (Section 8.15.8.19.2).

8.15.8.21 Inspiratory pressure transducer autozero solenoid (SOL1)

Caution

To prevent damage to tubing, do not attempt to remove silicone tubing from solenoid barbed fittings. Solenoid FRUs have tubing pre installed.

8.15.8.21.1 Removing SOL1

1. Remove right-side plate (Section 8.15.8.13.1) and left-side plate (Section 8.15.8.15).
2. Remove PSOL manifold (Section 8.15.8.16.1).
3. Disconnect vent tube from REG1 output port.
4. Using 7/16-in. socket or open-end wrench, remove two nuts that secure plate to regulators (Figure 8-62). Remove plate.
5. Remove two screws that secure SOL1 to regulator assembly plate. Remove SOL1 with tubes.

8.15.8.21.2 Installing SOL1

1. Align replacement SOL1 (with tubes attached) to two screwholes on regulator plate (Figure 8-62). Install two screws and tighten until snug. **Do not overtighten.**
2. Using 7/16-in. socket or open-end wrench, install two nuts that secure plate to regulators. Remove plate.
3. Connect vent tube to REG1 output port.
4. Install PSOL manifold (Section 8.15.8.16.2)
5. Install right-side plate (Section 8.15.8.13.2) and left-side plate (Section 8.15.8.15.2).

8.15.8.22 Inspiratory floor assembly

The inspiratory floor assembly consists of three subassemblies: gas inlet manifold, air filter head, and inspiratory floor plate. This section covers replacement of the damaged O-rings. To replace the oxygen or air filter, refer to Section 8.15.8.4 or Section 8.15.8.6. To replace the pressure switches, refer to Section 8.15.8.6.

8.15.8.22.1 Disassembling inspiratory floor assembly

1. Remove flow sensor manifold/regulator assembly/check valve assembly from inspiratory floor assembly (Section 8.15.8.19.1).
2. Remove two screws that secure gas inlet manifold to floor plate. Lower floor plate to unseat guideposts that insert into bottom of gas inlet manifold. Gently pull gas inlet manifold away from air filter head, peeling away adhesive seal as required.

8.15.8.22.2 Reassembling inspiratory floor assembly

1. Carefully slide air filter head inlet port into cavity on gas inlet manifold. Press gas inlet manifold until it seats flush against air filter head.
2. Hold floor with guide posts pointing up, lower air filter head into hole on mounting plate. Align two guide posts to mounting holes on bottom of gas inlet manifold. Seat floor until it is flush with manifold. Install seal.
3. From top of gas inlet manifold, install two screws that secure floor to manifold. Tighten screws until snug. **Do not overtighten.**
4. Install flow sensor manifold/regulator assembly/check valve assembly to inspiratory floor assembly (Section 8.15.8.19.2).

8.15.9 Exhalation module

8.15.9.1 Exhalation collector vial (ECV) and expiratory filter (F9)

1 Push the blue latch up to release collector vial/expiratory filter.

2 Remove assembly, and disassemble as required. For complete details on using the collector vial and expiratory filter, consult the *840 Operator's and Technical Reference Manual*.

NOTE:

To ensure that all patient circuit connections are leak-tight, perform a circuit leak test by running SST every time you install the filter on a ventilator. Consult the 840 Operator's and Technical Reference Manual.

8.15.9.2 Removing exhalation module cover

1 Remove collector vial and expiratory filter (Section 8.15.9.1).

2 Remove four screws that secure the cover to the exhalation module (Figure 8-63).

3 Slide cover off from front, making sure inside top bracket disengages from BDU chassis.

Figure 8-63. Removing exhalation module cover

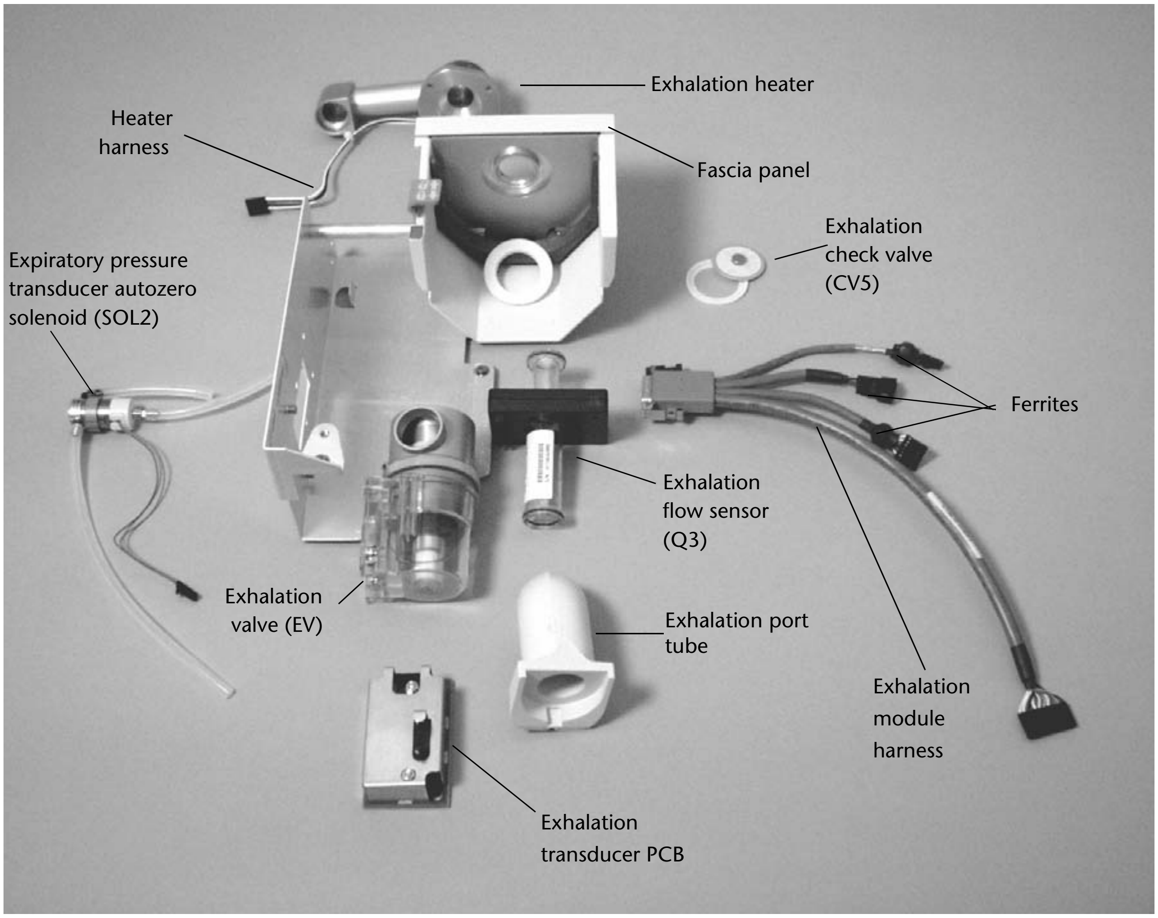


Figure 8-64. Exhalation module disassembled

8.15.9.2.1 Installing exhalation module cover

1. Make sure exhaust port is in place (Figure 8-67).
2. Align exhalation module cover (Figure 8-63) directly in front of exhalation compartment. Slide cover straight back, allowing head screw to drop into slot of alignment bracket.
3. Align cover screw locations to BDU chassis (three on front and one on rear); then tighten screws until snug. **Do not overtighten.**
4. Install collector vial and expiratory filter (Section 8.15.9.1).

8.15.9.3 Removing exhalation module

1. Remove exhalation module cover (Section 8.15.9.2).
2. Disconnect exhalation module harness from exhalation I/O cable connector (Figure 8-65).
3. Loosen six captive flat-head screws that secure exhalation module to BDU chassis (three beneath collector vial/expiratory filter, one at bottom of exhalation valve, one behind flow sensor Q3, and one at bottom front of exhalation module).
4. Slide bottom of exhalation module out from chassis; then carefully lower unit to clear top of module. Place exhalation module on a clean work surface.

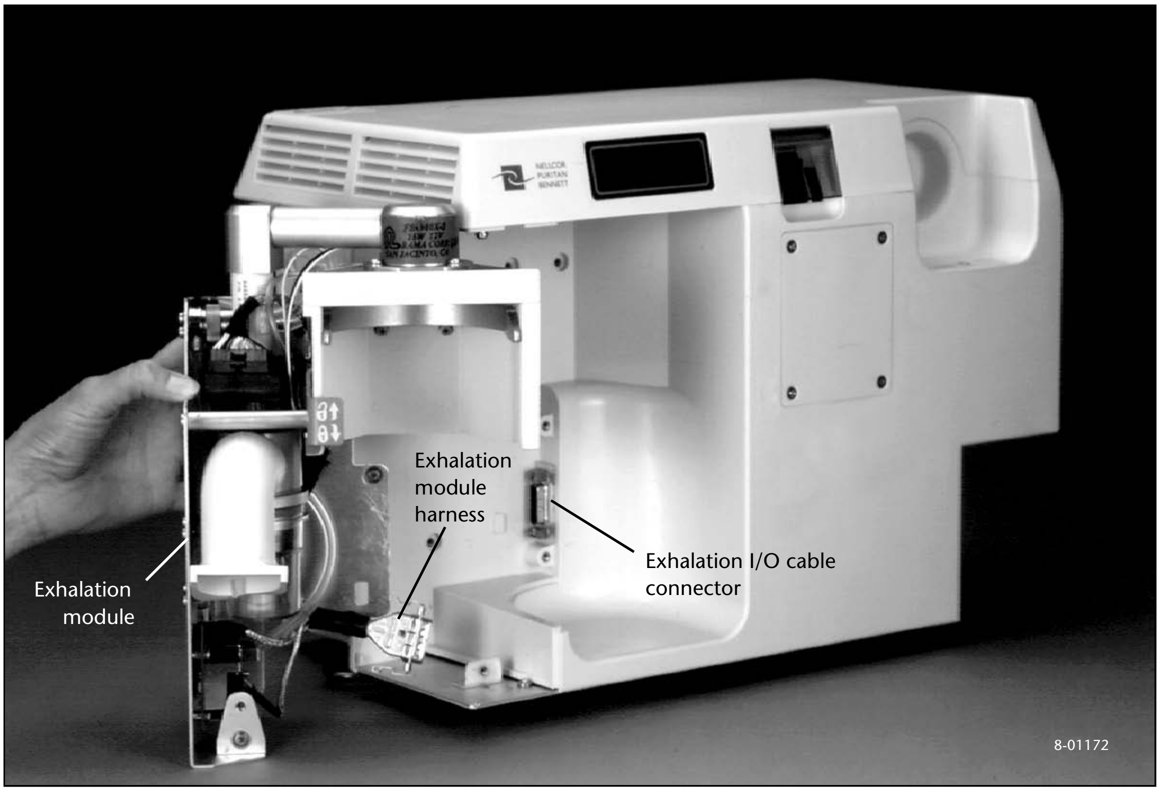


Figure 8-65. Replacing exhalation module

8.15.9.4 Installing exhalation module

1. Tilt top of exhalation module (Figure 8-65) back, and insert into top of exhalation compartment; then slide bottom of module into compartment while aligning (alignment) tab (on BDU chassis) to slot in exhalation module back panel. (This alignment aligns the captive screws to the screw locations on the BDU chassis.)
2. Tighten six captive screws until snug (three beneath collector vial/expiratory filter, one at bottom of exhalation valve, one behind flow sensor Q3, and one at bottom front of exhalation module). **Do not overtighten.**
3. Connect exhalation module harness to exhalation module I/O cable. Be sure clips on each side of cable latch into place.
4. Install exhalation module cover (Section 8.15.9.2).

8.15.9.5 Exhalation valve (EV)

8.15.9.5.1 Exhalation metabolic sample port

The 800 Series ventilators were initially equipped with a metabolic sample port, located on the front fascia panel of the exhalation module (Figure 8-66). This sample port has since been eliminated and a different style exhalation valve has been implemented.

This new exhalation valve can be used on original 840 ventilators with the metabolic sample port, but a minor modification to the exhalation module is required. When replacing an exhalation valve with a metabolic port, you must first eliminate the metabolic port from the unit, as described in the following instructions.

8.15.9.5.2 Eliminating the exhalation metabolic sample port

1 Remove exhalation module (Section 8.15.9.3).

2 Remove two flat-head screws that secure sample port fascia panel (Figure 8-66) to exhalation module.

3 Unseat fascia panel and disconnect tube from sample port.

4 Using needlenose pliers, loosen plastic nut that secures sample port to fascia panel. Remove nut, luer fitting, and green ring.

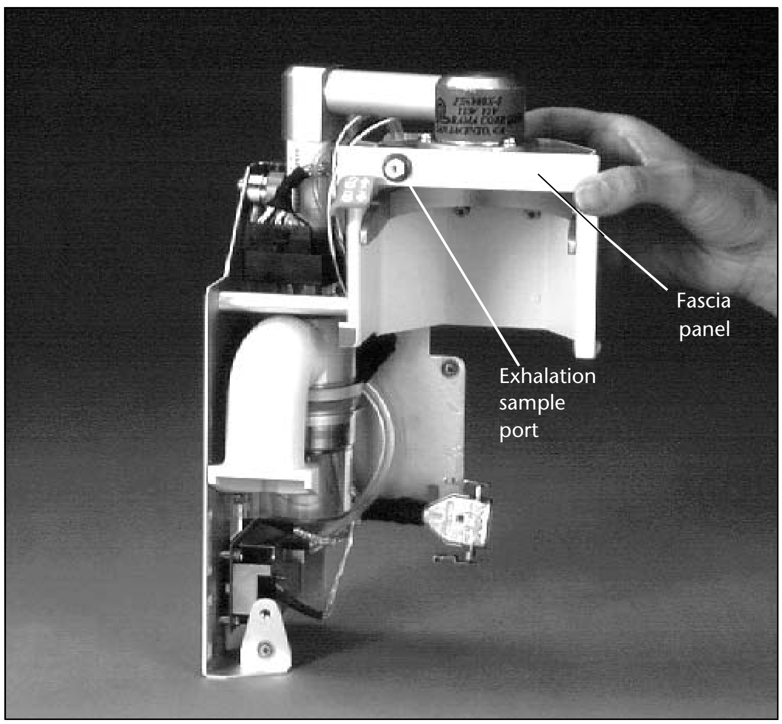


Figure 8-66. Exhalation sample port

5 Remove and discard the sample port tubing and the Luer fitting components.

6 Cover the sample port opening in the fascia panel with the label provided with the new exhalation valve FRU.

7 Remove exhalation valve from the exhalation module. (Section 8.15.9.5.3)

8 Install new exhalation valve. (Section 8.15.9.5.4)

9 Install exhalation module in BDU. (Section 8.15.9.4).

8.15.9.5.3 Removing exhalation valve

Caution

- To prevent equipment damage, do not attempt to disassemble the exhalation valve. It is factory-tested as an assembly.
- When removing the exhalation valve, take care not to damage the flow sensor that sits atop the exhalation valve. Do not drop or jar the valve.

1. Remove exhalation module cover (Section 8.15.9.2).
2. Unlatch and disconnect exhalation module harness (Figure 8-67) from exhalation I/O cable connector.
3. If necessary, gently pull top of exhaust port away from exhalation valve port; then slide exhaust port down port guide and off exhalation valve.
4. Remove four screws that secure exhalation valve to exhalation compartment side panel.
5. While holding exhalation flow sensor (Q3) in place, maneuver exhalation valve to disconnect it from Q3.
6. Disconnect exhalation module harness from valve.
7. Remove exhalation valve.

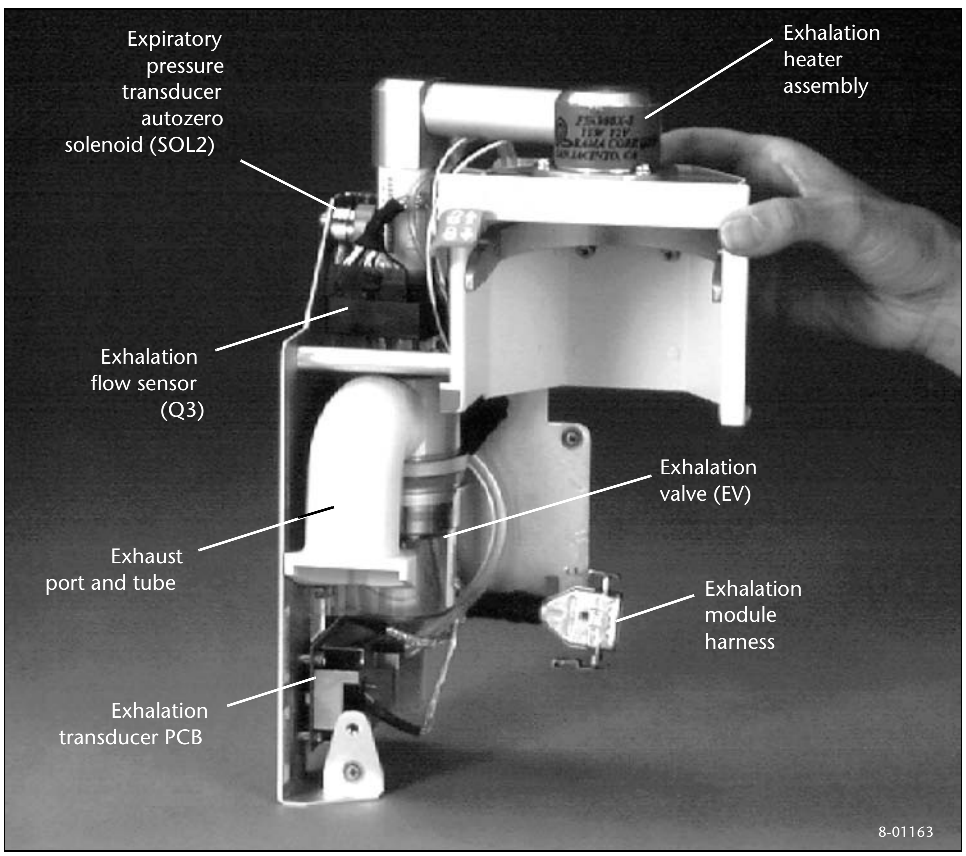


Figure 8-67. Replacing exhalation module components

8.15.9.5.4 Installing exhalation valve (EV)

Caution

- When installing the exhalation valve, take care not to pinch or damage the O-ring at the bottom of the flow sensor tube.
- Note that improperly installing the exhaust port can result in oxygen accumulation in the exhalation compartment.

NOTE:

If replacing the exhalation valve with the newer version, note the absence of the metabolic port. Refer to Section 8.15.9.5.1 for details regarding the elimination of the metabolic port.

1 Connect exhalation module harness to connector on exhalation valve (Figure 8-67).

2 With exhalation valve port facing out, carefully maneuver exhalation valve so it slides up onto bottom of flow sensor tube.

3 Connect sample port tube to top of valve.

4 Align four exhalation valve screwholes to exhalation module side panel.

5 While holding exhalation valve in place, manually insert and tighten four screws to hold valve in place; then using screwdriver, tighten screws until snug. **Do not overtighten.**

6 Install exhaust port by sliding grooved portion of exhaust port onto plastic guide; then slip top of exhaust port over exhalation port. Make sure port is firmly in place.

7 Connect exhalation module harness to exhalation I/O cable connector.

8 Install exhalation module cover (Section 8.15.9.2.1).

8.15.9.5.5 Cleaning exhalation valve

Although the exhalation filter assembly is designed to protect the exhalation valve from contaminates, certain particulate are small enough to pass through the filter element. Over time, these particulate can collect on the sealing surfaces. This build-up can eventually lead to leak failures in EST.

The functionality of the exhalation valve can be fully restored by cleaning the sealing surfaces.

Have the following available:

- Cotton swabs, 6-inches long
- Isopropyl alcohol
- Sterile water
- Can of compressed air or equivalent
- Protective gloves

1 Remove the exhalation module cover. (Section 8.15.9.2)

2 Remove the exhalation exhaust port tube.

3 Using two cotton swabs at a time, wet the swabs with a 50% mixture of isopropyl alcohol and sterile water.

4 Insert the cotton swabs between the poppet seal and the metallic seat of the exhalation valve. With your index finger, lightly touch the poppet to prevent rotation while cleaning.

Caution

Do not attempt to remove the seal from the poppet for cleaning. Otherwise, permanent damage to the seal may result.

5 Clean the metallic seat in a circular pattern.

6 Clean the poppet in a crosswise and circular pattern.

7 Repeat steps 3-6 again using two new cotton swabs.

8 Repeat steps 4-6 again using two new dry cotton swabs.

9 Blow the poppet and the seat lightly with a can of compressed air (or equivalent) to ensure removal of lint or other particulate.

Caution

Care should be taken to prevent dislodging the seal from the popet while blowing.

10 Reinstall the exhaust port tube.

11 Reinstall the exhalation module cover. (Section 8.15.9.2.1)

12 Perform Exhalation Calibration.

8.15.9.6 Exhalation flow sensor (Q3)

8.15.9.6.1 Removing Q3

Caution

When disconnecting Q3, be careful not to jar or drop it.

1 Remove exhalation valve (Section 8.15.9.5.3).

2 While holding Q3 (Figure 8-68), disconnect attached cable (Figure 8-67).

3 Gently pull Q3 down to unseat it from heater body.

4 If you are installing a new Q3, remove caps from new flow sensor, and install them on flow sensor that you just removed.

5 Set Q3 on a clean surface to prevent contamination.

6 Inspect O-rings.

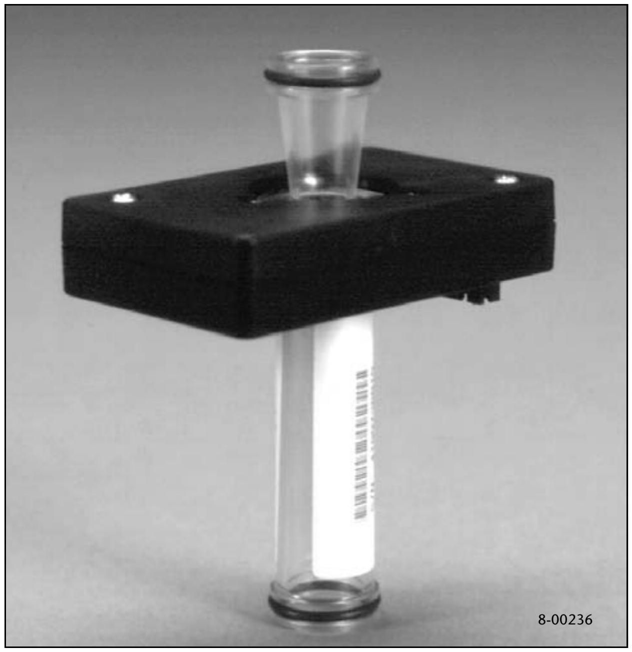


Figure 8-68. Exhalation flow sensor (Q3)

8.15.9.6.2 Installing exhalation flow sensor (Q3)

1 If you are installing a new Q3 (Figure 8-68), remove caps from both ends.

2 Make sure O-rings at both ends of Q3 tube are in place.

3 Orient body of Q3 with harness connection facing up (Figure 8-67).

4 Gently insert longer portion of tube into heater port.

Caution

Ensure that no damage to the O-ring occurs during installation of Q3.

5 Connect cable to connector on Q3.

6 Install exhalation valve (Section 8.15.9.5.4).

8.15.9.7 Exhalation transducer PCB

8.15.9.7.1 Removing exhalation transducer PCB

1 Remove exhalation module (Section 8.15.9.3).

2 Disconnect transducer cable from exhalation transducer PCB (Figure 8-69).

3 Disconnect tube from PCB transducer port.

4 Remove three screws that secure exhalation transducer PCB to exhalation module plate. Remove PCB and place in conductive bag or on ESD-protected mat.

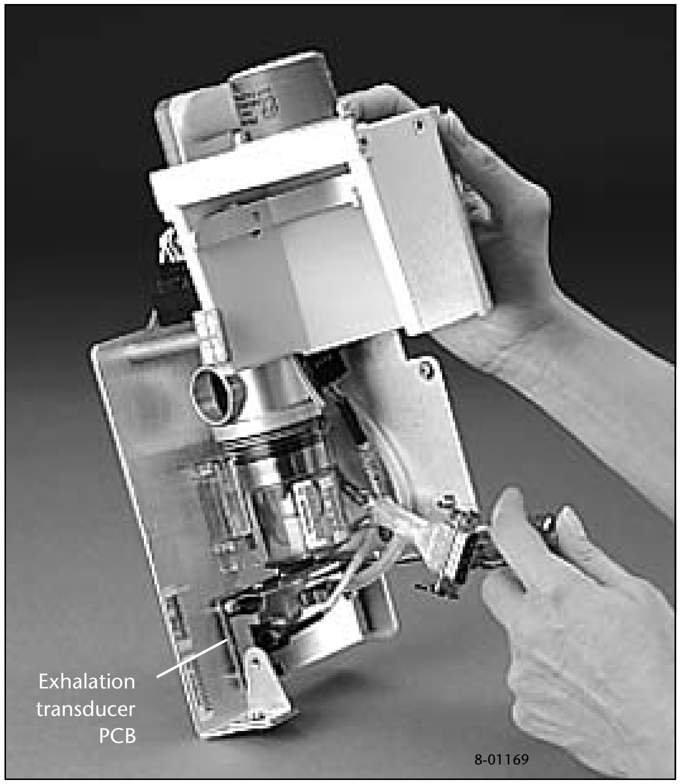


Figure 8-69. Replacing exhalation transducer PCB

8.15.9.7.2 Installing exhalation transducer PCB

1. Align exhalation transducer PCB to three screwholes on exhalation module plate (Figure 8-69). Install three screws that secure PCB to plate and tighten until snug. **Do not overtighten.**
2. Connect tube to transducer port.
3. Connect exhalation transducer PCB cable to exhalation transducer PCB.
4. Install exhalation module (Section 8.15.9.4).

8.15.9.8 Expiratory pressure transducer autozero solenoid (SOL2)

Caution

To prevent damage to tubing, do not attempt to remove silicone tubing from solenoid barbed fittings. Solenoid FRUs have tubing pre installed.

8.15.9.8.1 Removing SOL2

1. Remove exhalation module (Section 8.15.9.3).
2. Disconnect SOL2 tubes from exhalation module connector and exhalation transducer PCB (Figure 8-67).
3. Disconnect harness from SOL2.
4. Remove two screws that secure SOL2 to exhalation module plate. Remove SOL2.

8.15.9.8.2 Installing SOL2

1. Orient SOL2 so that connector on side faces downward (Figure 8-67). Install SOL2 to exhalation module plate using two screws. **Do not overtighten.**
2. Connect exhalation module harness to SOL2.
3. Connect tube from top of SOL2 to connector near top of exhalation module. Connect tube from side of SOL2 to transducer on exhalation transducer PCB.
4. Install exhalation module (Section 8.15.9.4).

8.15.9.9 Exhalation heater (EXH HTR) and check valve (CV5)

Caution

The exhalation heater may be hot. Be careful when removing it.

8.15.9.9.1 Removing exhalation heater (EXH HTR) and check valve (CV5)

1. Remove exhalation module (Section 8.15.9.3).
2. Disconnect exhalation heater (Figure 8-70) cable from exhalation module harness.
3. Loosen three screws that secure heater to module.
4. Gently lift heater to separate it from flow sensor tube. Place heater on flat surface.
5. Gently remove check valve from orifice on exhalation module.

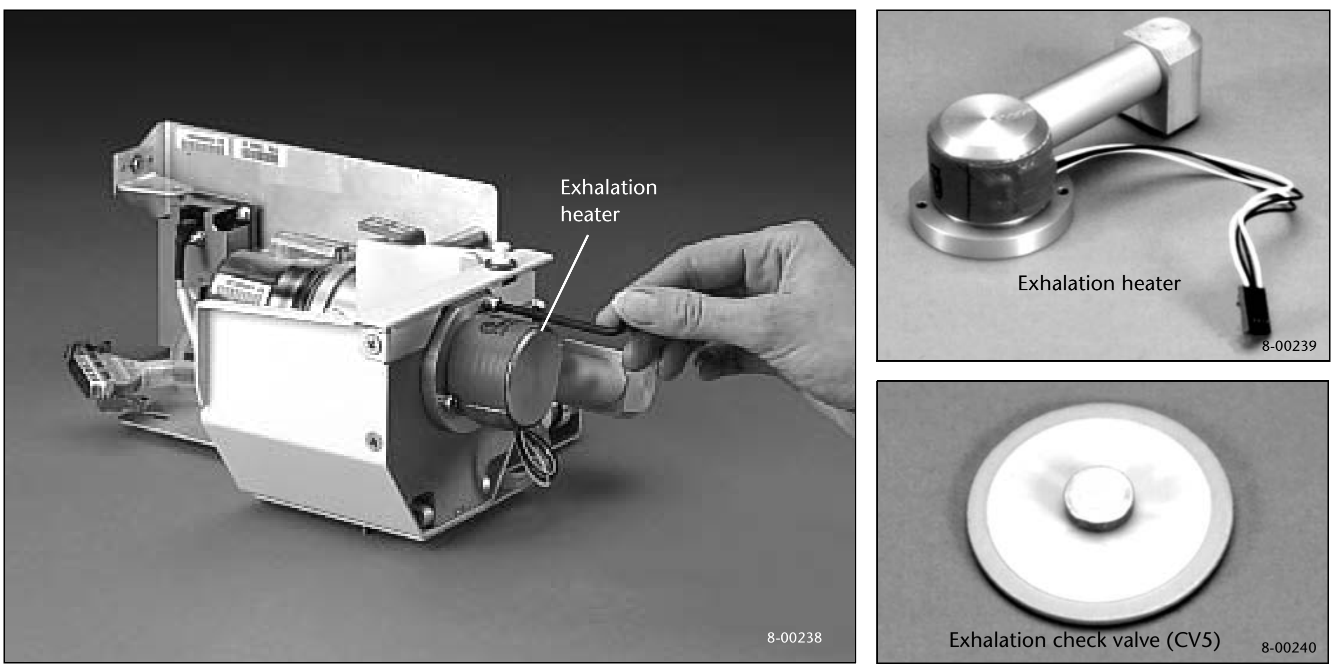


Figure 8-70. Replacing exhalation heater (EXH HTR) and check valve (CV5)

8.15.9.9.2 Installing exhalation heater (EXH HTR) and check valve (CV5)

1. Inspect seal surrounding orifice that supports exhalation check valve for cracks or damage. Replace CV5 assembly if required (seal is part of assembly).
2. Make sure leaf is lying flat, then place check valve (Figure 8-70) (leaf side up) into groove of seal surrounding orifice.
3. Make sure O-ring at top of flow sensor tube is in place.

4 Align heater over flow sensor tube and gently press heater assembly onto tube while aligning three screw locations to exhalation module.

5 Tighten three screws until snug. **Do not overtighten.**

6 Connect heater cable to exhalation module harness.

7 Install exhalation module (Section 8.15.9.4).

8.15.10 BDU housing

8.15.10.1 Removing BDU housing

The BDU housing must be removed from the chassis to access the motherboard PCB, alarm, humidifier receptacle, and blindmate cable assemblies. Remove the housing from the chassis as follows, referring to Figure 8-71.

1 Remove BDU (Section 8.15.1).

2 Remove power supply assembly (Section 8.15.5.1).

3 Remove inspiratory module (Section 8.15.8.8).

4 Remove exhalation module (Section 8.15.9.3).

5 Disconnect BDU LED PCB cable from PCB connector on top inside plate of exhalation compartment.

6 Slip BDU LED PCB cable through slot to inside of chassis.

7 Reach inside power supply cavity, and disconnect harnesses from power indicator and power switch.

8 From inside exhalation compartment, remove two screws and locking blocks that secure exhalation I/O cable connector to chassis.

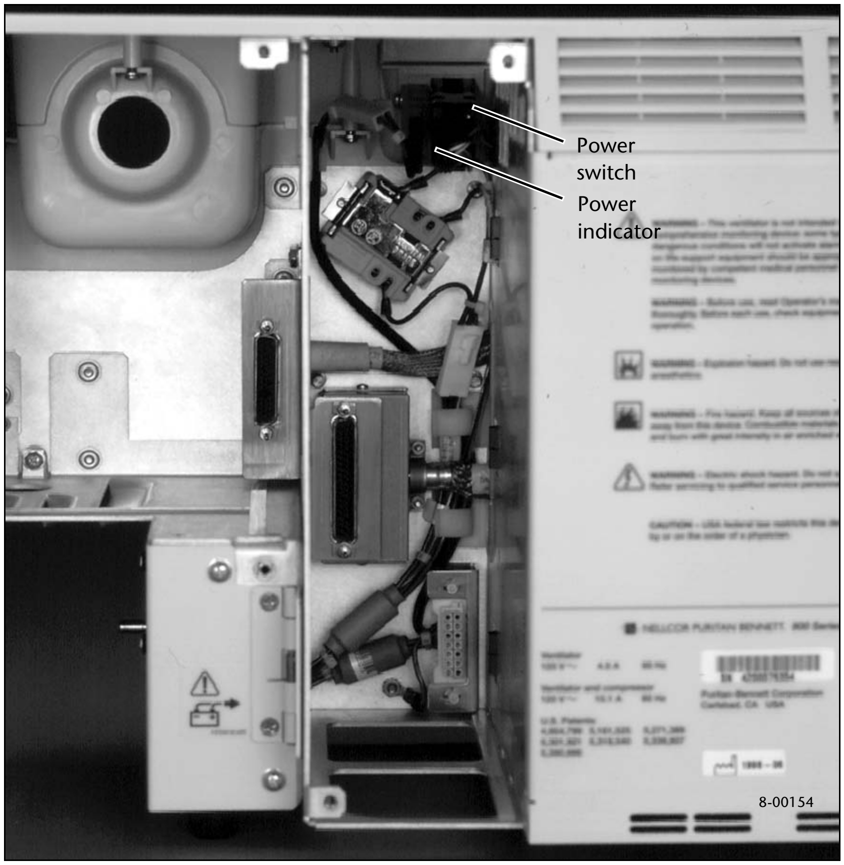
9 Stretch silicone gasket over and off of exhalation I/O cable connector.

10 Remove these 11 screws that attach BDU plastic housing to BDU chassis:

- Four flat-head screws that attach humidifier plate to BDU chassis
- One screw at vent inside inspiratory compartment
- Two screws on left side of ac panel
- One screw from ceiling of power supply compartment
- Two flat-head screws above card cage

11 From rear of BDU, lift plastic housing up and tilt it forward over front of chassis.

12 Slide exhalation I/O cable connector back into chassis. To accomplish this, it is helpful to slide your hand between card cage body and plastic rear housing of exhalation compartment. This allows you to maneuver plastic housing when positioning connector to slide through slot.



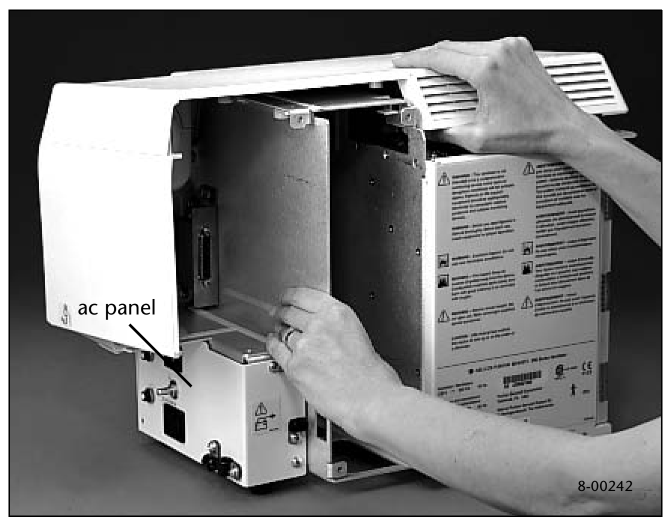


Figure 8-71. Removing BDU housing

8.15.10.2 Installing BDU housing

1 From front of BDU, align plastic housing to front of BDU. Route exhalation I/O and BDU LED PCB cables through openings. Place plastic housing over chassis.

2 Install these eleven screws:

- One screw at vent inside inspiratory compartment
- One screw and washer inside power supply compartment
- Two flat-head screws above card cage
- Two screws on left side of ac panel
- Four flat-head screws that attach humidifier plate to BDU chassis

3 Stretch silicone gasket over exhalation I/O cable and position in place.

Warning

To reduce the risk of fire hazard due to oxygen enrichment in the power supply compartment, make sure the gasket forms a complete seal between the exhalation module and power supply compartment.

4 From inside exhalation compartment, install two screws and standoffs that secure exhalation I/O cable connector to chassis. Make sure latching block “barbs” are facing out.

5 Reach inside power supply compartment and connect harness to power indicator and power switch.

6 Connect BDU LED PCB cable to PCB.

7 Install exhalation module (Section 8.15.9.4).

8 Install inspiratory module (Section 8.15.8.10).

9 Install power supply assembly (Section 8.15.5.2).

10 Install BDU (Section 8.15.3).

8.15.10.3 Motherboard PCB

8.15.10.3.1 Removing motherboard PCB

1 Remove BDU housing (Section 8.15.10.1).

2 Remove upper and lower card guides from inside card cage (Figure 8-72). Gently pry end of guide to snap connecting tab out of insert.

Caution

Be careful not to damage the upper and lower card guides.

3 Using 1/8-in. (3-mm) flat-bladed screwdriver, loosen two captive screws on each of four blindmate cables connected to motherboard PCB (Figure 8-73). Disconnect cables.

4 Using 3/16-in. nutdriver, remove eight standoffs that secure motherboard PCB connectors to chassis.

5 Remove seven screws that secure motherboard PCB to back panel of card cage (Figure 8-72). Gently remove motherboard PCB through card cage opening.

6 Place PCB in a conductive bag or on ESD-protected mat.

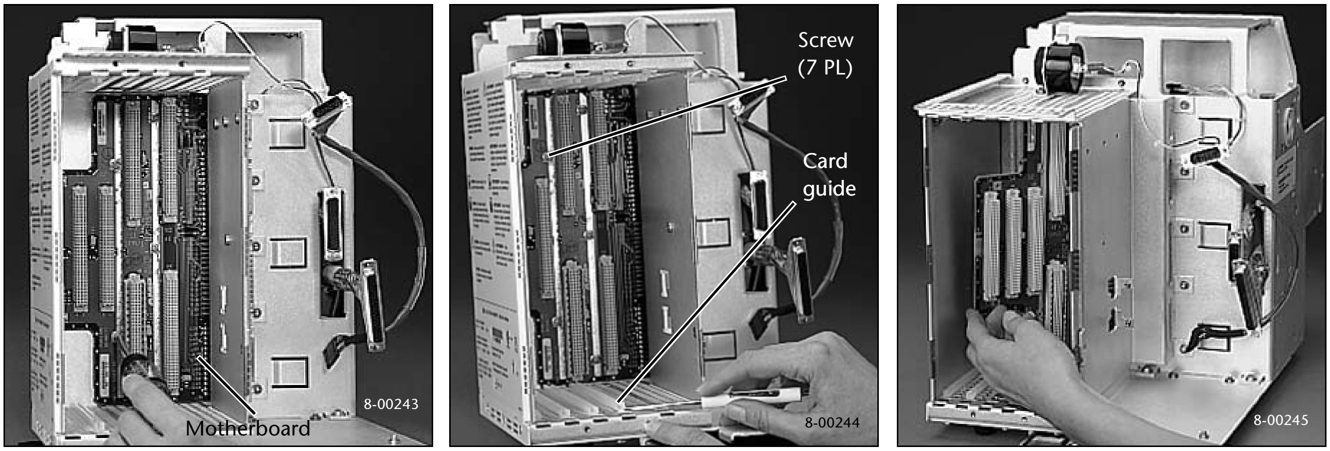


Figure 8-72. Removing motherboard PCB

8.15.10.3.2 Installing motherboard PCB

1. Carefully insert motherboard PCB into card cage (Figure 8-72 and Figure 8-73) and align D-sub connectors with cutouts in chassis.
2. Using a 3/16” nutdriver install eight standoffs but *do not tighten*.
3. Install seven screws that secure motherboard PCB to back panel of card cage. Tighten until snug. **Do not overtighten.**
4. Using a 3/16” nutdriver tighten eight standoffs until snug. **Do not overtighten.**
5. Connect four blindmate cables to motherboard PCB. Using 1/8-in. (3-mm) flat-bladed screwdriver, tighten two captive screws (per cable) to each of four connectors. **Do not overtighten.**
6. Install card guides.
7. Install BDU housing (Section 8.15.10.2).

8.15.10.4 BDU alarm assembly

8.15.10.4.1 Removing BDU alarm assembly

1. Remove BDU housing (Section 8.15.10.1).
2. Remove two screws that secure harness to BDU alarm assembly (Figure 8-73).
3. Unscrew ring at front of alarm. Remove alarm from mounting bracket.

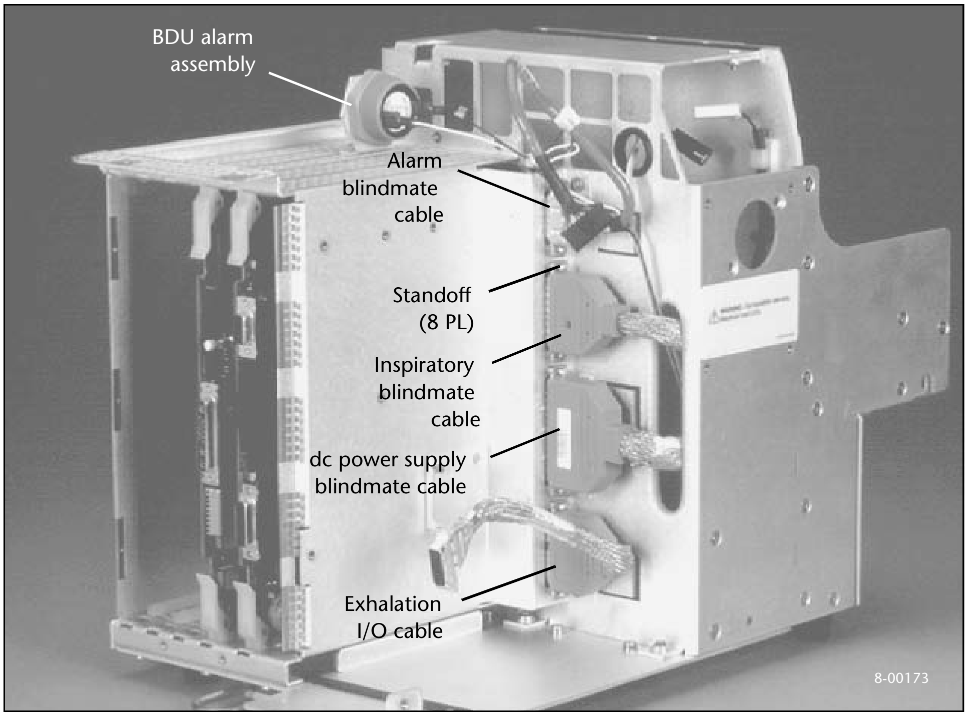


Figure 8-73. BDU alarm and motherboard PCB cable connections

8.15.10.4.2 Installing BDU alarm assembly

1. Position BDU alarm assembly so that speaker portion is inserted through bracket facing back of BDU and so that polarity notch is aligned with bracket (Figure 8-73).
2. Screw alarm ring onto threaded base. Tighten until snug. **Do not overtighten.**
3. Using two screws, connect harness to alarm.
4. Install BDU housing (Section 8.15.10.2).

8.15.11 Power indicator

Warning

To prevent electrical shock hazard, always unplug the power cord from facility power and disconnect the BPS cable from the power supply assembly before servicing ac components.

8.15.11.1 Removing power indicator

1. Remove BDU housing (Section 8.15.10.1).
2. Remove screw that secures sleeve to indicator (Figure 8-41). Remove insert and sleeve; save for reinstallation. Push indicator through opening.

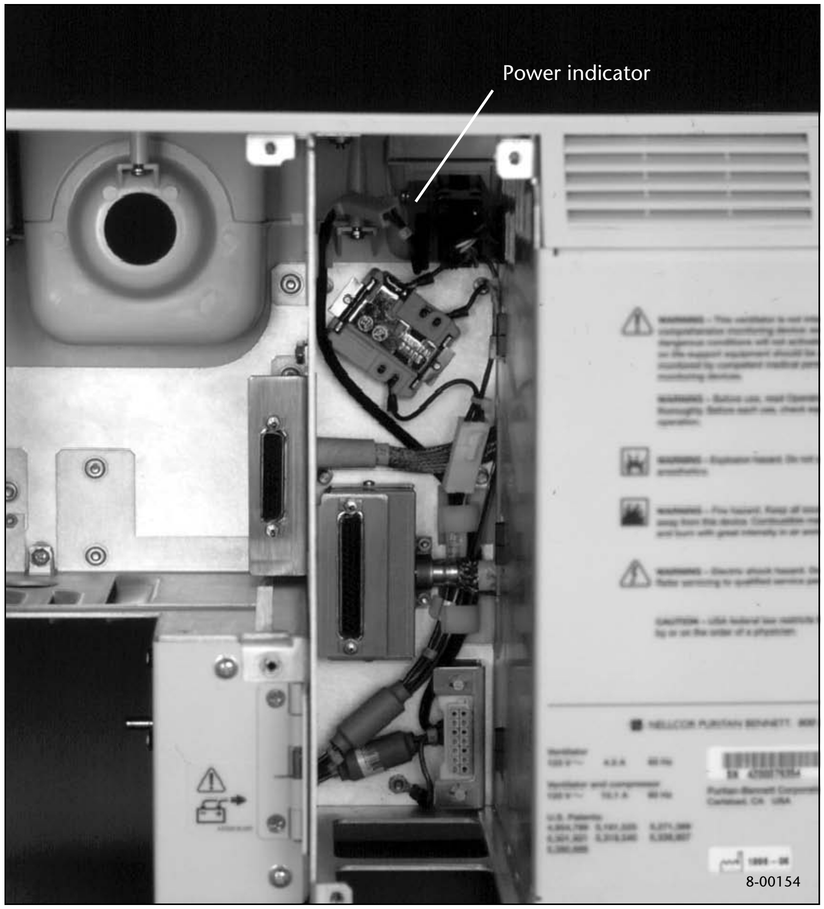


Figure 8-74. Replacing power indicator

8.15.11.2 Installing power indicator

1 From front of BDU, insert indicator (Figure 8-41). Place sleeve over indicator. Place insert over sleeve and secure with screw.

2 Install BDU housing (Section 8.15.10.2).

8.15.11.3 Alarm blindmate cable

8.15.11.3.1 Removing alarm blindmate cable

1 Remove BDU housing (Section 8.15.10.1).

2 Remove four screws that retain ac panel to chassis from rear of ac panel.

3 Cut tie wraps used to bundle this harness with other harnesses or to secure it to chassis.

4 Detach harness from BDU alarm assembly (Figure 8-73) by removing two screws.

5 Detach harness from power relay (Figure 8-75) by using needlenose pliers to disconnect two fast-on connectors. Pull these two wires back through grommet and through blindmate cable opening at rear of power supply compartment cavity.

6 Using 1/8-in. (3-mm) flat-bladed screwdriver, loosen two captive screws that secure cable to motherboard PCB connector (Figure 8-73). Disconnect cable.

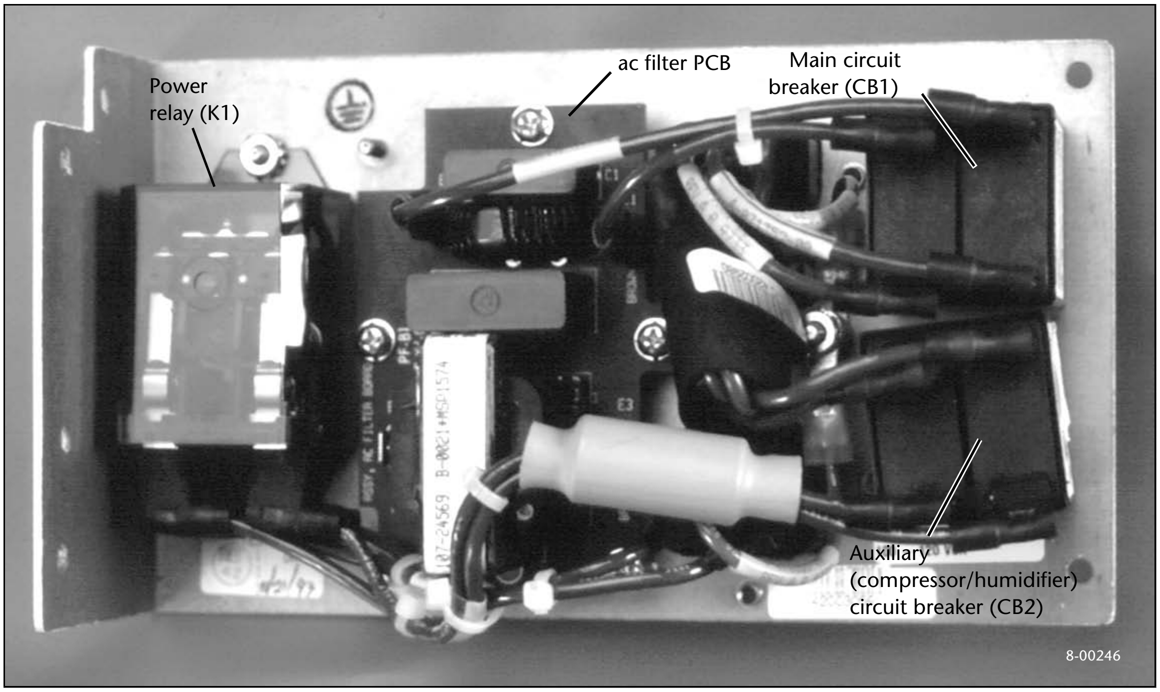


Figure 8-75. Cable connections to ac panel

8.15.11.3.2 Installing alarm blindmate cable

1. Connect cable to motherboard PCB. Using 1/8-in. (3-mm) flat-bladed screwdriver, tighten two captive screws until snug (Figure 8-73).
2. Connect cable to power relay (Figure 8-75):
   a. Route clear plastic tube containing black and red wires through opening into power supply compartment and through grommet into ac power distribution area.
   a. Using needlenose pliers, connect two fast-on connectors to relay. The red wire goes to terminal 10. The black wire goes to terminal 12.
3. Connect cable to BDU alarm assembly with two screws (Figure 8-73).
4. Install four screws that retain ac panel to chassis from rear of ac panel. Tighten until snug. **Do not overtighten.**
5. Install BDU housing (Section 8.15.10.2).

8.15.11.4 Inspiratory blindmate cable

Replacing the inspiratory blindmate cable requires an 11/32-in. nutdriver with a 6-in. (15.2-cm) shaft or a socket wrench with a 6-in. (15.2-cm) extension.

8.15.11.4.1 Removing inspiratory blindmate cable

1. Remove BDU housing (Section 8.15.10.1).
2. Using 1/8-in. (3-mm) flat-bladed screwdriver, loosen two captive screws that secure inspiratory blindmate cable to motherboard PCB connector (Figure 8-73). Disconnect cable.
3. Using 11/32-in. nutdriver or socket wrench, remove three nuts that secure cable to chassis (Figure 8-76).
4. Gently feed firewall gasket into inspiratory compartment. Feed rest of cable through power supply module compartment into inspiratory module, and remove.

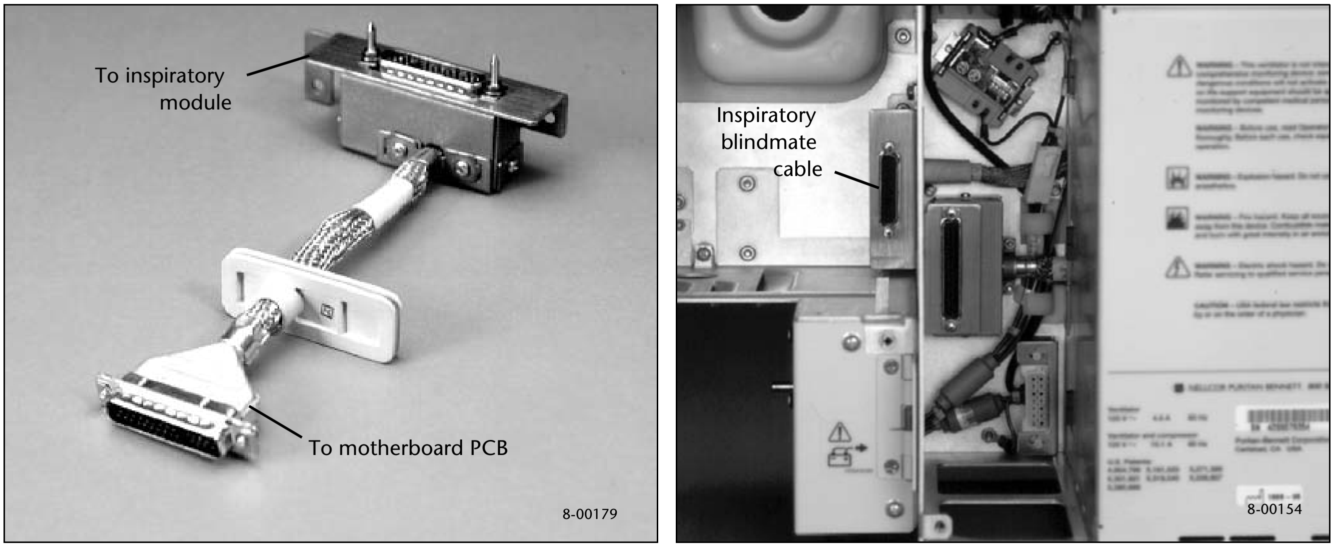


Figure 8-76. Replacing inspiratory blindmate cable

8.15.11.4.2 Installing inspiratory blindmate cable

1 Feed cable's D-sub connector through inspiratory and power supply compartments.

2 Connect cable to motherboard PCB. Using 1/8-in. (3-mm) flat-bladed screwdriver, tighten captive screws until snug (Figure 8-73). **Do not overtighten.**

3 Seat gasket firmly in firewall to create a complete seal. The hole for the cable should be towards the bottom of the gasket.

Warning

To reduce the risk of fire hazard due to oxygen enrichment in the power supply compartment, make sure the gasket forms a complete seal between the inspiratory module and power supply compartment.

4 Place bracket over chassis studs and secure with three locknuts. Using 11/32-in. nutdriver or socket wrench, tighten until snug (Figure 8-76). **Do not overtighten.**

5 Install BDU housing (Section 8.15.10.2).

8.15.11.5 dc power supply blindmate cable

Replacing the dc power blindmate cable requires #1 Phillips screwdriver with a minimum 6-in. (15.2-cm) shaft.

8.15.11.5.1 Removing dc power supply blindmate cable

1 Remove BDU housing (Section 8.15.10.1).

2 Using 1/8-in. (3-mm) flat-bladed screwdriver, loosen two captive screws that secure dc power supply blindmate cable to motherboard PCB connector (Figure 8-73). Disconnect cable.

3 Allow for access to dc power supply blindmate cable retaining screws:

a. Remove inspiratory blindmate cable (Section 8.15.11.4.1).

b. Remove four chassis-retaining screws from rear of ac panel.

4 Remove two screws that secure cable (Figure 8-77) to chassis. Feed both connectors into power supply compartment, and remove cable.

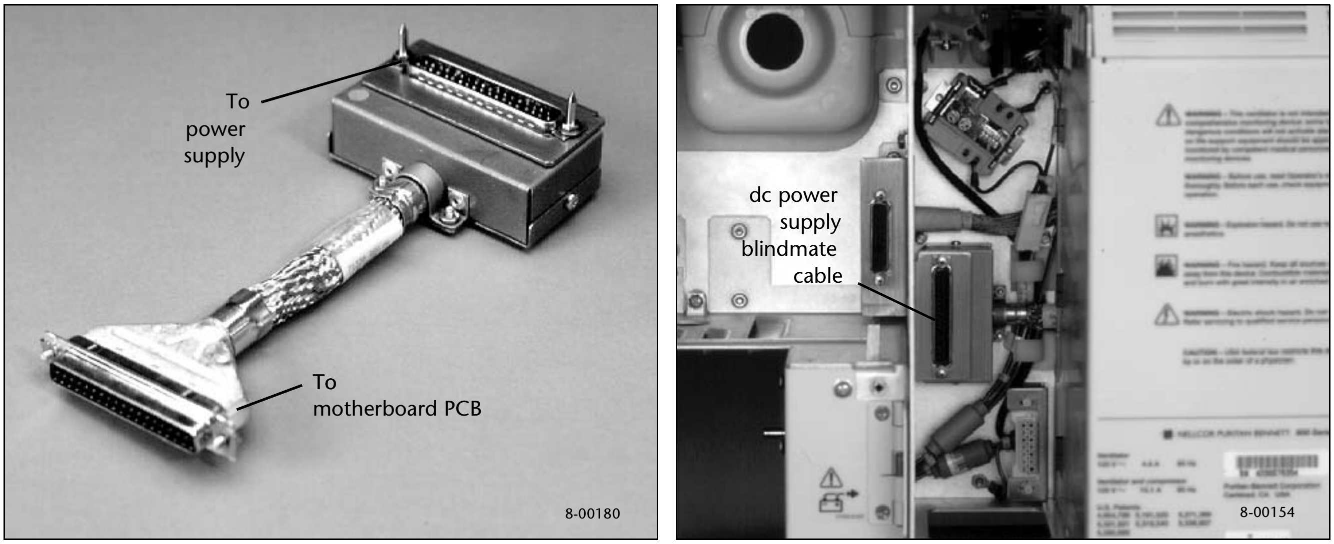


Figure 8-77. Replacing dc power supply blindmate cable

8.15.11.5.2 Installing dc power supply blindmate cable

1. Feed cable's D-sub connector through power supply compartment.
2. Connect cable to motherboard PCB. Using 1/8-in. (3-mm) flat-bladed screwdriver, tighten two captive screws until snug (Figure 8-73). **Do not overtighten.**
3. Align bracket end of cable with mounting holes and secure with two flat-head screws, one through inspiratory module and one through ac power distribution compartment. Tighten until snug. **Do not overtighten.**
4. Install inspiratory blindmate cable (Section 8.15.11.4.2).
5. Install four chassis-retaining screws at rear of ac panel.
6. Install BDU housing (Section 8.15.10.2).

8.15.11.6 ac power supply blindmate harness

8.15.11.6.1 Removing ac power supply blindmate harness

1. Remove BDU housing (Section 8.15.10.1).
2. Remove four chassis-retaining screws from rear of ac panel.
3. Cut tie wraps that secure harness to chassis or to other harnesses, as required.Cut tie wraps that secure the harness to the chassis or to other harnesses, as required.
4. Disconnect harness from ac filter PCB and ground stud in ac panel.
5. Remove two flat-head screws securing harness bracket to front of chassis. Remove harness (Figure 8-78) through power supply compartment.

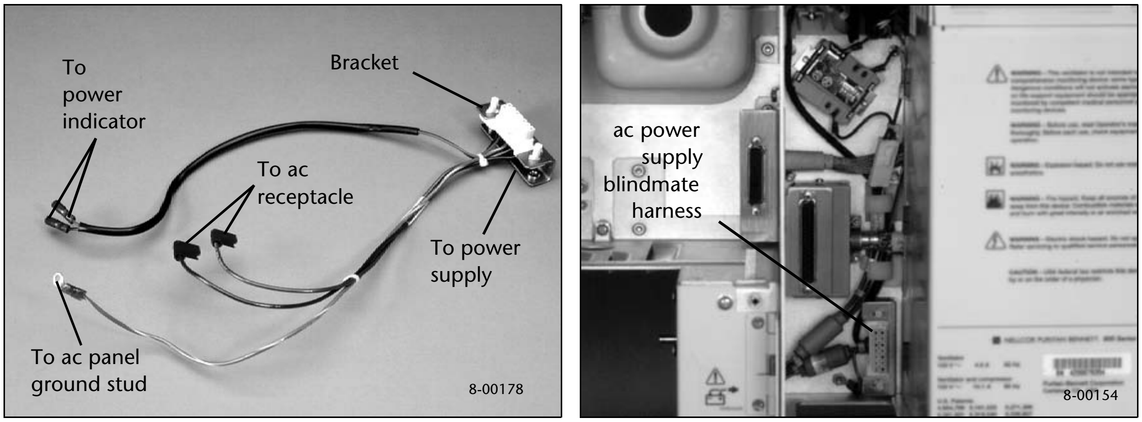


Figure 8-78. Replacing ac power supply blindmate harness

8.15.11.6.2 Installing ac power supply blindmate harness

Warning

To reduce the risk of fire hazard due to oxygen enrichment in the power supply compartment, make sure the gasket forms a complete seal between the inspiratory module and power supply compartment.

1. Insert harness into power supply compartment (Figure 8-78).
2. Route blue, brown, and green wires through round grommet into ac power distribution compartment.
3. Install harness bracket to chassis with two flat-head screws.
4. Route power indicator LED cable (with black sleeving) behind blindmate cables and through top of chassis.
5. Using two small tie wraps, secure power indicator LED cable and other wires to power supply wall at two places. Cut tie wrap ends flush with the tie wrap body.
6. Connect blue wire to top left-hand terminal of ac filter PCB (PCB viewed from back, rightside up) (Figure 8-75). Connect brown wire to top right-hand terminal of ac filter PCB. Connect green wire to top left-hand ground stud.
7. Verify that wires move freely in bracket and are not obstructed by other wires in area.

Caution

The obstruction of the harness within the bracket could prevent proper alignment of power supply contacts.

8. Using two small tie wraps, rebundle wires on either side of round grommet. Cut tie wrap ends flush with the tie wrap body.
9. Install four chassis-retaining screws at rear of ac panel.
10. Install BDU housing (Section 8.15.10.2).

8.15.12 Release handle

8.15.12.1 Removing release handle

1. Remove BDU. (Section 8.15.1)
2. Slide BDU out from its mounting bracket and lay unit, face up, on a firm work surface.
3. Remove three flat-head screws that secure latch slide mount to bottom of chassis.
4. Slide loop portion of release handle out of bracket and remove handle and slide mount.

8.15.12.2 Installing release handle

1. Slide loop portion of release handle into bracket slot. Ensure spring is on inside of bracket.
2. Align latch slide mount to three screw locations at bottom of chassis.
3. Install three flat-head screws and tighten until snug. **Do not overtighten.**
4. Install BDU (Section 8.15.3).

8.16 806 compressor unit

NOTE:
The 806 compressor is the replacement for the 804 compressor assembly.

The 806 compressor unit is a detachable module consisting of the compressor, compressor PCB, accumulator, and heat exchanger. The compressor unit is mountable only when used with the optional cart.

Most routine repairs and preventive maintenance to the compressor unit require that the compressor be removed from the cart. This section describes how to perform service and repairs on the 806 compressor, as well as performance verification.

To ensure that reassembly is correctly done, label all wires and tube positions before you begin disconnecting parts. Take precautions to prevent dirt and other particles from entering the interior of the compressor. Always properly dispose of the original parts that have been replaced by new parts.

Replacement parts for the original compressor, model 804, are no longer available. Contact Puritan-Bennett Technical Support for additional information.

Be sure to read all applicable instructions completely before disassembly.

8.17 Servicing the 806 compressor

NOTE:
To disconnect a pneumatic hose held in place by a compressible clip, use flat-nosed pliers to compress the nubs on the clamp. Slide the clamp up the hose 1 to 2 inches.

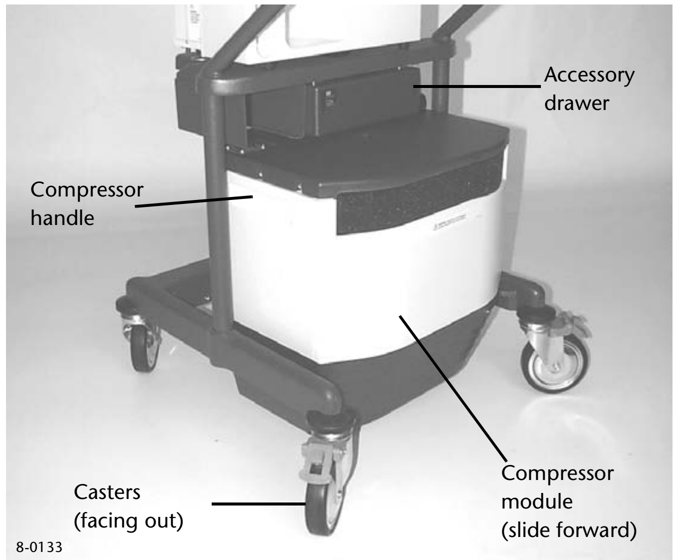


Figure 8-79. 806 compressor mounted on cart

8.17.1 Compressor inlet filter

The compressor inlet filter provides pre-filtration for the compressor inlet silencer filter. The inlet filter is located in the top front panel of the compressor.

Remove and clean the filter more often than the recommended PM (Preventative Maintenance) schedule of every 250 hours if necessary. Some environments can cause particulate to collect more quickly.

8.17.2 Removing and installing the compressor inlet filter

1 To remove inlet filter, gently pull at one corner.
2 Wash the filter in a mild soap solution.
3 Rinse filter well and dry thoroughly to ensure an unrestricted flow of air through the compressor compartment. Replace filter if damaged.
4 To install the inlet filter, align the clean dry filter over the opening in the front panel of the compressor. Gently tuck in the edges of the filter.

8.17.3 Removing compressor from cart

8.17.3.1 Disconnecting compressor from BDU

1 Disconnect the ventilator power cord from the wall outlet.
2 Disconnect the high pressure hoses.
3 Disconnect the following:
   - compressor power cable
   - compressor data cable
   - compressor supply hose

8.17.3.2 Removing compressor from cart

1 Disconnect the ventilator power cord from the wall outlet.

2 Disconnect the high pressure hoses.

3 Confirm the compressor is fully disconnected from the BDU.

4 Remove the cart accessory drawer to allow room for the compressor data cable to clear the cart.

5 Orient the cart with the front casters facing out. Lock front casters in place.

6 Loosen the two captive screws under the bottom shelf at the rear of the cart. (These screws secure the compressor to the cart.)

7 Slide the compressor to the front of the cart.

8 Grasp the handles on both sides of the compressor and gently lift.

Warning

To prevent personal injury and equipment damage, have someone assist you when lifting the heavy ventilator and its components.

9 Place compressor on a strong, firm work surface.

8.17.4 Removing top cover

1 Remove the top cover assembly from the compressor.

2 Loosen, but do not remove, the four (4) Phillips screws that secure the cover to the rear panel .

3 Loosen the four (4) screws (two on each side) that secure the cover to the side panels.

4 Lift the top cover assembly off the compressor and set aside.

5 Remove the main inlet filter and support baffle by lifting them out of the unit.

Figure 8-80. Top cover removed from compressor

8.17.5 Installing top cover

1 Place the main inlet filter and support baffle into position at top of front panel.

2 Place the top cover assembly on the compressor.

3 Tighten the four (4) screws (two on each side) to secure the cover to the side panels.

8.17.6 Cooling fans

The cooling fans provide a source of ambient air to cool both the heat exchanger and the exhaust heat from the compressor.

8.17.6.1 Removing a cooling fan

1 Remove the top cover and panels (Section 8.17.4).

2 Using diagonal cutting pliers, cut and discard the tie wraps securing the fan cable to the fan's upper inside mounting screws.

Caution

When removing the fan hardware:

- Be careful not to drop the screws or washers into the plenum assembly and onto the heat exchanger.
- Be careful not to misplace the star washers as they provide ground to the fans.

3 Facing the front of the compressor, remove the four (4) Phillips screws and star washers that secure the fan to the top of the plenum assembly.

4 Disconnect the electrical cable from the fan.

5 Remove the fan.

Figure 8-81. Fans installed in compressor

8.17.6.2 Installing a fan

Caution

Verify the flow direction of the fan prior to installing the fan in place. The flow should be directed into the compressor compartment.

1 Based on flow direction, properly orient the replacement fan and place over the hole in the plenum assembly.
2 Connect the fan cord to the fan and place the fan on the fan-support panel.
3 Reinstall the four (4) screws and star washers.
4 Secure the fan cable to the fan's mounting screw with a cable tie.
5 Reinstall the baffle and intake filter.
6 Reinstall top cover and secure screws.

8.17.7 Removing the back panel

1 Remove the top cover and set aside (Section 8.17.4).
1 Remove the six (6) Phillips screws from the sides of the rear panel and set them aside.
2 Lean the top of the back panel away from the compressor (Figure 8-82).
3 While supporting the back panel, slide the compressible hose clamp back and disconnect the hose from the accumulator intake port.
4 Remove the accumulator and back panel from the compressor. Set aside.

8.17.8 Reinstalling the back panel

1 While supporting the back panel, reconnect the hose to the accumulator intake port.
2 Reposition the hose clamp to secure the hose to the accumulator intake port.
3 Position the back panel on rear of compressor.
4 Replace the six (6) Phillips screws from the sides of the back panel.
5 Reinstall the top cover (Section 8.17.5).

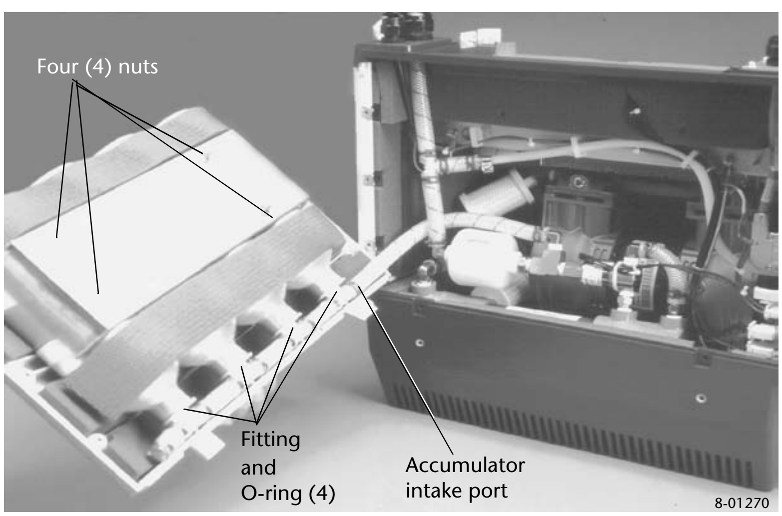


Figure 8-82. Removing the back panel of the compressor

8.17.9 Replacing an accumulator fitting and O-ring

Each of the four accumulators has a fitting with an O-ring that connects the accumulator to the accumulator intake port.

1. Remove back panel (Section 8.17.7).
2. While supporting the back panel, disconnect the hose from the accumulator intake port.
3. Using a nut driver, remove the four (4) nuts that secure the bottles to the rear panel.
4. Remove the accumulator assembly from the back panel.
5. Remove the compressible hose clamps and disconnect the hoses from either side of the accumulator.
6. Unscrew the accumulator fitting and remove from the bottle.
7. Replace the accumulator fitting, applying a small amount of Krytox grease to the O-ring before reinstalling on the accumulator.
8. Resecure the hoses to the accumulator with the compressible hose clamps.
9. Reinstall the accumulator assembly and place the accumulator cover over the four (4) studs.
10. Secure the accumulator assembly to the back panel using four (4) nuts. Hand tighten.

8.17.10 Pneumatic hoses

NOTE:

- To prevent the shredding of the silicone hoses when disconnecting from barbed fittings, gently pull while turning the hose.
- Use a flat-nosed pliers to compress the nubs on compressible clamp.

8.17.10.0.1 Disconnecting pneumatic hoses

1. Remove top cover (Section 8.17.4).
2. Remove rear panel assembly (Section 8.17.7).
3. Using a 3/16" flathead screwdriver, loosen the screw on the hose clamp that secures the pressure transducer to the compressor PCB.
4. Disconnect the tube from the PCB. (See Figure 8-85.)
5. Disconnect the main supply hose at the solenoid filter outlet port. (See Figure 8-83.)

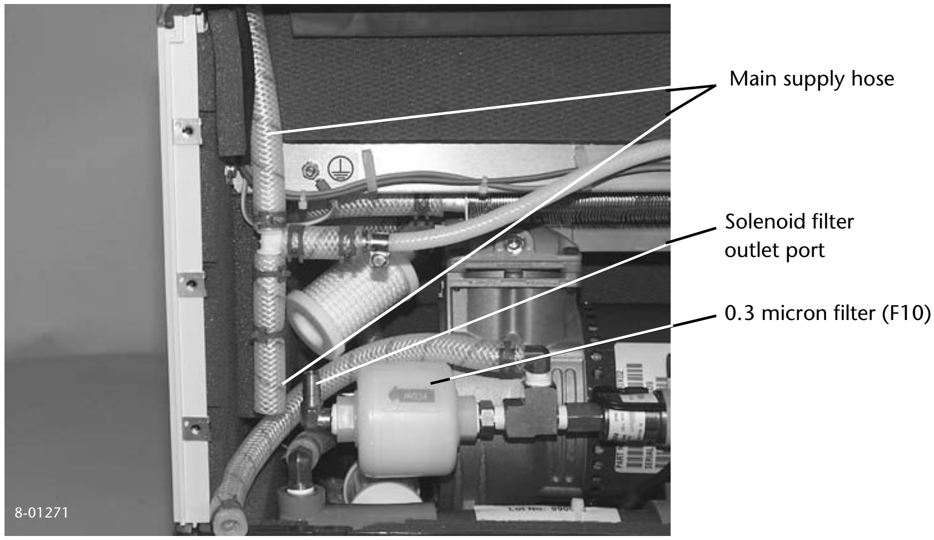


Figure 8-83. Disconnecting filter outlet port from main supply hose

6 Disconnect the hose at the heat exchanger inlet connection that runs from the compressor outlet (Figure 8-84).

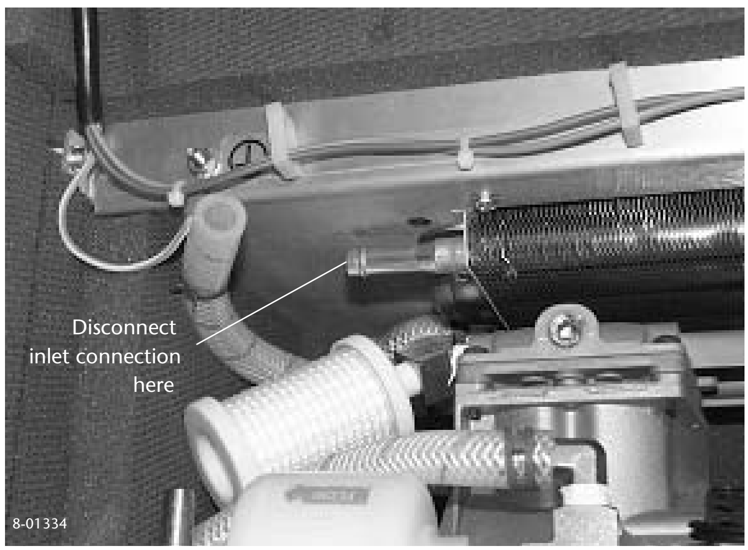


Figure 8-84. Disconnecting heat exchanger inlet connection

7 Disconnect the hose at the water trap outlet that runs to the air dryer inlet port.

8 Loosen the two (2) Phillips screws that secure the internal plenum panel to the left and right panels.

9 Loosen the two (2) Phillips screws that secure the external plenum panel the left and right panels.

8.17.11 Plenum assembly

The plenum assembly contains the cooling fans, heat exchanger, ac and dc cables, and the compressor air supply hose. The plenum assembly is accessed by removing the top cover and accumulator assembly, which is mounted to the back panel, and the electrical connections from the compressor PCB.

8.17.11.1 Removing the plenum assembly

1 Remove top cover (Section 8.17.4).

2 Remove rear panel assembly (Section 8.17.7).

3 Disconnect the electrical cables from the compressor PCB as follows (Figure 8-85):

- solenoid cable at J1
- two (2) fan cables at J2 and J3.
- ac input cord at J6
- motor cable at J5

4 Release the data cable by sliding the lock bracket up and carefully disconnecting the cable.

5 Use a 11/32" nut driver to remove the nut securing the ground cable to the grounding lug. (Locate the ground connection on the plenum base, adjacent to the compressor PCB.)

6 Disconnect the grounding cable and reinstall the nut for reconnecting the ground later.

7 Disconnect the pneumatic hoses (Section 8.17.10.0.1).

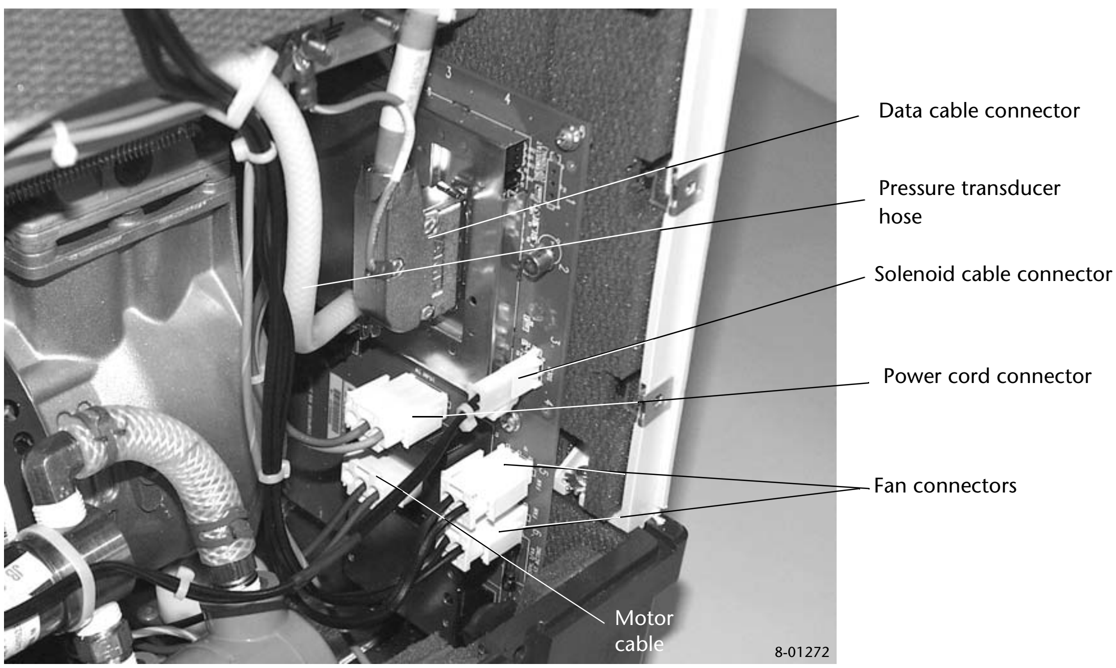


Figure 8-85. 806 printed circuit board (PCB)

8 Facing the rear of the compressor, place your thumbs under the edge of the plenum assembly top panel and lift the panel free from the side panel.

9 Slightly lift (or prop open) the plenum assembly enough to gain access to the heat exchanger ports.

10 Disconnect the hose at the heat exchanger outlet port that runs to the water trap inlet.

11 Taking care not to damage the heat exchanger fins, carefully lift the plenum assembly from the top of the compressor and set assembly aside.

8.17.12 Heat exchanger (HE)

8.17.12.1 Replacing the heat exchanger

1 Remove the plenum (Section 8.17.11.1).

1 Remove the four (4) screws and the two (2) heat exchanger straps that secure the heat exchanger plate to the plenum.

2 Install the new heat exchanger assembly.

3 Secure the heat exchanger plate to the plenum with the two (2) straps and four (4) screws. **Do not overtighten these four screws.**

8.17.13 Removing and replacing the ac power cord

The ac and dc cables are accessed by removing the rear access panel assembly. Verify power is disconnected before performing this operation.

1 Remove the back cover (Section 8.17.7).

1 Disconnect the power cord from the compressor PCB (Figure 8-85).

2 Using diagonal cutters, cut the cable tie near the plenum assembly.

3 Sever the power cord.

4 Loosen the strain relief and remove and discard both halves of the cable.

5 Install a new power cord by feeding the loose pins through the strain relief.

6 Insert the power cord connector onto loose pins by placing the connector onto the PCB and confirming the orientation.

7 Insert the brown wire into the middle socket.

8 Insert the blue wire into the right socket.

9 Remove the connector from the PCB and verify the wires are fully inserted.

10 Install a small cable tie onto the power cord just below the strain relief.

11 Reinstall the power cord onto the PCB.

12 Tighten strain relief.

8.17.14 Removing and replacing the data cable

1 Remove the back cover (Section 8.17.7).

2 Disconnect the data cable from the compressor PCB (Figure 8-85).

3 Cut the tie wrap that secures the data cable to the plenum assembly.

4 Using a screwdriver, remove the four (4) screws that secure the strain relief to the top panel.

5 Disconnect the data ground cable from the plenum assembly.

6 Gently remove the data cable from the compressor.

7 Feed the new data cable end through the top of the plenum.

8 Secure the strain relief with four (4) screws and hand tighten.

9 Secure the data ground cable to the plenum and tighten the nut.

10 Attach the data cable to the PCB and slide its lock into place.

11 Attach the cable to the plenum assembly with a tie wrap.

8.17.15 Compressor PCB

The removal of the compressor PCB requires the partial or complete remove of the plenum to gain needed access.

8.17.15.1 Removing and replacing the compressor PCB

1. Remove top cover (Section 8.17.4).
2. Remove rear panel (Section 8.17.7).
3. Remove plenum (Section 8.17.11.1), as needed
4. Disconnect the electrical cables from the compressor PCB as follows:
   - solenoid cable at J1
   - two (2) fan cables at J2 and J3.
   - ac input cord at J6
   - motor cable at J5
5. Release the data cable by sliding the lock bracket up and carefully disconnecting the cable.
6. Disconnect the pressure transducer hose from the PCB.
7. Remove the three screws that secure the PCB to the side panel. Set aside the screws.
8. Remove the compressor PCB by leaning the board away from the side panel and sliding the board up toe remove it from its board retainer.

NOTE:

If you are installing a new PCB, it is necessary to transfer the compressor serial number and operational hours information by removing the EEPROM from the old board and transferring it to the new board.

Caution

Verify the polarity of the EEPROM before installing on the new PCB: When transferring the EEPROM, ensure that the notch on the EEPROM matches the notch on the 806 PCB before installing.

9. Reinstall the new board by first aligning the board with the side panel and placing the bottom of the board into the board retainer.
10. Reattach the cable connections to the PCB as follows:
    - solenoid cable at J1
    - two (2) fan cables at J2 and J3.
    - ac input cord at J6
    - motor cable at J5
11. Attach the data cable to the PCB and slide its lock into place.

8.17.16 Air dryer (dryer) and solenoid valve assembly

The air dryer assembly removes water vapor from the compressed gas supply . The solenoid valve assembly opens to allow the compressor motor to start. The air dryer assembly is accessed by removing the back panel assembly and disconnecting the supply tubing. The filters are normally replaced as part of the 15,000 hour PM kit.

8.17.16.1 Removing and reinstalling the air dryer and solenoid valve assembly and replacing filters

1. Remove the top cover assembly and set aside (Section 8.17.4).
2. Remove the rear panel and set aside (Section 8.17.7).
3. Cut the cable tie securing the air dryer assembly to the clamp (Figure 8-86).

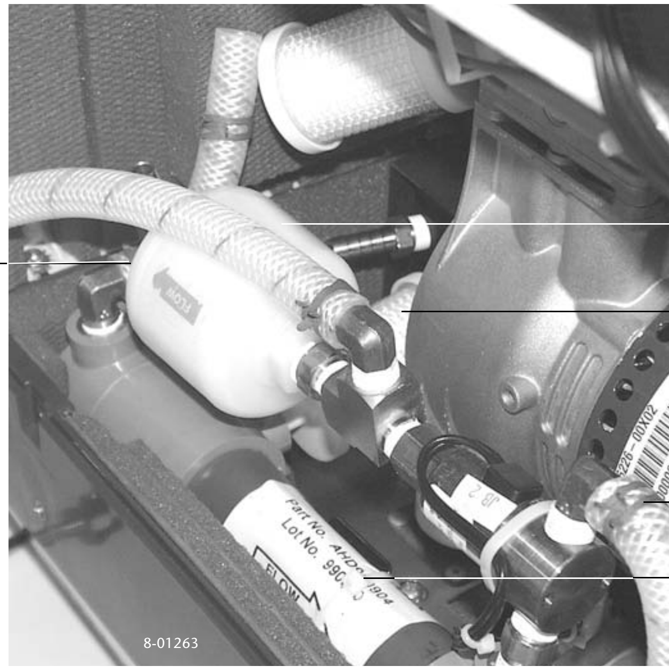


Figure 8-86. Air dryer/solenoid valve assemblies installed

4. Disconnect hose to the air dryer.
5. Grasp the air dryer and solenoid valve assembly at the top and firmly pull up to detach from the clamp that holds the assembly in place.
6. Remove the assembly from the compressor and place on a work surface.
7. Disconnect the short hose at the solenoid purge outlet port.
8. Unscrew the air dryer filter/muffler and discard.
9. Slightly rotate the solenoid valve assembly away from the air dryer to remove the solenoid outlet filter.
10. Unscrew the solenoid outlet filter. Set the air dryer/solenoid valve assembly aside.
11. Unscrew the barbed fitting from the end of the solenoid outlet filter. Set barbed fitting aside and discard the filter.
12. Remove the Teflon tape from the threaded end of the barbed fitting.
13. Apply a new layer of Teflon tape.
14. Install the new solenoid outlet filter on the solenoid by screwing it in place.
15. Reattach the barbed fitting to the outlet filter by screwing it in place.
16. Rotate the solenoid valve assembly back to its original position (parallel with the air dryer assembly).
17. Apply Teflon tape to the threaded end of the new air dryer filter/muffler.
18. Install the new filter by screwing it in place. on the air dryer assembly.

19 Reconnect the short hose from the air dryer to the solenoid purge outlet fitting.

Use a flat-nose pliers to slide the hose clamp over the fitting to hold the hose in place.

20 Reinstall the air dryer and solenoid valve assembly in the compressor.

21 Secure the assembly with a cable tie (Figure 8-86) by sliding the cable tie under the bracket and around the air dryer assembly.

22 Tighten cable tie and cut off excess.

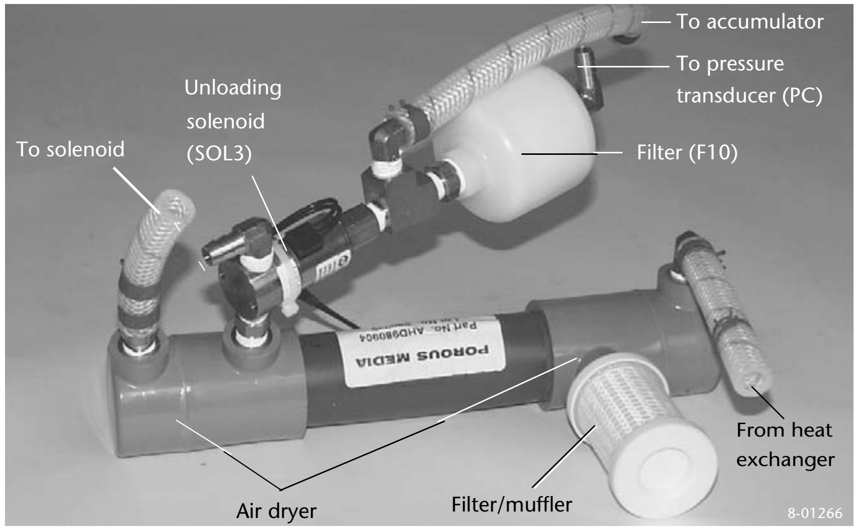


Figure 8-87. Air dryer and solenoid valve assemblies

8.17.17 Compressor assembly

The compressor assembly comprises the motor/compressor, motor starting capacitor, the motor mounts, and the mounting plate. The compressor/motor is only available as part of the 15,000 hour PM kit. Refer to the PM kit instructions.

8.17.17.1 Removing the compressor assembly

1 Remove the top cover assembly and set aside (Section 8.17.4).

2 Remove the rear panel and set aside (Section 8.17.7).

3 Remove the air dryer assembly and set aside (Section 8.17.16.1).

4 Using a magnetic Phillips screwdriver, remove the four (4) Phillips screws that secure the compressor assembly to the base of the compressor (Figure 8-88). A pair of screws are located to the left and to the right of the compressor. Set the screws aside.

5 Grasp the compressor assembly at the top and slight lift and move the assembly toward the rear of the unit.

6 Lift the compressor assembly out of the compressor compartment.

Warning

To prevent personal injury and equipment damage, have someone assist you when lifting the heavy compressor assembly.

7 Reinstall the compressor assembly by orienting the compressor assembly with the compressor intake filter on the left.

8 Carefully lower the compressor into the compartment. Slightly tilt the compressor forward to position in place.

9 Using a magnetic Phillips screwdriver, reinstall the four (4) original screws that secure the compressor assembly to the base of the unit.

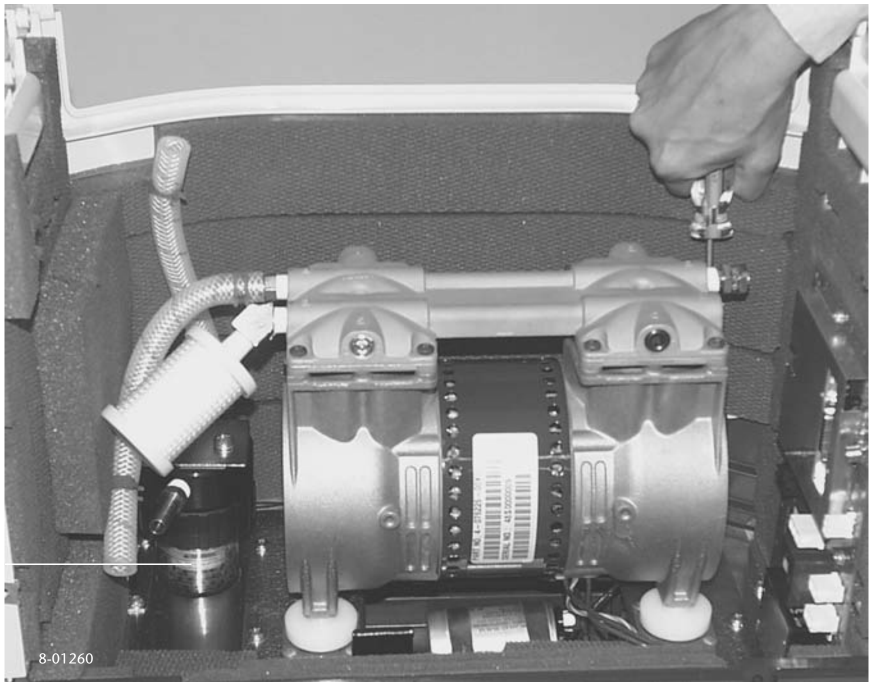


Figure 8-88. 806 compressor motor

8.17.17.2 Replacing the coalescing filter element

1 Remove the back panel assembly (Section 8.17.7) and set aside.

2 Remove the air dryer assembly (Section 8.17.16.1) and set aside·

3 Remove the plenum assembly (Section 8.17.11.1) and set aside.

4 Remove hose to outlet side of the coalescing filter. (Figure 8-88).

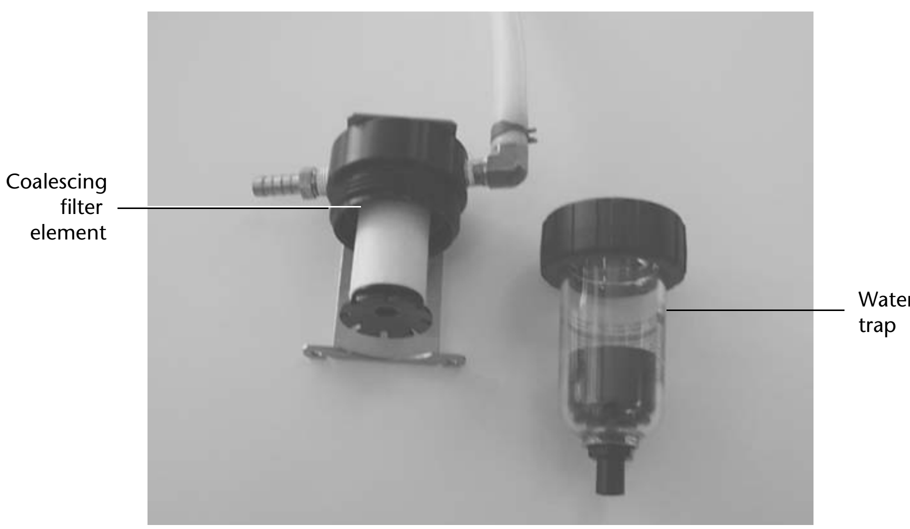


Figure 8-89. Water trap assembly

5 Using a magnetic Phillips screwdriver, remove the two (2) screws that secure the water trap bracket to the base of the module. Set the screws aside.

6 Place the water trap assembly on a work surface.

7 Unscrew the ring that secures the water trap bowl to the filter head.
8 Remove the bowl and ring and set aside.
9 Unscrew the filter element retainer and set aside.
10 Verify that the O-ring is in place around the filter head.
11 Install the new coalescing filter element.
12 Replace the original filter element retainer.
13 Reinstall the water trap bowl and hold it in place by reinstalling the original ring.
14 Using a magnetic Phillips screwdriver, remount the water trap assembly bracket to the base of the compressor using the original two (2) screws.
15 Reinstall hose on outlet side of coalescing filter.
16 Reinstall air dryer (Section 8.17.16.1).
17 Reinstall the back panel assembly (Section 8.17.8) and the plenum assembly (Section 8.17.11.1).

8.17.18 Replacing the compressor panels

The individual panels of 806 compressor enclosure are replaceable. The front and side panels are attached to the base assembly. The base assembly is replaced as a single unit. The panels are accessed by first removing the rear panel, the plenum, the compressor, and the water trap assemblies.

1 Remove the panels by first removing the following components. See the appropriate instructions in this manual for their removal.
- Top cover assembly
- Back panel/accumulator assembly
- Plenum assembly
- Air dryer assembly
- Compressor module
- Air dryer assembly
- PCB (only replacing the right panel)

2 Remove the respective panel by loosening all of the socket head screws and sliding the panel out.
3 Reinstall the panel by sliding the new panel under the hardware.
4 Tighten the socket head screw using an Allen driver. **Do not over tighten.**
5 Install the appropriate labels.
6 Reinstall all the above removed components.

NOTE:

If replacing a side panel, use the spare piece of foam in the foam kit to configure the panel to match the panel removed. Install the Tinnerman clips to the rear of the panel.

8.17.19 Reinstalling the plenum assembly

While facing the rear of the compressor, lower the plenum assembly onto the compressor while aligning the rim (at the front of the plenum assembly) to the top of the front panel.

1. Tilt the plenum assembly up enough to reconnect the hose running from the water trap inlet to the heat exchanger outlet port.
2. Using a flat-nosed pliers, slide the hose clamp over the port to hold the hose in place.
3. Reconnect the hose running from the compressor outlet to the heat exchanger inlet port.
4. Using a flat-nosed pliers, slide the hose clamp over the exchanger inlet port to hold the hose in place.
5. Reconnect the pressure transducer hose to the port on the compressor PCB.
6. Slide the hose clamp over the PCB port and tighten the clamp screw to hold the hose in place.
7. Align the plenum assembly to the side panel mounting screws and press the assembly down in place.

   Do not tighten screws at this time.
8. Reconnect pneumatic hoses (Section 8.17.16.1).

8.17.20 Reconnecting electrical cables

1. Reconnect the data cable to the compressor PCB.
2. Push the locking bracket up to lock in place.
3. Reconnect the following electrical cables to the compressor PCB:
   - Two (2) fan cables at J2 and J3
   - ac input cord at J6
   - Motor cable at J5.
4. Reconnect the ground wire connector to the ground lug at the base of the module. Use an 11/32-inch nutdriver to tighten the nut.

NOTE:

The solenoid electrical cable also connects to the PCB at J1. Refer to reinstallation instructions for the air dryer and solenoid valve assemblies in (Section 8.17.16).

8.17.21 Replacing the Tinnerman clips

1. Remove the Tinnerman clips by sliding them off the rear panel mounting holes.
2. With the flat-side of the clip facing out, install the new clip by sliding it over the rear panel mounting holes.

8.17.22 Reinstalling the back panel/accumulator assembly

1. Replace the plenum assembly on the top of the compressor module.
2. Slightly tighten the four (4) Phillips screws that secure the plenum assembly to the right and left panels.

   Do not fully tighten the four Phillips screws in order to leave enough space to allow for clearance when reinstalling the rear panel/accumulator assembly.

3 While resting the bottom of the rear panel on the base of the unit.

4 Take the hose that connects the solenoid outlet to the accumulator inlet port and route this hose behind the main supply hose.

5 While supporting the rear panel in place, reconnect the hose running from the main supply tee to the accumulator inlet port.

6 Reposition the hose clamp over the inlet port to hold the hose in place.

7 Taking care not to crimp hoses or cables, press the back panel into place and secure to the unit using the original six (6) Phillips screws.

8 Once the rear panel/accumulator assembly is secured in place, finish tightening the four (4) Phillips screws the secure the plenum assembly to the side panels.

8.17.23 Replacing the main inlet filter and reinstalling the top

1 Reinstall the support baffle by setting on the inside slot at the top of the front panel.

It should fit easily into the slot; if not, turn the baffle over and try the other side.

2 Reinstall the compressor top cover assembly and secure in place by tightening the eight (8) captive screws.

3 Once the top cover assembly is in place, install the new main inlet filter by pressing it into the slot between the supporting baffle and the rear panel.

Ensure all filter edges are in place.

8.17.24 Reinstalling the compressor module

Warning

To prevent personal injury and equipment damage, have someone assist you when lifting the heavy ventilator and its components.

1 Reinstall the compressor onto the cart and secure using the captive hardware on the cart.

2 Reattach and secure the compressor data cable.

3 Reattach the compressor power cord.

4 Secure the power cord using the power cord retainer. Secure the retainer with two (2) screws.

5 Reattach the compressor supply tube.

8.17.25 Running performance verification test

It is necessary to run a Performance Verification on the entire ventilator, as described in Section 5 of this manual.

8.18 Backup power source (BPS)

The BPS consists of a +24 V battery pack and corresponding charging circuitry on its PCB assembly. The battery and related components are enclosed in a sturdy aluminum chassis and mounted to the (optional) cart.

8.18.1 Removing BPS

1. Loosen two captive screws that secure battery cable to connector on side of power supply assembly. Disconnect cable.
2. Loosen two captive screws at rear of BPS.
3. Slide BPS forward off slide mounts and place unit on a firm work surface (Figure 8-90).

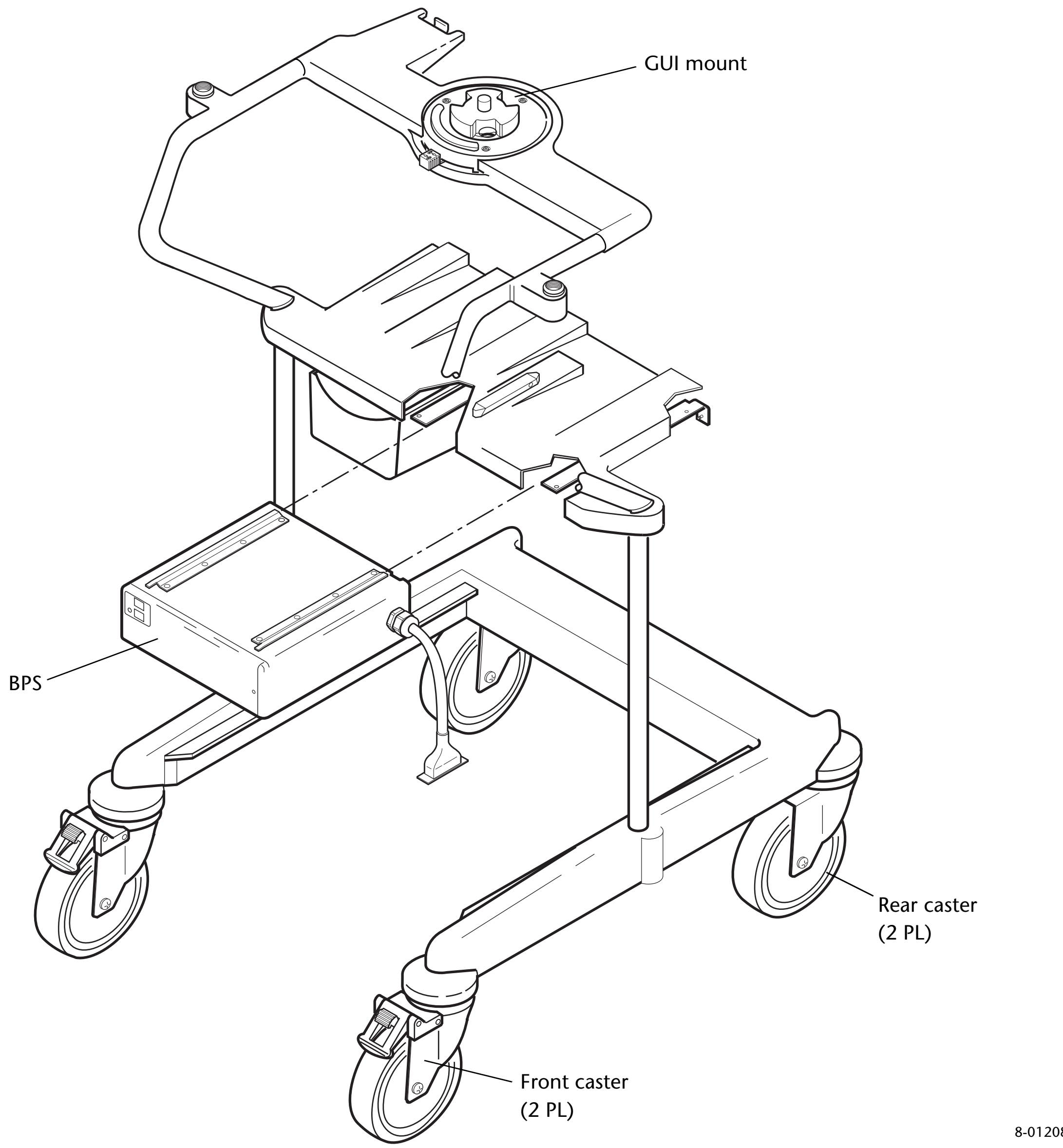


Figure 8-90. BPS and cart

8.18.2 Installing BPS

1. From front of cart, slide brackets at top of BPS onto rails, then push BPS to back (Figure 8-90). Secure BPS to rails with captive screws.
2. Open protective cover on BDU connector, and connect BPS cable to BDU (Figure 8-91). Tighten captive screws.

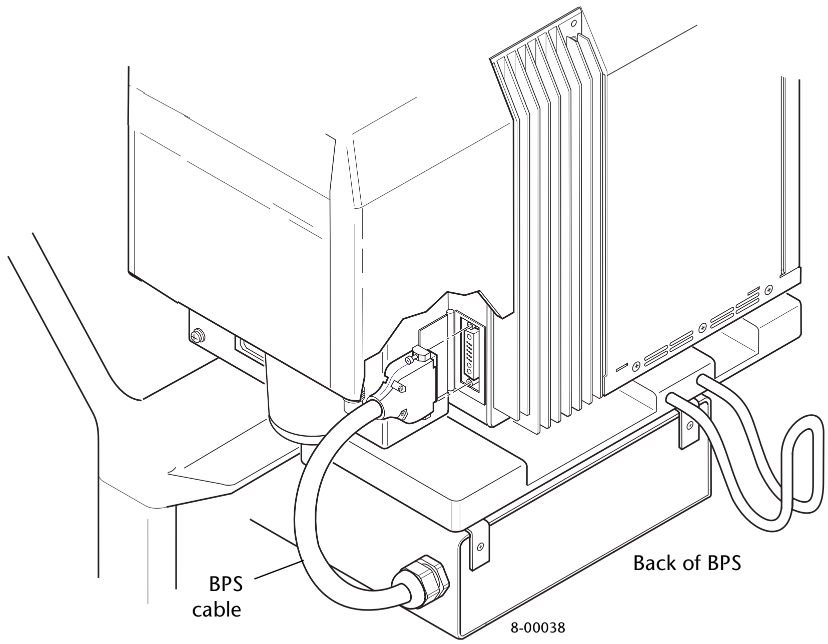


Figure 8-91. Connecting BPS to BDU

8.18.3 Battery pack

Caution

To prevent damage to ESD-sensitive components, always follow ESD guidelines when disassembling the BPS.

8.18.3.1 Removing battery pack

1. Remove BPS (Section 8.18.1).
2. Remove two flat-head screws that secure fascia panel to BPS front plate (Figure 8-92).
3. Remove four flat-head screws that secure BPS front plate to unit.
4. Just inside unit, disconnect battery cable connector from PCB.
5. Grasp pull loop and slide battery pack (attached to plate) out of enclosure.

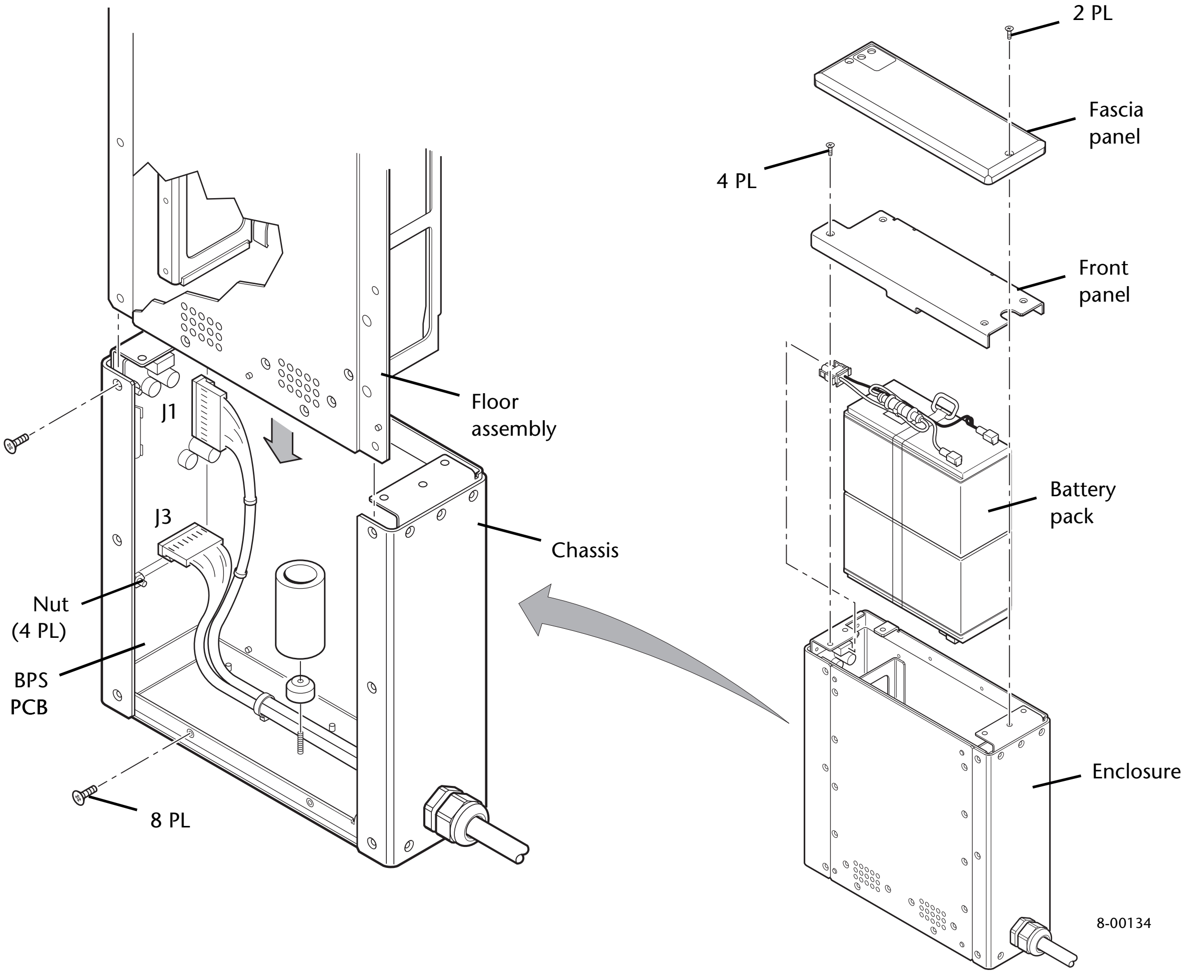


Figure 8-92. Replacing battery pack and BPS PCB

8.18.3.2 Installing battery pack

1 Slide battery onto plate and connect battery cable to PCB (Figure 8-92).

2 Align front plate to four screw locations on front of BPS housing. Install four flat-head screws and tighten until snug.

3 Align fascia panel to two screw locations on front plate. Install two flat-head screws and tighten until snug. **Do not overtighten.**

4 Orient battery pack housing with two LEDs toward front of cart, and slide unit onto slide mounts located under BDU platform

5 Install BPS (Section 8.18.2).

8.18.4 BPS PCB

8.18.4.1 Removing BPS PCB

1. Remove battery pack (Section 8.18.3.1).
2. Remove eight flat-head screws that secure floor assembly of BPS (Figure 8-92).
3. Disconnect battery cable connections from PCB at J1 and J3.
4. Using a 5/16-in. nutdriver, remove four retaining nuts that secure PCB to BPS chassis. Remove PCB.

8.18.4.2 Installing BPS PCB

1. Orient PCB to four retaining screws mounted to BPS chassis and set PCB in place .
2. Using 5/16-in. nutdriver, install four retaining nuts and tighten until snug. **Do not overtighten**.
3. Connect battery cable connections to PCB at J1 and J3.
4. Place BPS enclosure on flat surface with two mounting guides on top.
5. Lift battery plate with plate down and battery cable connection toward you.
6. Align bottom of plate under brackets of BPS enclosure and slide unit into housing.
7. Install eight flat-head screws that secure BPS bottom plate to unit. Tighten until snug.
8. Install battery pack (Section 8.18.3.2).

8.19 Cart

8.19.1 Casters

8.19.1.1 Removing casters

1. Remove GUI (Section 8.14.5).
2. Remove BDU (Section 8.15.1).
3. Remove compressor unit from cart (Section 8.17.3.2).
4. Remove BPS (Section 8.18.1).
5. Lay cart on nonabrasive surface and remove caster using caster wrench (Figure 8-93).

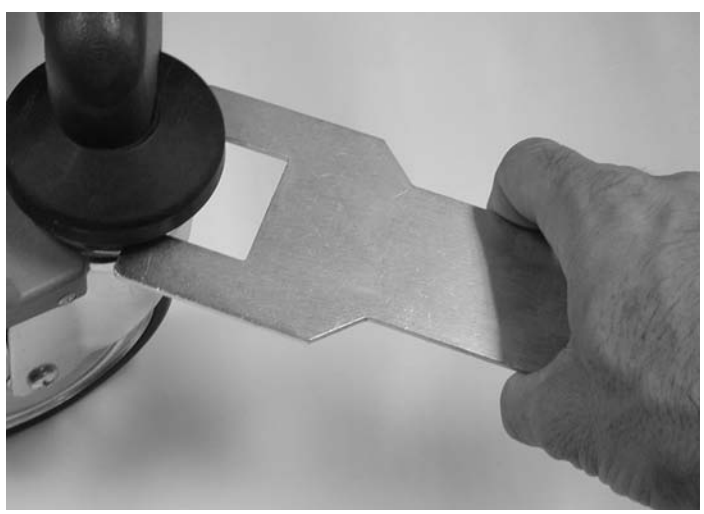


Figure 8-93. Removing caster

8.19.1.2 Installing casters

1 Insert caster through bumper and thread caster into chassis. Tighten with caster wrench until snug.

2 Install BPS (Section 8.18.2).

3 Install compressor unit onto cart (Section 8.17.24).

4 Install BDU (Section 8.15.3).

5 Install GUI (Section 8.14.5).

8.19.2 Removing/installing GUI mount

1 Remove GUI (Section 8.14.5) and place on flat work surface.

2 Remove three screws that retain GUI mount (Figure 8-94).

3 Lift entire GUI housing assembly and place on flat work surface.

4 Gently pull cover away from release handle.

5 Install assembly by placing release cover upside down on work surface and installing spring over boss (Figure 8-94).

6 Place release handle into cover and align post with opposite end of spring.

7 Place entire assembly onto cart, aligning three mounting holes with cover. Install three screws and tighten until snug.

8 Verify release handle freely returns to “home position” when released.

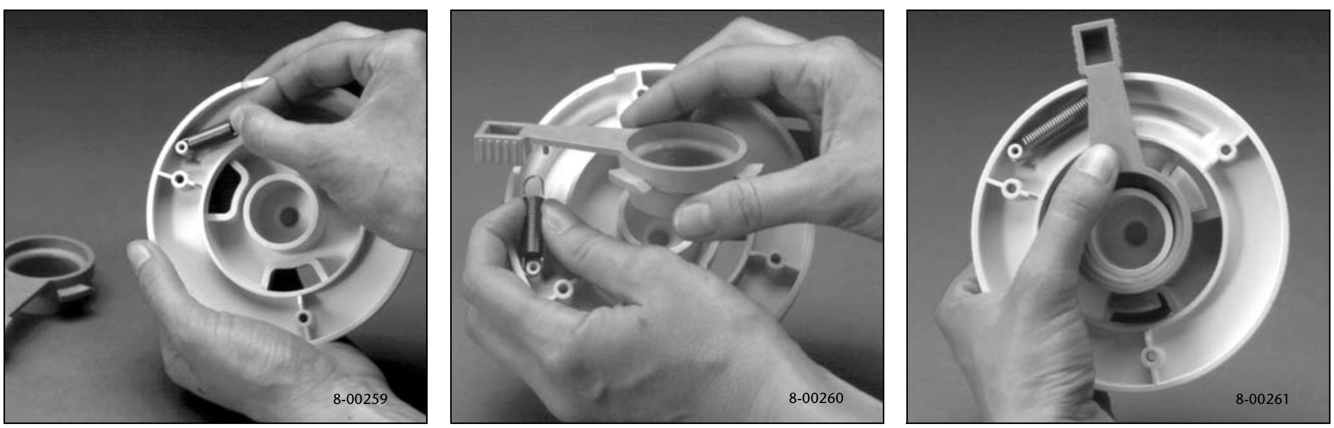


Figure 8-94. Assembling GUI mount

8.19.3 Removing/installing flex arm inserts

On older style carts, remove and install the flex arm inserts as follows:

1 Remove flex arm or any item secured in flex arm insert (socket).

2 Remove flat-head screw from cart directly beneath insert in cart. Remove insert.

Figure 8-95. Flex arm insert

3 Place insert into cavity in cart, aligning screwholes in cart and insert.

4 From beneath the cavity of the cart, insert flat-head screw into insert and tighten until snug. Verify insert is tight and does not rotate.

On newer. ready to assemble (RTA) carts, remove and instal the flex are inserts as follows:

1 Slide locking ring off the GUI mount.

2 Install new insert.

3 Reinstall locking ring.

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