

Puritan Bennett™

980 Series Ventilator



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1 Introduction

1.1 Overview

This manual contains information for operating the Puritan Bennett™ 980 Series Ventilators. Before operating the ventilator system, thoroughly read this manual. The latest version of this manual is available on the Internet at:

www.medtronic.com/covidien/support/product-manuals

Click Acute Care Ventilation > PuritanBennett™ 980 Ventilator, then follow the prompts to select the desired manual.

To order an additional copy of this manual, contact Covidien Customer Service or your local representative.

1.1.1 Related Documents

Documentation is available online at the URL above. Covidien makes available all appropriate information relevant to use and service of the ventilator. For further assistance, contact your local Covidien representative.

- ***The Puritan Bennett™ 980 Series Ventilator Operator's Manual***—Provides basic information on operating the ventilator and troubleshooting errors or malfunctions. Before using the ventilator, thoroughly read this manual.
- ***The Puritan Bennett™ 980 Series Ventilator Service Manual***—Provides information to Covidien-trained service technicians for use when testing, troubleshooting, repairing, and upgrading the ventilator.

This chapter contains the following:

- Symbol definitions
- Safety Information, including warnings, cautions, and notes
- Technical assistance information
- How to access on-screen help
- How to access warranty information

- Serial number interpretation
- Information regarding electromagnetic susceptibility

1.2 Global Symbol Definitions

Table 1-1. describes the symbols shown on the ventilator shipping cartons. Other symbols appearing on various labels are shown in Chapter 2.

Table 1-1. Shipping Carton Symbols and Descriptions

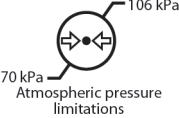
Symbol	Description
	Serial number
	Part number
	Manufacturer
	This side up
	Fragile
	Humidity limitations: 10% to 95% relative humidity, non-condensing (operation and storage)
	Temperature limitations: 10°C to 40°C (50°F to 104°F) (operation) –20°C to 70°C (–68°F to 158°F) (storage)
	Atmospheric pressure limitations: 70 kPa to 106 kPa (10.2 psi to 15.4 psi)
	Keep dry
	CSA certification mark that signifies the product has been evaluated to the applicable ANSI/Underwriters Laboratories Inc. (UL) and CSA standards for use in the U.S. and Canada.

Table 1-1. Shipping Carton Symbols and Descriptions (Continued)

Symbol	Description
	U.S. federal law restricts this device to sale by or on the order of a physician.
	Refer to instruction manual.

1.3 Safety Information

1.3.1 Safety Symbol Definitions

This section contains safety information for users, who should always exercise appropriate caution while using the ventilator.

Table 1-2. Safety Symbol Definitions

Symbol	Definition
	WARNING Warnings alert users to potential serious outcomes (death, injury, or adverse events) to the patient, user, or environment.
	Caution Cautions alert users to exercise appropriate care for safe and effective use of the product.
	Note Notes provide additional guidelines or information.

1.3.2 Warnings Regarding Fire Hazards



WARNING:

Explosion hazard—Do not use in the presence of flammable gases. An oxygen-rich environment accelerates combustibility.



WARNING:

To avoid a fire hazard, keep all components of the system away from all sources of ignition (such as matches, lighted cigarettes, flammable medical gases, or heaters). Oxygen-rich environments accelerate combustibility.



WARNING:

In case of fire or a burning smell, immediately take the following actions if it is safe to do so: disconnect the patient from the ventilator and disconnect the ventilator from the oxygen supply, facility power, and all batteries. Provide alternate method of ventilatory support to the patient, if required.



WARNING:

Replacement of batteries by inadequately trained personnel could result in an unacceptable risk, such as excessive temperatures, fire, or explosion.



WARNING:

To minimize fire hazard, inspect and clean or replace, as necessary, any damaged ventilator parts that come into contact with oxygen.



WARNING:

To prevent electrostatic discharge (ESD) and potential fire hazard, do not use antistatic or electrically conductive hoses or tubing in or near the ventilator breathing system.

1.3.3 General Warnings



WARNING:

To ensure proper operation and avoid the possibility of physical injury, only qualified medical personnel should attempt to set up the ventilator and administer treatment with the ventilator.



WARNING:

In case of ventilator failure, the lack of immediate access to appropriate alternative means of ventilation can result in patient death. An alternative source of ventilation, such as a self-inflating, manually-powered resuscitator (as specified in ISO 10651-4 with mask) should always be available when using the ventilator.



WARNING:

Patients on mechanical ventilation should be monitored by clinicians for proper patient ventilation.



WARNING:

The ventilator system is not intended to be a comprehensive monitoring device and does not activate alarms for all types of conditions. For a detailed understanding of ventilator operations, be sure to thoroughly read this manual before attempting to use the ventilator system.

**WARNING:**

To prevent patient injury, do not use the ventilator if it has a known malfunction. Never attempt to override serious malfunctions. Replace the ventilator and have the faulty unit repaired by trained service personnel.

**WARNING:**

To prevent patient injury, do not make unauthorized modifications to the ventilator.

**WARNING:**

To prevent injury and avoid interfering with ventilator operation, do not insert tools or any other objects into any of the ventilator's openings or ports.

**WARNING:**

The audio alarm volume level is adjustable. The operator should set the volume at a level that allows the operator to distinguish the audio alarm above background noise levels. See [To adjust alarm volume](#), page 3-37 for instructions on alarm volume adjustment.

**WARNING:**

Do not pause, disable, or decrease the volume of the ventilator's audible alarm if patient safety could be compromised.

**WARNING:**

If increased pressures are observed during ventilation, it may indicate a problem with the ventilator. Check for blocked airway, circuit occlusion, and run SST.

**WARNING:**

The LCD panel contains toxic chemicals. Do not touch broken LCD panels. Physical contact with a broken LCD panel can result in transmission or ingestion of toxic substances.

**WARNING:**

If the graphical user interface (GUI) display/LCD panel is blank or experiences interference and cannot be read, check the patient, then verify via the status display that ventilation is continuing as set. Because breath delivery is controlled *independently* from the GUI, problems with the display will not, by themselves, affect ventilation. The ventilator, however, should be replaced as soon as possible and repaired by qualified service personnel.

**WARNING:**

The Puritan Bennett™ 980 Series Ventilator contains phthalates. When used as indicated, very limited exposure to trace amounts of phthalates may occur. There is no clear clinical evidence that this degree of exposure increases clinical risk. However, to minimize risk of phthalate exposure in children and nursing or pregnant women, this product should only be used as directed.

**WARNING:**

Although the 980 Series Ventilator meets the standards listed in Chapter 11, the internal lithium-ion battery of the device is considered to be Dangerous Goods (DG) Class 9 - Miscellaneous, when transported in commerce. The 980 Series Ventilator and the associated lithium-ion battery are subject to strict transport conditions under the Dangerous Goods Regulation for air transport (IATA: International Air Transport Association), International Maritime Dangerous Goods code for sea and the European Agreement concerning the International Carriage of Dangerous Goods by Road (ADR) for Europe. Private individuals who transport the device are excluded from these regulations although for air transport some requirements may apply.

1.3.4 Warnings Regarding Environment of Use

**WARNING:**

Do not position the ventilator next to anything that blocks or restricts the gas inlet or cooling air circulation openings, gas exhaust port, fan intake, or alarm speaker, as this may:

- limit the air circulation around the ventilator, potentially causing overheating;
- limit the ventilator's ability to exhaust patient exhaled gas leading to potential harm;
- limit the clinician's ability to hear ventilator alarms.

**WARNING:**

To avoid injury, do not position the ventilator in a way that makes it difficult to disconnect the patient.

**WARNING:**

To ensure proper operation, do not position the ventilator in a way that makes it difficult to access the AC power cord.

**WARNING:**

Do not use the ventilator in a hyperbaric chamber. It has not been validated for use in this environment.

**WARNING:**

Do not use the ventilator in the presence of strong magnetic fields. Doing so could cause a ventilator malfunction.

**WARNING:**

Do not use the ventilator during radiotherapy (i.e. cancer treatment using ionizing radiation), as doing so could cause a ventilator malfunction.

**WARNING:**

To avoid the risk of ventilator malfunction, operate the ventilator in an environment that meets specifications. See [Table 11-8.](#) on page [11-6](#).

**WARNING:**

Do not use the ventilator as an EMS transport ventilator. It has not been approved or validated for this use.

1.3.5 Warnings Before Using Equipment

**WARNING:**

Before activating any part of the ventilator, be sure to check the equipment for proper operation and, if appropriate, run SST as described in this manual. See [To run SST](#), page 3-43.

**WARNING:**

Check for leaks in the ventilator breathing system by running SST prior to ventilating a patient.

**WARNING:**

Lock the ventilator's casters during use to avoid the possibility of extubation due to inadvertent ventilator movement.

**WARNING:**

The ventilator accuracies listed in [Table 11-12.](#) , [Table 11-13.](#) , and [Table 11-14.](#) are applicable only under specified operating conditions. See [Table 11-8.](#) on page [11-6](#) for environmental specifications. If the ventilator is operated outside specified ranges, the ventilator may supply incorrect information and the accuracies listed in the aforementioned tables do not apply. A hospital biomedical technician must verify the ventilator is operated in the environmental conditions specified.

1.3.6 Warnings Regarding Electrical Power

**WARNING:**

To avoid the risk of electrical shock:

Use only Covidien batteries, adapters, and cables.

- Do not use batteries, adapters or cables with visible signs of damage.
- Do not touch internal components.

1.3.7 Warnings Regarding Ventilator Settings



WARNING:

The ventilator offers a variety of breath delivery options. Throughout the patient's treatment, the clinician should carefully select the ventilation mode and settings to use for that patient, based on clinical judgment, the condition and needs of the patient, and the benefits, limitations, and characteristics of the breath delivery options. As the patient's condition changes over time, periodically assess the chosen modes and settings to determine whether or not those are best for the patient's current needs.



WARNING:

Avoid nuisance alarms by applying appropriate alarm settings.



WARNING:

To prevent inappropriate ventilation, select the correct Tube Type (ET or Tracheostomy) and tube inner diameter (ID) for the patient's ventilatory needs. Inappropriate ventilatory support leading to over- or under-ventilation could result if an ET tube or trach tube setting larger or smaller than the actual value is entered.



WARNING:

Setting expiratory volume alarms to OFF increases the risk of not detecting a low returned volume.



WARNING:

Setting any alarm limits to OFF or extreme high or low values can cause the associated alarm not to activate during ventilation, which reduces its efficacy for monitoring the patient and alerting the clinician to situations that may require intervention.

1.3.8 Warnings Regarding Hoses, Tubing, and Accessories



WARNING:

To prevent electrostatic discharge (ESD) and potential fire hazard, do not use antistatic or electrically conductive hoses or tubing in or near the ventilator breathing system.



WARNING:

Adding accessories to or removing accessories from the *ventilator breathing system (VBS)* can change the pressure gradient across the VBS and affect ventilator performance. Ensure that any changes to the ventilator circuit configurations do not exceed the specified values for circuit compliance and for inspiratory or expiratory limb total resistance. See [Table 11-4](#) on page 11-3. If adding accessories to or removing accessories from the VBS, always run SST to establish circuit compliance and resistance prior to ventilating the patient.

**WARNING:**

Use of a nebulizer or humidifier can lead to an increase in the resistance of inspiratory and exhalation filters. Monitor the filters frequently for increased resistance or blockage.

**WARNING:**

During transport, the use of breathing tubing without the appropriate cuffed connectors may result in the circuit becoming detached from the ventilator.

**WARNING:**

The added gas from an external pneumatic nebulizer can adversely affect spirometry, delivered O₂%, delivered tidal volumes, and breath triggering. Additionally, aerosolized particulates in the ventilator circuit can lead to an increase in exhalation filter resistance.

**WARNING:**

Carefully route patient tubing and cabling to reduce the possibility of patient entanglement or strangulation.

**WARNING:**

Always use filters designed for use with the Puritan Bennett™ 980 Series Ventilator. Do not use filters designed for use with other ventilators. See [Table 9-1](#) for relevant filter part numbers.

**WARNING:**

To avoid liquid entering the ventilator, empty the expiratory condensate vial before fluid reaches the maximum fill line.

**WARNING:**

Accessory equipment connected to the analog and digital interfaces must be certified according to IEC 60601-1. Furthermore, all configurations shall comply with the system standard IEC 60601-1-1. Any person who connects additional equipment to the signal input part or signal output part of the ventilator system configures a medical system, and is therefore responsible for ensuring the system complies with the requirements of the system standard IEC 60601-1-1. If in doubt, consult Covidien Technical Services at 1 800 255 6774 or your local representative.

**WARNING:**

Do not use HMEs (heat and moisture exchangers) and heated humidifiers together. This may result in the HME absorbing water and becoming obstructed, resulting in high airway pressures.

1.3.9 Warnings Regarding Gas Sources

**WARNING:**

Do not use nitric oxide, helium or mixtures containing helium with the ventilator. It has not been validated for use with these gas mixtures.

**WARNING:**

To avoid the risk of ventilator malfunction, do not use the ventilator with anesthetic gases.

**WARNING:**

For proper ventilator operation, use only clean, dry, medical grade gases when ventilating a patient.

**WARNING:**

Use of only one gas source could lead to loss of ventilation or hypoxemia if that one gas source fails and is not available. Therefore, always connect at least two gas sources to the ventilator to ensure a constant gas supply is available to the patient in case one of the gas sources fails. The ventilator has two connections for gas sources: air inlet, and oxygen inlet.

**WARNING:**

Use of the ventilator in altitudes higher or barometric pressures lower than those specified could compromise ventilator operation. See [Table 11-8.](#) on page [11-6](#) for a complete list of environmental specifications.

**WARNING:**

The ventilator should be connected to a gas pipeline system compliant to ISO 7396-1:2007 because:

- Installation of the ventilator on a non-ISO 7396-1:2007 compliant gas pipeline system may exceed the pipeline design flow capacity.
- The ventilator is a high-flow device and can interfere with the operation of other equipment using the same gas source if the gas pipeline system is not compliant to ISO 7396-1:2007.

1.3.10 Warnings Regarding Infection Control

**WARNING:**

Patients receiving mechanical ventilation may experience increased vulnerability to the risk of infection. Dirty or contaminated equipment is a potential source of infection. It is recognized that cleaning, sterilization, sanitation, and disinfection practices vary widely among health care institutions. Always follow your hospital infection control guidelines for handling infectious material. Follow the instructions in this manual and your institution's protocol for cleaning and

sterilizing the ventilator and its components. Use all cleaning solutions and products with caution. Follow manufacturer's instructions for individual cleaning solutions. See [Chapter 7](#).



WARNING:

To prevent infection and contamination, always ensure inspiratory and exhalation bacteria filters are installed before ventilating the patient.



WARNING:

Never attempt to reuse single-use components or accessories. Doing so increases risk of cross-contamination and reprocessing of single-use components or accessories may compromise functionality leading to possible loss of ventilation.

1.3.11 Warnings Regarding Ventilator Maintenance



WARNING:

To ensure proper operation and avoid the possibility of physical injury, this ventilator should only be serviced by qualified technicians who have received appropriate Covidien-provided training for the maintenance of this ventilator.



WARNING:

Follow preventive maintenance according to specified intervals listed in these tables. See [Table 7-1](#). on page [7-2](#) and [Table 7-4](#). on page [7-15](#).

1.3.12 Cautions



Caution:

To prevent possible equipment damage, ensure the casters are locked to prevent inadvertent movement of the ventilator during routine maintenance, or when the ventilator is on an incline.



Caution:

Do not use sharp objects to make selections on the display or keyboard.



Caution:

To ensure optimal performance, keep the GUI touch screen and keyboard clean and free from foreign substances. See [Table 7-2](#). on page [7-4](#).



Caution:

To avoid moisture entering the ventilator and possibly causing a malfunction, Covidien recommends using a wall air water trap when using piped medical air from a facility-based air compressor.

-  **Caution:**
Use only the cleaning agents specified. See [Table 7-2.](#) on page [7-4](#) for approved cleaning agents.
-  **Caution:**
Clean the compressor inlet filter according to the interval listed in Chapter [7](#). See [Table 7-1.](#) on page [7-2](#).
-  **Caution:**
Do not block cooling vents.
-  **Caution:**
Ensure proper connection and engagement of exhalation and inspiratory filters.
-  **Caution:**
Follow instructions for proper GUI and BDU (breath delivery unit) mounting as described in the *Puritan Bennett™ 980 Series Ventilator Installation Instructions*.
-  **Caution:**
To prevent possible damage to electronic circuitry, do not connect the GUI to the BDU while power is applied.
-  **Caution:**
Follow proper battery installation instructions as described in this manual.
-  **Caution:**
When transferring the ventilator from storage conditions, allow its temperature to stabilize at ambient conditions prior to use.
-  **Caution:**
Remove extended and primary batteries from ventilator prior to transporting in a vehicle. Failure to do so could result in damage to the ventilator.

1.3.13 Notes

-  **Note:**
Federal law (U.S.A.) restricts the sale of this device except by or on the order of a physician.
-  **Note:**
When using non-invasive ventilation (NIV), the patient's actual exhaled volume may differ from the exhaled volume reported by the ventilator due to leaks around the mask.

**Note:**

When utilizing a closed-suction catheter system, the suctioning procedure can be executed using existing mode, breath type, and settings. To reduce potential for hypoxemia during the procedure, elevated delivered oxygen can be enabled using the Elevate O₂ control. See *To adjust the amount of elevated O₂ delivered for 2 minutes*, page 3-36.

1.4 Obtaining Technical Assistance

1.4.1 Technical Services

For technical information and assistance, to order parts, or to order an operator's manual or service manual, contact Covidien Technical Services at 1 800 255 6774 or a local Covidien representative. The *Puritan Bennett™ 980 Series Ventilator Service Manual* includes information necessary to service or repair the ventilator when used by qualified service personnel.

When calling Covidien Technical Services, or a local Covidien representative, have the BDU and GUI serial numbers available, as well as the firmware version number of the ventilator system.



The ventilator's configuration is available by touching the wrench icon on the GUI screen, then touching the Options tab. Have this information available whenever requesting technical assistance.



Manufacturer's address

Covidien USA
2101 Faraday Ave.
Carlsbad, CA 92008
Phone: 1 800 255 6774 option 4
Email: VentTechSupport@covidien.com



For online technical support, visit the SolvITSM Center Knowledge Base at solvitcenter.puritanbennett.com/ and follow the prompts.

The SolvIT Center provides answers to frequently asked questions about the ventilator system and other Puritan Bennett products 24 hours a day, 7 days a week.

1.4.2 On-screen Help

The ventilator is equipped with an on-screen help system that enables users to select an item on the screen and display a description of that item. Follow the procedure below to access and use on-screen help.

Accessing On-screen Help Topics

Help topics on the ventilator are called tooltips. If a tooltip is available, a glowing blue outline appears around the item in question.



To access tooltips

1. Touch the item in question for a period of at least 0.5 second, or drag the help icon (the question mark icon appearing at the lower right of the GUI screen) to the item in question. A tooltip appears with a short description of the item. Most screen items have tooltips associated with them, providing the operator with access to a multitude of help topics.
2. Touch “more” on the dialog to display an expanded description.
3. Touch “close” to close the dialog, or let it fade away after 5 seconds.



Note:

Dragging the help icon causes the tooltip to display in its unexpanded state.



Note:

Dragging the help icon and pausing causes a tooltip to display. Continue dragging to another item to dismiss the last tooltip and display another tooltip.

Other Resources

Additional resources for information about the ventilator can be found in the *Puritan Bennett™ 980 Series Ventilator Service Manual* and appendices in this manual for BiLevel 2.0, Leak Sync, PAV+, NeoMode 2.0, Proximal Flow, and Trending functions.

1.5 Warranty Information

To obtain warranty information for a covered product, contact Covidien Technical Services at 1 800 255 6774 or call a local Covidien representative.

1.6 Manufacture Date



The graphical user interface (GUI) and breath delivery unit (BDU) each possess a specific year of manufacture applicable only for that assembly. These dates are contained in the serial numbers for each assembly or option. Serial numbers for the 980 Ventilator final units consist of 10 digits, in the following format:

35ZYYXXXXX

where

- 35 signifies the unit was manufactured in Galway, Ireland.

- Z represents the product code (B = breath delivery unit, G = GUI, C = DC compressor, P = Proximal Flow monitoring option). The product codes shown here are typically the most common. There may be other product codes shown in the serial number depending upon the particular option(s) purchased.
- YY is a two-digit year code that changes with each year.
- XXXXX is a sequential number that resets at the beginning of each new year.

Serial numbers are located on labels on the back panels of the GUI and BDU, and in various locations on product options.

1.7 Manufacturer



Covidien Inc, 15 Hampshire Street, Mansfield, MA 02048 USA.

1.8 Electromagnetic Compatibility

The ventilator system complies with the requirements of IEC 60601-1-2:2007, IEC 60601-1-2: 2014 (EMC Collateral Standard) and AIM Standard 7351731 Rev 2.00.2017. Certain transmitting devices (cellular phones, two-way radios, cordless phones, paging transmitters, RFID devices, etc.) emit radio frequencies that could interrupt ventilator operation if operated in a range too close to the ventilator. Practitioners should be aware of possible radio frequency interference if portable devices are operated in close proximity to the ventilator.

The Puritan Bennett™ 980 Series Ventilator requires special precautions to be taken regarding electromagnetic compatibility (EMC) and must be installed and put into service according to the EMC information provided in Chapter [11](#).

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2 Product Overview

2.1 Overview

This chapter contains introductory information for the Puritan Bennett™ 980 Series Ventilator.



Note:

- Items shown in ***bold-italic*** font are contained as entries in the glossary.
- Items shown in **bold** font are physical hardware features (e.g., **to patient** port, **exhaust** port)
- Alarms are shown in ALL CAPITAL letters.

Communication between the ventilator's ***graphical user interface (GUI)*** and the ***breath delivery unit (BDU)*** occurs continuously via independent ***central processing units (CPUs)***.

See [Figure 2-12](#), on page 2-36 and [Figure 2-13](#), on page 2-38 and their associated reference designators when reading the following paragraphs.

Gas delivery starts with the ventilator connected to wall (or bottled) air and oxygen. Gas travels to the mix module where gas pressures are regulated by their respective ***proportional solenoid valves (PSOLs)***. The PSOLs meter the gases according to the ventilator settings entered, then the gases flow through individual air and oxygen flow sensors into the mix manifold and accumulator for mixing. The individual gas pressures are continuously monitored both before and after they are mixed in the mix manifold and accumulator assemblies. The mixed gas then flows to the inspiratory pneumatic system where it flows through the breath delivery flow sensor and then the inspiratory PSOL for delivery to the patient.

Before the gas reaches the patient, it passes through an internal inspiratory bacteria filter, then through an external inspiratory bacteria filter attached to the ventilator's gas outlet (the **to patient** port) where the breathing circuit is attached. When the gas returns from the patient, it flows through the expiratory limb of the breathing circuit, to the **from patient** port on the exhalation bacteria filter (which includes a condensate vial) before flowing through the exhalation flow sensor and ***exhalation valve (EV)***. A gas exhaust port allows exhaled gas to exit the ventilator and flow to the room.

The ventilator recognizes the patient's breathing effort using pressure triggering (***P-Trig***) or flow triggering (***v-Trig***). During pressure triggering, as the patient inhales, the airway pressure decreases and the inspiratory pressure transducer (***PI***) monitors this pressure decrease. When the pressure drops to at least the value of the pressure sensitivity (P_{SENS}) setting, the ventilator delivers a breath. During flow triggering, the difference between inspiratory and expiratory

flows is monitored. As the patient inhales, the exhalation flow sensor measures less flow, while the delivery flow sensor measurement remains constant. When the difference between the two measurements is at least the value of the operator-set flow sensitivity ($\dot{V}_{\text{SENS}}$), the ventilator delivers a breath. If the patient is not inhaling, any difference between delivered flow and expiratory flow is due to flow sensor inaccuracy or leaks in the ventilator breathing circuit. To compensate for leaks, which can cause autotriggering, the clinician can increase the $\dot{V}_{\text{SENS}}$ setting or enable Leak Sync.

**Note:**

Leak Sync is a software function that is enabled by the clinician. Details on its operation are provided in Appendix B.

A backup pressure triggering threshold of 2 cmH₂O is also in effect. This provides enough pressure sensitivity to avoid autotriggering, but will still allow the ventilator to trigger with acceptable patient effort.

The exhalation valve controls positive end expiratory pressure (**PEEP**) using feedback from the expiratory pressure transducer (**PE**). The valve controller also cycles the ventilator into the expiratory phase if the expiratory pressure measurement (P_E) equals or exceeds the operator-set high circuit pressure limit. The P_E measurement also controls when the safety valve (**SV**) opens. If P_E measures 110 cmH₂O or more in the ventilator breathing circuit, the safety valve opens, allowing the patient to breathe room air (if able to do so) through the valve.

2.2 Ventilator Description

The ventilator system is available in three models. All ventilators provide continuous ventilation to patients requiring respiratory support.

- **Puritan Bennett™ 980 Pediatric–Adult Ventilator** — The Pediatric–Adult model ventilates pediatric or adult patients with predicted body weights from 3.5 kg to 150 kg, and with tidal volumes from 25 mL to 2500 mL.
- **Puritan Bennett™ 980 Neonatal Ventilator** — The Neonatal model ventilates neonatal patients with predicted body weights from 0.3 kg to 7.0 kg, and with tidal volumes for mandatory volume-controlled breaths from 2 mL to 315 mL.
- **Puritan Bennett™ 980 Universal Ventilator** — The Universal model ventilates neonatal, pediatric, and adult patients with predicted body weights from 0.3 kg to 150 kg, and with tidal volumes for mandatory volume-controlled breaths from 2 mL to 2500 mL.

To ventilate neonatal patients on the Pediatric–Adult or Universal models, the NeoMode 2.0 software option is required. For details regarding the NeoMode 2.0 software option, see Appendix D.

The estimated service life of the ventilator is approximately 10 years, provided the preventive maintenance schedule stated in the *Puritan Bennett™ 980 Series Ventilator Service Manual* is followed; however, service life of individual units may vary.

The ventilator's IEC 60601-1/EN 60601-1 classification is:

- Protection class I
- Type BF
- Mobile
- Internally powered
- IP 21 equipment
- Continuous operation
- Not suitable for use with flammable medical gases (not AP or APG)

See [Table 2-3](#) on page 2-9 for a description of the meaning of the IP classification.

The ventilator system uses a **graphical user interface (GUI)** and **breath delivery unit (BDU)** for entering patient settings and delivering breaths to the patient. The GUI contains electronics capable of transferring the clinician's input (by touching the screen) to the BDU where pneumatic and electronic systems, respectively, generate the breathing parameters.

2.3 Indications for Use

The Puritan Bennett™ 980 Series Ventilator is designed for use on patient population sizes from Neonatal (NICU) through Adult who require respiratory support or mechanical ventilation and weigh a minimum of 0.3 kg (0.66 lb). It is suitable for service in hospital (institutions) and intra-hospital transport to provide continuous positive pressure ventilatory support using medical oxygen and compressed medical air from either an internal air compressor or external air sources to deliver oxygen concentrations of 21% to 100%. Ventilatory support can be delivered invasively or non-invasively, to patients who require the following types of ventilator support:

- Positive Pressure Ventilation, delivered invasively (via endotracheal tube or trach tube) or non-invasively (via mask or nasal prongs).
- Assist/ Control, SIMV or Spontaneous modes of ventilation.



Note:

Intended typical usage may be defined to include the following for the ventilator system:

Hospital Use — Typically covers areas such as operating rooms, special procedure areas, intensive and critical care areas within the hospital and in hospital-type facilities. Hospital-type facilities include skilled nursing facilities, surgicenters, and sub-acute centers.

Intra-hospital transport — Includes transport of a patient within the hospital or hospital-type facility. All external hospital transportation (i.e. ambulance or aircraft) is excluded.



Note:

Federal law (U.S.A) restricts the sale of this device except by or on the order of a physician.

2.4 Contraindications

Do not operate the ventilator in a magnetic resonance imaging (MRI) environment.

2.5 Components List



Note:

The ventilator has no components made of natural rubber latex.



Note:

The components in the gas pathway that can become contaminated with bodily fluids or expired gases during both normal and single fault conditions are:

- External inspiratory filter
- Internal inspiratory filter
- Exhalation filter and condensate vial
- Exhalation valve assembly

The typical ventilator system ships with the packing list shown in [Table 2-1](#). Depending upon the ventilator system purchased, your list may vary.

Table 2-1. Typical Packing List

Quantity	Item
1	Graphical user interface
1	Breath delivery unit
1	Inspiratory filter
1	Exhalation filter/condensate vial
2	Gas hoses (air and oxygen)
1	Standard caster base
1	DC compressor (optional)
1	Power cord
1	Operator's manual CD

Table 2-1. Typical Packing List (Continued)

Quantity	Item
1	<i>Puritan Bennett™ 980 Series Ventilator Installation Instructions</i>
1	Flex arm
1	Drain bag
1	Gold standard circuit (for running EST)

2.6 Product Views

2.6.1 GUI Front View

Figure 2-1. GUI Front View

VEN_10319_B

- | | |
|--------------------------|--|
| 1 Display brightness key | 6 Inspiratory pause key |
| 2 Display lock key | 7 Expiratory pause key |
| 3 Alarm volume key | 8 Alarm reset key |
| 4 Manual inspiration key | 9 Audio paused ¹ key |

5 Rotary encoder (knob)

1 The terms “audio paused” and “alarm silence” are interchangeable.

2.6.2 GUI Rear View

Figure 2-2. GUI Rear View



VEN_10320_A

See [Table 2-4](#), on page [2-11](#) for symbols found on the GUI or BDU. The “Do Not Push” symbol found on the GUI, only, is shown in this table.

2.6.3 BDU Front View

Figure 2-3. BDU Front View



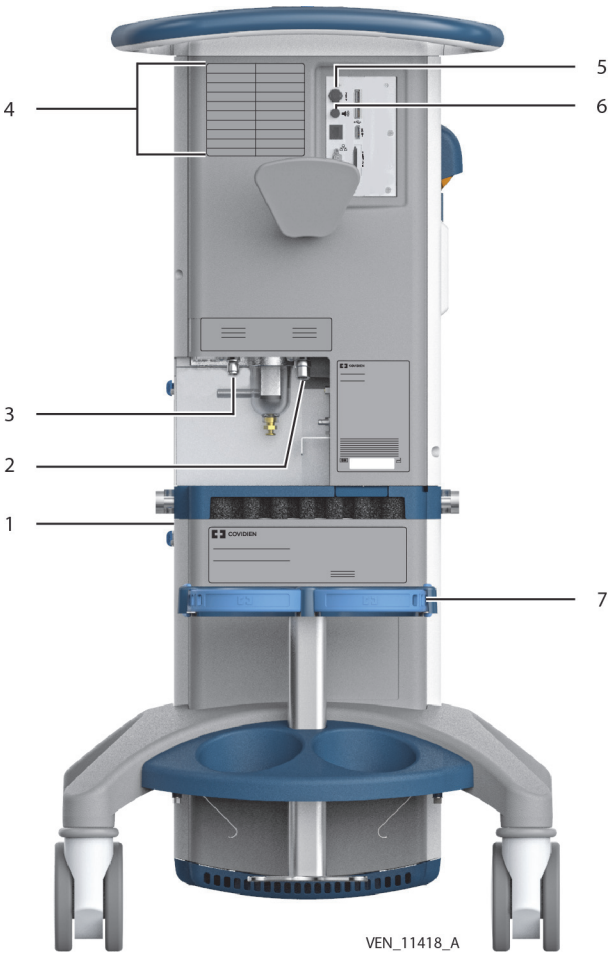
- | | | | |
|---|-------------------------|---|-----------------------------|
| 1 | Power switch | 5 | Condensate vial |
| 2 | AC power indicator | 6 | Status display |
| 3 | Exhalation filter latch | 7 | Internal inspiratory filter |
| 4 | Exhalation filter | 8 | Option connector panel door |

Table 2-2. BDU Front Label Symbols and Descriptions

Symbol	Description
	To patient port
	From patient port
	Exhalation filter latch locked (down)/unlocked (up)

2.6.4 BDU Rear View

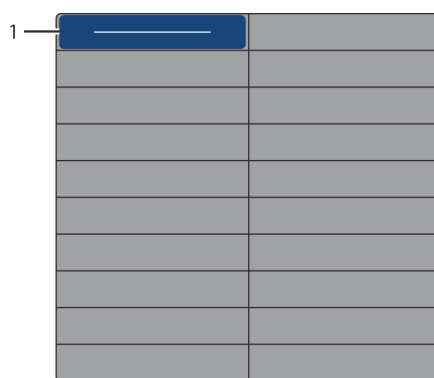
Figure 2-4. BDU Rear View



- | | | | |
|---|---|---|---------------------------|
| 1 | DC compressor base (if the DC compressor is installed). If no compressor is present, the standard base is included. | 5 | Service mode button |
| 2 | Air inlet | 6 | Remote alarm port |
| 3 | Oxygen inlet | 7 | Cylinder mount (optional) |
| 4 | Labels indicating installed software options | | |

Software option labels are applied to the grid located on the back of the ventilator, as shown in [Figure 2-4](#). (item 4) and [Figure 2-5](#). (item 1).

Figure 2-5. Installed Software Options



VEN_10284_A

[Table 2-3](#). lists the symbols and descriptions found on the BDU or base labels.

Table 2-3. BDU Rear Label or Panel Symbols and Descriptions

Symbol	Description
Rx ONLY	U.S. federal law restricts this device to sale by or on the order of a physician.
	User must consult instructions for use. Symbol is also found on "Do not obstruct" labels on both left and right sides of the ventilator, and on label indication supply gas connections.
	Keep away from fire or flame. Oxygen rich environments accelerate combustibility.
	Atmospheric pressure limitations—The operational atmospheric pressure range 70 kPa to 106 kPa (10.2 psi to 15.4 psi).

Table 2-3. BDU Rear Label or Panel Symbols and Descriptions (Continued)

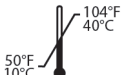
Symbol	Description
	Humidity limitations—The operational humidity limit range 10% to 95%.
	Temperature limitations—The operational temperature limit range 10°C to 40°C (50°F to 104°F).
	Type BF applied part.
IP21	IEC Ingress protection classification—Protected against ingress of fingers or similar objects and protected from condensation.
	Explosive hazard. Do not use in the presence of flammable gases.
	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.
	The ventilator contains components manufactured with phthalates.
	Unsafe to use the ventilator in magnetic resonance imaging environments.
	Potential equalization point (ground) (on AC panel).
CB1	BDU circuit breaker (on AC panel).
CB2	Compressor circuit breaker (on AC panel).
	USB port (at rear of ventilator).
HDMI	HDMI port (at rear of ventilator).

Table 2-3. BDU Rear Label or Panel Symbols and Descriptions (Continued)

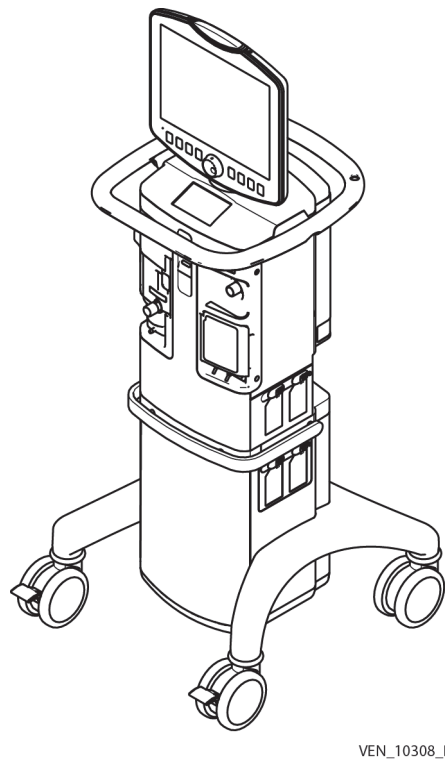
Symbol	Description
	Service port (at rear of ventilator).
	Service mode button (at rear of ventilator).
	Remote alarm port (at rear of ventilator).
	Ethernet connector (at rear of ventilator).
	Serial port (at rear of ventilator).

Table 2-4. Common Symbols Found on GUI or BDU Labels

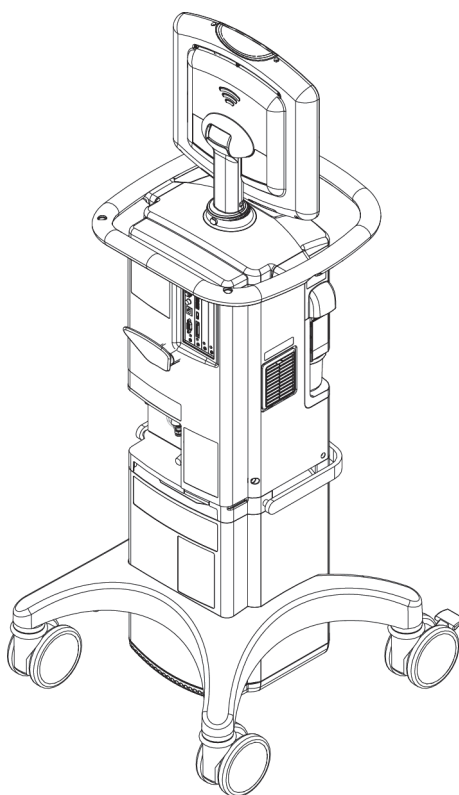
Symbol	Description
	Do Not Push—Do not push on the GUI
	Manufacturer—Name of the ventilator manufacturer.
	Serial number.
	Manufacture date—The manufacture date is contained in the serial number. See Manufacture Date (1.6) on page 1-14 for details regarding interpretation of the serial number.
	WEEE—Proper waste disposal. Follow local governing ordinances regarding disposing of waste labeled with the WEEE symbol.

2.6.5 Ventilator Side Views

Figure 2-6. Ventilator Right Side View



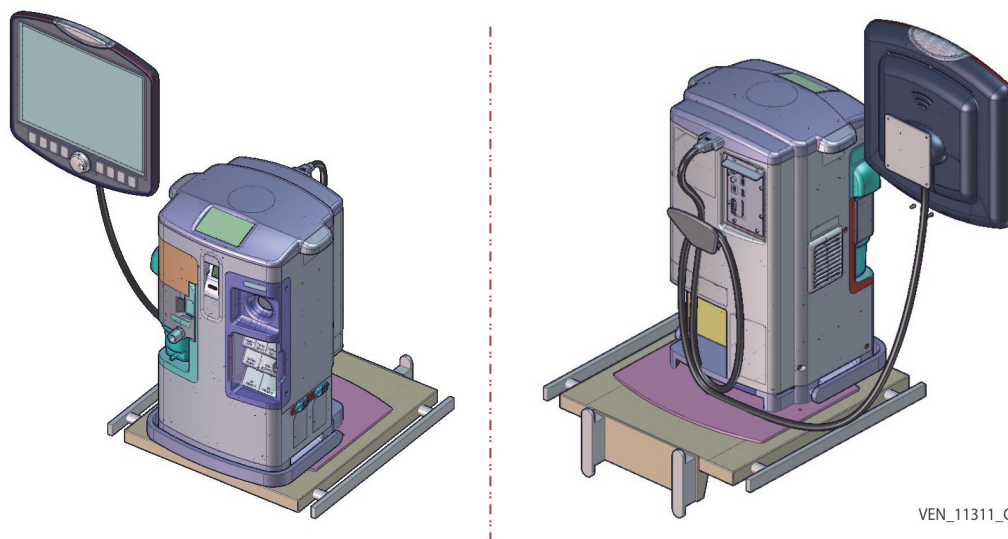
VEN_10308_B

Figure 2-7. Ventilator Left Side View

VEN_10331_A

2.7 Mounting Configurations

The ventilator system can be mounted as a free-standing unit standing at the patient's bedside; the BDU with the GUI is mounted on a base with casters and includes a handle for ease of movement. The ventilator system may also be purchased in a pendant-mount configuration, as shown in [Figure 2-8](#). Contact your local representative for more information.

Figure 2-8. Pendant-mount Ventilator Configuration

2.8 Battery Backup

The ventilator system uses a battery to provide backup power in case AC power is lost. When operating on battery power, the status display shows the “On Battery Power” image, and the GUI displays a representation of battery charge levels. See [Table 2-9](#) on page 2-27 for a description of the status display images and messages. An optional, extended battery is available to lengthen the amount of time the ventilator can operate on battery power. See [Using Battery Power](#), page 3-2.

2.9 Graphical User Interface

There are two displays on the ventilator—the primary display (GUI) and the status display.

2.9.1 Primary Display

The GUI incorporates a 15 inch display that rotates throughout a 170° angle about a vertical axis in either direction. The GUI can also be tilted up to 45° from vertical.

The clinician enters ventilation parameters via the GUI’s touch screen, also known as the ventilator’s primary display. The GUI’s keys activate other ventilator functions including screen brightness, display lock, alarm volume, manual inspiration, inspiratory pause, expiratory pause, alarm reset, and audio paused.

The GUI displays the following information depending on the state of the ventilator:

- Ventilator, apnea, and alarm settings
- Patient data
- Waveforms
- Current alarm banners

2.10 GUI Controls and Indicators

2.10.1 Control Keys

The GUI bezel has eight off-screen control keys as shown in [Table 2-5](#).

Table 2-5. GUI Control Keys

Key symbol	Description
 	Display brightness key—Adjusts the GUI screen brightness. Press the key and turn the knob to adjust the brightness.
	Display lock key—Actuates a lock to prevent inadvertent settings changes to the ventilator (including the knob function) while the display is locked. The display lock is useful when cleaning the touch screen. Press the key again to unlock the display. Also use the display lock key to reset the GUI touch screen as described in GUI Touch Screen Reset (2.10.2).
 	Alarm volume key—Adjusts the alarm volume. The alarm volume cannot be turned off.
	Manual inspiration key—In A/C, SIMV, and SPONT modes, delivers one manual breath to the patient in accordance with the current mandatory breath parameters. In BiLevel mode, transitions from low pressure (P_L) to high pressure (P_H) (or vice versa). To avoid breath stacking, a manual inspiration is not delivered during inspiration or during the restricted phase of exhalation. See Manual Inspiration (10.7.5) on page 10-18 for information on the restricted phase of exhalation. The Manual inspiration key can be used to deliver mandatory breaths to the patient or to run an inspiratory pause maneuver in SPONT mode. The manual inspiration key cannot be used to run an expiratory pause maneuver in SPONT mode.

Table 2-5. GUI Control Keys (Continued)

Key symbol	Description
	Inspiratory pause key—Initiates an inspiratory pause maneuver, which closes the inspiratory and exhalation valves and extends the inspiratory phase of a mandatory breath for the purposes of measuring end inspiratory pressure ($P_{I\text{ END}}$) for calculation of plateau pressure (P_{PL}), static compliance (C_{STAT}), and static resistance (R_{STAT}).
	Expiratory pause key—Initiates an expiratory pause maneuver, which extends the expiratory phase of the current breath to measure total PEEP ($PEEP_{TOT}$).
	Alarm reset key—Clears active alarms or resets high-priority alarms and cancels an active audio paused interval. An alarm reset is recorded in the alarm log if there is an active alarm. DEVICE ALERT alarms cannot be reset.
	Audio paused key—Pauses alarms for 2 minutes. Cancel the audio paused function by touching the on-screen Cancel button.

2.10.2 GUI Touch Screen Reset

On rare occasions, the GUI touch screen may become unresponsive. If you observe an unresponsive GUI, inaccurate GUI responses, or unintended GUI responses, reset the touch screen to restore proper touch screen functionality.

To reset the touch screen



1. Touch the display lock key on the GUI bezel to lock the screen. The locked padlock icon appears on the screen and the display lock key illuminates.
2. Touch the display lock key again. Doing so displays a progress bar below the locked padlock icon, after which time the locked icon will “unlock,” indicating a successful GUI touch screen reset.

Alternatively, ensure that a patient is **not** connected to the ventilator and power cycle the ventilator.



Note:

Do not touch the screen during the unlock period.



Note:

The manual GUI touch screen reset described in this section is different than the automatic 30-second transient reset of the GUI described in [Table 2-9](#).

2.10.3 Visual Indicators

[Table 2-6](#) shows the GUI's visual indicators. See [Figure 4-1](#) on page 4-3 for area names.

The audio paused function has two visual indicators—the audio paused key on the GUI bezel glows yellow during an audio paused interval, and a visual countdown timer appears, showing the amount of time the audio paused interval has remaining.

Table 2-6. GUI Visual Indicators

Symbol	Description
	Ventilator Setup (Vent Setup) button. Located at the lower left corner of the GUI. Touch this button to open the ventilator setup screen.
	Adult patient circuit indicator. Indicates adult circuit type tested during SST, and in use. Appears above the Vent Setup button.
	Pediatric patient circuit indicator. Indicates pediatric circuit type tested during SST, and in use. Appears above the Vent Setup button.
	Neonatal patient circuit indicator. Indicates neonatal circuit type tested during SST, and in use. Appears above the Vent Setup button.
	Home icon. A constant access icon. See Figure 4-1 on page 4-3. Touch this icon to dismiss all open dialogs on the GUI screen. The display resumes showing the ventilator waveforms.
Manual Event	This text appears below the Home icon. Touching this text causes the manual event screen to appear, where a variety of events can be recorded for viewing in the Trending layout. See Appendix F for more information about events.
	Alarms icon. A constant access icon. See Figure 4-1 on page 4-3. Touch this icon to display the alarm settings screen, which allows alarm limits to be changed.
	Logs icon. A constant access icon. See Figure 4-1 on page 4-3. Touch this icon to display the logs screen, which contains tabs for Alarms, Settings, Patient Data, Diagnostics, EST/SST status, General Event, and Service logs.

Table 2-6. GUI Visual Indicators (Continued)

Symbol	Description
	Elevate O₂ control. A constant access icon. See Figure 4-1, on page 4-3. Touch this icon to temporarily increase the delivered oxygen concentration by the percent displayed in the Elevate O₂ dialog. The ventilator will deliver the elevated O₂ concentration for 2 minutes and then return the O₂ concentration to the set O₂% value. For the 2-minute period, the Elevate O₂ concentration can be set to result in any value between 22% and 100% O₂ delivery. Touching “Extend” restarts the 2-minute interval. The Elevate O₂ function can be terminated prior to completion of the 2-minute interval by touching Stop. Any time the Elevate O₂ control is activated, an entry is made to the patient data log.
	Screen capture icon. A constant access icon. See Figure 4-1, on page 4-3. Touch this icon to capture the image displayed on the GUI screen. See To capture GUI screens, page 5-2 to read the complete procedure for capturing screen images.
	Help icon. A constant access icon. See Figure 4-1, on page 4-3. Drag this icon to the item in question and release. A tooltip will appear describing the item’s function.
	Unread items icon. When this icon appears overlaid on another icon or tab (the logs icon, for example) it indicates there are unread items at this location.
	Configure icon. A constant access icon. See Figure 4-1, on page 4-3. Touch this icon to display the configure screen. Tabs with SST results, options, Comm setup, and date/ time change are displayed.
	Pause icon. Located above the constant access icons. Touch this icon to pause the waveform graph.
	Waveform layout icon. Located above the constant access icons area. Touch this icon to open the waveform layout dialog.
	Grid lines icon. Located above the constant access icons area. Touch this icon to turn waveform grid lines on or off.
	Maximize waveform icon. Located at the upper right portion of each waveform. Touch this icon to enlarge the waveform to its maximum size.

Table 2-6. GUI Visual Indicators (Continued)

Symbol	Description
	Restore waveform icon. Restores waveform to its original size. Located at the upper right of the maximized waveform.
	Pushpin icon – pinned state. When in the pinned state, prevents a dialog from closing (under certain conditions). Located in the upper right corner of the GUI on the vent setup screen. See Figure 4-2. on page 4-4.
	Pushpin icon – unpinned state. When the unpinned icon is touched, the pinned state becomes active. Located in the upper right corner of the GUI on the vent setup screen. See Figure 4-2. on page 4-4.
!	Low priority alarm icon (appears on alarm banner).
!!	Medium priority alarm icon (appears on alarm banner).
!!!	High priority alarm icon (appears on alarm banner).
	Audio paused symbol. The audio paused symbol appears together with a 2-minute countdown timer in the constant access area when the audio paused key is pressed. See Figure 4-1. on page 4-3.

2.10.4 On-screen Symbols and Abbreviations

Touch an on-screen symbol briefly (0.5 second) to display a tooltip on the GUI screen. The tooltip contains a definition of the symbol and other descriptive text, available with either short or long descriptions. The short description expands to show more information by touching “more” on the tooltip dialog or collapses by touching “less”. The tooltip closes by touching “close” or fades in 5 seconds if left alone. Expanding the tooltip dialog prevents the tooltip from timing out. Touching outside the tooltip causes the dialog to close.

[Table 2-7.](#) summarizes the ventilator’s symbols and abbreviations.



Note:

[Table 2-7.](#) is subject to change.

Table 2-7. Symbols and Abbreviations

Symbol or abbreviation	Definition
T_A	Apnea interval
D_{SENS}	Disconnect sensitivity

Table 2-7. Symbols and Abbreviations (Continued)

Symbol or abbreviation	Definition
C_{DYN}	Dynamic compliance
R_{DYN}	Dynamic resistance
EEF	End expiratory flow
$P_{I\,END}$	End inspiratory pressure
LEAK	Exhalation leak
P_{CIRC}	Monitored total circuit pressure
$LEAK_Y$	Exhalation leak at PEEP (Leak Sync enabled) as measured by the proximal flow sensor
$V_{TE\,MAND}$	Exhaled mandatory tidal volume
$\dot{V}_{E\,TOT}$	Exhaled minute volume
$\dot{V}_{E\,SPONT}$	Exhaled spontaneous minute volume
$V_{TE\,SPONT}$	Exhaled spontaneous tidal volume
V_{TE}	Exhaled tidal volume
E_{SENS}	Expiratory sensitivity
T_E	Expiratory time
	Flow pattern (ramp)
	Flow pattern (square)
$\dot{V}_{CIRC}$	Monitored total inspiratory and expiratory flow
$\dot{V}_{SENS}$	Flow sensitivity
$\dot{V}$ -Trig	Flow triggering
$\dot{V}_Y$	Monitored inspiratory and expiratory flow measured at the proximal airway
P_H	High pressure setting (in BiLevel)
P_Y	Monitored circuit pressure throughout the breath cycle measured at the proximal airway
T_H	High pressure time (in BiLevel)
$T_H:T_L$	High pressure time to low pressure time ratio (in BiLevel)
I:E	Inspiratory time to expiratory time (I:E)
C_{20}/C	Inspiration compliance ratio
V_{LEAK}	Inspiratory leak

Table 2-7. Symbols and Abbreviations (Continued)

Symbol or abbreviation	Definition
T_I	Inspiratory time
$3\tau_{I_i}$	Inspiratory time constant
P_I	Inspiratory pressure
V_{TI}	Inspired tidal volume
V_{TL}	Inspired tidal volume (when Leak Sync is enabled)
$PEEP_I$	Intrinsic PEEP (auto PEEP)
$PEEP_{I_{PAV}}$	PAV-based intrinsic PEEP
P_L	Low pressure setting (in BiLevel)
T_L	Low pressure time (in BiLevel)
P_{MEAN}	Mean circuit pressure
NIF	Negative inspiratory force
$O_2\%$	Oxygen percentage
$P_{0.1}$	Airway occlusion pressure at 100 ms
C_{PAV}	PAV-based lung compliance
E_{PAV}	PAV-based lung elastance
% Supp	Percent support setting for tube compensation and PAV+
R_{PAV}	PAV-based patient resistance
R_{TOT}	PAV-based total airway resistance
WOB_{TOT}	PAV-based work of breathing of patient and ventilator during inspiration
P_{PEAK}	Peak circuit pressure
PEF	Peak expiratory flow
$\dot{V}_{MAX}$	Peak inspiratory flow
PSF	Peak spontaneous flow
PEEP	Set or monitored positive end expiratory pressure
%Leak	Percent leak
P_{PL}	Plateau pressure
T_{PL}	Plateau time
P_{COMP}	Compensation pressure
P_{SENS}	Pressure sensitivity

Table 2-7. Symbols and Abbreviations (Continued)

Symbol or abbreviation	Definition
P_{SUPP}	Pressure support level
P-Trig	Pressure triggering
V_{TIY}	Proximal inspired tidal volume
V_{TEY}	Proximal exhaled tidal volume
$V_{TIMANDY}$	Proximal mandatory inspired tidal volume
$V_{TISPONTY}$	Proximal spontaneous inspired tidal volume
V_{TLY}	Proximal inspired tidal volume with Leak Sync enabled
f	Respiratory rate or apnea respiratory rate
$\nearrow P$	Rise time percent
f/V_T	Spontaneous rapid/shallow breathing index
T_{ISPONT}	Spontaneous inspiratory time
T_I/T_{TOT}	Spontaneous inspiratory time ratio
C_{STAT}	Static compliance
R_{STAT}	Static resistance
V_T	Tidal volume
V_{TCIRC}	Monitored total inspiratory and expiratory volumes
V_{TY}	Monitored Inspiratory and expiratory patient volumes measured throughout the breath cycle measured at the proximal airway
$PEEP_{TOT}$	Total PEEP
f_{TOT}	Total respiratory rate (monitored)
VC	Vital capacity
VS	Volume support

2.10.5 Audible Indicators

A tone sounds when a button on the GUI is touched, and also when settings are accepted. Audible indicators include pitched tones, beeps, and key clicks. Key clicks sound whenever a key on the GUI is pressed. Various tones annunciate patient alarms.



Note:

Pressing the audio paused key pauses alarms for the 2-minute audio paused period.



Caregivers may choose to pause alarms by pressing the audio paused key. A 2-minute count-down timer appears on the GUI during the audio paused interval. Cancel the audio paused function by touching Cancel.

Click each icon in [Table 2-8](#). to listen to a sample of the corresponding tones:



Note:

To hear the tones, Adobe Reader version 10 or higher must be installed on your computer.

[Get Adobe Reader, free.](#)

Table 2-8. GUI Audible Indicator Functions

Function	Description
Low priority alarm tone 	A series of two tones. Sounds when a low priority alarm occurs.
Medium priority alarm tone 	A repeating series of three tones. Sounds when a medium priority alarm occurs.
High priority alarm tone 	A repeating series of five tones. Sounds when a high priority alarm occurs.
Soft bound tone 	One tone. Sounds when a soft bound is reached when making changes to ventilator settings. A soft bound is a selected value that exceeds or goes below its limit and requires acknowledgment to continue.
Hard bound tone (invalid entry) 	The invalid entry sound occurs when a hard bound is reached when making changes to ventilator settings. A hard bound defines the upper or lower limit of the setting, where the setting cannot be adjusted higher or lower.

The clinician enters ventilation parameters via the GUI's touch screen. See [Figure 2-1](#). on page 2-5. The keys activate other ventilator functions. See [Table 2-5](#). on page 2-15.

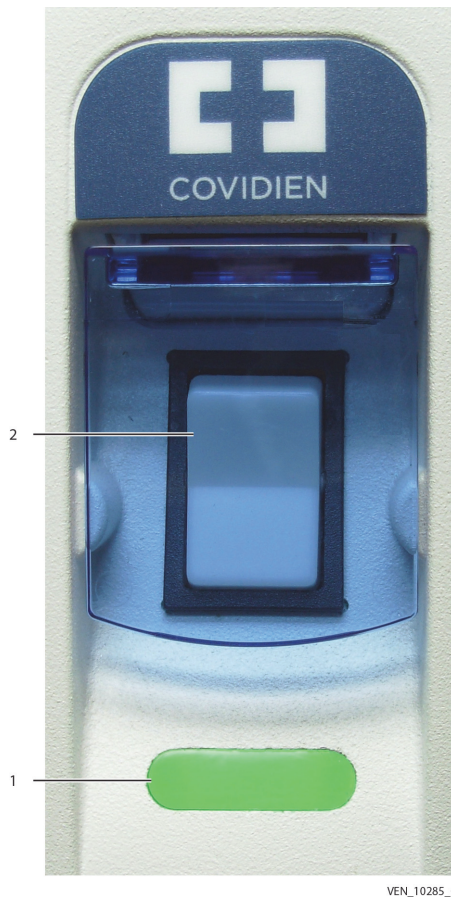
2.11 Breath Delivery Unit

The breath delivery unit contains the hardware and software to enable the ventilator to provide patient support.

2.11.1 BDU Controls and Indicators

BDU Controls

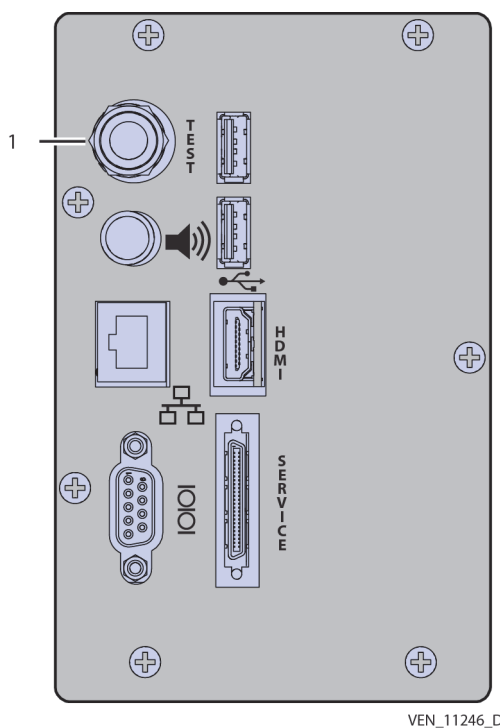
Figure 2-9. Ventilator Power Switch and AC Indicator



1 AC power indicator

2 On/Off switch

- On/Off switch—Lift the switch cover and turn the ventilator on or off.
- Service mode button—Press and release this button when the Covidien splash screen appears on the status display after powering on the ventilator to enter Service mode. See [Figure 2-10](#), item 1.

Figure 2-10. Service Mode Button (TEST)

1 Service mode button

**Note:**

The Covidien splash screen shows the Covidien logo and appears momentarily as a banner on the status display. See [Table 2-9](#) for an image of the splash screen.

BDU AC Indicator

The status display and the AC power indicator are the only visual indicators on the BDU. The AC indicator illuminates green whenever the ventilator is connected to AC power. All other visual indicators on the ventilator are on the GUI. See [Typical Status Display Indicators and Messages](#), page 2-27 for a description of the status display indicators and symbols. See the next section for a summary of the information appearing on the status display.

Status Display

The status display is a separate display located on the BDU. See [Figure 2-3](#), item 6 on page 2-7. The status display provides the following information according to the state of the ventilator:

During normal ventilation the status display shows:

- Current power source (AC or DC)
- Safe state status (safety valve open (SVO) or vent inop)

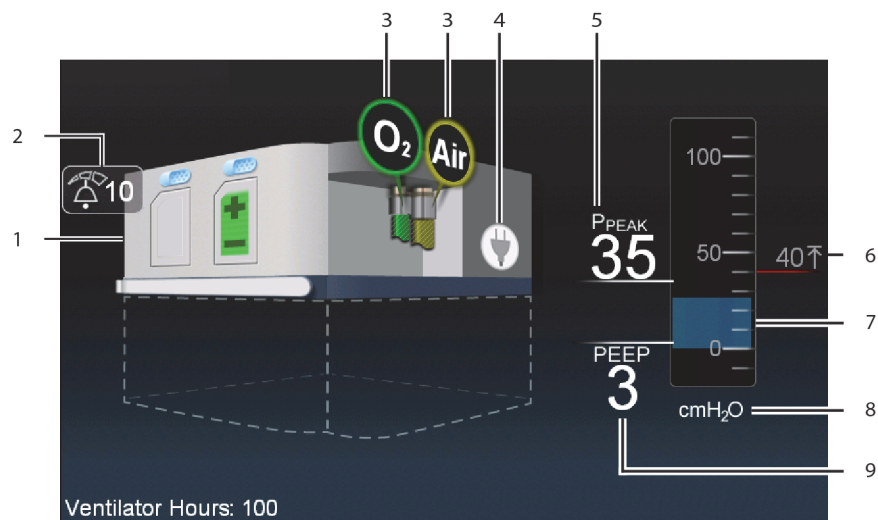
- Presence of primary and extended batteries and their charging status
- Relative available battery charge level
- Circuit pressure graph displaying pressure units, $\uparrow P_{PEAK}$ alarm setting and current P_{PEAK} and PEEP values
- Connection of air and oxygen
- Ventilator operational hours
- Visual indication of current alarm volume setting



Note:
The status display provides a redundant check of ventilator operation. If the GUI stops operating for any reason, ventilation continues as set.

Figure 2-11. shows a sample of the status display during normal ventilation (compressor option not installed).

Figure 2-11. Sample Status Display During Normal Ventilation



1	Primary and extended battery status (presence or absence).	6	P_{PEAK} alarm setting
2	Alarm volume setting	7	Measured inspiratory pressure (changes as pressure changes)
3	Gas connection status	8	Selected pressure units
4	Power status	9	Measured PEEP

- 5 Measured peak circuit pressure (updated at the end of the current breath)

During Service mode the status display shows:

- Ventilator serial number
- Ventilator operational time
- EST and SST history
- Power on self test (POST) status
- Hours until next preventive maintenance is due
- Gas pressure at the manifold inlets

See [Table 2-9](#) for status display possibilities.

Typical Status Display Indicators and Messages



Note:

Status display images are shown without the optional DC compressor installed.

[Table 2-9](#) lists indicators and messages that appear on the status display:

Table 2-9. Status Display Indicators and Descriptions

Status display indicator or message	Meaning
	Splash screen. Appears when the ventilator's power switch is turned on. When this image appears, press and release the TEST button at the back of the ventilator to enter Service mode.
	POST failure. This image appears if a POST error occurs at ventilator startup, along with the error code (in this case a missing primary battery).

Table 2-9. Status Display Indicators and Descriptions (Continued)

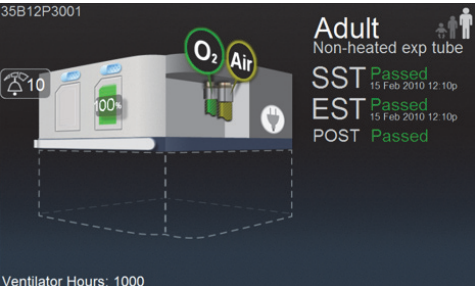
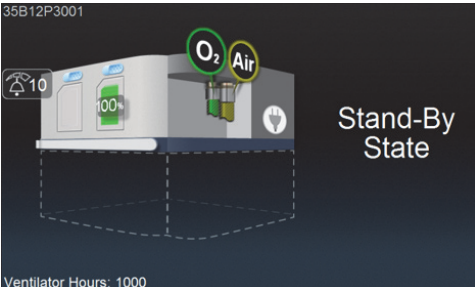
Status display indicator or message	Meaning
 Reinstall EVQ	Failure of the exhalation flow sensor assembly (EVQ) during power on self test. Confirm proper installation of the exhalation flow sensor assembly and power cycle the ventilator.
 LP0127 Reinstall or Replace EVQ	Failure of the EVQ during power on self test. Reinstall or replace the EVQ and run flow sensor calibration from Service mode.
 Ventilator Hours: 1000	Prior to patient connection. The status display appears as shown when the patient has not been connected to the ventilator. Note the absence of P_{PEAK} and PEEP values.
 Ventilator Hours: 1000	Stand-By state. The status display appears as shown when the ventilator is in Stand-By state.

Table 2-9. Status Display Indicators and Descriptions (Continued)

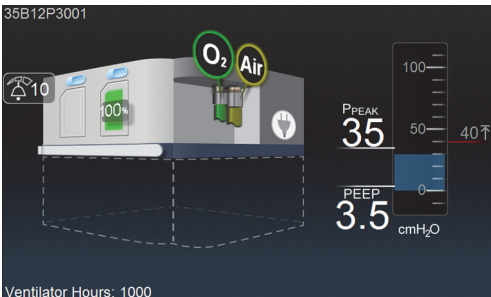
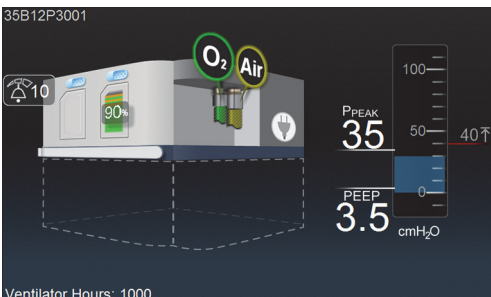
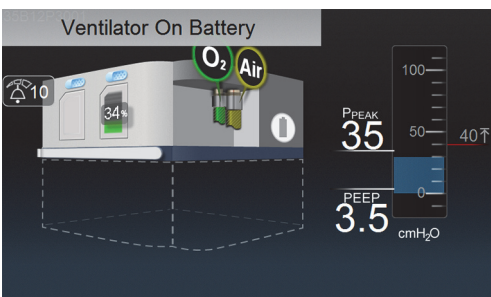
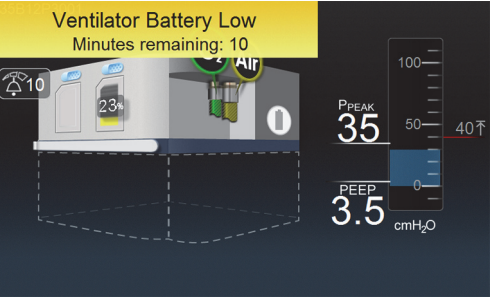
Status display indicator or message	Meaning
 35B12P3001 Ventilator Hours: 1000	Battery charged. The ventilator's primary battery (in the right-most slot) is shown fully charged. The percentage indicator shows 100%.
 35B12P3001 Ventilator Hours: 1000	Battery charging/discharging. Identifies that the ventilator's primary battery is charging or discharging, and provides its relative capacity. If an extended battery is installed, the image shows a similar representation in the extended battery location (left-most receptacle).
	Battery icon. Denotes the ventilator is operating on battery power when this image appears on any status display indicator. Alerts the operator there is insufficient AC power to operate the ventilator. The indicator is replaced by the "on AC power" indicator when adequate AC power is restored.
 Ventilator On Battery 35B12P3001 Ventilator Hours: 1000	On battery power. Alerts the operator there is insufficient AC power to operate the ventilator. Ventilator is operating on battery power with greater than 10 minutes of capacity remaining. Note the appearance of the battery icon.
 Ventilator Battery Low Minutes remaining: 10 35B12P3001 Ventilator Hours: 1000	Low battery. Identifies that the ventilator's primary battery (right-most receptacle) is discharging and there are 10 minutes or less of battery capacity remaining. A percentage indicator shows the remaining battery capacity. If an extended battery is installed, the image would show a similar representation in the extended battery location (left-most receptacle).

Table 2-9. Status Display Indicators and Descriptions (Continued)

Status display indicator or message	Meaning
	Critically low battery. Identifies that the ventilator's primary battery has less than 5 minutes of battery capacity remaining. A percentage indicator shows the remaining battery capacity. If an extended battery is installed, the image would show a similar representation in the extended battery location.
	Power failure. Alerts the user that the ventilator's battery is depleted or depletion is imminent. Replace primary or extended battery with a fully charged batter or connect ventilator to AC power.
	Battery inoperative. This image appears on the status display when a battery fault renders the battery inoperative.
	Battery not installed. This image appears when there is no primary battery installed, and renders ventilator inoperative. This image displays when the primary battery is removed during ventilator operation.

Table 2-9. Status Display Indicators and Descriptions (Continued)

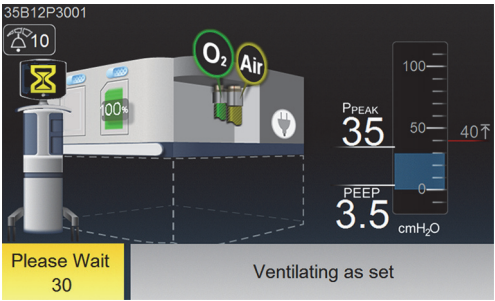
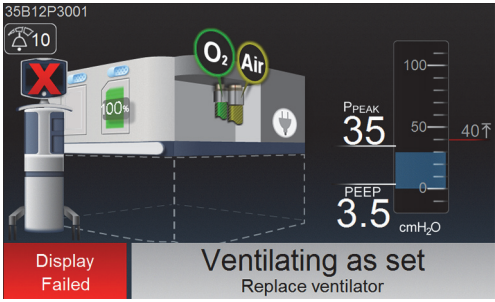
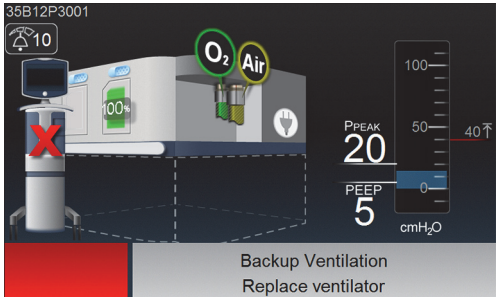
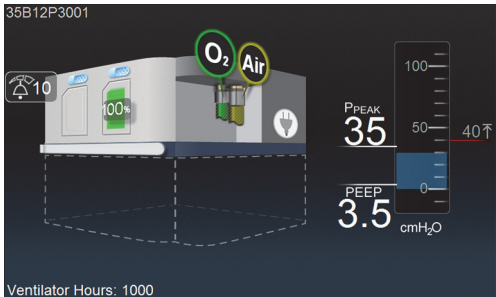
Status display indicator or message	Meaning
 The status display shows a yellow banner at the bottom left with the text "Please Wait 30". The main display area shows "Ventilating as set". The background features a 3D model of the ventilator with O₂ and Air flow indicators. On the right, there are gauges for P_{PEAK} (35) and PEEP (3.5 cmH₂O).	GUI transient reset. Indicates there is a transient loss of communication between the BDU and the GUI. It occurs in the ventilator by design to maintain full GUI display functionality. During the GUI transient reset, ventilation continues as currently set, audible and visual alarms are not annunciated, and the status display shows a count-down timer until the completion of the GUI transient reset. The count-down timer lasts for approximately 30 s.
 The status display shows a red banner at the bottom left with the text "Display Failed". The main display area shows "Ventilating as set" and "Replace ventilator". The background features a 3D model of the ventilator with O₂ and Air flow indicators. On the right, there are gauges for P_{PEAK} (35) and PEEP (3.5 cmH₂O).	GUI failure. Indicates a loss of communication between the BDU and the GUI that cannot be recovered by the ventilator system. During the GUI failure, ventilation continues as currently set, audible and visual alarms are annunciated, and the status display shows "Display Failed". Replace the ventilator as soon as it is appropriate to do so. Service the ventilator prior to returning it for use on patients. Recommended actions for GUI failure condition: • Verify the patient's respiratory and physiological stability. • Confirm that the patient is receiving ventilatory support by observing expansion and contraction of the patient's chest. • Assess patient status by reviewing other monitoring indicators (e.g., oxygen saturation, heart rate, blood pressure, etc.) • Transfer the patient to an alternate source of ventilation consistent with your institution's protocol.
 The status display shows a large red banner across the bottom with the text "Ventilator Inoperative" and "Replace Ventilator". The background features a 3D model of the ventilator with O₂ and Air flow indicators. On the right, there are gauges for P_{PEAK} (0) and PEEP (0).	Ventilator inoperative (vent inop). Indicates the ventilator is no longer capable of ventilating a patient and requires service. The alarm reset key cannot be used to restore function to the ventilator during a ventilator inoperative condition. Provide alternate means of ventilation immediately. Note the display of the safety valve open indicator.
 The status display shows a large red banner across the bottom with the text "Safety Valve Open". The background features a 3D model of the ventilator with O₂ and Air flow indicators. On the right, there are gauges for P_{PEAK} (0) and PEEP (0).	Safety valve open (SVO) indicator. During SVO, the patient can breathe room air through the safety valve, to the extent the patient is able to breathe unaided. See Safety Valve Open (SVO) (4.11.6) on page 4-32 for more information on the SVO state.

Table 2-9. Status Display Indicators and Descriptions (Continued)

Status display indicator or message	Meaning
 35B12P3001 Backup Ventilation Replace ventilator	Backup ventilation (BUV) indicator. Indicates the ventilator has entered the backup ventilation state. See Background Diagnostic System (10.16.4) on page 10-61 for a description of BUV.
	On AC power indicator. When this image appears on any status display indicator, indicates the ventilator is operating on AC power.
 35B12P3001 Ventilator Hours: 1000	Status display appearance when the ventilator is breathing in Normal mode. Note the appearance of the AC power icon.
	Air available indicator. When this image appears on any status display indicator, indicates the ventilator is connected to a pressurized air source.
	O₂ available indicator. When this image appears on any status display indicator, indicates the ventilator is connected to a pressurized O₂ source.

BDU Audible Indicators

The continuous tone alarm is the only audible indicator in the BDU, and is described in [Table 2-10](#).

Table 2-10. BDU Audible Indicator Functions

Indicator	Description
Continuous tone alarm (Immediate priority)	A continuous tone annunciated when there is a Ventilator Inoperative (vent inop) condition. This alarm lasts for a minimum of 2 minutes.

2.11.2 Connectors

The ventilator incorporates the following connectors:

- **Ventilator outlet port (to patient)** — A coaxial 15 mm (ID) / 22 mm (OD) conical connection to which the external inspiratory bacteria filter attaches.
- **Exhalation port (from patient)** — The expiratory limb of the patient circuit attaches to the inlet of the exhalation bacteria filter. This port is compatible with a standard 22mm (OD) conical connection.
- **Proximal flow sensor** — A keyed pneumatic connector for the proximal flow sensor is provided with a locking feature to prevent inadvertent disconnection. The proximal flow sensor measures flow and pressure at the patient wye. The proximal flow sensor is an optional sensor. Details on operation are provided in Appendix E.
- **Standard interface connectors** — USB, HDMI, and Ethernet connectors are provided. The USB connector allows images to be captured on an external USB storage device and allows communication with an external patient monitor via serial-over-USB protocol, and the HDMI connector allows the GUI image to be displayed on an external video display device. The Ethernet connector is used by service personnel to upload new software and options. See [Port Use \(5.5.1\)](#) on page 5-17 for more information. See [To configure Comm ports](#), page 5-4 for information on serial-over-USB data transfer when configuring Comm ports for external devices.

2.12 Additional Equipment

An optional DC compressor is available to provide compressed air in the event the wall or bottled air supply is lost or is unavailable. The compressor receives DC power from its own power supply if AC power is present. If there is no AC power available, the compressor is powered by its internal battery. The compressor interface printed circuit board assembly (PCBA) communicates with the breath delivery CPU PCBA. See the *Compressor Operator's Manual Addendum* for details regarding compressor operation.



WARNING:

Use of the compressor in altitudes higher or barometric pressures lower than those specified could compromise ventilator or compressor operation. See [Table 11-8](#) on page 11-6 for environmental specifications.

2.13 Special Features

A Proximal Flow option is available. The proximal flow sensor is used to measure low flows and pressures associated with neonatal ventilation. If the ventilator is configured with this option, see Appendix [E](#) for more information.

2.14 Color Definitions

[Table 2-11.](#) provides a legend to interpret gas colors in the pneumatic diagrams shown in [Figure 2-12.](#) and [Figure 2-13.](#)

Table 2-11. Color Legend

Color or symbol	Description
	High-pressure oxygen (NFPA 99 designation)
	High-pressure air (NFPA 99 designation)
	Mixed gases, including air
	Atmosphere
	Vacuum
	Water

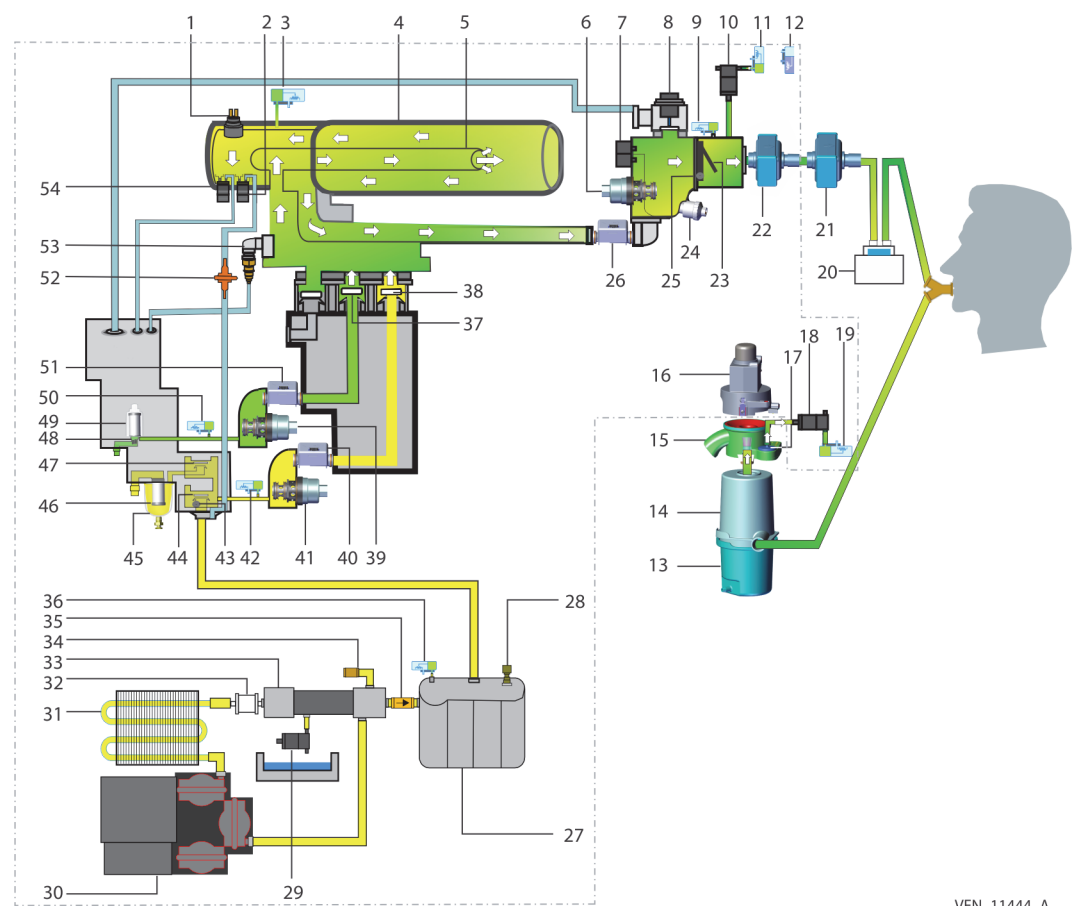
2.15 Pneumatic Diagrams

**Note:**

Both the compressor and the Proximal Flow option are hardware options.

Figure 2-12. and *Figure 2-13.* illustrate the ventilator's pneumatics with and without the optional Proximal Flow option. The Proximal Flow option is only for use with neonatal patients.

Figure 2-12. Pneumatic Diagram (Compressor Shown)

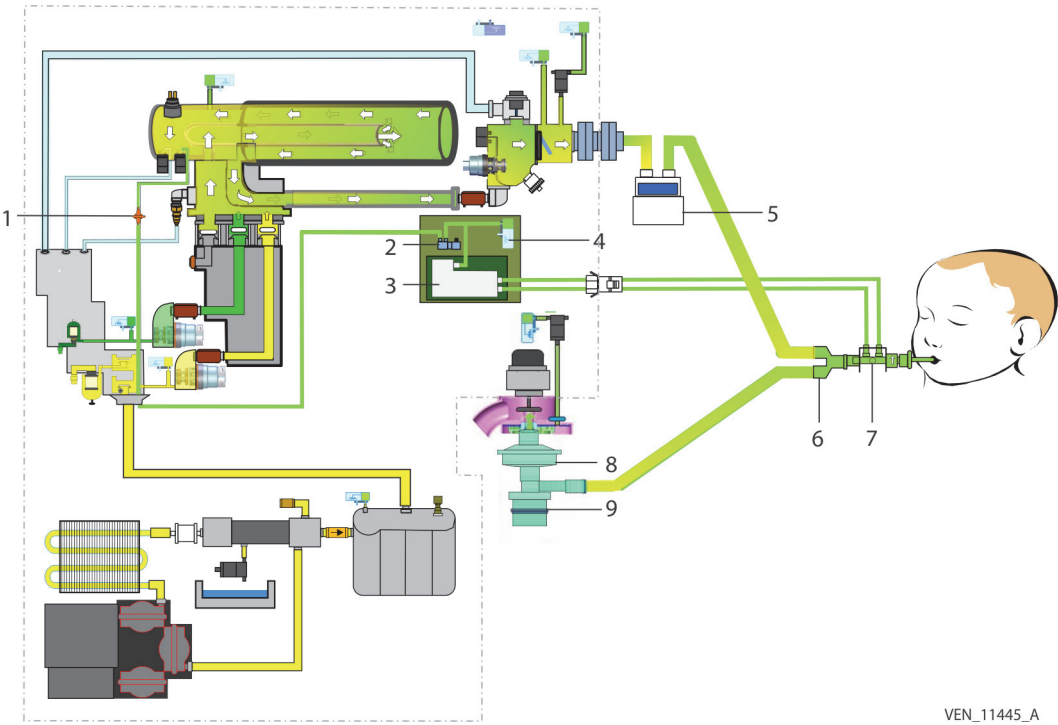


VEN_11444_A

1	Pressure switch, mix accumulator (PS1)	28	Relief valve, compressor accumulator (RVCA)
2	Solenoid valve, options supply (SOL2)	29	Solenoid valve, compressor unload (SOL7)
3	Pressure sensor, mix accumulator (P _{MX})	30	Motor compressor (MC)
4	Accumulator, mix (ACC _M)	31	Heat exchanger, compressor (HE)
5	Tube, mix (T _M)	32	Filter, compressor air (F7)
6	Proportional solenoid valve, patient gas delivery (PSOL _D)	33	Dryer, compressor
7	Solenoid valve, BUUV (SOL 3)	34	Filter, muffler (F6)
8	Safety valve (SV)	35	Check valve, compressor accumulator (CV _{CA})
9	Pressure sensor, safety valve (P _{SV})	36	Pressure sensor, compressor accumulator (PC)
10	Solenoid valve, inspiratory pressure sensor autozero (SOL4)	37	Check valve, oxygen (CVO ₂)
11	Pressure sensor, inspiratory (P _I)	38	Check valve, air (CV _{Air})
12	Pressure sensor, barometric (PA)	39	Proportional solenoid valve, oxygen (PSOLO ₂)
13	Vial, exhalation condensate (ECV)	40	Flow sensor, air (FS _{Air})
14	Filter, exhalation (F4)	41	Proportional solenoid valve, air (PSOL _{Air})
15	Flow sensor assembly, exhalation valve	42	Pressure sensor, air gas inlet (P _{Air})
16	Exhalation valve (EV)	43	Restrictor, wall air bleed outlet (R1)
17	Filter, exhalation pressure line (F5)	44	Check valve, compressor air inlet (CV _{CAir})
18	Solenoid valve, exhalation pressure autozero (SOL 5)	45	Filter bowl assembly, air (WT2)
19	Pressure sensor, exhalation (PE)	46	Filter element, air (F2)
20	Humidifier	47	Check valve, wall air inlet (CV _{WAir})
21	Filter, external bacteria (F _{D2})	48	Filter, oxygen impact (F1)
22	Filter, internal bacteria (F _{D1})	49	Filter element, oxygen (F3)
23	Check valve, patient gas delivery (CV _D)	50	Pressure sensor, oxygen gas inlet (PO ₂)
24	Sensor, oxygen (OS)	51	Flow sensor, oxygen (FSO ₂)
25	Restrictor, breath delivery bypass (R2)	52	Restrictor, prox flow (R4)
26	Flow sensor, patient gas delivery (FS _D)	53	Relief valve, mix accumulator (RVMA)

- 27 Accumulator, compressor (ACC_C)
- 54 Solenoid valve, mix accumulator purge (SOL1)

Figure 2-13. Pneumatic Diagram—Compressor and Prox Flow Options



- | | |
|---|--|
| 1 Restrictor, prox flow (R4) | 6 Wye, patient circuit |
| 2 Solenoid valve, prox flow (SOL 6) | 7 Sensor, proximal flow |
| 3 Module, proximal flow system | 8 Filter, neonatal exhalation |
| 4 Pressure sensor, prox flow accumulator (P _{PROX}) | 9 Condensate vial, neonatal expiratory |
| 5 Humidifier | |



Note:

Items enclosed by the dotted line represent components internal to the ventilator.

3 Installation

3.1 Overview

This chapter contains information for the installation and set up of the Puritan Bennett™ 980 Series Ventilator. Before operating the ventilator system thoroughly read this operator's manual.

Topics include:

- Safety reminders
- Ventilator setup
- Battery information
- Ventilator operating modes
- Preparing the ventilator for use
- Tests to perform prior to ventilating a patient

3.2 Safety Reminders



WARNING:

Explosion hazard—Do not use in the presence of flammable gases. An oxygen-rich environment accelerates combustibility.



WARNING:

To ensure proper operation and avoid the possibility of physical injury, only qualified medical personnel should attempt to set up the ventilator and administer treatment with the ventilator.



WARNING:

To prevent electrostatic discharge (ESD) and potential fire hazard, do not use antistatic or electrically conductive hoses or tubing in or near the ventilator breathing system.



WARNING:

Use only gas supply hoses approved by Covidien. Other hoses may be restrictive and may cause improper ventilator operation.

**WARNING:**

To avoid possible injury, lock the ventilator's casters prior to installing or removing ventilator components.

**Caution:**

To ensure optimum performance, Covidien recommends preventive maintenance be performed by qualified biomedical engineers per the schedule specified. See [Table 7-4.](#) on page [7-15.](#)

**Note:**

U.S. federal law restricts this device to sale by or on the order of a physician.

3.3 Product Assembly

3.3.1 How to Assemble Ventilator Components

Ventilator setup, including a successful EST, should have already been completed by qualified service personnel. This manual does not include ventilator assembly instructions.

3.3.2 Product Power Sources

Using AC Power

The ventilator is normally AC-powered. See [Connecting the Ventilator to AC Power \(3.5.1\)](#) on page [3-5](#) to connect the ventilator to AC power.

Using Battery Power

**WARNING:**

Use only Covidien batteries. Using other manufacturer's brands could result in the batteries operating the ventilator for less than the specified amount of time or could cause a fire hazard.

**WARNING:**

One primary battery must be installed at all times in the BDU's primary battery slot for proper ventilator operation. The ventilator will not complete the startup process without the primary battery installed. See [Figure 3-13.](#) on page [3-20](#) to identify battery slots.

The ventilator's primary battery must be installed by qualified service personnel (as it is shipped separately) before patient use. The ventilator will not complete **power on self test (POST)** if the battery is not present, and ventilation is prohibited. Ensure the battery is fully charged before placing the ventilator into service.

The ventilator employs a battery backup system if AC power becomes unavailable or drops below approximately 90 volts. A new, fully charged battery provides at least 1 hour of power to the ventilator assuming ambient temperature of 20°C (68°F) to 25°C (77°F), PBW=70 kg, and at factory default ventilator settings.

The battery back-up systems for the ventilator and compressor contain one primary battery each. Backup power is supplied to the ventilator in the event of an AC power loss.

One extended battery receptacle is available for the ventilator and one extended battery receptacle is available for the compressor. If both primary and extended ventilator and compressor batteries are present, these batteries can power the ventilator and compressor for 2 hours (1 hour for the primary battery and 1 hour for the extended battery) under the environmental conditions described above. When using battery power, the ventilator and compressor operate from their extended batteries, if present, first and then switch to the primary batteries. The ventilator and compressor primary and extended batteries are charged whenever the ventilator is plugged into AC power (the ventilator does not have to be powered up). If the ventilator or compressor is operating on battery power, the status display shows which battery is in use and its charge level, and the remaining time the battery will operate before charging is required again.

Battery Charging

Batteries requiring charging are charged whenever the ventilator is connected to AC power, whether operating or not.

The ventilator and compressor charge their primary batteries first, then their extended batteries. The time required to charge a single battery (either primary or extended) is approximately 6 hours at room temperature whether the ventilator is turned off (but connected to AC power) or operating, but charging time can vary based on temperature or depletion state of the battery. The status display provides the batteries' capacities.

Green LED bars located on the ends of both primary and extended batteries (if installed) scroll upwards indicating battery charging. A white LED bar represents the battery is in use and a round LED indicator illuminates red if there is a battery fault. When running on battery power, battery capacity is determined by the number of green LED bars illuminated. See [Figure 3-12](#) on page [3-19](#) to view the LEDs. See page [3-18](#) for information on interpreting the battery capacity. Green LED bars do not scroll if the battery is not charging or is in use.

The compressor's battery charging system (if a compressor is present) operates independently from the ventilator's charging system and batteries are charged in parallel.

If a battery fault occurs, the fault is annunciated, charging of the faulty battery discontinues, but charging of any other non-faulty battery continues. A faulty battery will cause annunciation of the error and battery power will not be available from that battery.

The ventilator status display indicates the charge level of the installed batteries, the presence of one or more battery faults, and which battery is being charged.

The ventilator operates no differently when its batteries are charging than it does when the batteries are fully charged.

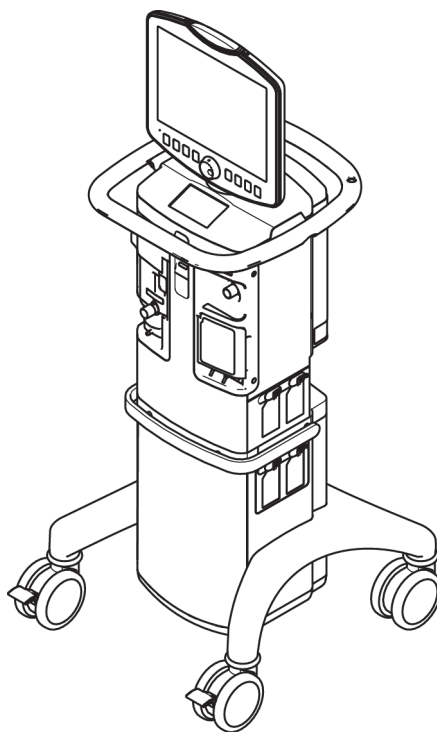
The ventilator continues operating as set when the ventilator switches from AC power to battery power and illuminates an indicator on the status display alerting the operator that the ventilator is now operating on battery power and AC POWER LOSS alarm annunciates. A medium priority alarm annunciates when the remaining run-time for the ventilator drops to 10 minutes and a high priority alarm annunciates when the remaining time drops to 5 minutes.

3.4 Product Placement

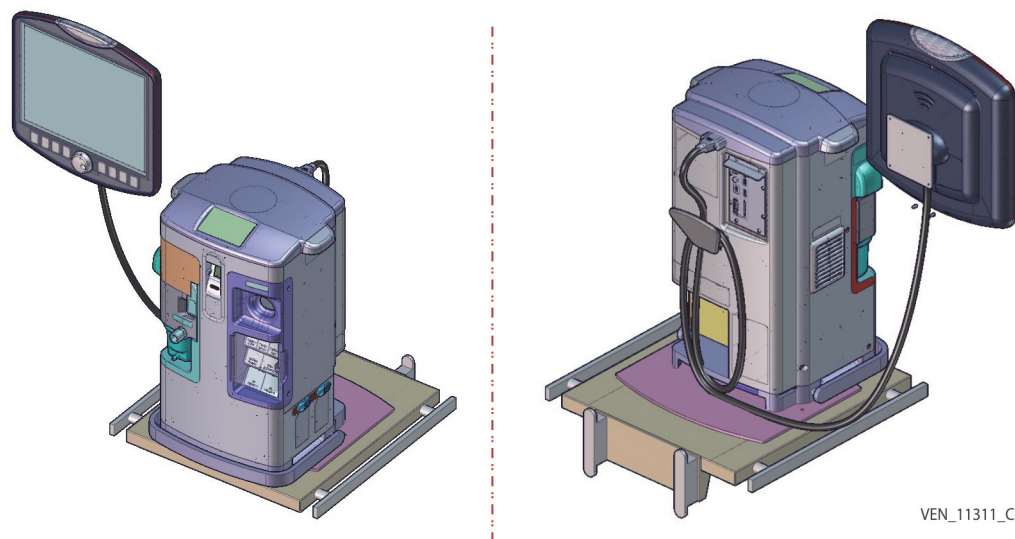
The ventilator is positioned standing on its casters next to the patient's bedside, as shown in [Figure 3-1](#), or if using a pendant-mounted configuration, [Figure 3-2](#).

Move the ventilator using the handle encircling the BDU and roll the ventilator to the desired location.

Figure 3-1. Example of Freestanding Ventilator Placement



VEN_10308_B

Figure 3-2. Example of Pendant-mounted Ventilator

3.5 Product Connectivity

3.5.1 Connecting the Ventilator to AC Power

**Note:**

Power outlet access and power cord position—Ensure that the power outlet used for the ventilator is easily accessible; disconnection from the outlet is the only way to completely remove power from the ventilator.

To connect the power cord to AC power

1. Plug the ventilator into a properly grounded power outlet rated for at least 15 A.
2. Verify the connection by checking the AC indicator below the power switch on the front of the BDU. See [Figure 2-9.](#) on page 2-24 for the power switch and AC indicator locations.

To connect the power cord to the ventilator

1. Remove the power cord retainer and connect the female end of the power cord to the ventilator's power cord receptacle. See [Figure 3-3.](#) on page 3-6 and [Figure 3-4.](#) on page 3-7.
2. Set hex nuts and spacers, if present, aside for reassembly.
3. Replace the power cord retainer, using the hex nuts and spacers removed during disassembly. See [Figure 3-3.](#) on page 3-6 or [Figure 3-4.](#) on page 3-7.

**Note:**

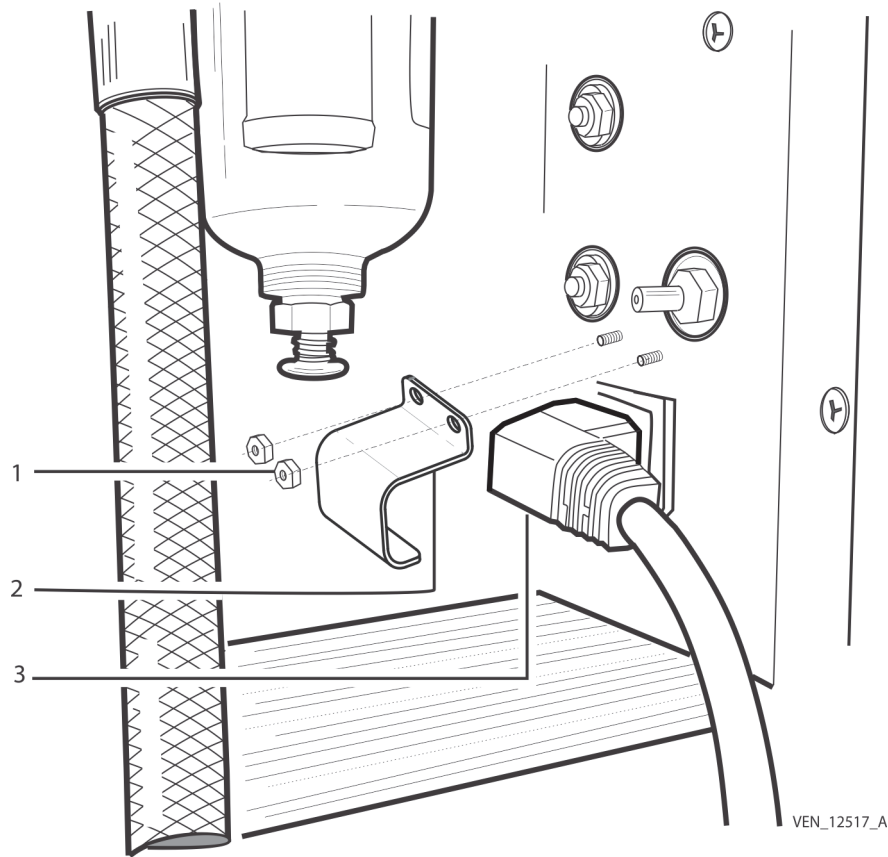
Your ventilator may have either combination of power cord and retainer.

Use the power cord hook located at the back of the ventilator for power cord storage.

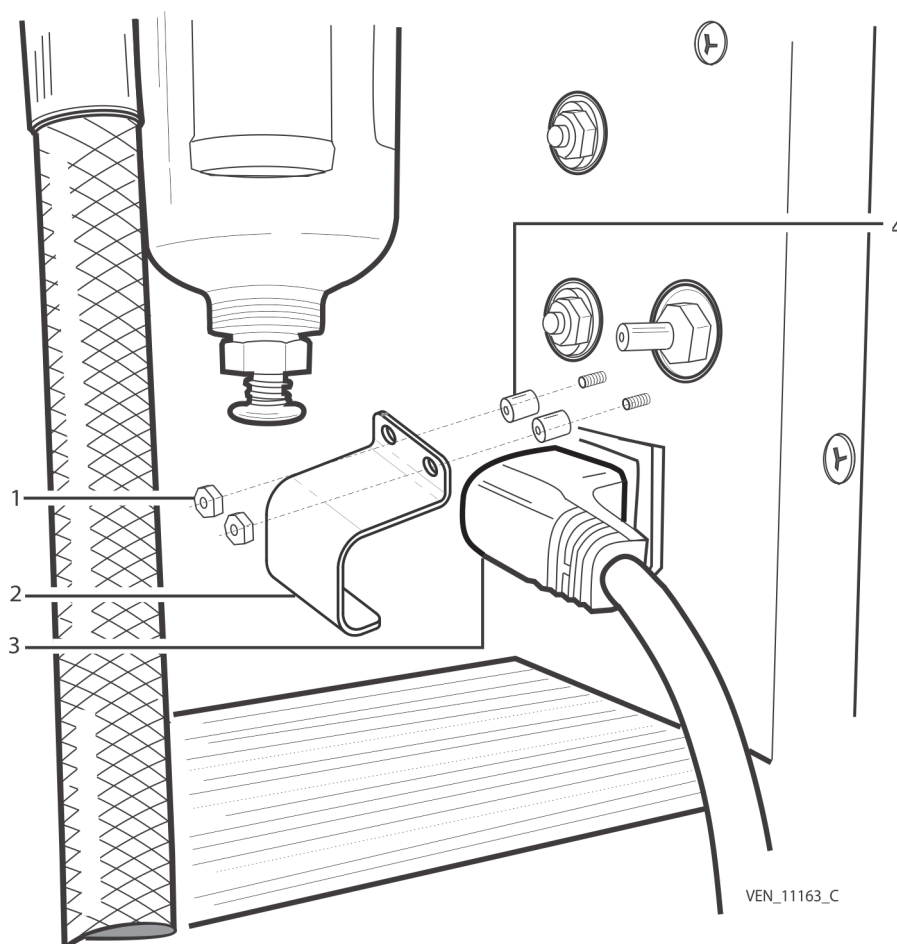


WARNING:
For proper ventilator operation, and to avoid the risk of electric shock, connect the ventilator to a grounded, hospital-grade, AC electrical outlet.

Figure 3-3. Power cord Retainer on BDU (without spacers)



- | | | | |
|---|---------------------|---|---------------|
| 1 | 1/4 in. hex nuts | 3 | AC power cord |
| 2 | Power cord retainer | | |

Figure 3-4. Power Cord Retainer on BDU (with spacers)

1 1/4 in. hex nuts

2 Power cord retainer

3 AC power cord

4 Spacers

3.5.2 Connecting the Gas Supplies

The ventilator can be connected to hospital grade wall or bottled air and oxygen. See [Figure 3-5.](#) on page 3-8. Both air and O₂ supply pressure ranges must be between 241.3 kPa to 599.8 kPa (35 psig and 87 psig) and the average flow requirement for both gases is 60 L/min at 280 kPa (40.61 psi). The transient will not exceed 200 L/min for ≥3 seconds.



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 <345 k Pa (50 psi) are employed.

Gas cross flow from one high pressure input port of one type of gas to another high pressure input port of a different gas will not exceed 100 mL/h under normal or single fault conditions. If, during a single fault condition, cross flow exceeds 100 mL/h, an audible alarm annunciates.

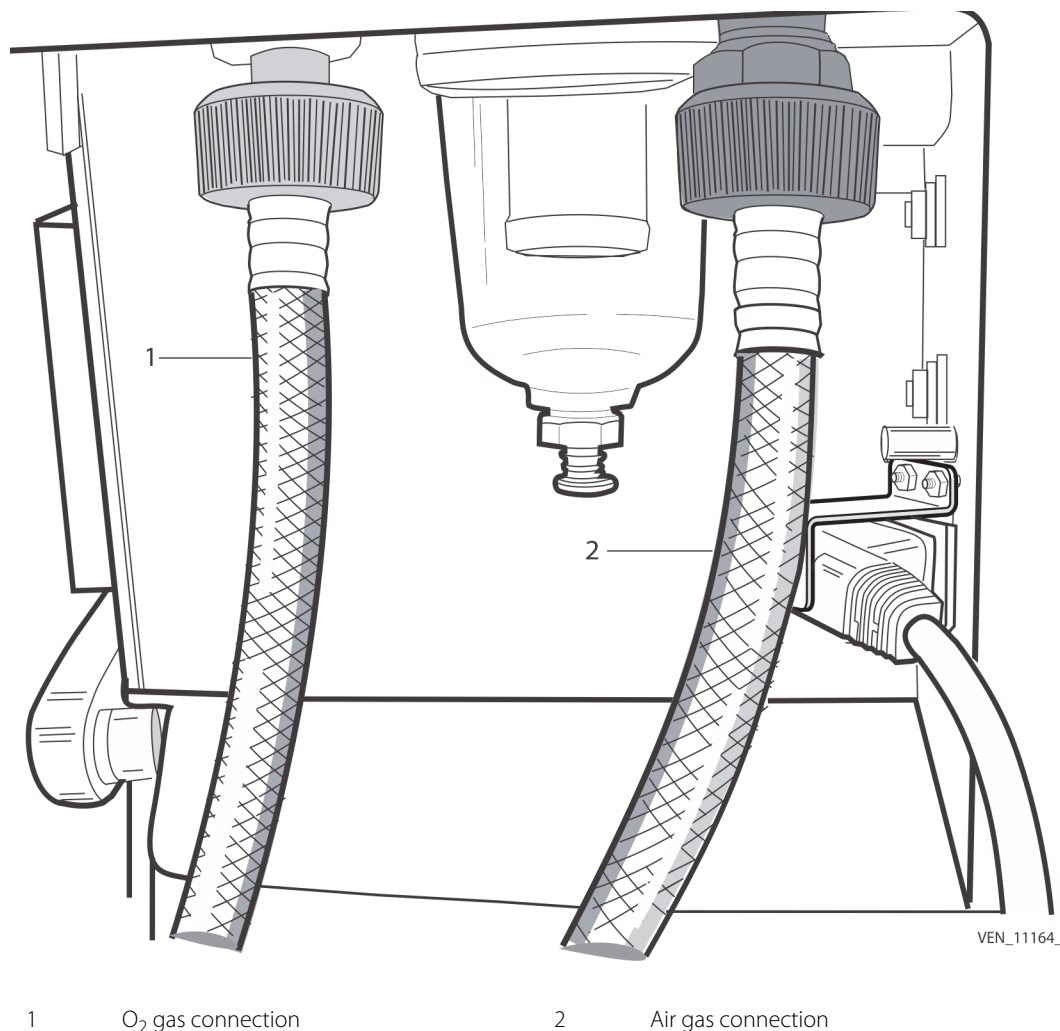
**WARNING:**

Use of only one gas source could lead to loss of ventilation or hypoxemia if that one gas source fails and is not available. Therefore, always connect at least two gas sources to the ventilator to ensure a constant gas supply is available to the patient in case one of the gas sources fails. The ventilator has two connections for gas sources: air inlet, and oxygen inlet. See [Table 6-5](#), on page 6-16 for alarms that occur due to a loss of gas supplies.

To connect the gas sources

1. Connect the oxygen hose to the oxygen inlet fitting (item 1) as shown. Ensure use of a medical grade oxygen source.
2. Connect the air hose to the air inlet fitting (item 2) See [Figure 3-5](#), on page 3-8.

Figure 3-5. Connecting the Ventilator to the Gas Supplies



**WARNING:**

To prevent a potential fire hazard and possible damage to the ventilator, ensure the connections to the gas supplies are clean and unlubricated, and there is no water in the supply gas. If water is suspected, use an external wall air water trap to prevent damage to the ventilator or its components.

The ventilator system can be purchased with the following gas inlet fittings for both air and O₂: BOC, DISS, female, NIST, Air Liquide, SIS, and Dräger.

See [Table 9-1.](#) on page [9-3](#) for part numbers of gas hoses.

3.5.3 Filter Installation

The ventilator is shipped with internal and external inspiratory filters. See [Table 9-1.](#) on page [9-3](#) for the part numbers of exhalation filters. To prevent infection and contamination, both inspiratory and exhalation filters must be used with the ventilator.

**WARNING:**

To reduce the risk of infection, always use the ventilator with inspiratory and exhalation bacteria filters.

**WARNING:**

Do not attempt to use inspiratory or exhalation filters designed for use with ventilators other than the Puritan Bennett 980 Series Ventilator. See [Table 9-1.](#) on page [9-3](#) for relevant part numbers.

**WARNING:**

Refer to the filter's instructions for use (IFU) for details such as cleaning requirements, filtration efficiency, proper filter usage, and maximum filter resistance, particularly when using aerosolized medications.

**Caution:**

Ensure both inspiratory and exhalation filters are properly attached to the ventilator.

**Note:**

Refer to the inspiratory filter IFU for information on proper use and handling of the filter.

To install the inspiratory filter

1. Attach the inspiratory filter to the **to patient** port.
2. Ensure the direction of flow arrow is pointing outward, toward the patient circuit's inspiratory limb.

**Note:**

Refer to the inspiratory filter IFU for information on proper use and handling of the filter.

**Note:**

Refer to the exhalation filter IFU for information on proper use and handling of the filter and for emptying the condensate vial for adult and pediatric patients. See Appendix [D](#) for information on emptying the condensate vial when using neonatal exhalation filters.

**WARNING:**

Do not reuse disposable inspiratory or exhalation filters, and dispose of the filters according to your institution's policy for discarding contaminated waste.

To install the adult/pediatric exhalation filter

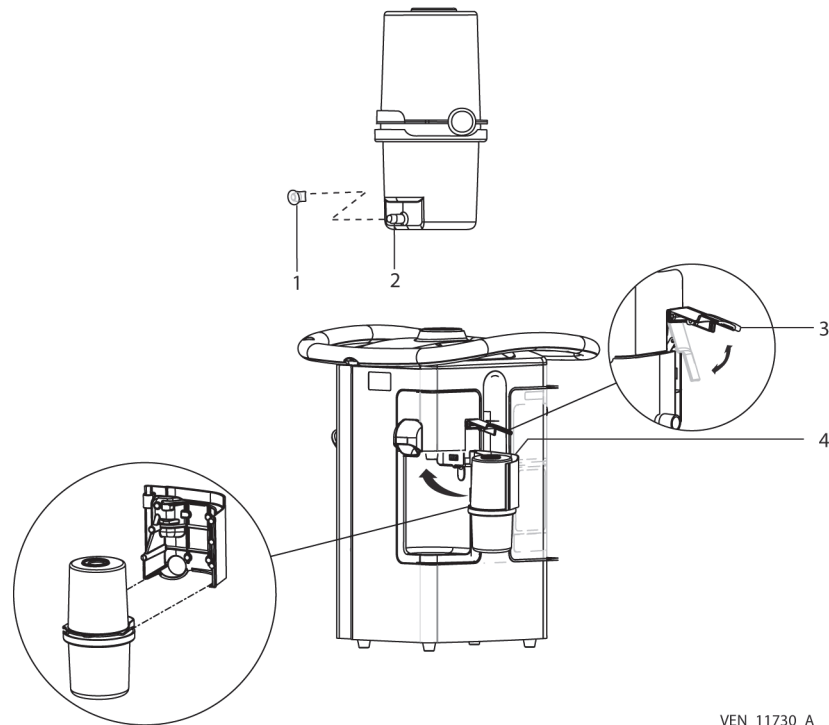
1. If necessary, remove the expiratory limb of the patient circuit from the exhalation filter.
2. Raise the exhalation filter latch to unlock (item 3). See [Figure 3-6](#), on page [3-11](#). This raises the exhalation valve assembly and allows the filter door to swing away from the ventilator.
3. Open the exhalation filter door.
4. Remove the existing filter.
5. Insert the new filter by sliding the filter along the tracks in the door. Ensure the **from patient** port aligns with the cutout in the door and points away from the ventilator.
6. Close the exhalation filter door.
7. Lower the exhalation filter latch to secure the filter.

**WARNING:**

Do not operate the exhalation filter latch during patient ventilation. Opening the latch during ventilation will result in a patient disconnect condition and corresponding alarm.

**Note:**

To prevent EVQ misalignment and potential damage, ensure there is an exhalation filter in place any time the ventilator is transported from one location to another.

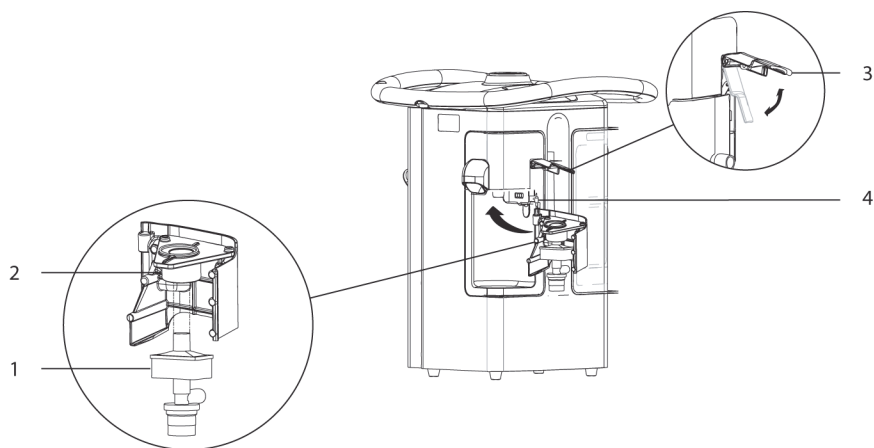
Figure 3-6. Adult/Pediatric Filter Installation

VEN_11730_A

- | | | | |
|---|---------------------------|---|-------------------------|
| 1 | Condensate drain port cap | 3 | Exhalation filter latch |
| 2 | Condensate drain port | 4 | Exhalation filter door |

To install the neonatal exhalation filter adapter door

1. If necessary, remove the expiratory limb of patient circuit from the exhalation filter.
2. Lift the exhalation filter latch. See [Figure 3-7](#). (item 3).
3. Remove the existing exhalation filter door by lifting it off of the pivot pins.
4. Fit neonatal adapter door onto the pivot pins.

Figure 3-7. Installing the Neonatal Filter

VEN_11162_A

- | | | | |
|---|----------------------------|---|-------------------------|
| 1 | Neonatal exhalation filter | 3 | Exhalation filter latch |
| 2 | Neonatal adapter door | 4 | Filter door pivot pin |

**Note:**

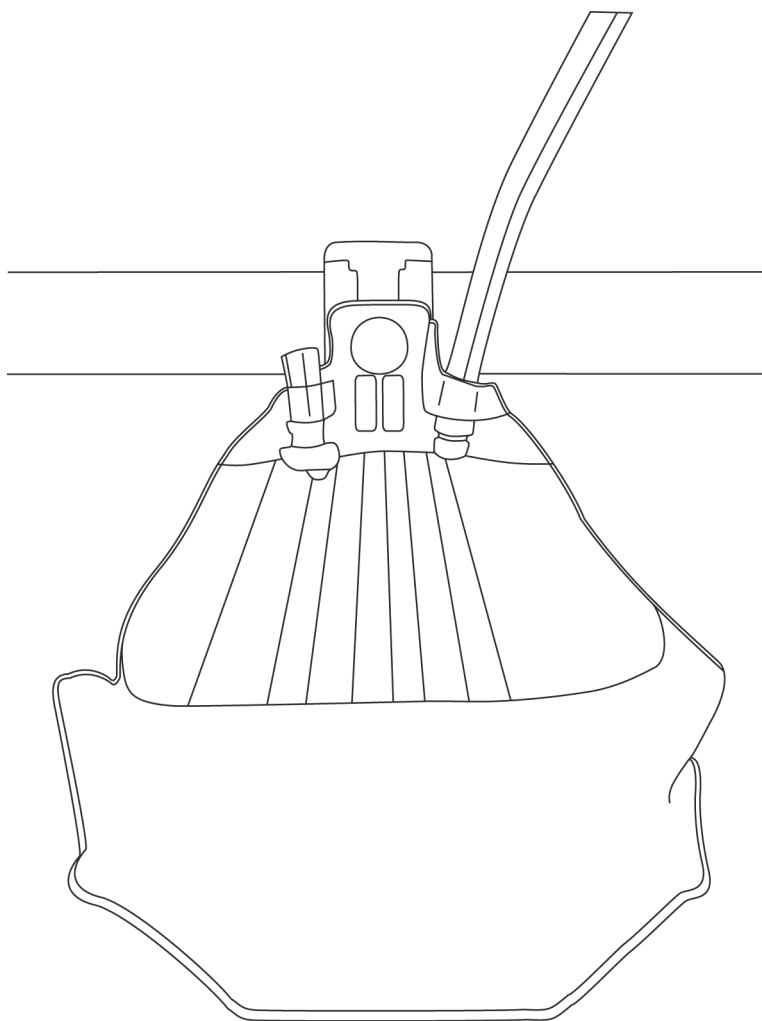
The condensate vial is removable for discarding accumulated liquid, by turning the vial clockwise to remove and counterclockwise to install.

To install the neonatal exhalation filter assembly

1. With the door still open, push the neonatal filter assembly straight up into the adapter.
2. Close the door.
3. Lower the exhalation filter latch.
4. Re-attach the expiratory limb of the patient circuit to the filter.

To use the drain bag

1. Remove the drain port cap from the exhalation filter condensate vial drain port.
2. Attach the drain bag tube to the condensate vial's drain port.
3. Hang the drain bag on the holder located on the ventilator's accessory rail, as shown in [Figure 3-8.](#) on page [3-13](#). See [Table 9-1.](#) on page [9-3](#) for the part number of the drain bag holder.

Figure 3-8. Drain Bag

VEN_11209_A

3.5.4 Connecting the Patient Circuit

See [Figure 3-9.](#) on page 3-15 or [Figure 3-10.](#) on page 3-16 to connect the adult, pediatric, or neonatal patient circuits, respectively.

**WARNING:**

Use patient circuits of the lowest compliance possible with the ventilator system to ensure optimal compliance compensation and to avoid reaching the compliance compensation limit. See [Table 3-1.](#) for circuit types corresponding with predicted body weight (PBW).

Table 3-1. Patient Types and PBW Values

Circuit type	PBW in kg (lb)	Allowed but not recommended
Neonatal	0.3 kg to 7.0 kg (0.66 lb to 15 lb)	Not applicable
Pediatric	7.0 kg to 24 kg (15 lb to 53 lb)	3.5 kg to 6.9 kg and 25 kg to 35 kg (7.7 lb to 15 lb and (55 lb to 77 lb)
Adult	25 kg to 150 kg (55 lb to 331 lb)	7.0 kg to 24 kg (16 lb to 53 lb)

**Note:**

Refer to the patient circuit's IFU for information on proper use and handling and care and maintenance of the circuit.

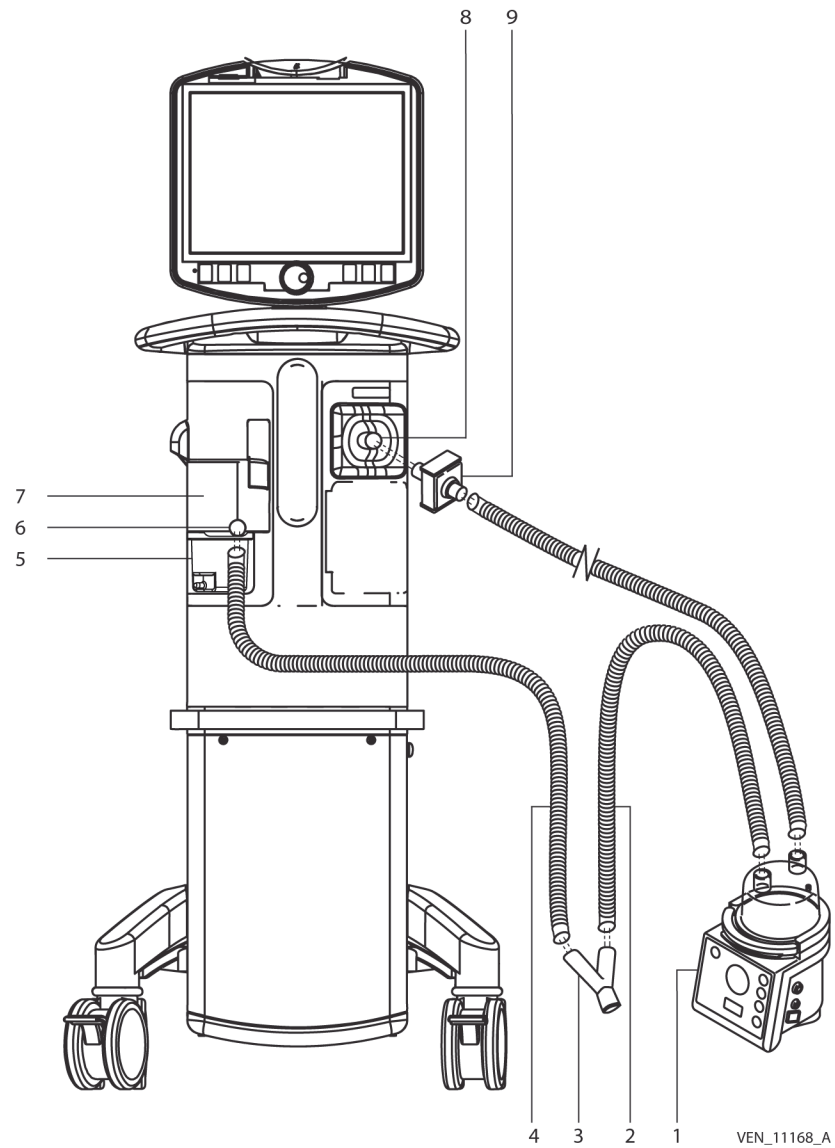
A list of breathing system components and accessories is provided. See [Table 9-1](#), on page 9-3. Use only Covidien components and accessories in the patient circuit.

Follow your institution's protocol for safe disposal of the patient circuit.

Follow the patient circuit's IFU for cleaning and disinfection information for reusable circuits.

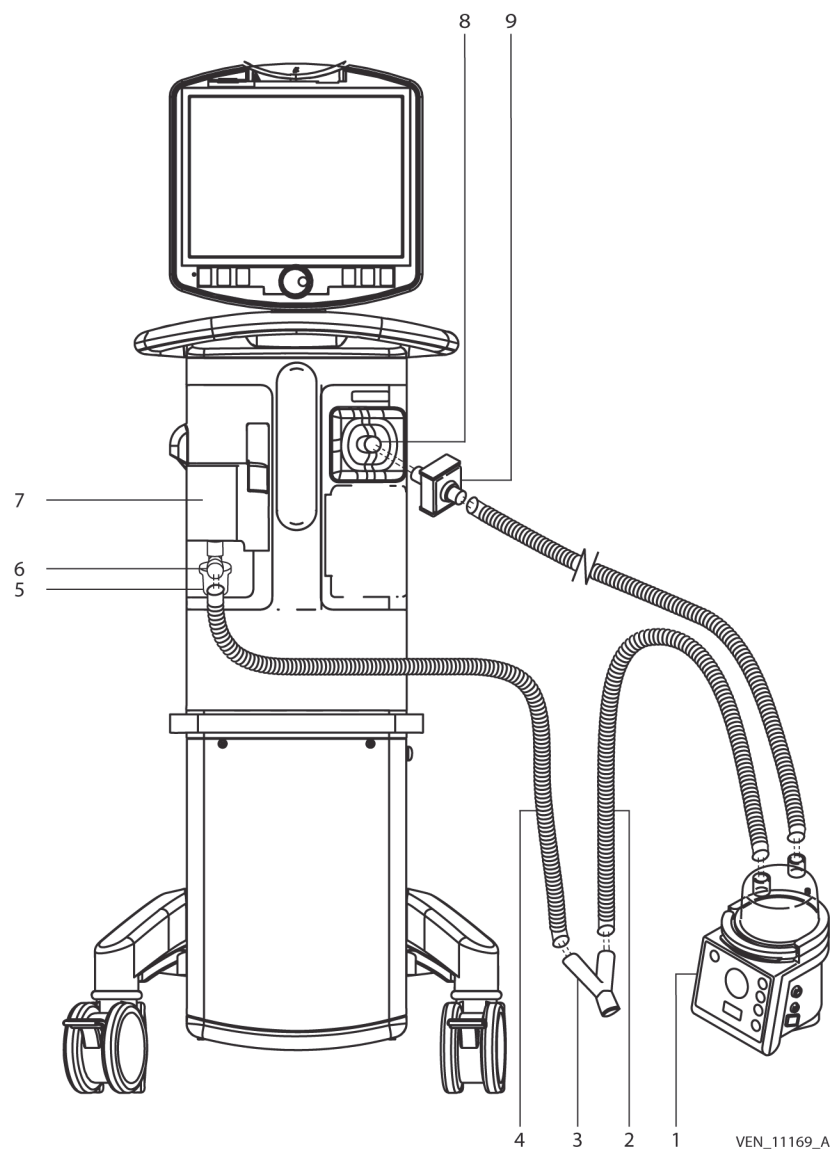
Orient the patient circuit by hanging the patient circuit on the circuit management supports provided with the flex arm.

Figure 3-9. Connecting the Adult or Pediatric Patient Circuit



- | | | | |
|---|------------------|---|--------------------------|
| 1 | Humidifier | 6 | From patient port |
| 2 | Inspiratory limb | 7 | Exhalation filter |
| 3 | Circuit wye | 8 | To patient port |
| 4 | Expiratory limb | 9 | Inspiratory filter |
| 5 | Condensate vial | | |

Figure 3-10. Connecting the Neonatal Patient Circuit



- | | | | |
|---|----------------------------------|---|--|
| 1 | Humidifier | 6 | From patient port |
| 2 | Patient circuit inspiratory limb | 7 | Neonatal exhalation filter (installed in adapter door) |
| 3 | Circuit wye | 8 | To patient port |
| 4 | Patient circuit expiratory limb | 9 | Inspiratory filter |
| 5 | Condensate vial | | |



WARNING:
Do not attempt to sterilize single-use circuits.

3.6 How to Install Accessories

3.6.1 Batteries



WARNING:

Use only Covidien batteries. Using other manufacturer's brands or remanufactured batteries could result in the batteries operating the ventilator for less than the specified amount of time or could cause a fire hazard.



WARNING:

To reduce the risk of infection due to cross-contamination, using a damp cloth, disinfect the batteries with one of the solutions listed before installation and whenever transferring to or from another ventilator. During use, clean external surfaces of batteries as necessary. See [Table 7-2](#) on page 7-4. Do not spray disinfectant directly onto the battery or its connector.



WARNING:

Although the Puritan Bennett 980 Ventilator meets the standards listed in Chapter 11, the internal lithium-ion battery of the device is considered to be Dangerous Goods (DG) Class 9 - Miscellaneous, when transported in commerce. As such, the Puritan Bennett 980 Ventilator and the associated lithium-ion battery are subject to strict transport conditions under the Dangerous Goods Regulation for air transport (IATA: International Air Transport Association), International Maritime Dangerous Goods code for sea and the European Agreement concerning the International Carriage of Dangerous Goods by Road (ADR) for Europe. Private individuals who transport the device are excluded from these regulations although for air transport some requirements may apply.



WARNING:

To avoid the risk of fire, explosion, electric shock, or burns, do not short circuit, puncture, crush, heat above 60°C, incinerate, disassemble the battery, or immerse the battery in water.



Caution:

Ensure that the batteries are oriented properly. See [Figure 3-12](#) on page 3-19.

Figure 3-11. Battery

VEN_11449_A

1 Battery connector

Primary Batteries

The ventilator's primary battery is located in the rearward battery receptacle on the right side of the BDU. The compressor's primary battery is located in the rearward battery receptacle in the compressor base. See [Figure 3-13.](#) on page 3-20. The primary battery may be "hot swapped," that is it can be replaced while the ventilator is operating.

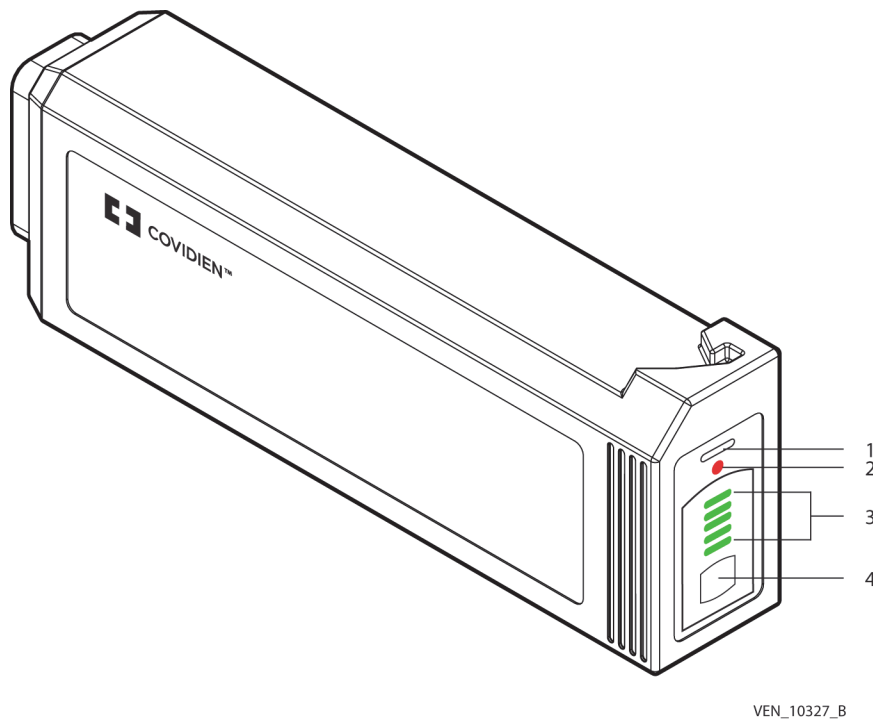
To install or replace the primary battery in the BDU or compressor

1. With the battery not installed in the ventilator, or if the ventilator is turned off and not connected to AC power, check the charge level by pressing the charge level button on the battery and verifying the charge level LEDs illuminate. See [Figure 3-12.](#) on page 3-19. for the location of the charge level button. Five green LED segments illuminate, indicating $\geq 90\%$ battery capacity. From bottom to top, the first LED indicates $\geq 10\%$ capacity, the second LED indicates $\geq 25\%$ capacity, the third LED indicates $\geq 50\%$ capacity, and the fourth LED indicates $\geq 75\%$ capacity. An illuminated red LED at the top of the battery indicates a battery fault. If no LEDs illuminate it means there is $< 10\%$ battery capacity remaining.
2. If the charge level is sufficient, orient the battery as shown in [Figure 3-13.](#) on page 3-20, face the front of the ventilator and locate the battery compartments on the right side of the appropriate module. The

receptacle towards the rear of the ventilator houses the primary battery while the receptacle towards the front of the ventilator houses the extended battery.

3. The primary battery is fastened in place with a thumbscrew (item 3). Loosen the thumbscrew approximately four to five turns to allow battery installation.
4. Insert the battery and push into its receptacle all the way until it clicks, indicating it is latched. The battery will only fit into the slot one way.

Figure 3-12. Proper Battery Orientation



- | | | | |
|---|-----------------------------|---|--------------------------|
| 1 | White battery in-use LED | 3 | Green charge status LEDs |
| 2 | Red battery fault indicator | 4 | Charge level button |

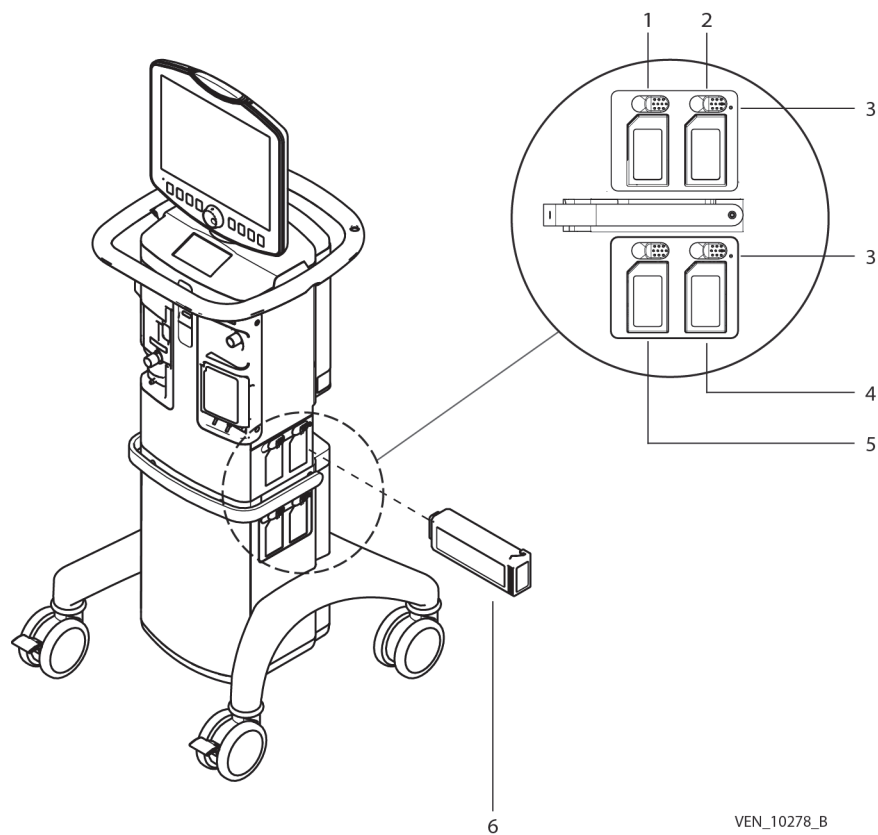
5. Tighten the thumbscrew to secure the battery and prevent the primary battery from being removed.



Note:

Remove either primary battery by reversing the steps. After loosening the thumbscrew, slide the battery ejector to the left to eject the battery.

Figure 3-13. Battery Compartment Locations



VEN_10278_B

- | | | | |
|---|--|---|--|
| 1 | BDU extended battery receptacle and ejector | 4 | Compressor primary battery receptacle and ejector |
| 2 | BDU primary battery receptacle and ejector | 5 | Compressor extended battery receptacle and ejector |
| 3 | BDU and compressor primary battery thumbscrews | 6 | BDU primary battery (positioned for installation) |

Extended batteries

The extended battery receptacle is located forward of the primary battery. Like the primary battery, the extended battery may be hot swapped.

To install or remove an extended battery in either the BDU or compressor

1. Properly orient the battery as shown in [Figure 3-13](#), on page 3-20.
2. Push the battery into the forward receptacle in the BDU all the way until it clicks, indicating the battery is latched.

**Note:**

Remove the battery by sliding the battery ejector to the left. The battery ejects itself from its receptacle. There is no thumbscrew for extended batteries.

**Note:**

See [Battery Charging](#), page 3-3 for battery charging information when batteries are installed in the ventilator.

3.6.2 Battery Testing

To test the batteries

1. Push the battery charge level button located on the battery. A series of LEDs illuminates, indicating the charge level of the battery. When the bottom LED is illuminated, there is $\geq 10\%$ of full battery capacity. The next LED illuminates when there is $\geq 25\%$ capacity. the third lamp illuminates when there is $\geq 50\%$ capacity available. The fourth LED illuminates when there is $\geq 75\%$ capacity, and when the top LED is illuminated, it represents $\geq 90\%$ capacity. See [Figure 3-12](#). on page [3-19](#) to view the battery test button and LEDs.

3.6.3 Battery Performance Test Results

Performance testing on a sample of new batteries and batteries charged and discharged at least 1000 times was completed to demonstrate that the ventilator's LOW BATTERY alarms remain effective. Testing demonstrated that the batteries have a minimum of 10 minutes time remaining from the activation of the low battery alarm and a minimum of 5 minutes time remaining from the critically low battery alarm until ventilator shutdown. See [Table 2-9](#). on page [2-27](#) for images of the Status Display during low battery and critically low battery conditions.

Performance testing on a sample of new batteries and batteries charged and discharged at least 1000 times was completed to demonstrate the expected run time of the ventilator on battery. This testing was performed for both typical ventilator settings and adult high demand ventilator settings.

The typical ventilator settings used were:

- Ventilator settings
 - Assist/Control Ventilation with Volume Control (VC) mandatory type
 - Tidal volume (V_T)=500 mL
 - Peak flow ($\dot{V}_{MAX}$)=30 L/min
 - Respiratory rate (f)=20 1/min
 - PEEP=8 cmH₂O

- Oxygen concentration (FiO_2)=60%
- Flow trigger ($\dot{V}$ -Trig)=3 L/min
- Approximate respiratory monitored parameters during simulation
 - Peak pressure (P_{PEAK})=27 cmH₂O
 - Plateau pressure (P_{PL}) during manual inspiratory pause =23 cmH₂O
 - Exhaled tidal volume (V_{TE})= 442 mL (BTPS)
 - Total respiratory rate (R_{TOT})=20 1/min
 - I:E ratio =1:2
 - PEEP=8 cmH₂O / Total PEEP (PEEP_{TOT}) during expiratory pause =8 cmH₂O
 - Exhaled minute volume ($\dot{V}_{\text{E TOT}}$)=8.84 L/min
- Adult high-demand ventilator settings
 - Assist/Control Ventilation with Pressure Control (PC) mandatory type
 - Inspiratory pressure (P_i)=55 cmH₂O
 - Inspiratory time (T_i)=0.55 s
 - Respiratory rate (f)=60 1/min
 - PEEP=35 cmH₂O
 - Oxygen concentration (FiO_2)=60%
 - Flow trigger ($\dot{V}$ -Trig)=20 L/min
- Approximate respiratory monitored parameters during adult high-demand simulation
 - Peak pressure (P_{PEAK})=90 cmH₂O
 - Plateau pressure (P_{PL}) during manual inspiratory pause =79 cmH₂O
 - Exhaled tidal volume (V_{TE})=900 mL (BTPS)
 - Total respiratory rate (R_{TOT})=60 1/min
 - I:E ratio =1:1
 - PEEP=39 cmH₂O / Total PEEP (PEEP_{TOT}) during expiratory pause =49 cmH₂O

- Exhaled minute volume ($\dot{V}_{E\text{TOT}}$)=52 L/min

The run time does not vary significantly between typical and heavy load settings. The ventilator can be expected to run approximately 75 minutes at typical settings with new batteries. When running batteries nearing end of life (batteries with 1000 charge/discharge cycles were used for this data) the run time can be expected to be approximately 55 minutes.

3.6.4 Battery Life

Battery life for both primary and extended batteries is approximately 3 years. Actual battery life depends on the history of use and ambient conditions. As the batteries age with use, the time the ventilator will operate on battery power from a fully charged battery will decrease. Replace the battery every 3 years or sooner if battery operation time is insufficient for your usage.

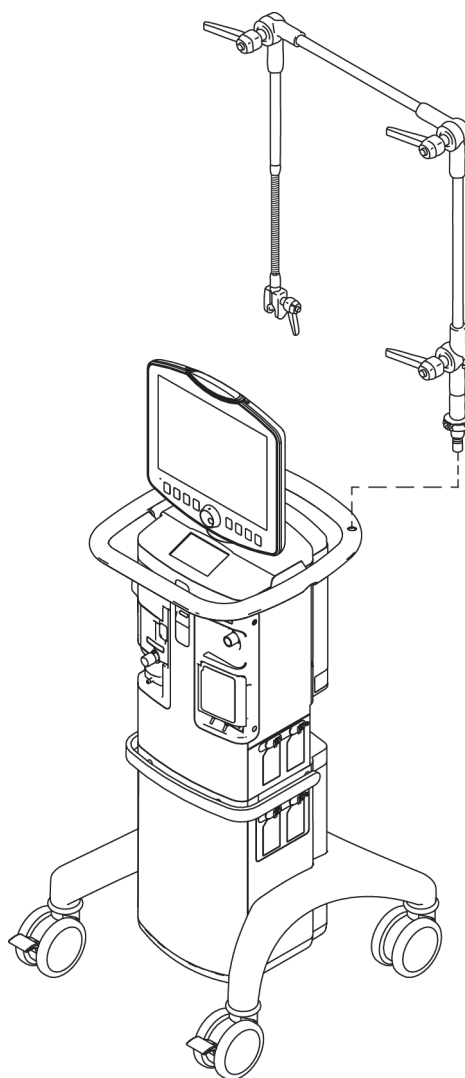
3.6.5 Battery Disposal



The battery is considered electronic waste and must be disposed of according to local regulations. Follow local governing ordinances and recycling plans regarding disposal or recycling of the battery.

3.6.6 Flex Arm

Use the flex arm to support the patient circuit between the patient and the ventilator. See [Figure 3-14](#) on page [3-24](#), which illustrates flex arm installation into the sockets provided.

Figure 3-14. Flex Arm Installation

VEN_10330_A

To attach or remove the flex arm

1. Locate the threaded inserts in the ventilator's handle.
2. Fasten the flex arm into one of the inserts.
3. Hang the patient circuit using the circuit management supports included with the flex arm.
4. Remove the flex arm by first removing the patient circuit, then unfastening the flex arm from the threaded fastener in the handle.

3.6.7 Humidifier

Use the humidifier to add heat and moisture to the inhaled gas. Connect the humidifier to a hospital grade electrical outlet. Choose the humidifier (type and volume appropriate for the patient).

The humidifier may be mounted with the humidifier bracket as shown in [Figure 3-15](#). on page 3-26. See [Table 9-1](#). on page 9-3 for the part number of the humidifier bracket.

**WARNING:**

Selection of the incorrect humidifier type or volume during SST or during patient ventilation can affect the accuracy of delivered volume to the patient by allowing the ventilator to incorrectly calculate the compliance correction factor used during breath delivery. This can be a problem, as the additional volume required for circuit compressibility compensation could be incorrectly calculated, resulting in over- or under-delivery of desired volume.

**WARNING:**

To ensure proper compliance and resistance calculations, perform SST with the humidifier and all accessories used for patient ventilation installed in the ventilator breathing system.

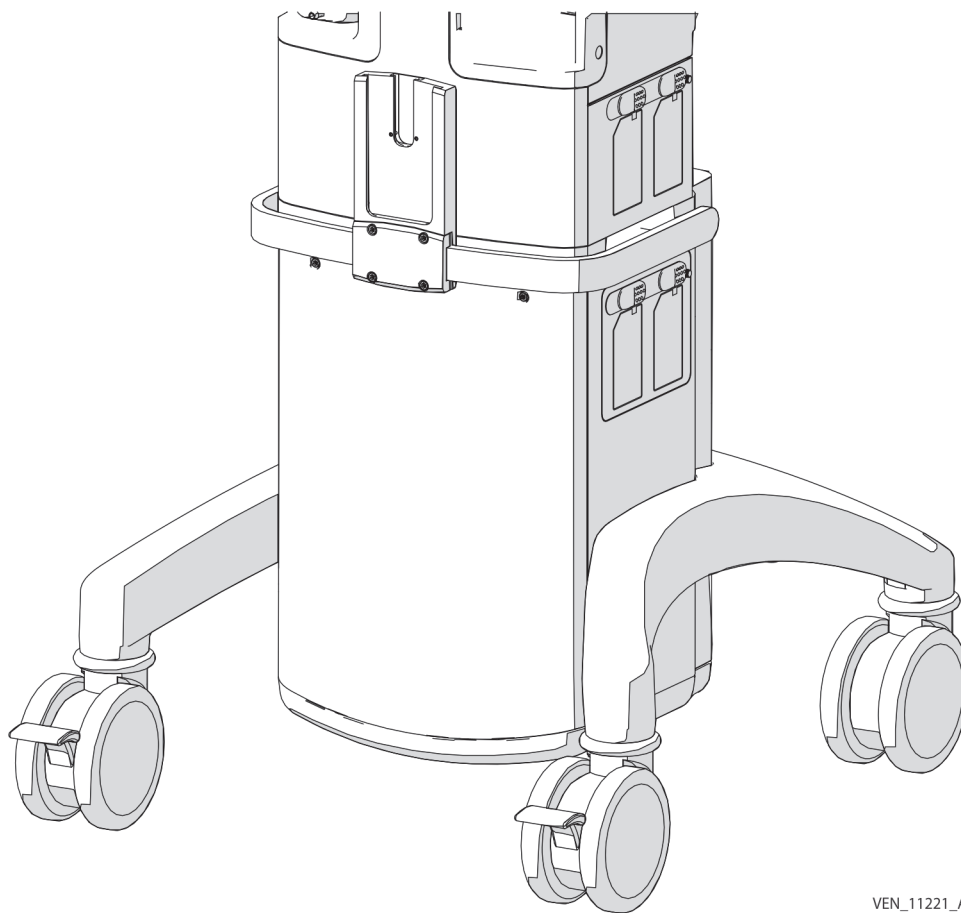
**WARNING:**

Follow the humidifier manufacturer's IFU when using a humidifier with patient ventilation.

**Caution:**

Follow the humidifier manufacturer's IFU for proper humidifier operation.

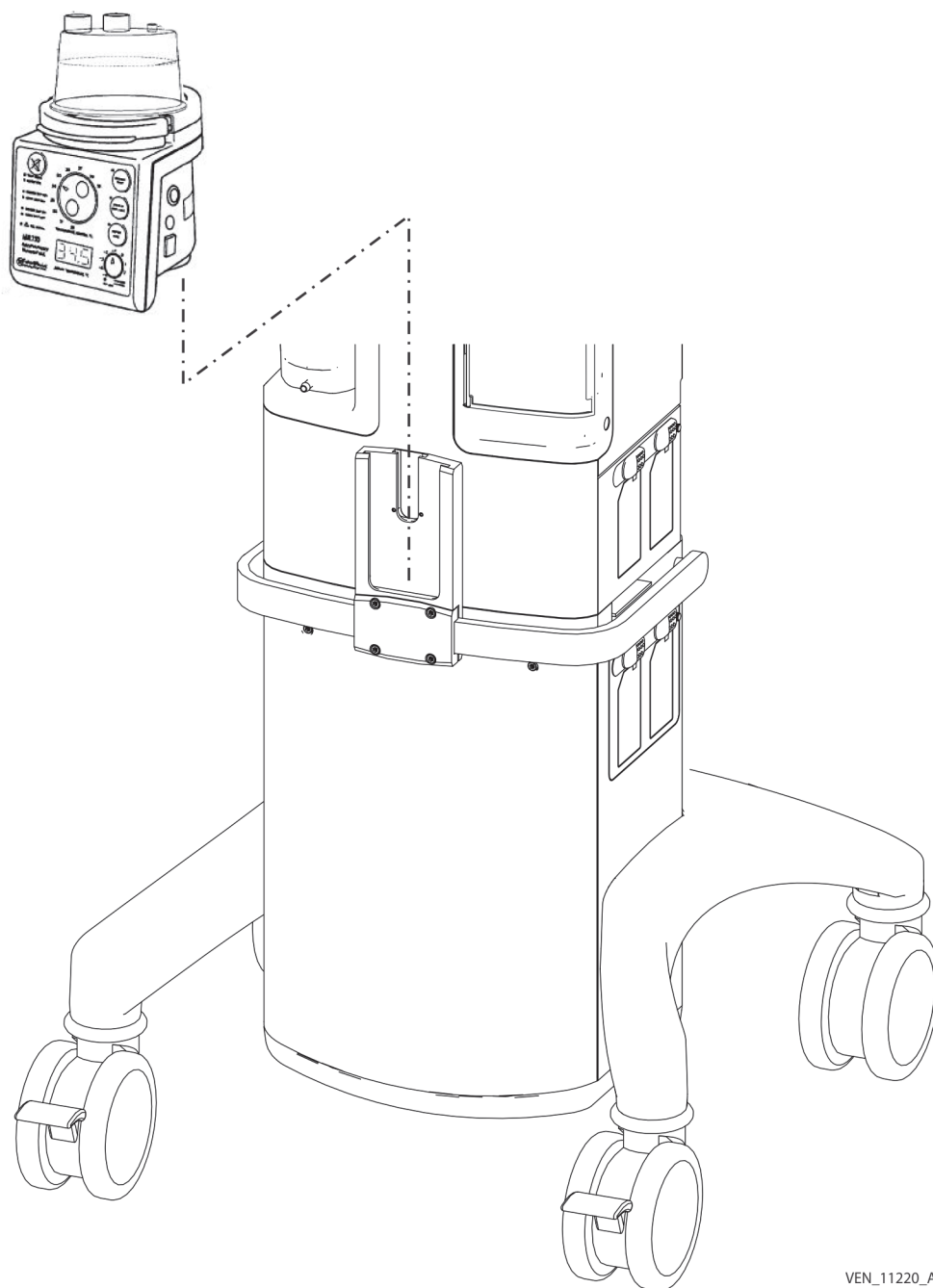
To install the humidifier bracket, attach it to the ventilator's accessory rail by placing it behind the railing and fastening the bracket clamp to the bracket with four 5/32 inch hex screws, capturing the railing between the bracket and the clamp. Ensure that the humidifier mounting slots are facing outward from the ventilator.

Figure 3-15. Bracket Installation on Rail

VEN_11221_A

To install the humidifier

1. Slide the rear of the humidifier into the corresponding slot on the humidifier bracket, until it is fully seated. See [Figure 3-16.](#) on page [3-27](#). Some humidifiers slide into the narrow slot in the humidifier bracket, and some humidifiers use the wide slot.

Figure 3-16. Humidifier Installation to Ventilator

VEN_11220_A†

2. Fill the humidification system with water to the desired volume.
3. Install the chamber to the humidifier, connect the patient circuit, then run SST.
4. Plug the humidifier into a grounded, hospital-grade electrical outlet.
5. Turn the humidifier on.

**Note:**

Complete instructions for the humidifier bracket and humidifier installation are given in the *Puritan Bennett™ 980 Series Ventilator Humidifier Bracket Installation Instructions*, which include humidifier bracket part numbers and descriptions.

3.7 Ventilator Operating Modes

3.7.1 Normal Mode

Normal mode is the default mode used for patient ventilation. The ventilator enters Normal mode after it has been turned on and POST completes, the ventilator is set up, and breath delivery parameters have been entered. The clinician may choose to select Quick Start which uses default values or institutionally configured breath delivery settings after PBW has been entered. Entry into Normal mode is not allowed if a primary battery is not detected in the ventilator BDU, a major POST fault occurs, or there is an uncorrected major system fault, or uncorrected **short self test (SST)** or **extended self test (EST)** failures or non-overridden alerts.

During Normal mode, the omni-directional LED on the top of the GUI appears green in color, in a steadily lit state. If an alarm occurs, the LED flashes in a color corresponding to the priority of the alarm. See [Table 6-2](#) on page 6-14 for details regarding alarm priority. If another alarm occurs concurrently with an existing alarm, the LED displays the color corresponding to the highest priority level. If the alarm de-escalates, the latched area (located on either side of the alarm LED indicator) of the alarm LED displays the color of the highest priority alarm while the center of the LED displays the color of the current alarm's priority. For more information on specific alarms, touch the logs icon in the constant access icons area of the GUI.

3.7.2 Quick Start

Quick Start is an extension of Normal mode, where institutionally configured default settings are applied after the patient's PBW or gender and height are entered and Quick Start is touched to begin ventilation.

3.7.3 Stand-By State

Stand-By state can be used when the clinician needs to disconnect the patient for any reason (prior to transporting a patient, for example). The ventilator enters Stand-By state if a request is made by the clinician, a patient is disconnected within a fixed time period determined by the ventilator software, and the clinician confirms the patient has been disconnected intentionally. If a patient becomes disconnected from the patient circuit after the time period elapses, an alarm sounds and the patient-disconnect sequence is initiated. In Stand-By state, gas output is reduced to 10 L/min to limit gas consumption and to allow for detection of patient reconnection, and O₂ concentration becomes 100% for adult and pediatric circuit types and 40% for neonatal circuit

types. Stand-By state is available in all ventilation modes except during inspiratory and expiratory **BUV**, **occlusion status cycling (OSC)**, **safety valve open (SVO)**, or **ventilator inoperative (vent inop)** conditions.



Note:

Do not block patient circuit wye while in Stand-By state. If the wye is blocked, the ventilator detects a patient connection and will attempt to resume normal ventilation.

To enter Stand-By state

1. Touch the Menu tab on the left side of the GUI. The menu appears.
2. Touch Stand-By. A Stand-By state pending dialog appears instructing the clinician to disconnect the patient circuit. A timer starts allowing 30 seconds to disconnect the patient.
3. Disconnect the patient circuit and confirm the disconnection by touching Confirm. A timer starts allowing 30 seconds for confirmation of disconnect.

To exit Stand-By state

1. Reconnect the patient circuit. The ventilator resumes ventilation at the settings in use before the disconnection.

The following ventilator settings become active during Stand-By state:

- Base flow is set to 10 L/min
- 100% O₂ for adult/pediatric patients
- 40% O₂ for neonatal patients

During Stand-By state:

- The exhalation valve is open.
- Current ventilator settings are retained in memory.
- Flow sensors are monitored to detect patient reconnection.
- Patient-related alarms are temporarily suppressed, as described below.
- Ventilator settings can be changed, if desired, and will be applied upon patient reconnection.
- The ventilator displays an indicator that it is in Stand-By State, and a timer indicating the elapsed time the ventilator has been in Stand-By state.
- Ventilator background checks continue to be made.

The ventilator automatically exits Stand-By state when patient reconnection is detected, the clinician completes patient setup (if ventilation was mistakenly started before setup was complete), or the ventilator power is cycled.

Prior to entering Stand-By state, the ventilator measures pressure and flow in the patient circuit to determine if a patient is attached. If a patient is detected, the ventilator continues ventilation as set prior to the request, alerts the operator that Stand-By state is pending, and requests the patient be disconnected. A countdown timer appears alerting the operator of the time remaining to disconnect the patient. After the patient is disconnected, the ventilator requests confirmation of the disconnection.

When the ventilator enters Stand-By state, a message appears on the GUI, any active alarms are silenced and reset and the associated alarm reset entries are logged in the Alarm Event Log. Alarm detection is suspended, and breath delivery is suspended while a bias flow is maintained for patient detection. During Stand-By state, the ventilator displays the elapsed time the patient has been without ventilation. As the ventilator maintains a bias flow for patient detection, it resumes ventilation at the previous settings when the patient is reconnected. There is no need to touch Exit Stand-By. Reconnecting the patient returns the ventilator to normal operation. During Stand-By state, patient data values are not displayed and the LED located at the top of the GUI cycles between yellow and green. Entry into and exit from Stand-By state are recorded in the General Event log.

3.7.4 Service Mode



WARNING:

Before entering Service mode, ensure a patient is not connected to the ventilator. Ventilatory support is not available in Service mode.

Service mode is used for extended self test (EST), ventilator calibration, configuration, software upgrades, option installation (all of which must be performed by qualified service personnel), and for making adjustments to institutional settings. All information stored in the individual logs is available in Service mode. Service mode logs include:

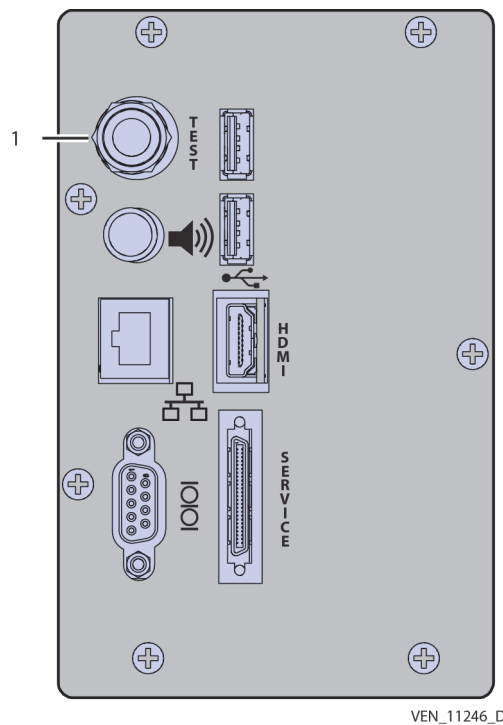
- System Diagnostic
- System Comm.
- EST/SST Diagnostic
- Settings
- Alarms
- General Event
- Service
- Patient Data

See the *Puritan Bennett™ 980 Series Ventilator Service Manual* for details about Service mode logs.

A patient must not be attached to the ventilator when entering Service mode. Specific actions must be performed to enter this mode, prior to POST completion.

To access Service mode

1. Remove the ventilator from patient usage.
2. Turn the ventilator's power switch on.
3. Press and release the Service mode button (TEST) at the back of the ventilator, when the Covidien splash screen appears on the status display after powering on the ventilator. See [Figure 3-17](#). on page 3-31. See [Table 2-9](#). on page 2-27 for an image of the splash screen. The ventilator prompts to confirm no patient is attached.

Figure 3-17. Service Mode Button (TEST)

1 Service mode button

4. Wait to enter Service mode.
5. Confirm that a patient is not connected to the ventilator by touching the corresponding button. The message SERVICE MODE VENTILATION SUPPORT IS NOT AVAILABLE appears on the graphical user interface.
6. Perform required service.
7. Turn off the ventilator to exit Service mode.

See the *Puritan Bennett™ 980 Series Ventilator Service Manual* for information on the keys that are disabled during EST.

In addition to allowing SST to be run, Service mode also allows configuration of various items. [Table 3-2](#) lists institutionally and operator-configurable items.

3.8 Product Configuration



WARNING:

If the ventilator fleet in your institution uses multiple institutionally configured presets or defaults, there can be risks of inappropriate alarm settings.

The ventilator is shipped configured with factory defaults for new patient parameters which can be configured to suit institutional preferences. The operator may configure any desired parameter as long as this option has not been locked out and rendered unavailable. When configuring the ventilator, it displays the parameters associated with the operator's last configuration.

[Table 3-2](#) lists the factory-configured settings, the institutionally configurable settings, and the operator-configurable settings.

Table 3-2. Ventilator Configuration

Feature	Factory-configured	Institutionally configurable	Operator-configurable	Configured by circuit type	User lockable
Vital patient data banner	X	X	X		X
Large font patient data panel	X	X	X		X
Waveform layout	X	X	X		X
Display brightness (Light settings)	X	X	X		
Alarm volume	X	X	X	X	
Elevate O ₂ control	X	X	X	X	
Date/time format	X	X	X		X
Default mL/kg ratio	X	X			Cannot be changed in Normal mode

Table 3-2. Ventilator Configuration (Continued)

Feature	Factory-configured	Institutionally configurable	Operator-configurable	Configured by circuit type	User lockable
New patient startup defaults (including PBW, ventilation type, mode, mandatory type, trigger type, O ₂ %, elevate O ₂)	X	X		X	
Opacity	X	X	X		X

3.8.1 Preparing the Ventilator for Use



Caution:

Do not lean on the GUI or use it to move the ventilator. Doing so could break the GUI, its locking mechanism, or tip the ventilator over.

Prior to ventilating a patient, configure the GUI so it is capable of displaying all the desired parameters, information, and patient data. This eliminates the necessity for taking the patient off the ventilator, as configuration of many of the items requires the unit to be in Service mode.

To perform institutional configuration

1. Enter Service mode, and confirm no patient is attached by touching Confirm. See [Service Mode \(3.7.4\)](#) on page 3-30 for instructions on entering Service mode.
2. Touch Configuration at the top of the screen in Service mode. A list of buttons appears allowing configuration of the corresponding parameters.
3. See the next sections for specific instructions on institutional configuration of each parameter.

To return to factory default configuration

1. Enter Service mode, and confirm no patient is attached by touching Confirm. See [Service Mode \(3.7.4\)](#) on page 3-30, for instructions on entering Service mode.
2. Touch Configuration at the top of the screen in Service mode. A list of buttons appears allowing configuration of the corresponding parameters.
3. Select the desired modified setting from the left-hand menu options.
4. Touch Default.

3.8.2 Configuring the GUI

The display can be configured in various ways. See [Table 3-2](#) on page 3-32 for the parameters that are factory-configured, institutionally configurable and operator-configurable. Once the factory- or institutionally configurable items have been configured, they remain the default values. Factory-configured values cannot be changed, however, if the parameters listed in the referenced table are institutionally configured, then those values remain in memory as default settings. If changes are made to operator-configurable parameters, they remain in memory during a ventilator power cycle as long as the same patient is set up when returned to ventilation. If a new patient is set up, the factory-configured values or institutionally configured values (if the parameter has been configured) are used. No alarm settings are institutionally configurable, which prevents changes to factory default alarm settings. However, the default mL/kg ratio is institutionally configurable, which can affect the default alarm setting values. Always review the alarm defaults prior to beginning ventilation, and set appropriately.

Date and Time Format

The date and time may be configured to the institution's preference. The time can be specified as 12-hour or 24-hour time in HH:MM:SS format with 1-hour and 1-minute resolutions, respectively. The date formats are:

- DD-MMM-YYYY where DD is a two-digit day format, MMM is a three-letter abbreviation for the month, and YYYY is a four-digit representation of the year.
- MM-DD-YYYY where MM is a two-digit month format, DD is a two-digit day format, and YYYY is a four-digit representation of the year.

The settable date corresponds to the number of days in the set month and accounts for leap years.

To institutionally configure the ventilator's date and time settings

1. Perform steps 1 and 2 of the section [To perform institutional configuration](#), page 3-33.
2. Touch Date and Time.
3. Touch the button corresponding to 12-hour or 24-hour time.
4. Touch Hour and turn the knob to enter the correct hour.
5. Repeat for the minutes, and am or pm.
6. Touch the button corresponding to the date format desired (DD-MM-YYYY or MM-DD-YYYY).
7. Touch Accept to confirm the date and time.
8. If done configuring parameters, exit Service mode.

Pressure Units

The ventilator's pressure units can be configured for hPa or cmH₂O.

To institutionally configure pressure units

1. Perform steps 1 and 2 of the section [To perform institutional configuration](#), page 3-33.
2. Touch the vent setup button.
3. Touch the button corresponding to the desired pressure units.
4. If done configuring parameters, exit Service mode by touching Exit.



Screen Brightness and Keyboard Backlight (Light Settings)

To institutionally configure screen brightness and keyboard backlight

1. Perform steps 1 and 2 of the section [To perform institutional configuration](#), page 3-33.
2. Touch Light Settings. Sliders appear to adjust the screen brightness and keyboard backlight.
3. Move the sliders to increase or decrease the brightness and backlight levels. Alternatively, turn the knob to increase or decrease the brightness and backlight levels.
4. Touch Accept to apply the changes, or Cancel to revert to original settings.
5. If done configuring parameters, exit Service mode.

To adjust display brightness



1. Press the display brightness key.
2. Slide the brightness slider or turn the knob to adjust the brightness level.
3. Dismiss the slider by touching anywhere on the GUI screen or allow to time out in 5 seconds.

New Patient Setup Defaults

To institutionally configure new patient default settings

1. Perform steps 1 and 2 of the section [To perform institutional configuration](#), page 3-33.
2. Touch the button corresponding to adult, pediatric, or neonatal new patient defaults.
3. Touch the Ventilation Type, Mode, Mandatory Type, and Trigger Type buttons corresponding to the desired parameters.
4. Configure the default PBW and mL/kg ratio, Elevate O₂ and O₂% by touching its button and turning the knob.
5. Repeat for each patient type by selecting the corresponding button.
6. Touch *Accept* or *Accept ALL* when the default configuration is complete.

7. If done configuring parameters, exit Service mode.

Elevate O₂



Note:

The Elevate O₂ control adds a percentage of O₂ to the breathing mixture for 2 minutes. The additional percentage is shown on the icon in the constant access icon area. The allowable range is 1% to 100%.

To adjust the amount of elevated O₂ delivered for 2 minutes



1. In the vent setup dialog in Normal mode, touch the Elevate O₂ icon in the constant access icons area of the GUI screen. The icon glows and a dialog appears with a countdown timer, Elev O₂ button highlighted and ready for changes, and Extend, Stop, and Close buttons.
2. Turn the knob to increase or decrease the amount of oxygen by the amount shown on the button. The allowable range is +1% to +100% oxygen.
3. Touch Extend to extend the 2-minute interval. Touching Extend restarts the 2-minute countdown timer.
4. Touch Stop to stop additional oxygen from being delivered and dismiss the countdown timer.

The Elevate O₂ function follows these rules:

- If apnea ventilation occurs during the 2-minute interval, the apnea % O₂ delivery also increases by the configured amount.
- During LOSS OF AIR SUPPLY or LOSS OF O₂ SUPPLY alarm conditions, the Elevate O₂ function is canceled if in progress, and is temporarily disabled until the alarm condition no longer exists.
- During Safety PCV, the Elevate O₂ control has no effect. During circuit disconnect and Stand-By states (when the ventilator is turned on but not ventilating) the Elevate O₂ function affects the currently delivered oxygen concentration, not the set oxygen concentration.

Alarm Volume



WARNING:

The audio alarm volume level is adjustable. The operator should set the volume at a level that allows the operator to distinguish the audio alarm above background noise levels.

To institutionally configure the alarm volume

1. Perform steps 1 and 2 of the section [To perform institutional configuration](#), page 3-33.
2. Touch Alarm Volume Defaults. A screen appears allowing configuration of the alarm volume by circuit type.
3. Slide the alarm slider for each circuit type (adult, pediatric, or neonatal) or turn the knob to configure the alarm volume. The volume settings range from 1 (minimum) to 10 (maximum).



4. If done configuring the alarm volume, exit Service mode.

To adjust alarm volume



1. Set the alarm volume by pressing the alarm volume key, then sliding the alarm volume slider or turning the knob. The alarm values range from 1 (minimum) to 10 (maximum). The new volume change takes effect immediately.
2. Dismiss the slider by touching anywhere on the GUI screen or allow to time out in 5 seconds.



Note:

A sample alarm tone sounds for verification at each volume level change. If necessary, re-adjust the alarm volume by moving the alarm volume slider to increase or decrease the volume.



Note:

The alarm volume reverts to the institutionally configured default alarm volume or factory default if the ventilator's power is cycled.

Vital Patient Data

Patient data are displayed in the Vital Patient Data banner. The operator can configure the banner for displaying the desired patient data. See [Figure 4-1](#) on page 4-3. A total of 14 values may be configured at one time, with eight values visible, and six more visible by scrolling the values using the left- and right- pointing arrows in the patient data area.

Two pages of additional patient data may be viewed by touching or swiping down on the patient data tab at the top of the GUI. Choose the respective buttons to view page one or page two. Additional patient data values may not be changed.

To institutionally configure patient data displayed on the GUI

1. Perform steps 1 and 2 of the section [To perform institutional configuration](#), page 3-33.
2. Touch Patient Data Defaults. Five layout preset buttons appear along with a list of parameters and descriptions.
3. Touch a preset button and individually select a parameter from the scrollable list below to appear in that preset's vital patient data banner. Use the right- and left- pointing arrows to configure default values for all available parameters. Additionally, touch the padlock icon above each patient data parameter on the data banner to allow (unlocked) or restrict (locked) operator configurability of that parameter during normal ventilation.
4. When done configuring the selected preset, touch Accept and select another preset to configure, if desired.
5. Touch Defaults to return configuration to factory settings.
6. If done configuring parameters, exit Service mode by touching Exit.

To configure the patient data displayed on the GUI

1. Double-tap a patient data parameter at the top of the GUI screen. A menu of buttons appears identified with patient data parameters. The parameter at the location touched will be replaced with the new parameter of choice. To view more parameters, touch the left- or right- pointing arrows to reveal more parameters.
2. Touch the button corresponding to the replacement parameter. The existing parameter is replaced with the new parameter.
3. Repeat steps 1 and 2 for as many parameters as desired.

Displaying Patient Data With a Larger Font

To improve visibility of patient data, a screen is available that appears with a larger font. Up to 14 data values may be displayed which include:

- Institutional default patient data values (if configured)
- Remaining user selected patient data values (up to 14, including waveforms and loops)

To institutionally configure the large font patient data defaults

1. Perform steps 1 and 2 of the section [To perform institutional configuration](#), page 3-33.
2. Touch Large Font Patient Data Defaults. Five layout presets appear along with a list of parameters and descriptions.
3. Touch a preset button and individually select a parameter for each of the desired patient data values.
4. Choose the desired scalar and loop waveforms for the large font patient data display. Waveform thumbnails appear in the three right-most cells of the large font data panel.
5. Touch any of the padlock icons along the right-most edge of the selected layout to prevent operator configurability of the selected row.
6. Touch *Accept* or *Accept ALL* when finished.
7. If factory defaults are desired for a preset, touch Defaults.
8. If done configuring parameters, exit Service mode by touching Exit.

To display the large font patient data panel

1. Swipe the vital patient data banner tab downward or touch the vital patient data tab. The additional patient data panel appears.
2. Swipe the additional patient data banner's tab downward or touch the additional patient data banner's tab. Patient data appear in a larger font.
3. Swipe the large font patient data panel tab upward or touch the tab to return to the banner to its normal font size.

The large font patient data parameters are configured in the same way as described in the patient data configuration section above.

Waveforms

Green waveforms denote a mandatory inspiration, yellow waveforms denote exhalation, and orange waveforms denote a spontaneous inspiration.

The GUI can be configured to display up to three waveforms and two loops simultaneously in the waveform area. See [Figure 4-1](#), on page 4-3. The allowable waveforms include flow vs. time, pressure vs. time and volume vs. time. Allowable loops include pressure vs. volume and flow vs. volume. The waveforms display 60 seconds of information and can be shown in a redrawing format, or paused with the ability to enable a cursor to trace the waveform by turning the knob.

The ventilator-generated waveforms provide immediate and dynamic qualitative information to the clinician about the subtleties of ventilation in real time. In many cases the shape and character of the drawn graphics for volume, flow, and pressure can provide advanced and early warning to the clinician of potential problems such as air leaks, air-trapping, breath asynchrony, over-distension, and flow mismatching.

The scalar waveforms are not intended to represent a patient physiological parameter nor a quantifiable characteristic of gas (air and O₂) delivered to, or removed from, the human body.

Symbol	Definition
$V_{T\text{CIRC}}$	The $V_{T\text{CIRC}}$ waveform is reflective of the volume going into and out of the breathing circuit throughout the breath cycle. The volume values expressed by the $V_{T\text{CIRC}}$ waveform are not compensated for circuit compliance or BTPS. The scale representing measured volume (mL) can be set from a minimum range of -1 mL to 2 mL to a maximum range of -2000 mL to 6000 mL.
$\dot{V}_{\text{CIRC}}$	$\dot{V}_{\text{CIRC}}$ waveform displays the total inspiratory and expiratory flow throughout the breath cycle measured by the ventilator's internal (inspiratory and expiratory) flow sensors. The flow values expressed by the waveforms are not compensated for circuit compliance or BTPS. The scale representing measured flow (L/min) can be set from a minimum range of -2 L/min to 2 L/min, to a maximum range of -200 L/min to 200 L/min.
P_{CIRC}	P_{CIRC} waveform displays the total circuit pressure at the wye of the breathing circuit throughout the breath cycle measured by the ventilator's internal (inspiratory and expiratory) pressure sensors. The scale representing pressure (cmH₂O or hPa) can be set from a minimum range of -2 (cmH₂O or hPa) to 10 (cmH₂O or hPa) to a maximum range of -20 (cmH₂O or hPa) to 120 (cmH₂O or hPa).

To institutionally configure waveforms and loops

1. Perform steps 1 and 2 of the section [To perform institutional configuration](#), page 3-33.
2. Touch Graph Defaults. Five layout presets appear along with a list of parameters and descriptions.

3. Touch a layout preset button. The parameter button outline glows, signifying that it can be changed. If more than one parameter can be changed, touch that parameter to make its outline glow.
4. Select the parameter from the list whose waveform is desired to appear on the waveforms screen.
5. Configure each of the graphic display layouts as described above.
6. Touch the padlock icon above each graphic layout to prevent operator configuration of the selected layout.
7. If factory defaults are desired for a preset, touch Defaults.
8. If done configuring parameters, exit Service mode by touching Exit.

To configure waveforms and loops



1. Touch the waveform layout icon, located below the displayed waveforms or the vent setup screen. The icon glows and a menu of various waveform layouts appears.
2. Touch the desired waveform icons to display. The selected waveforms appear on the GUI screen and the dialog closes.

To change the axis scaling

1. Touch the desired waveform axis.
2. Turn the knob to change the value. For each axis, turn the knob to the right to decrease the values, and turn to the left to increase the values.

To pause waveforms



1. Touch the pause icon, located below the waveforms area. The icon glows yellow and allows the breath to complete. A cursor appears and travels along the waveform while turning the knob, displaying the x- and y-axis values.
2. Touch the pause icon again to re-activate the waveform.

See [To capture GUI screens](#), page 5-2 for information on storing waveforms.



Opacity

To institutionally configure screen opacity

1. Perform steps 1 and 2 of the section [To perform institutional configuration](#), page 3-33.
2. Touch the opacity icon.
3. Turn the knob to increase or decrease the opacity.
4. Touch the padlock icon at the right side of the screen to allow or prevent operator adjustment of the screen opacity.
5. Touch Accept to close the dialog.

To adjust the screen opacity

1. Touch the opacity icon. The icon glows when the opacity can be changed.
2. Turn the knob to increase or decrease the opacity.

**Note:**

The opacity icon can be found on the vent setup screen and on any of the respiratory mechanics maneuvers screens.

3.9 Installation Testing

Fully charge the batteries before placing the ventilator into clinical use. See [Battery Charging](#), page 3-3 for information on battery charging. See page [3-18](#) for the meaning of battery charge status LEDs and page [3-19](#) for the location of battery test switch and status LEDs.

Prior to connecting a patient to the ventilator for the first time, a qualified service technician must have calibrated the ventilator's exhalation valve, flow sensors, and atmospheric pressure transducer and performed and successfully passed EST. See the *Puritan Bennett™ 980 Series Ventilator Service Manual* for instructions.

In addition, the clinician must also perform SST.

3.9.1 SST (Short Self Test)

**WARNING:**

Always disconnect the patient from the ventilator prior to running SST or EST. If SST or EST is performed while a patient is connected, patient injury may occur.

**WARNING:**

Check for circuit occlusion and run SST if increased pressures are observed during ventilation.

**WARNING:**

When changing any accessories in the patient circuit or changing the patient circuit itself, run SST to check for leaks and to ensure the correct circuit compliance and resistance values are used in ventilator calculations.

**Note:**

When extending ventilator circuits for neonatal patients, the resulting ventilator breathing system (VBS) compliance may trigger a COMPLIANCE LIMITED V_T alarm such that the VC+ or VS software will not continue to update the pressure target during breath delivery. In this case the user can change the breath type to pressure control (PC) or pressure support (PS).

When a patient is not attached to the ventilator, run SST to check the patient circuit for:

- Gas leaks
- Circuit compliance and resistance calculations

SST must be run under any of the following conditions:

- Prior to ventilating a new patient
- When replacing the patient circuit and exhalation filter
- When connecting a different patient circuit to the ventilator
- When changing the patient circuit type
- When installing a new exhalation filter
- When changing the humidification device type
- When adding accessories to or removing accessories from the breathing system (such as a humidifier or water trap)
- After installing a new exhalation flow sensor (see [Flow Sensor Calibration](#), page 3-47).

No external test equipment is required, and SST requires minimal operator participation.

Humidification type and volume can be adjusted after running SST, however the ventilator makes assumptions when calculating resistance and compliance if these changes are made without re-running SST. For optimal breath delivery, run SST after changing humidification type and humidifier volume.

SST results are recorded in the SST results log, viewable in Service mode and in Normal mode using the configuration (wrench) icon.

Required Equipment

- Proposed patient circuit for patient ventilation
- Accessories (water traps, etc.)
- Exhalation filter and condensate vial
- Humidifier, if applicable
- A number 1 stopper to block the patient airway at the patient wye
- Two gas sources (air and oxygen) connected to the ventilator at a pressure between 241.3 kPa and 599.8 kPa (35 psi and 87 psi)

SST Test Sequence

To run SST

1. Ensure a patient is **not** connected to the ventilator.
2. So that the ventilator does not detect a patient connection, ensure that the breathing circuit wye is not attached to a test lung or covered in any way that would cause an increase in pressure at the wye.
3. Turn the ventilator on using the power switch located at the front of the BDU, below the status display. The ventilator runs POST when the power switch is turned on. Ensure the ventilator is operating on full AC power. Otherwise, SST test failures may result.
4. Wait at least 15 minutes to allow the ventilator to warm up and stabilize to ensure accurate results.
-  5. At the ventilator startup screen, touch SST or the configure icon (wrench) displayed in the lower right area of the GUI. The SST history log appears along with Patient Setup, Run Leak Test, and Run All SST buttons.
6. Connect the patient circuit, filters/condensate vial, and all accessories to be used in patient ventilation. Ensure the patient wye is not blocked.
7. Touch Run All SST to perform all SST tests or touch Run Leak Test to perform the SST Leak test of the ventilator breathing circuit.
8. Touch Accept to continue or Cancel to go back to the previous screen.
9. After accepting, touch the Circuit Type button corresponding to the patient circuit type used to perform SST and to ventilate the patient (adult, pediatric, or neonatal).
10. Touch the Humidification Type button corresponding to the humidification type used for patient ventilation. If no humidifier is used, touch HME. If a humidifier is used, touch Humidification Volume and turn the knob to enter the volume. See [Table 3-4](#). for adult and pediatric patients or [Table 3-5](#). for neonatal patients to determine the correct volume to enter.
11. Touch Accept to start SST.
12. Follow the prompts. Certain SST tests require operator intervention, and will pause indefinitely for a response. See [Table 3-3](#). and [Table 3-6](#). for a summary of the SST tests and test step results, respectively.
13. After each test, the ventilator displays the results. If a particular test fails, the test result appears on the screen and a choice to repeat the test or perform the next test is given. When all of the SST tests are complete, the SST status screen displays the individual test results.
14. To proceed to patient set up, (if SST did not detect an Alert or failure) touch Exit SST, then touch Accept or cycle the ventilator's power.

[Table 3-3](#). lists the tests performed during SST.

Table 3-3. SST Tests

Test step	Function
SST Flow Sensor Cross Check Test	Tests O ₂ and air flow sensors
SST Exhalation Valve Performance	Calibrates the exhalation valve and creates a table for use during calculations
SST Circuit Pressure Test	Exercises delivery PSOL. Checks inspiratory and expiratory autozero solenoids. Cross-checks inspiratory and expiratory pressure transducers at various pressures.
SST Leak Test	Tests ventilator breathing system for leaks
SST Exhalation Filter Test	Checks for exhalation filter occlusion and exhalation compartment occlusion.
SST circuit Resistance Test	Checks for inspiratory and expiratory limb occlusions, and calculates and stores the inspiratory and expiratory limb resistance parameters.
SST circuit Compliance Test	Calculates the attached patient circuit compliance.
SST Prox (if the Proximal Flow option is installed)	Verifies functionality of the proximal flow subsystem

**Note:**

If you are running SST for a neonatal circuit with a humidifier, enter the volume listed in the shaded column in [Table 3-5](#).

Table 3-4. Humidifier Volumes—Adult and Pediatric Patients

Manufacturer	Model	Description	SST humidifier volume setting (mL)
Fisher & Paykel	MR225	Ped, disposable, manual feed	300
Fisher & Paykel	MR290	Ped/adult disposable, autofeed	380
Fisher & Paykel	MR250	Adult. disposable, manual feed	480
Fisher & Paykel	MR210	Adult. disposable, manual feed	480
Fisher & Paykel	MR370	Adult. reusable, manual feed	725
Teleflex (Concha)	382-10	ConchaSmart	300

Table 3-5. Humidifier Volumes—Neonatal Patients

Manufacturer	Model	Description	SST humidifier volume setting (mL)
Fisher & Paykel	MR290	Neo/adult, disposable, autofeed	550 ¹
Teleflex (Concha)	382-10	Concha Smart	390

1. If the following neonatal patient circuits are used with the Fisher & Paykel MR290 humidification chamber, enter 500mL as the humidifier volume:
- DAR neonatal patient circuit with single heated wire (DAR 307S9910)—for incubator use
 - DAR neonatal patient circuit with single heated wire (DAR 307/8682)—not for incubator use

**Note:**

For neonatal patient types, the SST Humidifier Volumes listed in [Table 3-5](#). must be entered during SST or when specifying the humidifier volume.

SST Results

SST reports results for each individual test. Three status indicators identify the SST results and actions to take for each.

- **Pass** — The individual SST test has met its requirements.
- **Alert** — Alerts occur when the ventilator detects one or more non-critical faults.
- **Failed** — The individual SST test did not meet its requirements.

Table 3-6. SST Test Step Results

Test status	Meaning	Response
Pass	Individual SST test passed	No need to do anything, unless prompted by the ventilator.
Alert 	The test result is not ideal, but is not critical. If SST is in progress, it halts further testing and prompts for decision.	When the system prompts, touch one of these buttons: • Repeat Test • Next Test ¹ • Exit SST
Failed 	The ventilator has detected a critical problem and SST cannot complete until the ventilator passes the failed test.	Eliminate leaks in the ventilator breathing system and re-run SST. Otherwise, service the ventilator and re-run SST.

¹ **WARNING**—Completing SST with an Alert status for an individual test produces an Override SST button. Overriding an Alert in SST may result in ventilator performance outside of the stated specification for accuracy. Choose to override the Alert status and authorize ventilation only when absolutely certain this cannot create a patient hazard or add to risks arising from other hazards. To override the alert, touch Override SST, then touch Accept.

SST Outcomes

When SST completes all of the tests, analyze the results.

Table 3-7. Overall SST Outcomes

Final outcome	Meaning	Response
PASS	All SST tests passed.	Touch Patient Setup to set up the patient for ventilation:
OVERRIDDEN	The ventilator detected one or more faults. Choose to override the ALERT status and authorize ventilation only when absolutely certain this cannot create a patient hazard or add to risks arising from other hazards.	Check the patient circuit to determine the problem or restart SST with a different patient circuit.
FAIL	One or more critical faults were detected. The ventilator enters the SVO state and cannot be used for normal ventilation until SST passes.	Check the patient circuit to determine the problem or restart SST with a different patient circuit.

If touching Override SST, observe the following warning:



WARNING:

Overriding an Alert in SST may result in ventilator performance outside of the stated specification for accuracy. Choose to override the ALERT status and authorize ventilation only when absolutely certain this cannot create a patient hazard or add to risks arising from other hazards.

A single circuit-leak test can be run without changing the SST outcome.

If a complete SST is interrupted and ventilation was allowed before starting SST, normal ventilation is allowed if all of the following conditions are met:

- SST did not detect any failures or alerts before the interruption
- No other errors that would prevent ventilation occurred
- There were no changes to the circuit type at the start of the interrupted SST

During SST, the ventilator displays the current SST status, including the test currently in progress, results of completed tests. Test data are available in Service mode where applicable or are displayed on the screen. The ventilator logs SST results, and that information is available following a power failure. The audio paused and alarm reset keys are disabled during SST, as well as the manual inspiration, inspiratory pause, and expiratory pause keys.

3.9.2 Flow Sensor Calibration



Note:

After replacement of the exhalation flow sensor, the flow sensor calibration may be performed with the ventilator in Normal mode. It is not necessary for the ventilator to be in Service mode for this calibration.

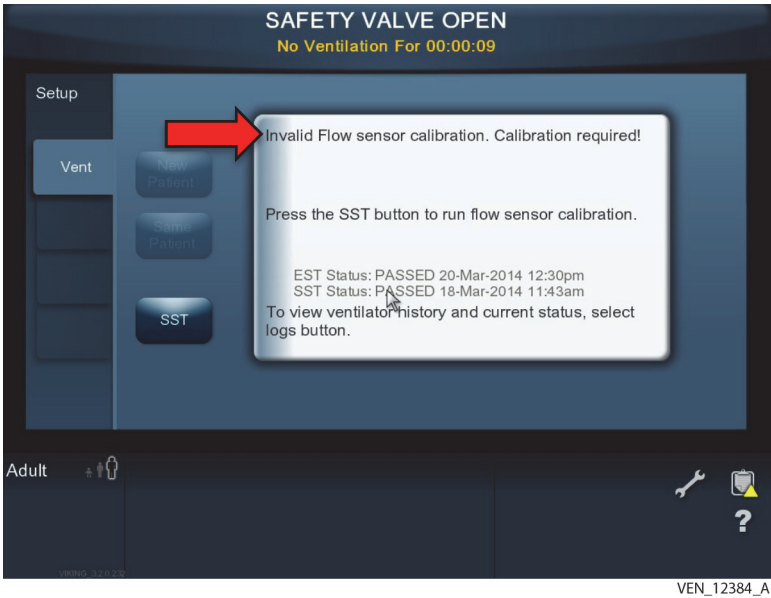


Note:

A gold standard test circuit (part number 4-018506-00) is required for calibrating the exhalation flow sensor.

After installing a new exhalation flow sensor, upon power-up and POST completion, the ventilator detects the new flow sensor. The GUI displays the messages shown in [Figure 3-18](#), alerting you that the flow sensor requires calibration. For instructions on exhalation flow sensor installation, see [EVQ Replacement](#), page 7-14.

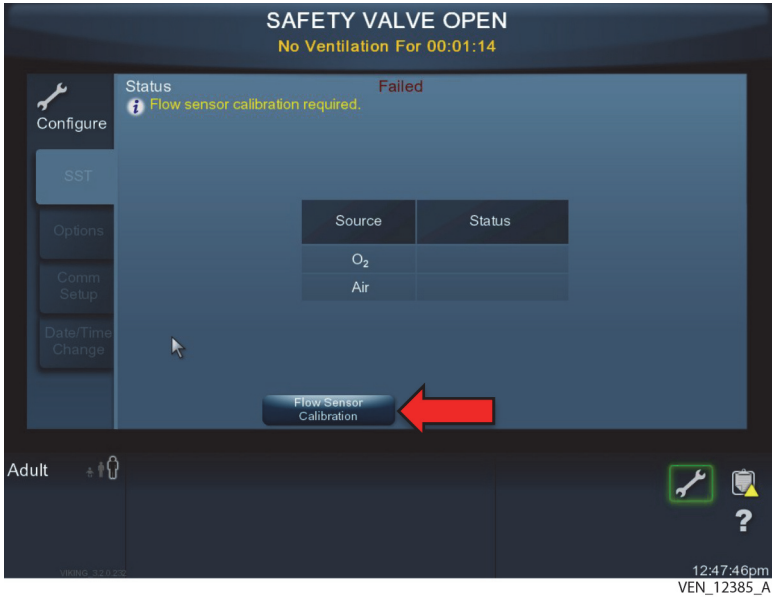
Figure 3-18. Flow Sensor Requires Calibration



To calibrate the flow sensor

- 1. Touch the SST button. The image shown in *Figure 3-19*. appears, allowing calibration.

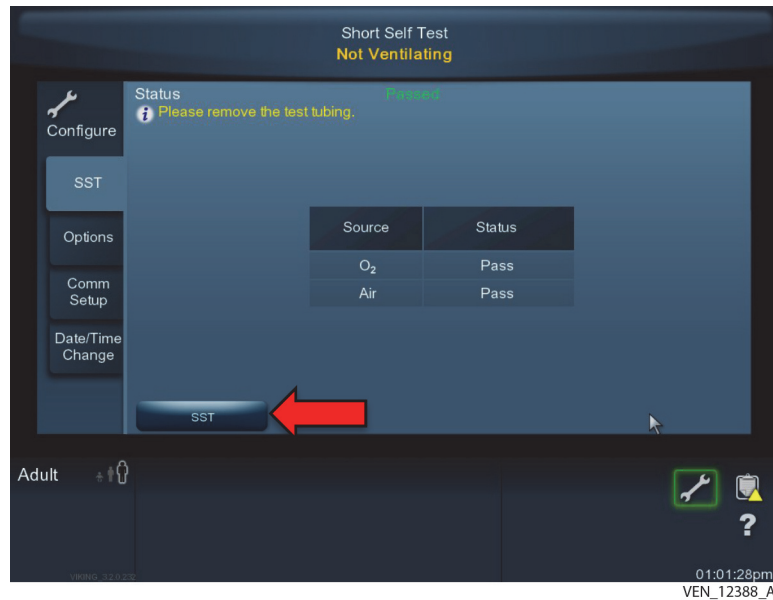
Figure 3-19. Calibrate The Flow Sensor



- 2. Touch the Flow Sensor Calibration button. The ventilator prompts you to remove the inspiratory filter and to connect the test tubing, as shown in *Figure 3-20*.

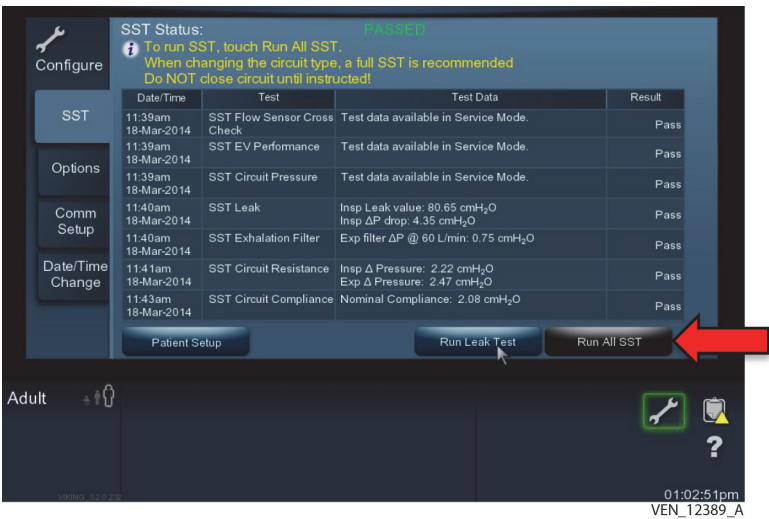
Figure 3-20. Waiting to Begin Calibration and Calibration Test Setup

3. Touch Accept, as shown in [Figure 3-20](#).
4. Calibration lasts approximately 8 1/2 minutes. When calibration passes, the screen shown in [Figure 3-21](#) appears,

Figure 3-21. Successful Calibration

5. Upon successful calibration, SST must be run. The GUI provides a button to run SST, as shown in [Figure 3-21](#).
6. Touch the SST button. The screen shown in [Figure 3-22](#) appears.

Figure 3-22. SST Prompts



- Touch the Run All SST button, and follow the prompts as described in [To run SST](#), page 3-43.



WARNING:
Adding accessories to or removing accessories from the ventilator can change the pressure gradient across the VBS and affect ventilator performance. Ensure that any changes to the ventilator circuit configurations do not exceed the specified values for circuit compliance and for inspiratory or expiratory limb total resistance. See [Table 11-4](#), on page 11-3. If adding accessories to or removing accessories from the VBS, always run SST to establish circuit compliance and resistance prior to ventilating the patient.

3.9.3 Extended Self Test (EST)

The ventilator's extended self test (EST) function is designed to verify the ventilator's operational subsystem integrity.

All required software support to perform EST is resident on the ventilator. EST requires approximately 10 minutes to complete.



Note:
SST is not part of the EST test suite. To determine patient circuit resistance and compliance, run SST.

EST Prerequisites

Follow all identified guidelines when performing EST. Inspect all equipment required for any self test to ensure it is not damaged in any way.

- Collect all required equipment prior to performing any self test of the ventilator. Successful self test is not possible without the use of the listed equipment.
- Disconnect the ventilator from the patient.

3. Fully charge the primary ventilator battery.
4. Connect the ventilator to AC power using the hospital-grade power cord until completion of any self test.
5. Ensure the ventilator is powered down.
6. Ensure both air and oxygen sources register pressure between 241 kPa to 599 kPa (35 psi and 87 psi).

To perform EST or to access additional service functions, the ventilator must be in Service mode. See [Service Mode \(3.7.4\)](#) on page 3-30.

**Note:**

While in the Service mode, normal ventilation is not allowed.

**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.

**WARNING:**

A fault identified during this test indicates the ventilator or an associated component is defective. Rectify the fault and perform any required repairs prior to releasing the ventilator for patient use, unless it can be determined with certainty that the defect cannot create a hazard for the patient, or add to the risks that may arise from other hazards.

Perform EST during any of the listed conditions:

- Prior to initial installation and first time usage of the ventilator
- Every 12 months
- Before any preventive maintenance
- Following ventilator service or repair
- As part of the ventilator's routine performance verification

During EST, the ventilator displays the current EST status, including the test currently in progress, results of completed tests, and measured data (where applicable). The ventilator logs EST results, and that information is available following a power failure. The ventilator disables several off-screen keys located on the bezel of the GUI during EST:

- Audio paused
- Alarm reset
- Manual inspiration
- Inspiratory pause

- Expiratory pause

Run tests either as a group or as single tests for troubleshooting purposes.

Equipment for EST

- Covidien gold standard test circuit
- Number 1 stopper
- Air and oxygen sources, both at 241 kPa to 599 kPa (35 psi to 87 psi)
- An adult-sized exhalation filter

**Note:**

Attempts to run EST with a neonatal filter can cause some EST tests to fail.

**Note:**

If using Air Liquide™, Dräger™, and SIS air/oxygen hose assemblies, certain EST tests may fail when using supply pressures less than 345 kPa (50 psi) based on excessive hose restriction.

3.9.4 EST Test Sequence

**Note:**

If the ventilator has not reached normal operating temperature from recent usage, allow it to warm up for at least 15 minutes in Service mode prior to running EST to ensure accurate testing.

To perform EST

1. Review and perform all self test prerequisites. See [EST Prerequisites](#), page 3-50.
2. Collect the appropriate equipment. See [Equipment for EST](#), page 3-52.
3. Access Service mode. See [Service Mode \(3.7.4\)](#) on page 3-30.
4. Verify that all calibration tests under the Calibration tab have passed.
5. Touch the Self Test tab from the horizontal banner at the top of the monitoring screen.
6. Touch the EST tab from the menu options on the left side.
7. Touch Run All to run all tests in sequence or select the desired individual test.
8. Choose one of the available options: touch Accept to continue; touch Cancel to go back to the previous screen; or touch Stop to cancel EST.
9. Follow the prompt to remove the inspiratory filter and connect the gold standard circuit.

10. Touch Accept.
11. Follow prompts to complete EST. The EST tests require operator intervention, and will pause indefinitely for a response.
12. At the Disconnect O₂ prompt, disconnect the high pressure oxygen source.
13. At the Disconnect air prompt, disconnect the high pressure air source.
14. At the Connect air and O₂ prompt, connect both high pressure air and oxygen sources.
15. Touch Run All or select the desired individual test. After each test, the ventilator displays the results.
16. If a particular test fails, either repeat the test or perform the next test.
17. When all of the EST tests complete, review test results by touching each individual test listed on the left side of the GUI.
18. At the top of the GUI, touch Exit.
19. Touch Confirm at the prompt to return to normal ventilation mode. The ventilator reruns POST and then displays the ventilator startup screen.

Table 3-8. EST Tests

EST test step	Function	Required user interaction
Zero Offset	Tests inspiratory and expiratory pressure transducers and flow sensors at ambient pressure.	Follow prompts
Leak Test	Determines ability of system to hold pressure.	Follow prompts
Mix Leak	Verifies integrity of the mix system.	Follow prompts
Mix PSOL	Verifies mix PSOL function.	None
Mix Accumulator	Verifies mix accumulator pressure sensor and overpressure switch function.	None
Circuit Pressure	• Checks inspiratory and expiratory autozero solenoids. • Cross-checks safety valve, inspiratory and expiratory pressure transducers at various pressures. • Verifies the autozero solenoid's function.	None
Flow Sensor Cross Check Test	Verifies all flow sensors and PSOLs at specified flow volumes.	None
Delivery PSOL	Verifies delivery PSOL current function.	None
Exhalation Valve (EV) Loopback	Verifies exhalation valve current and loopback current are within range.	None
Exhalation Valve (EV) Pressure Accuracy	Verifies current versus pressure values in flash memory correspond with actual installed exhalation valve.	None

Table 3-8. EST Tests (Continued)

EST test step	Function	Required user interaction
Exhalation Valve (EV) Performance	Verifies the exhalation valve operates within specifications of the last exhalation valve calibration.	None
Exhalation Valve (EV) Velocity Transducer	Verifies the velocity transducer is sending a signal and the control circuit recognizes it. It does not verify the quality of the signal.	None
Safety System	Tests safety valve operation.	None
Backup Ventilation	Verifies backup ventilation systems: mix, inspiratory, and exhalation.	None
Communication	Verifies GUI communication ports function, both serial and Ethernet.	None
Internal Storage	Verifies internal storage device function.	None
LCD Backlight	Verifies GUI LCD backlight intensity function.	None
Status Display	• Verifies status display function. • Verifies LCD function. • Communicates with BD CPU. • Communicates with compressor, if installed).	None
GUI Audio	Tests GUI alarm indicators, cycling through each alarm status indication.	Follow prompts
BD Audio	Verifies BD audible alarm is functional. Also verifies power fail capacitor can operate loss-of-power alarm.	Follow prompts
Rotary Knob Test	Verifies knob rotation function.	Follow prompts
Offscreen Key Test	Verifies GUI bezel key function.	Follow prompts
Ventilator Battery	Tests ventilator battery and power distribution.	Follow prompts
Run only if DC compressor installed		
Compressor Battery	Tests compressor battery function, as well as compressor power system and fan function.	Follow prompts
Compressor	Tests overall compressor operation: pressure transducer, fan, motor, and pressure relief valve.	Follow prompts
Compressor Leak	Checks compressor system for leaks.	None
Compressor Performance	Tests compressor operational performance under load.	None

3.9.5 EST Test Results

Table 3-9. EST Test Step Results

Test status	Meaning	Response
Pass	Individual EST test passed	No need to do anything unless prompted by the ventilator
ALERT	The test result is not ideal, but is not critical. If EST is in progress, it halts further testing and prompts for decision.	When the system prompts, select: Repeat Test, Next Test ¹ , or Stop, then touch Accept.
Failed	EST not successfully passed.	Select: Repeat Test, Next Test ¹ , or Stop, then touch Accept.
NEVER RUN	Test still requires successful PASS.	Run all EST tests.

¹ **WARNING**—Completing EST with an ALERT status for an individual test produces an Override EST button. Choose to override the ALERT status and authorize ventilation only when absolutely certain this cannot create a patient hazard or add to risks arising from other hazards. To override the alert, touch Override EST, then touch Accept.

When EST completes all of the tests, analyze the results.

Table 3-10. Overall EST Outcomes

Final outcome	Meaning	Response
PASSED	All EST tests passed	EST successfully completed. Select other Service mode functions or prepare for SST tests prior to returning the ventilator for patient usage.
OVERRIDDEN	ALERT status overridden by user.	Repair the ventilator and rerun EST.
FAIL	One or more critical faults were detected. The ventilator enters the SVO state and cannot be used for normal ventilation until SST passes. Service is required.	Repair the ventilator and rerun EST.

Touching Override EST results in the following warning:



WARNING:

Choose to override the ALERT status and authorize ventilation only when absolutely certain this cannot create a patient hazard or add to risks arising from other hazards.

3.10 Operation Verification

Before ventilating a patient, **you must perform SST and alarms tests with passing results**. See *To run SST*, page 3-43. See *Alarm Testing (6.5.5)* on page 6-8 as well.

4 Operation

4.1 Overview

This chapter describes Puritan Bennett™ 980 Series Ventilator operation and includes sections on:

- Setting up the ventilator
- How to use the ventilator
- How to use the ventilator's graphical user interface (GUI)
- How to set or change main, alarm, or apnea settings
- How to test alarms
- How to calibrate, enable, or disable the O₂ sensor
- How to perform inspiratory and expiratory pause maneuvers
- How to use non-invasive ventilation (NIV)

4.2 Ventilator Function

Air and oxygen from wall sources, cylinders, or the optional compressor enter the ventilator and flow through individual oxygen and air flow sensors. The gases are then mixed in the mix module's accumulator. A pressure-relief valve in the mix module's accumulator prevents over-pressurization. The mix module also contains an oxygen sensor that monitors the air-oxygen mixture according to the operator-set O₂% setting.

After the gas mixes, it flows to the inspiratory pneumatic system, where the breath delivery flow sensor measures the gas flow and controls a PSOL valve for proper breath delivery tidal volumes and pressures. The inspiratory pneumatic system contains a safety valve to avoid over-pressure conditions before flowing through bacteria filters to the patient through the inspiratory limb of the patient circuit. Upon exhalation, gas flows out the patient circuit expiratory limb, through the exhalation bacteria filter, through the exhalation valve, which includes the exhalation flow sensor, and through the exhalation port.

4.3 Ventilator Setup



WARNING:

To avoid interrupted ventilator operation or possible damage to the ventilator, always use the ventilator on a level surface in its proper orientation.

To set up the ventilator

1. Connect the ventilator to the electrical and gas supplies. See [Figure 3-3.](#) on page 3-6, [Figure 3-4.](#) on page 3-7, and [Figure 3-5.](#) on page 3-8.
2. Connect the patient circuit to the ventilator. See the figures on pages 3-11 and 3-16 to connect the adult/pediatric or neonatal patient circuits, respectively.
3. Turn the ventilator on using the power switch. See [Figure 2-9.](#) on page 2-24.
4. Before ventilating a patient, run SST to calculate the compliance and resistance with all items included in the patient circuit. See [To run SST](#), page 3-43.

4.4 User Interface Management

The user interface is structured with a GUI and a status display. The GUI provides access to ventilator controls and patient data. The status display is a small LCD panel that acts as a back up to the GUI in the event of a GUI failure. See [Status Display](#), page 2-25 for more information about the status display.

The status display is not interactive.

During normal ventilator operation, the following information appears on the status display:

- Current power state (AC or DC)
- Batteries installed / charge status (BDU and compressor, if present)
- Visual indication of audible alarm volume
- Circuit pressure graph displaying P_{PEAK} , PEEP, and pressure-related alarm settings

See [Status Display](#), page 2-25 for information about displayed items during Service mode.

4.4.1 Using the GUI

The GUI is used to interact with the ventilator while it is ventilating a patient or in any of its operating modes.

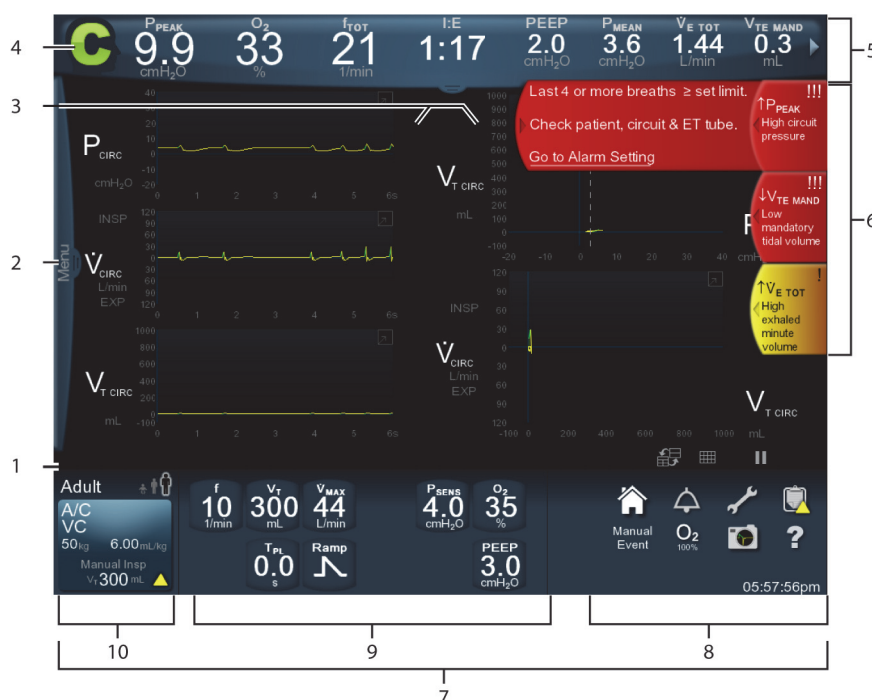


Caution:

Do not lean on the GUI or use it to move the ventilator. Doing so could break the GUI, its locking mechanism, or tip the ventilator over.

The GUI is divided into several areas.

Figure 4-1. Areas of the GUI



VEN_11149_F

1. **Prompt area** — Located beneath the waveforms. Any prompts or messages related to soft or hard bounds display here. Examples include soft bound and hard bound messages, PAV+ startup messages, oxygen sensor calibration-in-progress messages, and various other informational messages.
2. **Menu tab** — Located on the left side of the GUI screen. Swiping the tab to the right and touching Setup causes the Vent, Apnea, Alarm, and More Settings tabs to appear. Touching those tabs opens screens so that changes to ventilator settings, apnea settings, alarm settings, and more settings can be made.
3. **Waveform area** — Located in the center of the GUI screen. Shows various breath waveforms. See [Waveforms](#), page 3-39 for information on how to configure graphics.
4. **Breath Phase Indicator** — During normal ventilation, the GUI displays a breath indicator in the upper left corner that shows the type of breath [Assist (A), Control (C), or Spontaneous (S)] currently being delivered to the patient, and whether it is in the inspiratory or expiratory phase. The breath indicator is updated at the beginning of every inspiration, and persists until the next breath type update. During inspiration, assist (A) and control (C) breath indicators glow green and spontaneous (S) breath indicators glow orange, each appearing in inverse video where the indicator appears black surrounded by the colored glow. See [Figure 4-1](#), on page 4-3. During the expiratory phase the breath indicators appear as solid colors (green during assist or control breaths and orange during spontaneous breaths).
5. **Vital Patient data banner** — Located across the top of the GUI screen. The patient data banner displays monitored patient data and can be configured to show desired patient data. See [Vital Patient Data](#), page 3-37 for information on configuring patient data for display.

6. **Alarm banners** — Located on the right side of the GUI screen. Indicates to the operator the alarms that are active, and are shown in a color corresponding to priority (high is red and flashing, medium is yellow and flashing, low is yellow and steady).
7. **Constant access icons** — Located at the lower right of the GUI screen. This area allows access to home (house), configure (wrench), logs (clipboard), elevate oxygen percentage (O₂), and help (question mark) icon. These icons are always visible regardless of the function selected on the GUI.
8. **Constant access area** — Consists of the current settings area and the constant access icons. This area allows access to any of the patient setup variables shown in these areas. Touching an icon causes the particular menu for that variable to appear.
9. **Current settings area** — Located at the lower center of the GUI screen. The ventilator's current active settings display here. Touching any of the current settings buttons causes a dialog to appear, allowing changes using the knob.
10. **Vent setup button** — Located at the lower left of the GUI screen. Touching this button allows access to the ventilator setup screen.



Note:

A **soft bound** is a selected value that exceeds its recommended limit and requires acknowledgment to continue. Hard bounds have minimum and maximum limits beyond which values cannot be selected, however if the desired value is equal to a settings **hard bound**, then it is allowable.

4.4.2 Adjusting GUI Viewing Properties



Screen Opacity

The opacity control enables the operator to adjust the opacity of the displayed information between 50% and 100%. At 50%, the displayed image is semi-transparent, and at 100%, the displayed image is opaque. The opacity value remains as set if power is cycled and if the same patient is ventilated. If a new patient is ventilated, the opacity defaults to 85%. See [To adjust the screen opacity](#), page 3-41 for instructions on adjusting this feature.



Pushpin Feature

The pushpin feature prevents a dialog from closing under certain conditions when it is pinned. Like the opacity control, the pushpin appears on the settings screen after a new patient begins ventilation.

Figure 4-2. Pushpin Icon



1 Pushpin icon—unpinned state

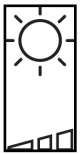
2 Pushpin icon—pinned state

To use the pushpin

1. When a dialog is open, for example, if *Accept* or *Accept ALL* buttons are available, touch the unpinned pushpin icon to pin the dialog and hold it open.
2. Touch Close to close the dialog.

Display Brightness

Display brightness can be controlled manually. This feature is institutionally configurable. See [Screen Brightness and Keyboard Backlight \(Light Settings\)](#), page 3-35. The brightness range is from 1% to 100% with 1% resolution. The default value is 80%.

**To manually adjust display brightness**

1. Press the display brightness key.
2. Slide the brightness slider to the right to increase the brightness level or to the left to decrease the brightness level. Alternatively, turn the knob to increase or decrease the brightness level. The control disappears from the screen in approximately 5 seconds.

Display Lock

The primary display provides a display lock key to prevent inadvertent changes to settings. When active, the display lock disables the touch screen, knob, and off-screen keys (other than the display lock key) and illuminates an LED on the display bezel. An image of the display lock icon appears transparently over anything displayed on the GUI, should the operator attempt to use the GUI. Any new alarm condition disables the display lock and enables normal use of the GUI.

To lock and unlock the display

1. Press the display lock key on the GUI. The keyboard LED illuminates and a transparent locked icon appears on the screen, indicating display lock.
2. To unlock the display, press the display lock key again. The display lock LED turns off and an unlocked image briefly appears on the screen.

4.4.3 Using Gestures When Operating the GUI

The GUI incorporates a gesture-based interface where features can be actuated with the fingers using different motions. [Table 4-1.](#) explains gestures used with the GUI.

Table 4-1. Gestures and Their Meanings

Gesture	Description	Used for	How to use
Swipe	Quickly brush the screen surface with the fingertip.	Opening or closing dialogs or panels that slide in and out from the screen sides or top, moving waveform data, expanding or collapsing tooltips, scrolling lists, or alarm banners, maximizing or minimizing waveforms.	Swipe toward the center of the screen to open dialogs or panels. Swipe toward the side of the screen (or upward if viewing the additional patient data or large font patient data panels) to close. To move a paused waveform, swipe in the desired direction. Swipe upward anywhere on a waveform to maximize it, and swipe downward on the maximized waveform to minimize it. Swipe a tooltip upward to expand to a long description and downward to collapse to a short description. A downward swipe anywhere in the patient data area opens the additional patient data panel, and another swipe on the additional patient data tab displays the large font patient data panel.
Double-tap	Rapidly touch the screen surface twice with one finger.	Maximizing or minimizing the viewable area of a dialog, control, or waveform, expanding or collapsing tooltips	Double-tapping maximizes the viewable waveform area or shows the long description of a tooltip. Double-tapping again minimizes the viewable waveform area or shows the short description of a tooltip. If the control is configurable, double tapping produces the configuration pop-up menu.
Drag	Move the fingertip over the screen surface without losing contact.	Changing x- and y- axis scales, moving the waveform cursor, moving scrollbars, scrolling lists. Scrolling speed varies depending upon how far outside the list boundary the finger is positioned.	Touch the axis and drag to the right to increase the waveform x-axis scale, and to the left to decrease. Touch the axis and drag upward to increase the y-axis scale and downward to decrease. To move the cursor (when the waveform is paused), touch the cursor and drag it right or left. The graph responds similarly. Scroll a list by dragging the scrollbar right or left or up or down. The list scrolls according to the direction of the finger movement. An automatic scrolling feature starts if the finger is dragged from the inside of a list to outside its boundary. The farther outside the boundary the finger is dragged, the faster the list scrolls.
Touch and hold	Touch an item and hold for at least 0.5 second.	Displaying a tooltip dialog on whatever item is touched. The tooltip appears to glow indicating the touch and hold action.	N/A
Drag and drop	Touch and drag an item to another location and lift finger to drop.	Dragging help icon to describe an onscreen item.	Drag the help icon, located at the lower right of the GUI screen, to the item in question and drop. If a blue glow appears, a tooltip is available and appears with information about that item (for example, a control or symbol).

4.5 Ventilator Operation

**WARNING:**

Prior to patient ventilation, select the proper tube type and tube ID.

**Caution:**

To prevent possible damage to electronic circuitry, do not connect the GUI to the BDU while power is applied.

**Caution:**

Do not set containers filled with liquids on the ventilator, as spilling may occur.

After turning on the ventilator, it will display a Covidien splash screen, and run power on self test (POST). After the splash screen appears, the ventilator gives a choice to ventilate the same patient or a new patient, or run SST.

Ventilation parameters are entered via the GUI using the following general steps:

1. Touch the setting displayed on the GUI.
2. Turn the knob to the right to increase or to the left to decrease the value.
3. Touch *Accept* to apply the setting or *Accept ALL* to apply several settings at once.

**Note:**

Quick Start allows for rapid setup and initiation of mechanical ventilation. Review Quick Start parameters and ensure they are consistent with institutional practice before using this feature.

To use Quick Start

1. Touch New Patient.
2. Touch PBW or Gender/Height.
3. Turn the knob to adjust the patient's PBW or gender and height (if gender is selected, the height selection becomes available).
4. Touch Quick Start.
5. Connect the circuit wye adapter to the patient's airway or interface connection. The patient is ventilated with the institutionally configured or factory configured Quick Start defaults according to the PBW or gender/height entered, and circuit type used during SST. There is no prompt to review the settings and the waveforms display appears.

**Note:**

Connecting the circuit wye adapter to the patient's airway or interface connection prior to making the ventilation settings causes the ventilator to begin ventilation using Safety Pressure Control Ventilation

(Safety PCV) and announce a PROCEDURE ERROR alarm. As soon as the ventilator receives confirmation of its settings (by touching *Accept* or *Accept ALL*), it transitions out of safety PCV, resets the alarm, and delivers the chosen settings. See [Table 10-10](#) on page 10-60 for a listing of these settings.

To resume ventilating the same patient

1. Touch Same Patient on the GUI screen. The previous ventilator settings appear for review prior to applying the settings to the patient.
2. If the settings are acceptable, touch START to confirm. To change any settings, touch the setting, turn the knob to increase or decrease the value of the setting, and touch *Accept* to confirm. To make several settings changes at once, make the desired changes, then touch *Accept ALL* to confirm. The appearance of the settings changes from white, non-italic font showing the current setting to yellow italics (noting the pending setting). After the settings are accepted, the appearance changes back to white non-italic font.
3. Connect the circuit to the patient's airway to initiate ventilation.

To ventilate a new patient

1. Touch New Patient on the GUI screen.

Figure 4-3. New Patient Settings



2. Enter the patient's PBW or gender and height (if gender is selected, the height selection becomes available). The ventilator settings screen appears allowing entry of ventilation parameters. See [Figure 4-3](#). If the default ventilator settings are appropriate for the patient, touch Quick START to confirm the settings. Otherwise, touch a ventilator setting and turn the knob to adjust the parameter. Continue this process for all parameters needing adjustment.
3. Touch START to confirm the changes.
4. Connect the circuit to the patient's airway to begin ventilation.

4.5.1 Ventilator Settings



WARNING:

The ventilator offers a variety of breath delivery options. Throughout the patient's treatment, the clinician should carefully select the ventilation mode and settings to use for that patient based on clinical judgment, the condition and needs of the patient, and the benefits, limitations, and characteristics of the breath delivery options. As the patient's condition changes over time, periodically assess the chosen modes and settings to determine whether or not those are best for the patient's current needs.

The following ventilator settings appear at the new patient setup screen:

- **Predicted Body Weight (PBW)**—Adjust the patient's PBW, or select the patient's gender and height. See [Predicted Body Weight \(PBW\) Calculation \(4.6\)](#) on page 4-19.
- **Ventilation type**—Determines the type of ventilation to be delivered [invasive or non-invasive (NIV)]
 - Invasive—Conventional ventilation using endotracheal (ET) or tracheostomy (trach) tubes
 - Non-invasive (NIV)—Ventilation using non-vented full-face masks, nasal masks, infant nasal prongs, or uncuffed ET tubes. See [Non-invasive Ventilation \(NIV\) \(4.7\)](#) on page 4-20.
- **Mode** — Specify the breathing mode (A/C (assist/control), SIMV (synchronized intermittent mandatory ventilation), SPONT (spontaneous ventilation), BiLevel or CPAP. CPAP is only available when the circuit type is neonatal and the ventilation type is NIV. See [Table 11-9](#) on page 11-7, Mode setting.
- **Mandatory type** — Select PC (pressure control), VC (volume control), or VC+ (volume control plus)
- **Spontaneous type** — If SIMV or BiLevel was selected as the mode, specify PS (pressure support) or TC (tube compensation. If SPONT was selected as the mode, specify PS (pressure support), TC (tube compensation), VS (volume support) or PAV+ (proportional assist ventilation).



Note:

VS, PAV+, and TC are only available during invasive ventilation.

- **Trigger type** — Select pressure- triggering (P-Trig) or flow-triggering (V̇-Trig). Pressure triggering is not available when the ventilation type is NIV. If ventilating a neonatal patient, only flow triggering is available.

Other ways to access the vent setup screen:



- Touch the vent setup button at the bottom left of the GUI display
- Swipe the Menu tab on the left side of the GUI and touch Setup.

Figure 4-4. Open Menu Tab



VEN_11349_D

- 1 Setup button

Figure 4-5. New Patient setup Screen



VEN_11350_D

To enter settings into the ventilator

1. Select Ventilation Type, Mode, Mandatory Type, Spontaneous Type and Trigger Type by touching the corresponding button.
2. Touch the ventilator setting button needing changes.

3. Adjust the setting value.
4. Continue in this manner until all changes are made, then touch *Accept* or *Accept ALL*.
5. Touch START. Ventilation does not begin until the breathing circuit is connected to the patient's airway. After ventilation begins, waveforms begin plotting on the displayed waveforms axes. See [Waveforms](#), page 3-39 for information on setting up the graphics display.

If changes to any settings are required, return to the vent setup screen as described above, or touch a setting icon in the current settings area. See [Figure 4-1](#), item 9.



Note:



A yellow triangle icon appears on tabs and buttons displayed on the GUI containing unread or unviewed items. When the item containing the icon is touched, the icon disappears.



Note:

To make any settings changes after completing patient setup, touch the Vent tab on the left side of the Setup dialog and make settings changes as described above. The current setting appears in white font and changes to yellow italics to note the new value is pending. Touch *Accept* or *Accept ALL* to confirm a single change or a batch of changes. Once the settings are accepted, their appearance changes to white font.



Note:

Selecting Quick Start, *Accept*, *Accept ALL* or Start from the setup dialog implements all settings in **all** four setup tabs (Vent Setup, Apnea, Alarms, and More Settings) and dismisses the setup dialog.

Tube Compensation

Tube compensation (TC) is a spontaneous breath type selected during ventilator setup. It allows the ventilator to deliver additional positive pressure to overcome the resistance imposed by the patient's artificial airway.

See [To enter settings into the ventilator](#), page 4-10 for more information on setting up the ventilator. See [Table 11-9](#) on page 11-7 for details of specific TC settings.

To enable TC

1. Touch the Vent tab on the GUI screen. See [Figure 4-5](#) on page 4-10.
2. Touch SPONT for the mode selection.
3. Touch TC for spontaneous type.
4. Finish setting up the ventilator as described (see page 4-10 for information on entering ventilator settings).
5. Select the tube type (either endotracheal or tracheostomy) and set the tube ID to correspond to patient settings.
6. After making the changes, touch *Accept ALL* to apply the new settings, or Cancel to cancel all changes and dismiss the dialog.

Adjust Tube Type, Tube ID, and Humidification



WARNING:

To prevent inappropriate ventilation with TC, select the correct Tube Type (ET or Tracheostomy) and tube inner diameter (ID) for the patient's ventilatory needs. Inappropriate ventilatory support leading to over- or under-ventilation could result if an ET tube or trach tube setting larger or smaller than the actual value is entered.



To select new settings for the tube

1. Touch the vent setup button on the GUI screen to display the ventilator setup screen.
2. Touch Tube Type or Tube ID for the value to be changed.
3. Turn the knob to change the setting.
4. Make other tube settings, as necessary.
5. Touch *Accept ALL* to apply the new settings, or Cancel to cancel all changes and dismiss the dialog.



Note:

The tube type and tube ID indicators flash if TC is a new selection, indicating the need for entry of the correct tube type and tube ID.



To select new settings for the humidifier

1. From the ventilator setup screen, touch the More Settings tab. A dialog appears containing selections for humidifier type and volume.



Note:

A humidifier Volume button appears below the selection only if Non-heated Expiratory Tube or Heated Expiratory Tube is selected as the humidifier type.

2. Turn the knob to enter a value equal to the dry volume of the humidifier chamber being used.
3. Touch *Accept* or *Accept ALL* to apply the new settings, or Cancel to cancel all changes and dismiss the dialog.

[Table 4-2](#). lists the allowable ventilator settings according to patient type and ventilation type.

Table 4-2. Allowable Ventilator Settings

Patient type	Adult		Pediatric		Neonatal	
Ventilation type	Invasive	NIV	Invasive	NIV	Invasive	NIV
Mode	A/C, SIMV, SPONT, BiLevel	A/C, SIMV, SPONT	A/C, SIMV, SPONT, BiLevel	A/C, SIMV, SPONT	A/C, SIMV, SPONT, BiLevel	A/C, SIMV, SPONT, CPAP
Mandatory type	PC, VC, VC+	PC, VC	PC, VC, VC+	PC, VC	PC, VC, VC+	PC, VC
Spontaneous type	PS, TC, VS, PAV+ (≥ 25 kg)	PS	PS, TC, (≥ 7.0 kg), VS	PS	PS, VS	PS
Trigger type	$\dot{V}$ -Trig, P-Trig	$\dot{V}$ -Trig	$\dot{V}$ -Trig, P-Trig	$\dot{V}$ -Trig	$\dot{V}$ -Trig	$\dot{V}$ -Trig

**Note:**

To use neonatal ventilator settings, the NeoMode 2.0 software option must be installed on the ventilator, or a Puritan Bennett™ 980 Neonatal Ventilator must be in use.

4.5.2 Apnea Settings

After making the necessary changes to the ventilator settings touch the Apnea tab on the left side of the setup dialog. Although changing the apnea settings is not required, confirm the default settings are appropriate for the patient. Apnea ventilation allows pressure control or volume control breath types. Parameters in pressure-controlled apnea breaths include f , P_I , T_I , $O_2\%$, and T_A . Volume controlled apnea breath parameters are f , V_T , $\dot{V}_{MAX}$, flow pattern, $O_2\%$, and T_A .

**Note:**

If Quick Start is chosen, the Apnea tab on the vent setup screen shows a yellow triangle, indicating the apnea settings have not been reviewed.

Figure 4-6. Apnea Setup Screen



VEN_11351_D

To set apnea parameters

1. Select the desired apnea breath type (PC or VC).
2. Enter the desired apnea settings in the same manner as for the ventilator settings.
3. Touch *Accept* or *Accept ALL* to confirm apnea settings.

During apnea pressure ventilation, apnea rise time% is fixed at 50%, and the constant parameter during a respiratory rate change is T_I .

4.5.3 Alarm Settings

After accepting the apnea settings, the display returns once more to show the waveforms. Return to the vent setup dialog and touch the Alarms tab on the left side of the GUI screen or touch the alarm icon in the constant access icons area of the GUI screen. The alarms screen appears with the default alarm settings. See [Figure 4-7](#) on page 4-15. Review and adjust the alarm settings appropriately for the patient.

**Note:**

If Quick Start is chosen, the alarms tab on the dialog shows a yellow triangle, indicating the alarm settings have not been reviewed.

**Note:**

The default alarm settings cannot be changed. The clinician can adjust alarm settings by following the procedure below. The alarm settings are retained in memory when the ventilator's power is cycled and

same patient is selected. Otherwise, current settings revert to new patient defaults when a new patient is selected.

Figure 4-7. Alarms Settings Screen



VEN_11352_D

To adjust the alarm settings

1. Touch each alarm setting slider of the alarms to change. Alarm settings are available for P_{PEAK} , f_{TOT} , $\dot{V}_{E\text{ TOT}}$, $V_{TE\text{ MAND}}$, $V_{TE\text{ SPONT}}$, and V_{TI} parameters.
2. Turn the knob to increase or decrease the value.
3. Continue until all desired alarms are set as necessary.
4. Touch *Accept ALL* to confirm the alarm settings.



Note:

There is an additional alarm setting for TC, PAV+, VS, and VC+ breath types: high inspired tidal volume ($\uparrow V_{TI}$). This alarm condition occurs when the inspired tidal volume is larger than the setting value. A $\uparrow V_{TI}$ alarm will also cause breath delivery to transition to the expiratory phase to avoid delivery of excessive inspiratory volumes.



WARNING:

Prior to initiating ventilation and whenever ventilator settings are changed, ensure the alarm settings are appropriate for the patient.



WARNING:

Setting any alarm limits to OFF or extreme high or low values, can cause the associated alarm not to activate during ventilation, which reduces its efficacy for monitoring the patient and alerting the clinician to situations that may require intervention.

See [To adjust alarm volume](#), page 3-37 to ensure alarm volume is adjusted properly.



Note:

A sample alarm tone sounds for verification at each volume level change. Readjust the alarm volume by moving the alarm volume slider to increase or decrease the alarm volume.



Note:

Do not block the patient wye while the ventilator is waiting for a patient connection. Otherwise the blockage could imitate a patient connection.

4.5.4 Alarm Screen During Operation

During ventilator operation, the alarm screen appears with indicators to let the operator know the current patient data value for each parameter (item 1), the parameter alarm settings (items 2 and 3), recent range of patient data values for the last 200 breaths (item 4). If an alarm occurs, the slider and corresponding limit button show a color matching the alarm's priority. See [Figure 4-8](#), on page 4-16.

Figure 4-8. Alarm Screen During Operation



VEN_11448_A

- | | | | |
|---|--|---|---|
| 1 | Pointers show current value of patient data corresponding to the alarm parameter | 3 | Low alarm setting (in this case $\downarrow V_{TE\ SPONT}$) |
| 2 | High alarm setting (in this case $\uparrow V_{TE\ SPONT}$) | 4 | Range of patient data values for the particular parameter during the last 200 breaths |

4.5.5 Making Ventilator Settings Changes

If, during ventilation, settings changes are necessary that don't involve changes to PBW, mode, breath types, or trigger types, the current settings area located at the lower portion of the GUI screen can be used. See [Figure 4-1](#) on page [4-3](#) for the location of the current settings area.

To change a ventilator setting using the current settings area

1. In the current settings area, touch the parameter whose value needs to be changed. A dialog appears containing buttons for all ventilator settings, with the selected setting highlighted.
2. Touch and turn the knob for any other settings that need to be changed.
3. Touch *Accept* or *Accept ALL*.

To change a setting using the vent setup button



1. Touch the vent setup button.
2. Change the settings as described previously.
3. Touch *Accept* or *Accept ALL* to confirm the changes.

The ventilator settings and the alarm settings chosen remain in memory after the a power cycle, as long as the same patient is chosen when the ventilator is set up again. If a new patient is being ventilated, the ventilator and alarm settings revert to their default values. If all power is lost (both AC and battery), the ventilator and alarm settings in effect prior to the power loss are automatically restored if the power loss duration is 5 minutes or less. If the power loss lasts longer than 5 minutes, ventilation resumes in Safety PCV. Ventilator and alarm settings must be reset for the patient being ventilated. See [Table 10-10](#) on page [10-60](#) for a list of these settings.

To use the Previous Setup button

1. To return to the previous setup, touch the vent setup button then touch Previous Setup on the GUI screen. The ventilator restores the main control and breath settings previously used, as well as the alarm and apnea settings, and prompts a review by highlighting the previous values in yellow. The ventilator, alarm, and apnea settings tab text is also shown in yellow and the tabs show a yellow triangle, indicating there are previous settings that have not been reviewed.
2. If the settings are acceptable, touch *Accept* or *Accept ALL*.

Previous Setup disappears when the previous settings are confirmed and re-appears when ventilating with new settings.

4.5.6 Constant Timing Variable During Respiratory Rate Changes

A breath timing graph appears at the bottom of the setup screen which illustrates the relationship between inspiratory time, expiratory time, I:E ratio, respiratory rate, and the effects on breath timing due to flow pattern, tidal volume, and $\dot{V}_{MAX}$ during mandatory PC, VC, BiLevel, or VC+ breaths. With BiLevel, PC and VC+ breaths, three padlock icons are located underneath the breath timing graph allowing the operator to select, from left to right, T_I , I:E ratio, or T_E as the constant variable during rate changes (or T_H , $T_H:T_L$ ratio, or T_L in BiLevel). If the ventilation mode is SPONT, the padlock icons do not appear, and the breath timing graph only displays T_I for a manual inspiration. If the mandatory type is VC, the icons do not appear, but the breath timing graph displays T_I , I:E ratio, and T_E .

To choose a constant timing variable for rate changes

1. Touch a padlock icon corresponding to the parameter to make constant during rate changes (this changes the padlock's appearance from unlocked to locked). The "locked" parameter glows in the settings area.
2. Turn the knob to adjust the parameter's value.
3. Touch *Accept*.

4.6 Predicted Body Weight (PBW) Calculation

Many default ventilator and alarm settings are based on patient PBW. Either through the entry of height and gender or directly via setting PBW. The PBW range spans at least 0.3 kg (0.66 lb) through at least 155 kg (342 lb) male and 150 kg (331 lb) female. Understanding how the ventilator operates at the very low end of the range of PBW requires awareness that an entry or prediction for PBW drives the value of a delivered volume, which has a lower limit of 2.0 mL (if using the NeoMode 2.0 option). Data for adult male and female PBW as a function of height are calculated by applying the equations presented on www.ards.net.

Assume the ventilator (via direct height or PBW entry) registered a PBW of 0.3 kg. If a delivered volume of 4 mL/kg (PBW) was specified, the required volume would equal only 1.2 mL, which is less than the ventilator minimum of 2.0 mL. At a desired 4 mL/kg, the infants' PBW would need to be at least 0.5 kg or the desired volume must be reset to greater than 4 mL/kg (PBW). Once the PBW of the premature infant approaches 1.0 kg (2.2 lb), this restriction disappears.

After entering PBW, review and change all settings as needed.

The correlation function $PBW = \text{height}$ was derived from the sources referenced. For subjects whose body weight/height data define the range of PBWs that include the 20- to 23-week gestational-age neonates and the young male and female adolescent adults at the foot of the ARDS tables, their PBW values were taken as the 50th percentile numbers in the Fenton tables and the CDC and NCHS charts and tables, respectively. Note that the Fenton tables provided the exclusive information for premature and infant data between 20 weeks and 50 weeks of fetal and gestational growth.^{1, 2, 3}

**Note:**

Any repeated values noted in the tables are the result of decimal rounding.

1 Fenton TR, BMC Pediatrics 2003, 3:13. www.biomedcentral.com/1471-2431/3/13.

2 Hamill, PV V. 1977 NCHS growth curves for children birth to 18 years for the United States: National Center for Health Stat (Vital and Health Statistics: Series 11, Data from the National Health Survey; no. 165) (DHEW publication; (PHS) 78-1650). 1977.

3 Kuczmarski RJ, Ogden CL, Guo SS, et al. 2000 CDC growth charts for the United States: Methods and development. National Center for Health Statistics. Vital Health Stat 11(246). 2002.

4.7 Non-invasive Ventilation (NIV)

**WARNING:**

Use only non-vented patient interfaces with NIV. Leaks associated with vented interfaces could result in the ventilator's inability to compensate for those leaks, even if Leak Sync is employed.

**WARNING:**

Full-face masks used for non-invasive ventilation should provide visibility of the patient's nose and mouth to reduce the risk of emesis aspiration.

**WARNING:**

When using NIV, the patient's exhaled tidal volume (V_{TE}) could differ from the ventilator's monitored patient data V_{TE} reading due to leaks around the interface. To avoid this, ensure Leak Sync is enabled.

Non-invasive ventilation (NIV) is used when the clinician determines a mask or other non-invasive patient interface rather than an endotracheal tube would result in the desired patient outcome.

4.7.1 NIV Intended Use

NIV is intended for use by neonatal, pediatric, and adult patients possessing adequate neural-ventilatory coupling and stable, sustainable, respiratory drive.

4.7.2 NIV Breathing Interfaces

Covidien has successfully tested the following non-vented interfaces with NIV:

- **Full-face mask:** Puritan Bennett^{TM*} Benefit full face mask (large), ResMed Mirage^{TM*} non-vented full face mask (medium)
- **Nasal mask:** ResMed Ultra Mirage^{TM*} non-vented mask (medium)
- **Infant nasal prongs:** Sherwood Davis & Geck Argyle^{TM*} CPAP nasal cannula (small), Hudson RCI^{TM*} infant nasal CPAP system (number 3)
- **Uncuffed neonatal ET tube:** Mallinckrodt uncuffed tracheal tube, Murphy (3.0 mm)

4.7.3 NIV Setup

NIV can be initiated from either the New Patient Setup screen during vent startup or while the patient is being ventilated invasively. See [Table 4-3](#) for NIV patient setup information.

Table 4-3. Setting Up a Patient for NIV

To set up a new patient	To set up a patient currently being ventilated
1. Turn on the ventilator. 2. Select New Patient. 3. Enter patient's PBW or gender and height. 4. Touch NIV ventilation type. 5. Select mode. 6. Select breath type. 7. Complete ventilator settings, including apnea and alarm settings.	1. Touch or swipe the menu tab on the left side of the GUI. 2. Touch Vent Setup. 3. Perform steps 4 through 7 as if setting up the ventilator for a new patient. 4. Review the settings, including apnea and alarm settings, and change if necessary.

To set D_{SENS} with NIV interfaces when Leak Sync is enabled

1. After adjusting the patient settings, start ventilation.
2. Ensure that Leak Sync is enabled.
3. With the NIV interface open to ambient (not connected to the patient), use the patient data leak value to quantify the leak in L/min.
4. Set the D_{SENS} (in L/min) below the leak rate (in L/min).
5. Periodically assess the leak rate, especially with PEEP changes, and adjust the D_{SENS} setting as needed.
6. Always use alternative methods of monitoring during NIV.

4.7.4 Conversion from Invasive to NIV Ventilation Type**WARNING:**

For proper ventilation when changing the ventilation type on the same patient, review the automatic settings changes described. Adjust appropriately based on the relevant tables.

Some ventilator settings available during invasive ventilation are not available during NIV. See [Table 4-4](#) for automatic settings changes when changing ventilation type from invasive to NIV.

Table 4-4. Invasive to NIV on Same Patient

Current invasive setting	New NIV setting
Breath Mode: BiLevel	Breath mode: A/C
Breath Mode: SIMV or SPONT	High $T_{I\ SPONT}$ ($\uparrow T_{I\ SPONT}$) limit setting available
Mandatory Type: VC+	Mandatory type: Neonatal: PC Adult/Pediatric: VC
Spontaneous Type: Any type except PS	Spontaneous type: PS
Trigger type: Pressure	Trigger type: Flow (Flow triggering is the only allowable trigger type during NIV)
Alarm settings: $\downarrow P_{PEAK}$ (if applicable), $\downarrow \dot{V}_{E\ TOT}$, $\downarrow V_{TE\ MAND}$, $\downarrow V_{TE\ SPONT}$, INSPIRATION TOO LONG (not user-settable)	Alarm settings: $\downarrow P_{PEAK}$, $\downarrow \dot{V}_{E\ TOT}$, $\downarrow V_{TE\ MAND}$, $\downarrow V_{TE\ SPONT}$ default to NIV new patient values. See Table 11-10 on page 11-14. INSPIRATION TOO LONG alarm not available.
D_{SENS}	D_{SENS} setting defaults to OFF if Leak Sync is disabled.

**Note:**

In any delivered spontaneous breath, either invasive or NIV, if pressure support is set to 0 cmH₂O, there is always a target inspiratory pressure of 1.5 cmH₂O applied.

When in NIV, the vent setup button's appearance changes, letting the operator know the ventilation type is NIV.

Figure 4-9. Vent Setup Button—"NIV" Indicating NIV Ventilation Type

VEN_11353_F

4.7.5 Conversion from NIV to Invasive Ventilation Type

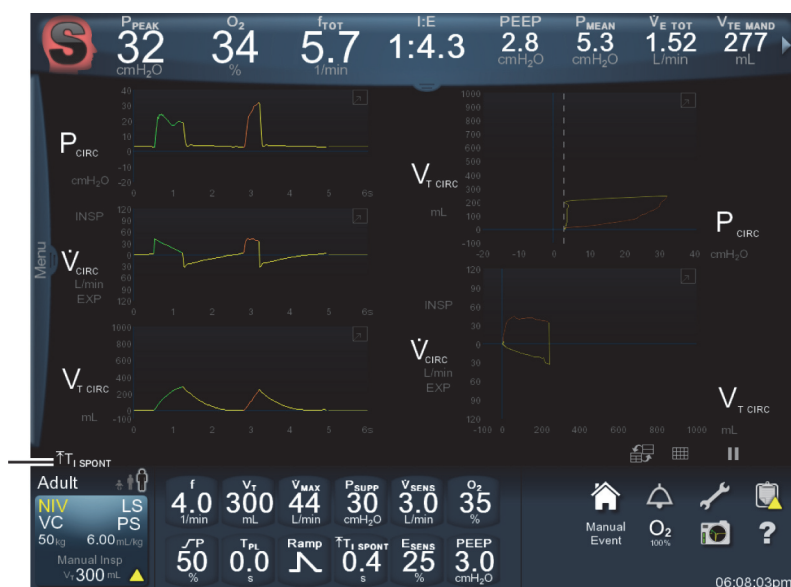
Table 4-5. shows automatic settings changes made when changing ventilation type from NIV to invasive.

Table 4-5. NIV to Invasive on Same Patient

Current NIV setting	New invasive setting
Ventilator settings: $\uparrow T_{I\text{ SPONT}}$	N/A
Alarm settings: $\downarrow P_{\text{PEAK}}$, $\downarrow V_{\text{E TOT}}$, $\downarrow V_{\text{TE MAND}}$, $\downarrow V_{\text{TE SPONT}}$	Alarm settings: Default to new patient values dependent upon selected invasive ventilator settings. INSPIRATION TOO LONG alarm becomes available.
D_{SENS}	D_{SENS} setting defaults to OFF if Leak Sync setting is enabled.

4.7.6 High Spontaneous Inspiratory Time Limit Setting

NIV includes a setting in SIMV or SPONT modes for high spontaneous inspiratory time limit ($\uparrow T_{I\text{ SPONT}}$). When a patient's inspiratory time reaches or exceeds the set limit, the ventilator transitions from inspiration to exhalation, and the $\uparrow T_{I\text{ SPONT}}$ symbol appears at the lower left on the GUI screen, indicating the ventilator has truncated inspiration (shown in [Figure 4-10.](#)). The $\uparrow T_{I\text{ SPONT}}$ setting does not restrict changes to PBW; if the PBW is decreased, $\uparrow T_{I\text{ SPONT}}$ may decrease automatically to remain within its allowable limits.

Figure 4-10. $\uparrow T_{I\text{ SPONT}}$ Indicator

VEN_11354_F

**WARNING:**

No audible alarm sounds in conjunction with the visual $\uparrow T_{I\text{ SPONT}}$ indicator, nor does the indicator appear in any alarm log or alarm message.

It is possible the target inspiratory pressure may not be reached if the $\uparrow T_{I\text{ SPONT}}$ setting is not long enough, or if system leaks are so large as to cause the ventilator to truncate the breath at the maximum allowable $\uparrow T_{I\text{ SPONT}}$ setting.

**Note:**

To reduce the potential for not reaching the target pressure, minimize the leaks in the system and increase the rise time% or decrease the E_{SENS} setting, if appropriate.

4.7.7 NIV Apnea Setup

Set the patient's apnea parameters as described. See [Apnea Settings \(4.5.2\)](#) on page 4-13. NIV does not change the way apnea parameters are set.

4.7.8 NIV Alarm Settings

The system initially sets most alarm settings based on the patient's PBW. Review all alarm settings, and change as necessary, but startup does not require confirmation of the settings. Alarm settings are made in exactly the same way in NIV as for invasive ventilation.

Figure 4-11. Default NIV Alarm Settings



VEN_11355_D

Touch the Alarms tab at any time during ventilation to show the current limits and the monitored patient value shown in white on the indicating arrows for each alarm. If an alarm is occurring, the indicator LED color changes based on alarm priority. See [Table 6-2](#) on page 6-14 for colors and meanings of alarms and their priorities.

**Note:**

The upper and lower limits of an alarm cannot conflict with each other.

**Note:**

The upper limits for the spontaneous exhaled tidal volume and mandatory exhaled tidal volume alarms are always the same value. Changing the upper limit of one alarm automatically changes the upper limit of the other.

4.8 Manual Inspiration



A manual inspiration is an operator-initiated mandatory (OIM) inspiration. When the operator presses the manual inspiration key while the ventilator is in a mode that includes mandatory breaths (including mixed modes BiLevel and SIMV), the ventilator delivers the manual inspiration using the currently set mandatory breath parameters. A manual inspiration performed while the ventilator is in the SPONT mode uses the currently set apnea breath parameters. A volume-based manual inspiration is compliance-compensated. Pressing the manual inspiration key while in BiLevel mode will transition from T_H to T_L or T_L to T_H depending on when in the breath cycle the key was pressed.

4.9 Respiratory Mechanics Maneuvers

To access respiratory mechanics maneuvers

1. Touch or swipe the Menu tab on the left side of the GUI.
2. Touch RM.

Figure 4-12. RM in Menu Tab



VEN_11348_D

3. Touch the particular tab for the desired maneuver.

Figure 4-13. Respiratory Maneuver Tabs



VEN_11356_D

- Follow the prompts on the GUI screen.
- Accept or reject the maneuver results. If the result is accepted, its value is saved.

4.9.1 Inspiratory Pause Maneuver

An inspiratory pause maneuver closes the inspiration and exhalation valves and extends the inspiratory phase of a single, mandatory breath for the purpose of measuring end inspiratory circuit pressure and plateau pressure (P_{PL}). Then lung static compliance (C_{STAT}), and static resistance (R_{STAT}) of the respiratory system are calculated. Pressures on either side of the artificial airway are allowed to equilibrate, which determine the pressure during a no-flow state. A request for an inspiratory pause is rejected during apnea ventilation, safety PCV, OSC, BUV, and in Stand-by state. Inspiratory pause maneuvers are allowed in A/C, SIMV, BiLevel and SPONT modes. If an inspiratory pause maneuver has already occurred during the breath, a second inspiratory pause maneuver is not allowed.

Inspiratory pause maneuvers can be classified as **automatic** or **manual**. The **automatic** inspiratory pause maneuver lasts at least 0.5 second but no longer than 3 seconds. A **manual** inspiratory pause maneuver starts by pressing and holding the inspiratory pause key. The pause maneuver lasts for the duration of the key-press (up to 7 seconds).

To perform an automatic inspiratory pause maneuver

- Press and release the inspiratory pause key on the GUI bezel or touch and release Start if performing an inspiratory pause maneuver from the GUI screen as shown in [Figure 4-13](#) on page 4-27. The ventilator performs the inspiratory pause maneuver and displays P_{PL} , C_{STAT} , and R_{STAT} along with the date and time.

2. Touch Accept or Reject to save or dismiss results. If Accept is touched, the results are displayed.

Cancel an automatic inspiratory pause maneuver by touching Cancel on the GUI screen.

To perform a manual inspiratory pause maneuver

1. Press and hold the inspiratory pause key on the GUI bezel or touch and hold Start on the GUI screen if performing an inspiratory pause from the GUI screen as shown above. The ventilator prompts that the maneuver has started, and to release to end the maneuver. The ventilator performs the inspiratory pause maneuver and displays P_{PL} , C_{STAT} , and R_{STAT} along with the date and time.
2. Touch Accept or Reject to save or dismiss results. If Accept is touched, the results are displayed.

Cancel a manual inspiratory pause maneuver by releasing the inspiratory pause key.

4.9.2 Expiratory Pause Maneuver

An expiratory pause maneuver extends the expiratory phase of the current breath for the purpose of measuring end expiratory lung pressure ($PEEP_{TOT}$) or total PEEP. It has no effect on the inspiratory phase of a breath, and only one expiratory pause per breath is allowed. For I:E ratio calculation purposes, the expiratory pause maneuver is considered part of the expiratory phase.

During an expiratory pause maneuver, both inspiratory and exhalation valves are closed, allowing the pressures on both sides of the artificial airway to equilibrate. This allows intrinsic PEEP ($PEEP_I$) to be calculated. $PEEP_I$ equals $PEEP_{TOT}$ minus the set PEEP level. An expiratory pause maneuver can be either automatically or manually administered, and is executed at the next mandatory breath in A/C, SIMV, or BiLevel modes. In SIMV, the breath cycle in which the pause maneuver becomes active (when the next scheduled ventilator-initiated mandatory (VIM) breath occurs) will be extended by the amount of time the pause is active. For A/C and SIMV, the expiratory pause maneuver is scheduled for the next end-of-exhalation prior to a mandatory breath. In BiLevel the expiratory pause maneuver is scheduled for the next end-of-exhalation prior to a transition from P_L to P_H . During the expiratory pause maneuver, $PEEP_I$ and $PEEP_{TOT}$ equilibration time values are displayed and regularly updated because stabilization of one of these values can indicate the pause can be ended. During the expiratory pause maneuver, the apnea interval T_A is extended by the amount of time the pause maneuver is active. Expiratory pause maneuver requests are ignored if the ventilator is in apnea ventilation, safety PCV, OSC, BUV, and Stand-By state. Additionally, SEVERE OCCLUSION alarms are suspended during expiratory pause maneuvers. If flow triggering is active, backup pressure sensitivity (P_{SENS}) detects patient breathing effort.

Maximum duration for a **manual** expiratory pause maneuver is 15 seconds and 3 seconds for an **automatic** expiratory pause maneuver.

During a manual or automatic expiratory pause maneuver, $PEEP_I$ and $PEEP_{TOT}$ appear on the GUI with the next VIM to allow the clinician to view when these values are stabilized, indicating the maneuver can be ended.

To perform an automatic expiratory pause maneuver

1. Press and release the expiratory pause key on the GUI or touch and release Start if performing the expiratory pause maneuver from the GUI screen. The ventilator performs the expiratory pause maneuver and displays a circuit pressure graph, $PEEP_{TOT}$, and $PEEP_I$, along with the date and time.
2. Accept or reject the pause maneuver results.

To perform a manual expiratory pause maneuver

1. Press and hold the expiratory pause key on the GUI bezel or touch and hold Start if performing the expiratory pause maneuver from the GUI screen. The ventilator prompts that the maneuver has started, and to release to end the maneuver. The ventilator performs the expiratory pause maneuver and displays a circuit pressure graph, $PEEP_{TOT}$, and $PEEP_I$ along with the date and time.
2. Accept or reject the pause maneuver results.

Touch Cancel on the GUI screen to cancel the expiratory pause maneuver.

4.9.3 Other Respiratory Maneuvers

To perform other respiratory maneuvers, touch the corresponding tab on the desired maneuver, and follow the prompts on the GUI screen.

4.10 Oxygen Sensor Function

The ventilator's oxygen sensor monitors $O_2\%$. This cell is mounted in the inspiratory module in the BDU and monitors the percentage of oxygen in the mixed gas delivered to the breathing circuit (it may not reflect the actual oxygen concentration in the gas the patient inspires).

See the *Puritan Bennett™ 980 Series Ventilator Service Manual* for instructions on replacing the O_2 sensor.

New patient default $O_2\%$ settings are as follows:

- O_2 sensor—enabled
- Neonatal—40% O_2
- Pediatric/adult—100% O_2

**Note:**

The oxygen sensor has three states: Enabled, Disabled, and Calibrate. The oxygen sensor is enabled at ventilator startup regardless if New Patient or Same Patient setup is selected.

To enable or disable the O_2 sensor

1. Touch the vent setup button.



2. Touch the More Settings tab. The more settings screen appears.

Figure 4-14. More Settings Screen with O₂ Sensor Enabled



VEN_11357_D

3. Touch the button corresponding to the desired O₂ sensor function (Enabled or Disabled).
4. Touch *Accept*.

4.10.1 Oxygen Sensor Life

The O₂% setting can range from room air (21% O₂) up to a maximum of 100% oxygen. The sensor reacts with oxygen to produce a voltage proportional to the partial pressure of the mixed gas. As ambient atmosphere contains approximately 21% oxygen, the sensor constantly reacts with oxygen and always produces a voltage. The useful life of the cell can also be shortened by exposure to elevated temperatures and pressures. During normal use in the ICU, the oxygen sensor lasts approximately 1 year—the interval for routine preventive maintenance.

Because the oxygen sensor constantly reacts with oxygen, it requires periodic calibration to prevent inaccurate O₂% alarm annunciation. Once a calibrated oxygen sensor and the ventilator reach a steady-state operating temperature, the monitored O₂% will be within three percentage points of the actual value for at least 24 hours. To ensure the oxygen sensor remains calibrated, recalibrate the oxygen sensor at least once every 24 hours.

Typically, the clinician uses an O₂ analyzer in conjunction with the information given by the ventilator. If a NO O₂ SUPPLY alarm occurs, compare the O₂ analyzer reading with the ventilator's O₂ reading for troubleshooting purposes. The ventilator automatically switches to delivering air, only (21% oxygen).

4.10.2 Oxygen Sensor Calibration

The oxygen sensor should be calibrated every 24 hours and before use. The calibration function provides a single-point O₂ sensor calibration.

To calibrate the O₂ sensor



1. Touch the vent setup button.
2. Touch the More Settings tab.
3. Touch Calibrate for the O₂ sensor. The calibration procedure results in 100% O₂ being delivered through the breathing circuit for the 2-minute calibration period. See [Figure 4-14](#) on page 4-30.

4.10.3 Oxygen Sensor Calibration Testing

To test the O₂ sensor calibration

1. Connect the ventilator's oxygen hose to a known 100% O₂ source (for example, a medical-grade oxygen cylinder).
2. Calibrate the oxygen sensor as described above.
3. Connect the ventilator oxygen hose to another known 100% O₂ source (for example, a second medical-grade oxygen cylinder).
4. Set O₂% to each of the following values, and allow 1 minute after each for the monitored value to stabilize: 21%, 40%, 90%
5. Watch the GUI screen to ensure the value for O₂ (delivered O₂%) is within 3% of each setting within 1 minute of selecting each setting.

4.11 Ventilator Protection Strategies

The ventilator incorporates a number of strategies to support patient safety. These include power on self test (POST), SST and a new strategy called **Ventilation Assurance**, which provides alternate means of ventilation in the case of certain serious faults in the breath delivery system. The descriptions below detail the system response to potential failures.

4.11.1 Power On Self Test (POST)

The first strategy is to detect potential problems before the ventilator is placed on a patient. POST checks the integrity of the ventilator's electronics and prevents ventilation if a critical fault is found. (See the *Puritan Bennett™ 980 Series Ventilator Service Manual* for a complete description of POST). POST may detect major or minor system faults which manifest themselves as device alerts. See [DEVICE ALERT Alarm \(6.5.13\)](#) on page 6-31 for more information.

4.11.2 Technical Fault

A technical fault occurs if a POST or background test has failed. See [Power On Self Test \(POST\) \(10.17\)](#) on page [10-63](#). Based on the test that failed, the ventilator will either ventilate with current settings, ventilate with modified settings, or enter the vent inop state. A technical fault cannot be cleared by pressing the alarm reset key. It can only be cleared by correcting the fault that caused it or if alarm reset criteria have been met.

4.11.3 SST

In addition to characterizing the ventilator breathing circuit, SST performs basic checks on the ventilator's pneumatic system including the breath delivery PSOL, the flow sensors and the exhalation valve. Faults detected during SST must be corrected before ventilation can be started.

4.11.4 Procedure Error

A procedure error occurs when the ventilator senses a patient connection before ventilator setup is complete. The ventilator provides ventilatory support using default Safety Pressure Controlled Ventilation (Safety PCV) settings. See [Table 10-10](#) on page [10-60](#).

4.11.5 Ventilation Assurance

During ventilation, the ventilator performs frequent background checks of its breath delivery subsystem (see [Safety Net \(10.16\)](#) on page [10-59](#)). In the event that certain critical components in the pneumatics fail, Ventilation Assurance provides for continued ventilatory support using one of three backup ventilation (BUV) strategies, bypassing the fault to maintain the highest degree of ventilation that can be safely delivered (see [Background Diagnostic System \(10.16.4\)](#) on page [10-61](#) for a full description of the backup ventilation strategies).

**Note:**

Do not confuse BUV with Safety PCV, which occurs when a patient is connected before ventilator setup is complete, or with apnea ventilation, which occurs in response to patient apnea.

4.11.6 Safety Valve Open (SVO)

In the event of a serious fault occurring that cannot be safely bypassed, the ventilator, as a last resort, reverts to a safe state. In Safe State, the ventilator opens the safety valve and the exhalation valve, allowing the patient to breathe room air (if able to do so), provided the patient circuit is not occluded, and the inspiratory PSOL valve is closed. During SVO, the patient (if connected) can breathe room air through the safety valve after it releases pressure in the patient circuit. The patient exhales through the exhalation valve with minimal resistance and the exhalation valve also acts like a check valve, limiting gas from being drawn in through the exhalation filter or expiratory limb of the circuit. SVO conditions are logged into the event and alarm logs as are the

events leading to the SVO condition. If the condition causing SVO clears, the ventilator clears the SVO state. Patient data do not display on the GUI, but graphics are still plotted. During SVO, the ventilator ignores circuit occlusions and disconnects. If the condition causing SVO can only be corrected by servicing the ventilator, the SVO alarm cannot be reset by pressing the alarm reset key.

4.11.7 Ventilator Inoperative (Vent Inop)

Vent Inop occurs when the ventilator detects a catastrophic error and prevents all other safety states from operating. Vent inop limits pressure to the patient as the ventilator enters the SVO state, disables (closes) the gas mixing PSOL valves, and purges the gas mixing system accumulator. The safety valve is opened, a vent inop indicator illuminates, a high priority alarm annunciates from the primary alarm, and the secondary alarm (continuous tone) is activated. The ventilator can only exit the vent inop state by power cycling and successfully passing EST. The vent inop alarm cannot be reset with the alarm reset key. All detection and annunciation of patient data alarm conditions is suspended.

During a vent inop condition, the inspiratory and expiratory pressure drop measured at the patient wye does not exceed 6.0 cmH₂O at 30 L/min.

4.12 Ventilator Shutdown

When the ventilator power switch is turned off, the ventilator executes an orderly shutdown routine, saving patient data before removing power. If the ventilator detects a patient connected when the power switch is turned off, a high priority alarm is annunciated and a banner on the display requires the operator to confirm that a power down was requested. Only after the operator confirms will the ventilator execute the shutdown command.

All logs are retained in the ventilator's memory upon ventilator shutdown. When the logs reach the maximum number of entries, the oldest values are overwritten with new values. See [Ventilator Logs \(8.5\)](#) on page 8-2 for information on ventilator logs.

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5 Product Data Output

5.1 Overview

This chapter describes the features of the Puritan Bennett™ 980 Series Ventilator designed to provide output to the clinician. This includes language, methods of displaying and transferring data, types of displayed data, and types of external device ports. Connectivity to an external patient monitoring system is also included.

5.2 Language

The language used on the ventilator is configured at the factory.

5.3 Data Display

Displayed data are updated in real-time. The practitioner can display up to 60 seconds of waveform data and pause and capture up to two loops using the screen capture function. The operator can pause the displays and when the displays are paused, a cursor appears with the relevant numeric values for the intersecting points of the cursor and waveform or loop. The scalar waveform contains a single value, but loops contain both x- and y-axis data. The operator can move the cursor along the waveform or loop using the knob, and read the corresponding data. See [Waveforms](#), page 3-39 for details regarding configuring and displaying waveforms.

5.4 Data Transfer

Data from the ventilator can be accessed via USB or RS-232 connectors. The following data are available for downloading via connection to a remote device or flash drive:

- Waveform images (screen capture function)—USB port
- Waveform data—RS-232 port, USB port with USB to serial conversion capability (per Comm port configuration)
- Results from DCI commands—RS-232 port, USB port with USB to serial conversion capability (per Comm port configuration)

5.4.1 GUI Screen Capture

**Caution:**

The USB interface should be used for saving screen captures and interfacing with an external patient monitor. It should not be used to provide power to other types of devices containing a USB interface.

**Caution:**

Only compatible USB devices should be used, otherwise GUI performance may be impacted.

A 128 MB flash drive storage device formatted in the 32-bit file format is required for downloading images from the USB ports. The USB device listed in [Table 9-1](#) is the ONLY compatible USB device currently available for use on the PB980. To order a compatible USB device, contact Covidien Technical Services at 800 255 6774 or a local Covidien representative.

To capture GUI screens

1. Navigate to the desired screen from which you wish to capture an image (for example, the waveforms screen). There is no need to pause the waveform before performing the screen capture.



2. Touch the screen capture icon in the constant access icons area of the GUI screen. If desired, navigate to another screen and repeat steps 1 and 2 for up to 10 images. If another image is captured, increasing the queue to 11 images, the newest image overwrites the oldest image so there are always only 10 images available.

**Note:**

If the camera icon appears dim, it means that the screen capture function is currently processing images and is unavailable. When processing is finished, the camera icon is no longer dim and the screen capture function is available.

To transfer the captured images to a USB storage device

1. Swipe the Menu on the left side of the GUI. See [Figure 4-4](#) on page 4-10.
2. Touch Screen Capture. A list of screen captures appears, identified by time and date. A slider also appears if more images than shown are present.
3. Insert a passive USB storage device (flash drive) into one of the USB ports at the rear of the ventilator. The proper orientation of the USB device is with metal contacts facing the test button. See [Figure 5-3](#) on page 5-17. If more than one USB storage device is installed in the ventilator, touch the button of the destination USB device where the image will be copied. If an incompatible device is inserted, the port becomes disabled until the device is removed, and removal is confirmed by touching the confirm button. The message shown in [Figure 5-1](#) appears.

Figure 5-1. Incompatible USB Device Message



VEN_12538_A

**Note:**

Removal of the external USB storage device while screenshot files are being written to it may result in incomplete file transfer and unusable files.

4. In the list of images, touch the image name.
5. Touch Copy. The image is stored on the destination USB storage device.
6. Alternatively, touch Select All, and all images in the list are stored on the USB device and can then be viewed and printed from a personal computer.

**Note:**

The file format of screen captures is PNG.

5.4.2 Communication Setup

To specify the communication configuration for the ventilator



1. Touch the configure icon in the constant access icons area of the GUI. A menu appears with several tabs.
2. Touch the Comm Setup tab. The Comm Setup screen appears allowing three ports to be configured. These ports can be designated as DCI, DCI 2.0, Philips, Spacelabs, or Waveforms.

**Note:**

Waveforms can be selected on any port, but only on one port at a time.

Figure 5-2. Comm Setup Screen



VEN_11358_D

5.4.3 Comm Port Configuration

Configuring the Comm port allows the ventilator to communicate with devices listed in the Comm Setup screen, or to capture waveform data (in ASCII format) from the ventilator.

To configure Comm ports

1. Touch COM1, COM2, or COM3.
2. Turn the knob indicating the desired device configuration.
3. Select the desired baud rate. If waveforms was selected, the baud rate automatically becomes configured to 38 400.
4. Select 7 or 8 data bits.
5. Select parity of even, odd, or none if data bits =8.

Connect the device to the previously configured port. See [Figure 5-3.](#) on page 5-17 for a description and the locations of the Comm ports.



Note:

When a USB port is configured as a Comm port, it is necessary to use a USB-to-serial adapter cable. This adapter must be based on the chipset manufactured by Prolific. For further information, contact your Covidien representative.

Selecting waveforms when configuring a Comm port allows the ventilator to continuously transmit pressure, flow, and sequence numbers in ASCII format from the selected serial port, at a baud rate of 38 400 bits/s, and the operator- selected stop bits, and parity. A sample of pressure and

flow readings is taken every 20 ms. This sample of readings is transmitted on the selected serial port at the end of each breath at breath rates of 10/min and higher. For longer duration breaths, at least the first 8 seconds of the breath is transmitted.

The format of the data is as follows:

- The beginning of inspiration is indicated by "BS, S:nnn,<LF>" where 'BS' identifies the Breath Start, 'S:nnn' is a sequence number incremented at every breath, and <LF> is a line feed character.
- The fff, and ppp fields show the breath flow and pressure data.
- The end of exhalation is indicated by: "BE<LF>" where 'BE' indicates Breath End, and <LF> is a line feed character.

5.4.4 Serial Commands

The ventilator system offers commands that allow communication to and from the ventilator using a Comm port. Commands to the ventilator from a remote device include:

- RSET: See [RSET Command \(5.4.5\)](#)
- SNDA: See [SNDA Command \(5.4.6\)](#)
- SNDF: See [SNDF Command \(5.4.7\)](#)



Note:

The ventilator responds only if it receives a carriage return <CR> after the command string.

5.4.5 RSET Command

The RSET command clears data from the ventilator receive buffer. The ventilator does not send a response to the host system. Enter the RSET command exactly as shown:

```
RSET<CR>
```

5.4.6 SNDA Command

The SNDA command instructs the ventilator to send information on ventilator settings and monitored patient data to the host system. Enter the SNDA command exactly as shown:

```
SNDA<CR>
```

When the ventilator receives the command SNDA<CR>, it responds with the code MISC A, followed by ventilator settings and monitored patient data information.

The MISCA response follows this format:

MISCA	706	97	<STX>	FIELD 5, ... FIELD 101,	<ETX>	<CR>
1	2	3	4	5	6	7
1	Response code to SNDA command			5	Data field, left-justified and padded with spaces	
2	Number of bytes between <STX> and <CR>			6	End of transmission (03 hex)	
3	Number of data fields between <STX> and <ETX>			7	Terminating carriage return	
4	Start of transmission (02 hex)					

Fields not available are marked as "Not used." Underscores represent one or more spaces that pad each character string.

Table 5-1. lists MISCA responses to SNDA commands.

Table 5-1. MISCA Response

Component	Description
MISCA	Response to SNDA command (5 characters)
706	The number of bytes between <STX> and <CR> (3 characters)
97	The number of fields between <STX> and <ETX> (2 characters)
<STX>	Start of transmission character (02 hex)
Field 5	Ventilator time (HH:MM_) (6 characters)
Field 6	Ventilator ID to allow external hosts to uniquely identify each Puritan Bennett™ 980 Series Ventilator (18 characters)
Field 7	Room number (6 characters)
Field 8	Date (MMM_DD_YYYY_) (12 characters)
Field 9	Mode (CMV___, SIMV___, CPAP___ or BiLevel) (CMV = A/C) setting (6 characters)
Field 10	Respiratory rate setting in breaths per minute (6 characters)
Field 11	Tidal volume setting in liters (6 characters)
Field 12	Peak flow setting in liters per minute (6 characters)
Field 13	O ₂ % setting (6 characters)
Field 14	Pressure sensitivity setting in cmH ₂ O (6 characters)
Field 15	PEEP or P _L (in BiLevel) setting in cmH ₂ O (6 characters)
Field 16	Plateau time in seconds (6 characters)

Table 5-1. MISCA Response (Continued)

Component	Description
Field 17–20	Not used (6 characters)
Field 21	Apnea interval in seconds (6 characters)
Field 22	Apnea tidal volume setting in liters (6 characters)
Field 23	Apnea respiratory rate setting in breaths per minute (6 characters)
Field 24	Apnea peak flow setting in liters per minute (6 characters)
Field 25	Apnea O ₂ % setting (6 characters)
Field 26	Pressure support setting in cmH ₂ O (6 characters)
Field 27	Flow pattern setting (SQUARE or RAMP__) (6 characters)
Field 28–29	Not used (6 characters)
Field 30	Elevate O ₂ state (ON____ or OFF____) (6 characters)
Field 31–33	Not used (6 characters)
Field 34	Total respiratory rate in breaths per minute (6 characters)
Field 35	Exhaled tidal volume in liters (6 characters)
Field 36	Exhaled minute volume in liters (6 characters)
Field 37	Spontaneous minute volume in liters (6 characters)
Field 38	Maximum circuit pressure in cmH ₂ O (6 characters)
Field 39	Mean airway pressure in cmH ₂ O (6 characters)
Field 40	End inspiratory pressure in cmH ₂ O (6 characters)
Field 41	Expiratory component of monitored value of I:E ratio, assuming inspiratory component of 1 (6 characters)
Field 42	High circuit pressure limit in cmH ₂ O (6 characters)
Field 43–44	Not used (6 characters)
Field 45	Low exhaled tidal volume limit in liters (6 characters)
Field 46	Low exhaled minute volume limit in liters (6 characters)
Field 47	High respiratory rate limit in breaths per minute (6 characters)
Field 48	High circuit pressure alarm status* (6 characters)
Field 49–50	Not used (6 characters)
Field 51	Low exhaled tidal volume (mandatory or spontaneous) alarm status* (6 characters)
Field 52	Low exhaled minute volume alarm status* (6 characters)
Field 53	High respiratory rate alarm status* (6 characters)
Field 54	No O ₂ supply alarm status* (6 characters)

Table 5-1. MISCA Response (Continued)

Component	Description
Field 55	No air supply alarm status* (6 characters)
Field 56	Not used (6 characters)
Field 57	Apnea alarm status* (6 characters)
Field 58–59	Not used (6 characters)
Field 60	Ventilator time (HH:MM_)(6 characters)
Field 61	Room number (6 characters)
Field 62	Date (MMM_DD_YYYY_)(12 characters)
Field 63	Static compliance (C_{STAT}) from inspiratory pause maneuver in mL/cmH ₂ O (6 characters)
Field 64	Static resistance (R_{STAT}) from inspiratory pause maneuver in cmH ₂ O/L/s (6 characters)
Field 65	Dynamic compliance (C_{DYN}) in mL/cmH ₂ O (6 characters)
Field 66	Dynamic resistance (R_{DYN}) in cmH ₂ O/L/s (6 characters)
Field 67	Negative inspiratory force (NIF) in cmH ₂ O (6 characters)
Field 68	Vital capacity (VC) in L (6 characters)
Field 69	Peak spontaneous flow (PSF) in L/min (6 characters)
Field 70	Ventilator-set base flow in liters per minute (6 characters)
Field 71	Flow sensitivity setting in L/min (6 characters)
Field 72–83	Not used (6 characters)
Field 84	End inspiratory pressure in cmH ₂ O (6 characters)
Field 85	Inspiratory pressure or P_H setting in cmH ₂ O (6 characters)
Field 86	Inspiratory time or T_H setting in seconds (6 characters)
Field 87	Apnea interval setting in seconds (6 characters)
Field 88	Apnea inspiratory pressure setting in cmH ₂ O (6 characters)
Field 89	Apnea respiratory rate setting in breaths per minute (6 characters)
Field 90	Apnea inspiratory time setting in seconds (6 characters)
Field 91	Apnea O ₂ % setting (6 characters)
Field 92	Apnea high circuit pressure limit in cmH ₂ O (6 characters)
Field 93	Audio paused state (ON____ or OFF____) (6 characters)
Field 94	Apnea alarm status* (6 characters)
Field 95	Severe Occlusion/Disconnect alarm status* (6 characters)

*Possible responses are: NORMAL, ALARM_, or RESET_

Table 5-1. MISCA Response (Continued)

Component	Description
Field 96	Inspiratory component of I:E ratio or High component of H:L (BiLevel) setting (6 characters)
Field 97	Expiratory component of I:E ratio setting or Low component of H:L (BiLevel) (6 characters)
Field 98	Inspiratory component of apnea I:E ratio setting (6 characters)
Field 99	Expiratory component of apnea I:E ratio setting (6 characters)
Field 100	Constant during rate setting change for pressure control mandatory breaths (I-TIME or I/E____ or _____) (6 characters) (where _____ represents T _E or PCV not active)
Field 101	Monitored value of I:E ratio (6 characters)
<ETX>	End of transmission character (03 hex)
<CR>	Terminating carriage return

*Possible responses are: NORMAL, ALARM_, or RESET_

5.4.7 SNDF Command

SNDF is a command sent from an external host device to the ventilator system instructing it to transmit all ventilator settings data, monitored patient data, and alarm settings and occurrences. Enter the SNDF command exactly as shown:

SNDF<CR>

When the ventilator receives the command SNDF<CR>, it responds with the code MISCF, followed by ventilator settings, monitored patient data, and alarm information.

The MISCF response follows this format:

MISCF	1225*	169	<STX>	FIELD 5, ... FIELD 169,	<ETX>	<CR>
1	2	3	4	5	6	7
1	Response code to SNDF command			5	Data field, left-justified and padded with spaces	
2	Number of bytes between <STX> and <CR>			6	End of transmission (03 hex)	
3	Number of data fields between <STX> and <ETX>			7	Terminating carriage return	
4	Start of transmission (02 hex)			*	1229 if Philips is selected for serial port in communication setup	

Table 5-2. lists MISCF responses to SNDF commands.



Note:

Non-applicable fields will either contain zero or be blank.

Table 5-2. MISCF Response

Component	Description
MISCF	Response to SNDF command (5 characters)
1225*	Number of bytes between <STX> and <CR> (4 characters) *1229 if Phillips is selected for the Comm port in Communication Setup
169	Number of fields between <STX> and <ETX> (3 characters)
<STX>	Start of transmission character (02 hex)
Field 5	Ventilator time (HH:MM_) (6 characters)
Field 6	Ventilator ID to allow external hosts to uniquely identify each Puritan Bennett™ 980 Series Ventilator (18 characters)
Field 7	Date (MMM_DD_YYYY_) (12 characters)
Field 8	Ventilation Type (NIV____ or INVASIVE_) (9 characters)
Field 9	Mode (A/C____, SIMV____, SPONT____, BILEVL____, or CPAP____) (6 characters)
Field 10	Mandatory Type (PC____, VC____, VC+____) (6 characters)
Field 11	Spontaneous Type (PS____, TC____, VS____, PA____) (6 characters)
Field 12	Trigger Type setting ($\dot{V}$ -Trig, P-Trig) (6 characters)
Field 13	Respiratory rate setting in breaths/min (6 characters)
Field 14	Tidal volume (V_T) setting in L (6 characters)
Field 15	Peak flow ($\dot{V}_{MAX}$) setting in L/min (6 characters)

Table 5-2. MISC Response (Continued)

Component	Description
Field 16	O ₂ % setting (6 characters)
Field 17	Pressure sensitivity setting in cmH ₂ O (6 characters)
Field 18	PEEP/CPAP in cmH ₂ O (6 characters)
Field 19	Plateau setting in seconds (6 characters)
Field 20	Apnea interval setting in seconds (6 characters)
Field 21	Apnea tidal volume setting in L (6 characters)
Field 22	Apnea respiratory rate setting in breaths/min (6 characters)
Field 23	Apnea peak flow setting in L/min (6 characters)
Field 24	Apnea O ₂ % setting (6 characters)
Field 25	PCV apnea inspiratory pressure setting in cmH ₂ O (6 characters)
Field 26	PCV Apnea Inspiratory Time setting in seconds (6 characters)
Field 27	Apnea flow pattern setting (SQUARE or RAMP) (6 characters)
Field 28	Apnea mandatory type setting (PC or VC) (6 characters)
Field 29	Inspiratory component of Apnea I:E ratio (if apnea mandatory type is PC) (6 characters)
Field 30	Expiratory component of Apnea I:E ratio (if apnea mandatory type is PC) (6 characters)
Field 31	Support pressure setting (cmH ₂ O) (6 characters)
Field 32	Flow pattern setting (SQUARE or RAMP) (6 characters)
Field 33	Elevate O ₂ state (ON or OFF) (6 characters)
Field 34	High inspiratory pressure alarm setting ($\uparrow P_{PEAK}$) in cmH ₂ O (6 characters)
Field 35	Low inspiratory pressure alarm setting ($\downarrow P_{PEAK}$) in cmH ₂ O or OFF (6 characters)
Field 36	High exhaled minute volume alarm setting ($\uparrow \dot{V}_{E\text{TOT}}$) in L/min or OFF (6 characters)
Field 37	Low exhaled minute volume alarm setting ($\downarrow \dot{V}_{E\text{TOT}}$) in L/min or OFF (6 characters)
Field 38	High exhaled mandatory tidal volume alarm setting ($\uparrow V_{TE\text{MAND}}$) in mL or OFF (6 characters)
Field 39	Low exhaled mandatory tidal volume alarm setting ($\downarrow V_{TE\text{MAND}}$) in mL or OFF (6 characters)
Field 40	High exhaled spontaneous tidal volume alarm setting ($\uparrow V_{TE\text{SPONT}}$) in mL or OFF (6 characters)
Field 41	Low exhaled spontaneous tidal volume alarm setting ($\downarrow V_{TE\text{SPONT}}$) in mL or OFF (6 characters)
Field 42	High respiratory rate alarm setting ($\uparrow f_{TOT}$) in breaths/min or OFF (6 characters)

Table 5-2. MISCF Response (Continued)

Component	Description
Field 43	High inspired tidal volume alarm setting ($\bar{T}V_{TI}$) in mL (6 characters)
Field 44	Base flow setting in L/min (6 characters)
Field 45	Flow sensitivity ($\dot{V}_{SENS}$) setting in L/min (6 characters)
Field 46	PCV inspiratory pressure (P_I) setting in cmH ₂ O (6 characters)
Field 47	PCV inspiratory time (T_I) setting in seconds (6 characters)
Field 48	Inspiratory component of I:E ratio setting or High component of H:L ratio setting (6 characters)
Field 49	Expiratory component of I:E ratio setting or Low component of H:L ratio setting (6 characters)
Field 50	Constant during rate change setting (I-time, I/E, or E-time) (6 characters)
Field 51	Tube ID setting in mm (6 characters)
Field 52	Tube Type setting (ET or TRACH) (6 characters)
Field 53	Humidification type setting (Non-heated exp tube, Heated exp tube, or HME) (18 characters)
Field 54	Humidifier volume setting in L (6 characters)
Field 55	O ₂ sensor setting (Enabled or Disabled) (9 characters)
Field 56	Disconnect sensitivity (D_{SENS}) setting in % or OFF (6 characters)
Field 57	Rise time% setting (6 characters)
Field 58	PAV+ percent support setting (6 characters)
Field 59	Expiratory sensitivity (E_{SENS}) setting in % or L/min for PAV+ breath type (6 characters)
Field 60	PBW setting in kg (6 characters)
Field 61	Target support volume ($V_{T SUPP}$) setting in L (6 characters)
Field 62	High pressure (P_H) setting (in BiLevel) in cmH ₂ O (6 characters)
Field 63	Low pressure (P_L) setting (in BiLevel) in cmH ₂ O (6 characters)
Field 64	High pressure time (T_H) setting (in BiLevel) in seconds (6 characters)
Field 65	High spontaneous inspiratory time limit setting ($\bar{T}T_{I SPONT}$) in seconds (6 characters)
Field 66	Circuit type setting (ADULT, PEDIATRIC, or NEONATAL) (9 characters)
Field 67	Low pressure time (T_L) setting (in BiLevel) in seconds (6 characters)
Field 68	Expiratory time (T_E) setting in seconds (6 characters)
Field 69	Monitored end inspiratory pressure ($P_{I END}$) in cmH ₂ O (6 characters)
Field 70	Monitored respiratory rate (f_{TOT}) in breaths/min (6 characters)

Table 5-2. MISC Response (Continued)

Component	Description
Field 71	Monitored exhaled tidal volume (V_{TE}) in L (6 characters)
Field 72	Monitored patient exhaled minute volume ($\dot{V}_{E_{TOT}}$) in L/min (6 characters)
Field 73	Monitored peak airway pressure (P_{PEAK}) in cmH ₂ O (6 characters)
Field 74	Monitored mean airway pressure (P_{MEAN}) in cmH ₂ O (6 characters)
Field 75	Monitored expiratory component of monitored value of I:E ratio, assuming inspiratory component of 1 (6 characters)
Field 76	Monitored I:E ratio (6 characters)
Field 77	Delivered O ₂ % (6 characters)
Field 78	Monitored inspired tidal volume (V_{TI}) in L (6 characters)
Field 79	Monitored intrinsic PEEP ($PEEP_i$) in cmH ₂ O (6 characters)
Field 80	Estimated total resistance (R_{TOT}) in cmH ₂ O/L/s (6 characters)
Field 81	Estimated patient resistance (R_{PAV}) in cmH ₂ O/L/s (6 characters)
Field 82	Estimated patient elastance (E_{PAV}) in cmH ₂ O/L (6 characters)
Field 83	Estimated patient compliance (C_{PAV}) in mL/cmH ₂ O (6 characters)
Field 84	Monitored normalized rapid shallow breathing index ($f/V_T/kg$) (6 characters)
Field 85	Monitored rapid shallow breathing index (f/V_T) (6 characters)
Field 86	Monitored spontaneous percent inspiratory time (T_I/T_{TOT}) (6 characters)
Field 87	Monitored cmH ₂ O (6 characters)
Field 88	Monitored spontaneous inspiratory time ($T_{I_{SPONT}}$) in seconds (6 characters)
Field 89	Monitored exhaled spontaneous minute volume ($\dot{V}_{E_{SPONT}}$) in L/min (6 characters)
Field 90	Monitored intrinsic PEEP ($PEEP_i$) from expiratory pause maneuver in cmH ₂ O (6 characters)
Field 91	Monitored total PEEP ($PEEP_{TOT}$) from expiratory pause maneuver in cmH ₂ O (6 characters)
Field 92	Monitored static compliance (C_{STAT}) from inspiratory pause maneuver in mL/cmH ₂ O (6 characters)
Field 93	Monitored static resistance (R_{STAT}) from inspiratory pause maneuver in cmH ₂ O/L/s (6 characters)
Field 94	Monitored plateau pressure (P_{PL}) from inspiratory pause maneuver in cmH ₂ O (6 characters)
Field 95	Monitored high spontaneous inspiratory time (ALERT_ or blank) (6 characters)
Field 96	Monitored dynamic compliance (C_{DYN}) in mL/cmH ₂ O (6 characters)

Table 5-2. MISCF Response (Continued)

Component	Description
Field 97	Monitored dynamic resistance (R_{DYN}) in cmH ₂ O/L/s (6 characters)
Field 98	Monitored peak spontaneous flow (PSF) in L/min (6 characters)
Field 99	Monitored peak expiratory flow (PEF) in L/min (6 characters)
Field 100	Monitored end expiratory flow (EEF) in L/min (6 characters)
Field 101	Proximal Flow Sensor state) ON or OFF) (6 characters)
Field 102	Monitored negative inspiratory force (NIF) in cmH ₂ O (6 characters)
Field 103	Monitored $P_{0.1}$ pressure change in cmH ₂ O (6 characters)
Field 104	Monitored vital capacity (VC) in L (6 characters)
Field 105	Audio paused (ON or OFF) (6 characters)
Field 106	Apnea ventilation alarm* (6 characters)
Field 107	High exhaled minute volume alarm* ($\uparrow \dot{V}_{E\text{TOT}}$) (6 characters)
Field 108	High exhaled tidal volume alarm* ($\uparrow V_{TE}$) (6 characters)
Field 109	High O ₂ % alarm* ($\uparrow O_2\%$) (6 characters)
Field 110	High inspiratory pressure alarm* ($\uparrow P_{PEAK}$) (6 characters)
Field 111	High ventilator pressure alarm* ($\uparrow P_{VENT}$) (6 characters)
Field 112	High respiratory rate alarm* ($\uparrow f_{TOT}$) (6 characters)
Field 113	AC power loss alarm* (6 characters)
Field 114	Inoperative battery alarm* (6 characters)
Field 115	Low battery alarm* (6 characters)
Field 116	Loss of power alarm* (6 characters)
Field 117	Low exhaled mandatory tidal volume alarm* ($\downarrow V_{TE\text{MAND}}$) (6 characters)
Field 118	Low exhaled minute volume alarm* ($\downarrow \dot{V}_{E\text{TOT}}$) (6 characters)
Field 119	Low exhaled spontaneous tidal volume ($\downarrow V_{TE\text{SPONT}}$) alarm* (6 characters)
Field 120	Low O ₂ % alarm* ($\downarrow O_2\%$) (6 characters)
Field 121	Low air supply pressure alarm* (6 characters)
Field 122	Low O ₂ supply pressure alarm* (6 characters)
Field 123	Compressor inoperative alarm* (6 characters)
Field 124	Disconnect alarm* (6 characters)

* Possible responses are: NORMAL, LOW, MEDIUM, HIGH, or RESET.

Table 5-2. MISCF Response (Continued)

Component	Description
Field 125	Severe occlusion alarm* (6 characters)
Field 126	Inspiration too long alarm* (6 characters)
Field 127	Procedure error* (6 characters)
Field 128	Compliance limited tidal volume (V_{Tl}) alarm* (6 characters)
Field 129	High inspired tidal volume* ($\uparrow V_{Ti}$) alarm (6 characters)
Field 130	High inspired tidal volume* ($\uparrow V_{Ti}$) alarm (6 characters)
Field 131	High compensation limit ($\uparrow P_{COMP}$) alarm* (6 characters)
Field 132	PAV+ startup too long alarm* (6 characters)
Field 133	PAV+ R and C not assessed alarm* (6 characters)
Field 134	Volume not delivered (VC+) alarm* (6 characters)
Field 135	Volume not delivered (VS) alarm* (6 characters)
Field 136	Low inspiratory pressure ($\downarrow P_{PEAK}$) alarm* (6 characters)
Field 137	Technical malfunction A5* (6 characters)
Field 138	Technical malfunction A10* (6 characters)
Field 139	Technical malfunction A15* (6 characters)
Field 140	Technical malfunction A20* (6 characters)
Field 141	Technical malfunction A25* (6 characters)
Field 142	Technical malfunction A30* (6 characters)
Field 143	Technical malfunction A35* (6 characters)
Field 144	Technical malfunction A40* (6 characters)
Field 145	Technical malfunction A45* (6 characters)
Field 146	Technical malfunction A50* (6 characters)
Field 147	Technical malfunction A55* (6 characters)
Field 148	Technical malfunction A60* (6 characters)
Field 149	Technical malfunction A65* (6 characters)
Field 150	Technical malfunction A70* (6 characters)
Field 151	Technical malfunction A75* (6 characters)
Field 152	Technical malfunction A80* (6 characters)
Field 153	Technical malfunction A85* (6 characters)
Field 154	Spontaneous exhaled tidal volume ($V_{TE\ SPONT}$) in liters (6 characters)

* Possible responses are: NORMAL, LOW, MEDIUM, HIGH, or RESET.

Table 5-2. MISCF Response (Continued)

Component	Description
Field 155	PAV total work of breathing (WOB_{TOT}) in Joules/L (6 characters)
Field 156	Leak Sync state (ON, or OFF) (6 characters)
Field 157	%LEAK (6 characters)
Field 158	LEAK (6 characters)
Field 159	V_{LEAK} (6 characters)
Field 160	Prox Inop alarm* (ALARM or NORMAL)
Field 161	ETCO ₂ when COM port is set to DCI 2.0 (6 characters)
Field 162–173	Reserved
<ETX>	End of transmission character (03 hex)
<CR>	Terminating carriage return

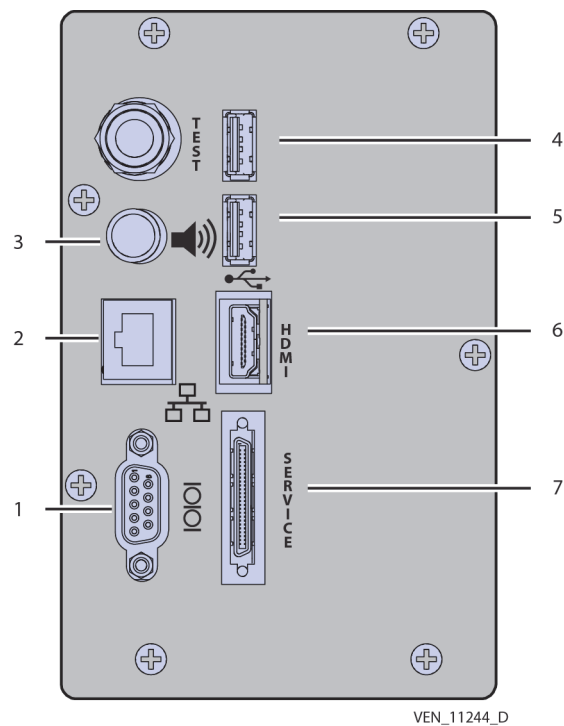
* Possible responses are: NORMAL, LOW, MEDIUM, HIGH, or RESET.

5.5 Communication Ports



WARNING:

To avoid possible injury, only connect devices that comply with IEC 60601-1 standard to any of the ports at the rear of the ventilator, with the exception of passive memory storage devices (“flash drives”) and serial-to-USB adapter cables. If a serial-to-USB adapter cable is used, it must be connected to an IEC 60601-1-compliant device.

Figure 5-3. Port Locations

- | | |
|---|-------------------------------------|
| 1 | RS-232 port (COM 1) |
| 2 | Ethernet port |
| 3 | Nurse call port (remote alarm port) |
| 4 | USB port (USB 1) (COM 2) |
| 5 | USB port (USB 2) (COM 3) |
| 6 | HDMI port |
| 7 | Service port |

5.5.1 Port Use

See [Data Transfer \(5.4\)](#) on page 5-1 for data transfer details.

RS-232 Port

To use the RS-232 port

1. Obtain a cable with a male DB-9 connector to connect to the RS-232 port on the ventilator.
2. Make the appropriate connection to a monitoring device. A gender changer, null modem cable or socket saver may be required. Consult with the institution's Information Technology professional as required.

3. Ensure to specify the baud rate, parity, and data bits in the ventilator communication setup to correctly match the parameters of the monitoring device.
4. A monitor designed to use this port is required for obtaining data from the ventilator. Set up the monitoring device to receive ventilator data. These data can include waveform data.
5. Program the remote device to send the appropriate RS-232 commands as described in the next section.

See [Table 5-1.](#) on page 5-6 and [Table 5-2.](#) on page 5-10 for MISCA and MISCF responses to SNDA and SNDF commands, respectively.

Ethernet Port

The Ethernet port is used by service personnel for accessing various logs and updating ventilator software.

Nurse Call Port

A remote alarm or nurse call interface is available on the ventilator system that can be used to remotely annunciate the alarm status of the ventilator. Medium and high priority alarms are remotely annunciated. The nurse call connector is located at the back of the ventilator, as shown. See [Figure 5-3.](#) on page 5-17.

See the remote alarm manufacturer's instructions for use for information regarding proper nurse call connection.

USB Ports

The USB ports are used for screen captures, or receiving serial data when a USB port has been configured as a serial port. This is also known as transferring data via a serial-over-USB protocol. See [Communication Setup \(5.4.2\)](#) on page 5-3 for Comm setup configuration. Screen captures require an external USB memory storage device ("flash drive") for screen captures. Instructions for using this port for screen captures are given. See [To capture GUI screens](#), page 5-2.

HDMI Port

An external display can be used via connection with the HDMI port.

To use the HDMI port with an external display

1. Connect one end of an HDMI cable to the HDMI port at the back of the ventilator ([Figure 5-3.](#) on page 5-17, item 6).
2. Connect the other end of the cable to the external display. An HDMI to DVI adapter may be used.
3. Turn the device on. The appearance of the GUI now displays on the external display device.

Service Port

The Service port is used by service personnel only.

5.6 Retrieving Stored Data



Ventilator data are stored in various logs, accessible using the logs icon. Some logs may be accessed during normal ventilation, and some are only available to Covidien personnel when the ventilator is in Service mode. See [Ventilator Logs \(8.5\)](#) on page 8-2 for more information on data stored in various logs.

5.7 Display Configurability

The operator can configure some ventilator parameters according to personal preference. See [Table 3-2](#) on page 3-32 for a table showing which parameters are configurable and by whom.

See [Preparing the Ventilator for Use \(3.8.1\)](#) on page 3-33 for information on configuring each display item.

5.8 Printing Data or Screen Captures

The ventilator cannot be connected directly to a printer.

Save screen captures to an external storage device, such as a USB flash drive, then print from a PC. See [GUI Screen Capture \(5.4.1\)](#) on page 5-2 for instructions on using the screen-capture feature.

5.9 Connectivity to External Systems

The ventilator is compatible with the Philips Medical IntelliVue MP50 and Spacelabs Ultraview patient monitoring systems.



Note:

Not all patient monitors are compatible with the Puritan Bennett™ 980 Series Ventilator.

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6 Performance

6.1 Overview

This chapter contains detailed information about Puritan Bennett™ 980 Series Ventilator performance including:

- Ventilator settings
- Alarm interpretation and alarm testing
- A detailed description of selected alarms
- Monitored patient data

6.2 System Options

Various software functions and options are available for the ventilator. Details for each of these functions and options are described in the appendices. Information regarding the DC compressor hardware option is included in the *Compressor Operator's Manual Addendum*.

6.3 Environmental Considerations



WARNING:

Use of the ventilator or compressor in altitudes higher or barometric pressures lower than those specified could compromise ventilator or compressor operation. See [Table 11-8](#) on page 11-6 for a complete list of environmental specifications.

6.4 Ventilator Settings

Default ventilator settings are based on the circuit type selected during SST. A neonatal, pediatric or adult patient circuit can be used, and all accessories needed to ventilate the patient should be attached when SST is performed.

6.4.1 Ventilation Type

The clinician enters the ventilation type, specifying how the patient will be ventilated; invasively or non-invasively (NIV). The ventilation type optimizes the alarm limits for NIV patients, and disables some settings for NIV ventilation.

6.4.2 Mode

Available ventilation modes are mandatory (A/C) or spontaneous (SPONT) modes, as well as two “mixed” modes: SIMV and BiLevel.

- **A/C (Assist-Control)** — A/C mode guarantees delivery of a minimum number of mandatory breaths based on the frequency (f) set by the clinician. Breaths in A/C can be patient-initiated (PIM) or ventilator-initiated (VIM).
- **SPONT (Spontaneous)** — SPONT mode delivers only spontaneous breaths that are all patient-initiated.
- **SIMV (Synchronized Intermittent Mandatory Ventilation)** — SIMV is a mixed mode allowing both mandatory and spontaneous breaths. SIMV guarantees at least one mandatory breath per set breath cycle, which is either patient-initiated or ventilator-initiated. The mandatory type of an SIMV breath can be PC, VC, or VC+.
- **BiLevel** — BiLevel is also a mixed mode that overlays the patient’s spontaneous breaths onto the breath structure for PC mandatory breaths. Two levels of pressure, P_L and P_H are employed. The breath cycle interval for both SIMV and BiLevel modes is $60/f$ where f is the respiratory rate set by the operator.
- **CPAP** — CPAP is available only when circuit type is neonatal and ventilation type is NIV. CPAP mode allows spontaneous breathing with a desired PEEP level. To limit inadvertent alarms associated with the absence of returned volumes in nasal CPAP breathing, CPAP does not make volume alarm settings available.

6.4.3 Breath Type

Mandatory breath types for A/C and SIMV modes include volume controlled (VC), pressure controlled (PC), or volume control plus (VC+) breath types, also called mandatory type.

- **VC (Volume Control)** — The ventilator delivers an operator-set tidal volume.
- **PC (Pressure Control)** — The ventilator delivers an operator-set pressure.
- **VC+ (Volume Control Plus)** — Volume control plus is a mandatory, pressure controlled breath type that does not restrict flow during the inspiratory phase, and automatically adjusts the inspiratory pressure target from breath to breath to achieve the desired tidal volume despite changing lung conditions. See [Mandatory Breath Delivery \(10.7\)](#) on page 10-13 for more information on VC+.

Mandatory inspirations are triggered in the following ways:

- **Pressure Trigger (P-Trig)** — Changes in circuit pressure cause the ventilator to deliver a breath. These pressure changes relate to the pressure sensitivity (P_{SENS}) set by the operator. If the patient makes an effort to inspire, the airway pressure drops. If the pressure drops by at least the value of P_{SENS} , the ventilator delivers a breath.
- **Flow Trigger ($\dot{V}$ -Trig)** — Changes in flow in the circuit cause the ventilator to deliver a breath. The breath delivery and exhalation flow sensors measure gas flow in the ventilator breathing system. As the patient inspires, the delivered flow remains constant and ventilator exhalation flow sensor measures decreased flow. When the difference between the two flow measurements is at least the operator-set value for flow sensitivity ($\dot{V}_{\text{SENS}}$), the ventilator delivers a breath.
- **Time Trigger** — The ventilator delivers a ventilator-initiated mandatory (VIM) breath after a specific amount of time elapses.
- **Operator Trigger (OIM)** — The operator presses the manual inspiration key. An operator initiated mandatory breath is also called an OIM breath. During an OIM breath, the breath delivered is based on the current settings for a mandatory breath.

Spontaneous breathing modes such as SIMV, BiLevel, and SPONT include the following breath types (called spontaneous types):

- **PS (Pressure Support)** — The ventilator delivers an operator-set positive pressure above PEEP (or above P_L in BiLevel) during a spontaneous breath. If SIMV is selected as the mode, PS is automatically selected for spontaneous type.
- **VS (Volume Support)** — The ventilator delivers an operator-set positive pressure above PEEP during a spontaneous breath and automatically adjusts the pressure level from breath to breath to consistently deliver the set tidal volume.
- **TC (Tube Compensation)** — Additional positive pressure delivered to the patient during spontaneous breaths to overcome resistance of the artificial airway.
- **PAV+ (Proportional Assist Ventilation)** — A software function that allows the ventilator to reduce the work of breathing (WOB) by assisting the patient's inspiration by an operator-set amount proportional to the breathing effort generated by the patient. See Appendix C for more information on PAV+.

The inspiratory trigger methods for spontaneous breaths are:

- **Pressure Trigger (P-Trig)** — Same as described for mandatory inspiration triggers.
- **Flow Trigger ($\dot{V}$ -Trig)** — Same as described for mandatory inspiration triggers.
- **Operator Trigger (OIM)** — As the operator can only initiate a mandatory breath by pressing the manual inspiration key, spontaneous mode allows OIMs, but the breath delivered is based on the current apnea breath settings.

See *Inspiration—Detection and Initiation (10.4)* on page 10-4 for details on the different trigger methods.

6.5 Alarms

**WARNING:**

The ventilator system is not intended to be a comprehensive monitoring device and does not activate alarms for all types of conditions. For a detailed understanding of ventilator operations, be sure to thoroughly read this manual before attempting to use the ventilator system.

**WARNING:**

Setting any alarm limits to OFF or extreme high or low values can cause the associated alarm not to activate during ventilation, which reduces its efficacy for monitoring the patient and alerting the clinician to situations that may require intervention.

This manual uses the following conventions when discussing alarms:

A description or name of an alarm without specifying the alarm setting is denoted with an upward or downward pointing arrow (↑ or ↓) preceding the specific alarm name. An alarm setting is denoted as an upward or downward pointing arrow with an additional horizontal limit symbol (↗ or ↘) preceding the specific alarm. Some alarm conditions actually limit breath delivery such as ↑P_{PEAK} and ↑V_{Ti} by truncating inspiration and transitioning to the expiratory phase. These alarm conditions are denoted as alarm **limits**. See [Table 6-1](#) on page 6-6.

6.5.1 Alarm Messages

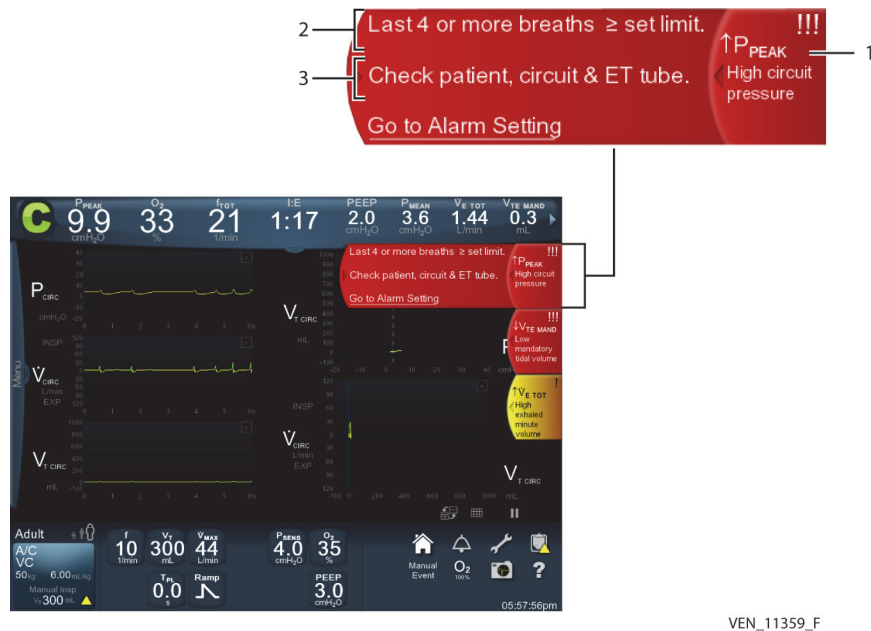
Alarms are visually annunciated using an indicator on the top of the GUI, which has a 360° field of view. If an alarm occurs, this indicator flashes at a frequency and color matching the alarm priority. The alarms also appear as colored banners on the right side of the GUI screen. If an alarm occurs, this indicator appears in the color matching the alarm priority (yellow for low (!) and medium (!!)) priority; red for high (!!!) priority). For technical alarm and non-technical alarm details, see the respective tables on page 6-16 and page 6-26.

An alarm is defined as a **primary alarm** if it is the initial alarm. A **dependent alarm** arises as a result of conditions that led to the primary alarm. This is also referred to as an augmentation. An augmentation strategy is built into the ventilator software to handle occurrences where the initial cause of the alarm has the potential to precipitate one or more additional alarms. When an alarm occurs, any subsequent alarm related to the cause of this initial alarm augments the initial alarm instead of appearing on the GUI as a new alarm. The initial alarm's displayed analysis message is updated with the related alarm's information, and the Alarm Log Event column shows the initial alarm as **Augmented**.

A primary alarm consists of a **base message**, **analysis message**, and a **remedy message**. The base message describes the primary alarm. The analysis message describes the likely cause of the alarm and may include alarm augmentations. The remedy message provides information on what to do to correct the alarm condition.

Alarm banners, when dragged leftward from the right side of the GUI, display messages for the indicated active alarms. [Figure 6-1](#) shows the alarm message format.

Figure 6-1. Alarm Message Format



- | | | | |
|---|------------------|---|----------------|
| 1 | Base message | 3 | Remedy message |
| 2 | Analysis message | | |

A ***latched alarm*** is one whose visual alarm indicator remains illuminated even if the alarm condition has autoreset. Latched alarm indicators are located on the sides of the omni-directional LED. A latched alarm can be manually reset by pressing the alarm reset key. If no alarms are active, the highest priority latched alarm appears on the omni-directional LED on the GUI. A ***lockable alarm*** is one that does not terminate an active audio paused function (it does not sound an audible alert during an active audio paused function), while a non-lockable alarm cancels the audio paused period and sounds an audible alert. All patient data alarms and the CIRCUIT DISCONNECT alarm are lockable alarms.



Note:

When a new lockable alarm occurs, the alarm will not start to sound audibly if the previous lockable alarm was silenced.

The following rules define how alarm messages are displayed:

- Primary alarms precede any dependent alarms.
- The system adds dependent alarms to the analysis messages of each active primary alarm with which they are associated. If a dependent alarm resets, the system removes it from the analysis message of the primary alarm.
- The priority level of a primary alarm is equal to or greater than the priority level of any of its active dependent alarms.

- An alarm cannot be a dependent alarm of any alarm that occurs subsequently.
- If a primary alarm resets, any active dependent alarms become primary unless they are also dependent alarms of another active primary alarm. This is due to different reset criteria for primary and dependent alarms.
- The system applies the new alarm limit to alarm calculations from the moment a change to an alarm limit is accepted.
- The priority level of a dependent alarm is based solely on its detection conditions (not the priority of any associated alarms).
- When an alarm causes the ventilator to enter OSC or safety valve open (SVO), the patient data display (including waveforms) is blanked. The elapsed time without ventilatory support (that is, since OSC or SVO began) appears on the GUI screen. If the alarm causing OSC or SVO is autoreset, the ventilator resets all patient data alarm detection algorithms.

Table 6-1. Alarm Descriptions and Symbols

Alarm description	Symbol
High compensation pressure	$\uparrow P_{\text{COMP}}$
High delivered oxygen percentage	$\uparrow O_2\%$
High exhaled minute volume	$\uparrow \dot{V}_{\text{E TOT}}$
High exhaled minute volume setting	$\overline{\uparrow} \dot{V}_{\text{E TOT}}$
High exhaled tidal volume	$\uparrow V_{\text{TE}}$
High exhaled tidal volume setting	$\overline{\uparrow} V_{\text{TE}}$
High inspired tidal volume limit	$\overline{\uparrow} V_{\text{TI}}$
High internal ventilator pressure	$\uparrow P_{\text{VENT}}$
High respiratory rate	$\uparrow f_{\text{TOT}}$
High respiratory rate setting	$\overline{\uparrow} f_{\text{TOT}}$
High spontaneous inspiratory time	$\uparrow T_{\text{I SPONT}}$
High spontaneous inspiratory time limit	$\overline{\uparrow} T_{\text{I SPONT}}$
High circuit pressure	$\uparrow P_{\text{PEAK}}$
High circuit pressure limit	$\overline{\uparrow} P_{\text{PEAK}}$
Low circuit pressure	$\downarrow P_{\text{PEAK}}$
Low circuit pressure setting	$\downarrow\downarrow P_{\text{PEAK}}$

Table 6-1. Alarm Descriptions and Symbols (Continued)

Alarm description	Symbol
Low exhaled mandatory tidal volume	$\downarrow V_{TE\ MAND}$
Low exhaled mandatory tidal volume setting	$\downarrow V_{TE\ MAND}$
Low exhaled minute volume	$\downarrow \dot{V}_{E\ TOT}$
Low exhaled minute volume setting	$\downarrow \dot{V}_{E\ TOT}$
Low exhaled spontaneous tidal volume	$\downarrow V_{TE\ SPONT}$
Low exhaled spontaneous tidal volume setting	$\downarrow V_{TE\ SPONT}$
Low delivered oxygen percentage	$\downarrow O_2\%$

6.5.2 Alarm Reset Key



The alarm reset function can be used for any **non-technical alarm**. See [Alarm Handling \(6.5.8\)](#) on page 6-13 for an explanation of **technical** vs. **non-technical alarms**. Alarm reset reinitializes the algorithm the ventilator uses to initially detect the alarm except for A/C POWER LOSS, COMPRESSOR INOPERATIVE, LOW BATTERY, NO AIR SUPPLY, NO O₂ SUPPLY, PROCEDURE ERROR alarms and active battery alarms. If the cause of the alarm still exists after the alarm reset key is pressed, the alarm becomes active again. The ventilator logs all actuations of the alarm reset key.

6.5.3 Audio Paused Key



WARNING:

Do not pause, disable, or decrease the volume of the ventilator's audible alarm if patient safety could be compromised.

The audio paused feature temporarily mutes the audible portion of an alarm for 2 minutes. After the 2-minute period, if the alarm condition still exists, the alarm sounds again. Pressing the audio paused key again restarts the 2-minute interval during which an alarm is muted. An LED within the key illuminates and a count-down timer appears on the GUI next to an audio paused indicator symbol, indicating an active audio paused function. The audio paused feature does not allow the audible alarm to be turned off; the audible portion of the alarm is temporarily muted for 2 minutes. The GUI's omni-directional LED flashes during an active alarm state and during an audio paused period and its appearance changes with the priority if the alarm escalates. Pressing the alarm reset key cancels an audio paused interval. If the condition that caused the alarm still exists, the alarm activates again.

6.5.4 Alarm Volume Key



An alarm volume key is available for setting the desired alarm volume. The alarm volume is automatically set to the factory default setting of 10 (maximum) or to the institutional default setting based on circuit type if it has been so configured. When setting the alarm volume, a sample tone is generated, allowing the practitioner to decide the appropriate alarm volume for the surrounding ambient conditions. If a high priority alarm occurs, the alarm volume increases one increment from its current volume level if it is not acknowledged within 30 seconds. If a high priority alarm is not acknowledged within 60 seconds, the audible alarm volume escalates to its maximum volume.

See [To adjust alarm volume](#), page 3-37 for instructions on adjusting the alarm volume.



WARNING:

The audio alarm volume level is adjustable. The operator should set the volume at a level that allows the operator to distinguish the audio alarm above background noise levels. See [To adjust alarm volume](#), page 3-37.

6.5.5 Alarm Testing

Testing the alarms requires oxygen and air sources and stable AC power. Test the alarms at least every 12 months, using the procedures described.

Required Equipment

- Test lung (P/N 4-000612-00)
- Adult patient circuit

If the alarm does not annunciate as indicated, verify the ventilator settings and repeat the test. The alarm tests check the operation of the following alarms:

- CIRCUIT DISCONNECT
- LOW EXHALED MANDATORY TIDAL VOLUME ($\downarrow V_{TE\ MAND}$)
- LOW EXHALED TOTAL MINUTE VOLUME ($\downarrow \dot{V}_{E\ TOT}$)
- HIGH CIRCUIT PRESSURE ($\uparrow P_{PEAK}$)
- SEVERE OCCLUSION
- AC POWER LOSS
- APNEA
- LOW EXHALED SPONTANEOUS TIDAL VOLUME ($\downarrow V_{TE\ SPONT}$)
- NO O₂ SUPPLY

- LOW DELIVERED $O_2\%$ ($\downarrow O_2\%$)
- HIGH DELIVERED $O_2\%$ ($\uparrow O_2\%$)

Ventilator setup for alarms tests

1. Disconnect the patient circuit from the ventilator and turn the ventilator off for at least 5 minutes.
2. Turn the ventilator on. The ventilator runs POST.
3. On the GUI, select New Patient.
4. Set up new patient using the following settings:

PBW: 70 kg

Ventilation type: invasive

Mode: A/C

Mandatory type: VC

Trigger type: $\dot{V}$ -Trig

5. Set the following new patient settings:

f: 6.0 1/min

V_T : 500 mL

$\dot{V}_{MAX}$: 30 L/min

T_{PL} : 0 s

Flow pattern: square

$\dot{V}_{SENS}$: 3 L/min

$O_2\%$: 21%

PEEP: 5 cmH₂O

6. Set the following apnea settings:

T_A : 10 s

f: 6.0 1/min

$O_2\%$: 21%

V_T : 500 mL

7. Set the following alarm settings:

$\uparrow P_{PEAK}$: 70 cmH₂O

f_{TOT} : OFF

$\downarrow \dot{V}_{E\ TOT}$: 1 L/min

$\uparrow \dot{V}_{E\ TOT}$: 3.5 L/min

$\downarrow V_{TE\ MAND}$: 300 mL

$\uparrow V_{TE\ MAND}$: OFF

$\downarrow V_{TE\ SPONT}$: OFF

$\uparrow V_{TE\ SPONT}$: OFF

8. Set the graphics display to a volume-time plot (for use in the APNEA alarm test).
9. Connect an adult patient circuit to the ventilator and attach a test lung to the patient wye.



Note:

To ensure proper test results, do not touch the test lung or patient circuit during the CIRCUIT DISCONNECT alarm test.

CIRCUIT DISCONNECT alarm test

1. Allow the ventilator to deliver at least four breaths. During the inspiratory phase of a breath, disconnect the inspiratory filter from the **to patient** port. The ventilator annunciates a CIRCUIT DISCONNECT alarm after the inspiratory filter is disconnected.
2. Connect the inspiratory filter to the **to patient** port to autoreset the alarm.

LOW EXHALED MANDATORY TIDAL VOLUME ($\downarrow V_{TE\ MAND}$) alarm test

Set V_T to 225 mL. The ventilator annunciates a LOW EXHALED MANDATORY TIDAL VOLUME ($\downarrow V_{TE\ MAND}$) alarm on the third consecutive breath after *Accept* is touched.

LOW EXHALED TOTAL MINUTE VOLUME ($\downarrow \dot{V}_{E\ TOT}$) alarm test

Set $\downarrow \dot{V}_{E\ TOT}$ alarm limit to 3.45 L/min. The ventilator annunciates a LOW EXHALED TOTAL MINUTE VOLUME ($\downarrow \dot{V}_{E\ TOT}$) alarm on the next breath after *Accept* is touched.

HIGH CIRCUIT PRESSURE ($\uparrow P_{PEAK}$) alarm test

1. Make the following patient and alarm settings changes:

V_T : 500 mL

$\dot{V}_{MAX}$: 30 L/min

$\uparrow P_{PEAK}$: 20 cmH₂O

2. After one breath, the ventilator annunciates a HIGH CIRCUIT PRESSURE ($\uparrow P_{PEAK}$) alarm. If the alarm does not sound, check the patient circuit for leaks.

SEVERE OCCLUSION alarm test

1. Make the following alarm settings changes:

$\uparrow P_{PEAK}$: 50 cmH₂O

2. Press the alarm reset key to reset all alarms.

3. Adjust D_{SENS} to the $\dot{V}_{\text{MAX}}$ setting.
4. Disconnect the ventilator breathing circuit from the **from patient** port and block the gas flow.
5. While maintaining the occlusion, ensure the safety valve open indicator appears on the status display, the GUI shows the elapsed time without normal ventilation support, and the test lung inflates and deflates rapidly with small pulses as the ventilator delivers trial pressure-based breaths.
6. Press the alarm reset key to reset all the alarms.

AC POWER LOSS alarm test

1. Allow the ventilator to deliver at least four breaths, then disconnect the power cord from AC facility power. If any battery is charged, the GUI annunciates an AC POWER LOSS alarm. If less than 10 minutes of battery backup are available, the GUI annunciates a LOW BATTERY alarm. If no battery power is available, the BDU annunciates a LOSS OF POWER alarm.
2. Connect the power cord to AC facility power. The AC POWER LOSS or LOW BATTERY alarm autoresets.

APNEA alarm test

1. Make the following alarm settings changes:

$\uparrow P_{\text{PEAK}}$: 70 cmH₂O

Mode: SPONT

Spontaneous type: PS

2. The GUI annunciates an APNEA alarm within 10 s after touching *Accept*.
3. Squeeze the test lung twice to simulate two subsequent patient-initiated breaths. The APNEA alarm autoresets.
4. Let the ventilator return to apnea ventilation.



Note:

To avoid triggering a breath during the apnea interval, do not touch the test lung or patient circuit.



Note:

For the apnea alarm test, the exhaled tidal volume (V_{TE}) displayed in the patient data area must be greater than half the delivered volume shown on the volume-time plot in the graphics display for apnea to autoreset. See [Apnea Ventilation \(10.12\)](#) on page 10-33 for a technical description of apnea ventilation.

LOW EXHALED SPONTANEOUS TIDAL VOLUME alarm test

1. Make the following patient and alarm settings changes:

Trigger type: P-Trig

$\uparrow P_{\text{SENS}}$: 4 cmH₂O

$\downarrow V_{\text{TE SPONT}}$: 2500 mL

2. Press the alarm reset key to reset the apnea alarm.

3. Slowly squeeze the test lung to simulate spontaneous breaths. The ventilator annunciates a LOW EXHALED SPONTANEOUS TIDAL VOLUME ($\downarrow V_{TE\ SPONT}$) alarm at the start of the fourth consecutive spontaneous inspiration.

4. Make the following patient settings changes:

Mode: A/C

$\downarrow V_{TE\ SPONT}$: OFF

5. Press the alarm reset key to reset the $\downarrow V_{TE\ SPONT}$ alarm.

NO O₂ SUPPLY alarm test

1. Disconnect the oxygen inlet supply. The ventilator annunciates a NO O₂ SUPPLY alarm within one breath.
2. Connect the oxygen inlet supply. The NO O₂ SUPPLY alarm autoresets within two breaths after oxygen is reconnected.

LOW DELIVERED O₂% and HIGH DELIVERED O₂% alarms tests

1. Make the following patient and alarm settings changes:

P_{SENS} : 2 cmH₂O

O₂%: 100%

2. Make the following apnea settings changes:

T_A : 60 s

3. Attach the ventilator's oxygen gas hose to a known air supply (for example, a medical grade air cylinder) or a wall air outlet.
4. attach the ventilator's air gas hose to a known medical oxygen supply.
5. Observe the GUI screen. The delivered O₂% display should decrease, and the ventilator should annunciate a medium priority $\downarrow O_2\%$ alarm within 60 seconds and a high priority $\downarrow O_2\%$ alarm within 2 minutes.
6. Set the O₂% to 21%.
7. Observe the GUI screen. The delivered O₂% display should increase, and the ventilator should annunciate a medium priority $\uparrow O_2\%$ alarm within 60 seconds and a high priority $\uparrow O_2\%$ alarm within 2 minutes.
8. Remove the air gas hose from the oxygen supply and reconnect the hose to a known medical air supply.
9. Remove the oxygen gas hose from the air supply and reconnect the hose to a known oxygen supply.
10. Press the alarm reset key to clear all alarms.

**WARNING:**

Before returning the ventilator to service, review all settings and set appropriately for the patient to be ventilated.

6.5.6 Viewing Alarms

When an alarm occurs, the omni-directional LED at the top of the GUI flashes in a color corresponding to the alarm priority, an audible series of tones sounds, and an alarm banner displays on the GUI. See [Figure 4-1](#) on page 6-5. When the alarm banner appears, it displays its base message. Touching the individual alarm causes an expanded explanation to appear, containing analysis and remedy messages, and may contain a link to the alarm log or the alarms settings screen. Touch the link to display requested information. The omni-directional LED remains steadily lit and may appear multicolored, meaning that multiple alarms with varying priority levels have occurred. During an event that causes multiple alarms, the ventilator simultaneously displays the two highest priority active alarms.

6.5.7 Alarm Delay

Determination of an Alarm Condition

The delay time from the moment the alarm condition first occurs until the alarm is annunciated is imperceptible.

Delay to/from a Distributed Alarm System

For alarm conditions relayed via the serial port, the overall delay is dependent upon the polling rate of the external device. The delay from the time the serial port is polled by the external device, until the alarm message leaves the serial port does not exceed 3 seconds. An example of an external device is a patient monitor.

6.5.8 Alarm Handling

Current alarm settings are saved in the ventilator's **non-volatile memory (NVRAM)**. If the alarm settings are changed by another clinician, those settings become applicable. For example, there are no operator-selectable default alarm settings.

The ventilator system's alarm handling strategy is intended to

- Detect and call attention to legitimate causes for caregiver concern as quickly as possible, while minimizing nuisance alarms.
- Identify the potential cause and suggest corrective action for certain types of alarms. However, the clinician must make the final decision regarding any clinical action.
- Make it easy to discern an alarm's priority level.

- Allow quick and easy alarm setup.

Ventilator alarms are categorized as high priority, medium priority, or low priority, and are classified as technical or non-technical.

The ventilator is equipped with two alarms—the primary alarm and secondary alarm. The primary alarm annunciates high, medium, and low priority alarms when they occur. The secondary alarm (also named **immediate** priority in [Table 6-2](#).) is a continuous tone alarm and annunciates during vent inop conditions or complete loss of power. This alarm is powered by a capacitor and lasts for at least 120 seconds.

[Table 6-2](#). lists alarm priority levels and their visual, audible, and autoreset characteristics. An alarm autoresets when the condition causing the alarm no longer exists.

Table 6-2. Alarm Priority

Priority level	Visual indicator	Audible indicator	Autoreset characteristics
Immediate	Specific to alarm condition or component failure.	Continuous tone alarm sounding for at least 120 s.	N/A
High: Immediate attention required to ensure patient safety.	Flashing red omni-directional LED located on the top of the GUI, red alarm banner on GUI screen, red bar next to alarm setting icon on Alarms screen. !!!	High-priority audible alarm (a sequence of five tones that repeats twice, pauses, then repeats again).	Visual alarm does not auto reset. Visual alarm indicators remain steadily illuminated following an autoreset. The alarm reset key must be pressed to extinguish visual indicator.
Medium: Prompt attention necessary.	Flashing yellow omni-directional LED located on the top of the GUI, yellow alarm banner on GUI screen, and yellow bar next to alarm setting icon on Alarms screen. !!	Medium-priority audible alarm (a repeating sequence of three tones).	LED indicator turns off and autoreset is entered into the alarm log.
Low: A change in the patient-ventilator system has occurred.	Steadily illuminated yellow omni-directional LED located on the top of the GUI, yellow alarm banner on GUI screen, and yellow bar next to alarm setting icon on Alarms screen. !	Low-priority audible alarm (two tones, non-repeating).	LED indicator turns off and autoreset is entered into the alarm log.

Table 6-2. Alarm Priority (Continued)

Priority level	Visual indicator	Audible indicator	Autoreset characteristics
Normal: Normal ventilator operation	Steadily illuminated green omni-directional LED located on the top of the GUI, no alarm banner, and white values next to alarm setting icon on Alarms screen.	None.	None
Immediate	Status display shows the GUI has failed.	The secondary alarm annunciates a repeating sequence of single tones, as the primary alarm (part of the GUI) has failed.	None

A **technical alarm** is one that is caused by a violation of any of the ventilator's self monitoring conditions, such as failure of POST or a fault detected by the ventilator's background diagnostic system. Technical alarms cannot be reset by pressing the alarm reset key. (See [Background Diagnostic System \(10.16.4\)](#) on page 10-61). Technical alarms fall into eight categories, shown in [Table 6-3](#).

Table 6-3. Technical Alarm Categories

Category	Name	Priority	System response
1	Vent-Inop	High	Ventilator goes to Safe State. See Ventilator Protection Strategies (4.11) on page 4-31.
2	Exh BUV	High	Backup ventilation
3	Insp BUV	High	Backup ventilation
4	Mix BUV	High	Backup ventilation
5	SVO	High	Ventilator goes to Safe State. See Ventilator Protection Strategies (4.11) on page 4-31.
6	Caution	High	Ventilation continues as set
7	Warning	Medium	Ventilation continues as set
8	Notification	Low	Ventilation continues as set (not displayed on alarm banner)

See [Table 6-4](#). for a list of ventilator technical alarms, their meaning, and what to do if they occur. See [Table 11-10](#). for the settings, ranges, and resolutions of all of the ventilator alarms.

Table 6-4. Technical Alarms

Alarm message	Meaning	What to do
O ₂ SENSOR	O ₂ sensor is out of calibration or has failed.	Re-calibrate or replace O ₂ sensor.
DEVICE ALERT	Various. Technical alarm category is described. See Table 6-3 .on page 6-15 . More information for the particular technical alarm can be found in the System diagnostic log, a link to which is provided on the expanded alarm banner.	Follow remedy message displayed on GUI.

A **non-technical alarm** is an alarm caused due to a fault in the patient-ventilator interaction or a fault in the electrical or gas supplies that the practitioner may be able to alleviate.

Table 6-5. Non-technical Alarm Summary

Base message	Priority	Analysis message	Remedy message	Comments
AC POWER LOSS	Low	Operating on vent main battery.	N/A	Ventilator's power switch is on. Ventilator automatically switches to battery power. AC power not available. Battery operating indicator on status display turns on. Resets when AC power is restored.
AC POWER LOSS	Low	Operating on vent main and compressor battery.	N/A	
APNEA (patient data alarm)	Medium	Apnea ventilation. Breath interval > apnea interval.	Check patient & settings.	The set apnea interval has elapsed without the ventilator, patient, or operator triggering a breath. Resets after patient initiates a third consecutive breath. Possible dependent alarm: $\downarrow \dot{V}_{ETOT}$
	High	Extended apnea duration or multiple apnea events.		

Table 6-5. Non-technical Alarm Summary (Continued)

Base message	Priority	Analysis message	Remedy message	Comments
CIRCUIT DISCONNECT	High	No ventilation	Check patient Reconnect circuit.	Ventilator has recovered from unintended power loss lasting more than 5 minutes, detects circuit disconnect. The GUI screen displays elapsed time without ventilator support. Resets when patient is reconnected.
	High	No ventilation	Check patient. Reconnect circuit.	Ventilator detects circuit disconnect and switches to Stand-By state; the GUI screen displays elapsed time without ventilator support. Resets when patient is reconnected.
COMPLIANCE LIMITED V_T (alarm is not adjustable) (patient data alarm)	Low	Compliance compensation limit reached	Check patient and circuit type. Inspired volume may be < set.	Compliance volume required to compensate delivery of a VC, VC+ or VS breath exceeds the maximum allowed for three consecutive breaths.
COMPRESSOR INOPERATIVE	Low	No compressor air.	Replace compressor.	No compressor ready indicator on status display.
$\uparrow P_{PEAK}$ (patient data alarm)	Low	Last breath $\geq$ set limit.	Check patient, circuit & ET tube.	Measured airway pressure $\geq$ set limit. Ventilator truncates current breath unless already in exhalation. Possible dependent alarms: $\downarrow V_{TE\ MAND}$, $\downarrow \dot{V}_{E\ TOT}$, $\uparrow f_{TOT}$. Corrective action: Check patient. Check tube type/ID setting. Consider reducing % Supp setting or increasing $\uparrow P_{PEAK}$.
	Medium	Last 3 breaths $\geq$ set limit.		
	High	Last 4 or more breaths $\geq$ set limit.		

Table 6-5. Non-technical Alarm Summary (Continued)

Base message	Priority	Analysis message	Remedy message	Comments
$\uparrow P_{\text{COMP}}$ (patient data alarm)	Low	Last spont breath $\geq$ set P_{PEAK} limit-5 cmH ₂ O.	In TC or PAV+: Check for leaks, tube type/ID setting.	Pressure of spontaneous breaths $\geq$ set limit. Possible dependent alarms: $\downarrow V_{\text{TE}}$ SPONT, $\downarrow \dot{V}_{\text{E TOT}}$, $\uparrow f_{\text{TOT}}$. Corrective action: Check for leaks. Check for the correct tube type. Check that the tube inside diameter corresponds to the patient PBW. Check the $\uparrow P_{\text{PEAK}}$ setting.
	Medium	Last 3 spont breaths $\geq$ set P_{PEAK} limit-5 cmH ₂ O.		
	High	Last 4 or more spont breaths $\geq$ set P_{PEAK} limit-5 cmH ₂ O.		
$\downarrow P_{\text{PEAK}}$ (patient data alarm)	Low	Last 2 breaths, pressure $\leq$ set limit.	Check for leaks.	Peak inspiratory pressure $\leq$ alarm setting. (Available only when mandatory type is VC+* or when ventilation type is NIV. Target pressure = the low limit: PEEP+3 cmH ₂ O. Ventilator cannot deliver target volume. Possible dependent alarms: $\uparrow f_{\text{TOT}}$. Corrective action: Check patient and settings; check for leaks.
	Medium	Last 4 breaths, pressure $\leq$ set limit		
	High	Last 10 or more breaths, pressure $\leq$ set limit		
* Because the VC+ pressure control algorithm does not allow the target inspiratory pressure to fall below PEEP+3 cmH ₂ O, attempting to set the $\downarrow P_{\text{PEAK}}$ alarm limit at or below this level will turn the alarm off.				
$\uparrow O_2\%$ (patient data alarm)	Medium	Measured O ₂ % > set for ≥ 30 s but <2 min	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 above the O ₂ % setting for at least 30 seconds. (These percentages increase by 5% for 4 minutes following a decrease in the O ₂ % setting.)
	High	Measured O ₂ % > set for ≥ 2 min.		

Table 6-5. Non-technical Alarm Summary (Continued)

Base message	Priority	Analysis message	Remedy message	Comments
$\downarrow O_2\%$ (patient data alarm)	High	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 seconds, or below 18%. (These percentages increase by 5% for 4 minutes following an increase in the $O_2\%$ setting.)
$\uparrow V_{TE}$ (patient data alarm)	Low	Last 2 breaths $\geq$ set limit.	Check settings, changes in patient's R & C.	Exhaled tidal volume $\geq$ set limit. Alarm updated whenever exhaled tidal volume is recalculated. Possible dependent alarm: $\uparrow V_{E\text{TOT}}$
	Medium	Last 4 breaths $\geq$ set limit.		
	High	Last 10 or more breaths $\geq$ set limit.		
$\uparrow \dot{V}_{E\text{TOT}}$ (patient data alarm)	Low	$\dot{V}_{E\text{TOT}} \geq$ set limit for ≤ 30 s	Check patient & settings.	Expiratory minute volume $\geq$ set limit. Alarm updated whenever an exhaled minute volume is recalculated. Possible dependent alarm: $\uparrow V_{TE}$.
	Medium	$\dot{V}_{E\text{TOT}} \geq$ set limit for > 30 s		
	High	$\dot{V}_{E\text{TOT}} \geq$ set limit for > 120 s		
$\uparrow f_{TOT}$ (patient data alarm)	Low	$f_{TOT} \geq$ set limit for ≤ 30 s.	Check patient & settings.	Total respiratory rate $\geq$ set limit. Alarm updated at the beginning of each inspiration. Reset when measured respiratory rate falls below the alarm limit. Possible dependent alarms: $\downarrow V_{TE}$ MAND, $\downarrow V_{TE\text{SPONT}}$, $\downarrow \dot{V}_{E\text{TOT}}$.
	Medium	$f_{TOT} \geq$ set limit for > 30 s.		
	High	$f_{TOT} \geq$ set limit for > 120 s.		

Table 6-5. Non-technical Alarm Summary (Continued)

Base message	Priority	Analysis message	Remedy message	Comments
$\uparrow P_{VENT}$ (patient data alarm)	Low	1 breath $\geq$ limit.	Check patient, circuit & ET tube.	Inspiratory pressure >100 cmH ₂ O and mandatory type is VC or spontaneous type is TC or PAV+. Ventilator truncates current breath unless already in exhalation. Possible dependent alarms: $\downarrow V_{TE\ MAND}$, $\downarrow \dot{V}_{E\ TOT}$, $\uparrow f_{TOT}$. Corrective action: • Check for agitation. Agitated breathing, combined with high % Supp setting in PAV+ can cause over assistance. Consider reducing % Supp setting. • Provide alternate ventilation. Remove ventilator from use and contact Service.
	Medium	2 breaths $\geq$ limit.		
	High	3 or more breaths $\geq$ limit.		
INOPERATIVE BATTERY	Low	Inadequate charge or non-functional vent main battery.	Service/replace vent main battery.	Battery installed but not functioning or charging for ≥ 6 hours. Resets when battery is functional.
INOPERATIVE BATTERY	Low	Inadequate charge or non-functional compressor battery.	Service/replace compressor battery.	
INOPERATIVE BATTERY	Low	Inadequate charge or non-functional vent main battery and compressor battery.	Service/replace vent main battery and compressor battery.	

Table 6-5. Non-technical Alarm Summary (Continued)

Base message	Priority	Analysis message	Remedy message	Comments
INSPIRATION TOO LONG (patient data alarm)	Low	Last 2 spont breaths = PBW based T_I limit.	Check patient. Check for leaks.	Inspiratory time for spontaneous breath $\geq$ PBW-based limit. Ventilator transitions to exhalation. Resets when T_I falls below PBW-based limit. Active only when ventilation type is invasive.
	Medium	Last 4 spont breaths = PBW based T_I limit.		
	High	Last 10 or more spont breaths = PBW based T_I limit.		
PAV STARTUP TOO LONG (patient data alarm) (occurs only if PAV+ is in use)	Low	PAV startup not complete for ≥ 45 s.	Check for leaks, shallow breathing, & settings for $\uparrow V_{TI}$ and $\uparrow P_{PEAK}$.	Unable to assess patient's resistance and compliance during PAV startup. Possible dependent alarms $\downarrow V_{TE SPONT}$, $\downarrow \dot{V}_{E TOT}$, $\uparrow f_{TOT}$. Corrective action: Check patient. (Patient's inspiratory times may be too short to evaluate resistance and compliance.) Check that selected humidification type and empty humidifier volume are correct.
	Medium	PAV startup not complete for ≥ 90 s.		
	High	PAV startup not complete for ≥ 120 s.		
PAV R & C NOT ASSESSED (patient data alarm) (occurs only if PAV+ is in use)	Low	R and/or C over 15 minutes old.	Check for leaks, shallow breathing, & settings for tube ID, $\uparrow V_{TI}$ and $\uparrow P_{PEAK}$.	Unable to assess resistance or compliance during PAV+ steady-state. Startup was successful, but later assessments were unsuccessful. Corrective action: Check patient. (Patient's inspiratory times may be too short to evaluate resistance and compliance.) Check that selected humidification type and empty humidifier volume are correct.
	Medium	R and/or C over 30 minutes old.		

Table 6-5. Non-technical Alarm Summary (Continued)

Base message	Priority	Analysis message	Remedy message	Comments
LOSS OF POWER	Immediate	N/A	N/A	The ventilator power switch is on and there is insufficient power from AC and the battery. There may not be a visual indicator for this alarm, but an independent audio alarm sounds for at least 120 seconds. Alarm annunciation can be reset by turning power switch to off position.
LOW BATTERY	Medium	Vent main battery operational time <10 minutes.	Replace or allow recharge vent main battery.	Resets when battery has ≥ 10 minutes of operational time remaining or when AC power is restored.
LOW BATTERY	Medium	Compressor battery operational time <10 minutes.	Replace or allow recharge compressor battery.	Resets when compressor battery has ≥ 10 minutes of operational time remaining or when AC power is restored
LOW BATTERY	Medium	Vent main battery operational time <10 minutes and compressor battery operational time <10 minutes.	Replace or allow recharge vent main battery and compressor battery.	Resets when main battery or compressor battery has ≥ 10 minutes of operational time remaining or when AC power is restored.
LOW BATTERY	High	Vent main battery operational time <5 minutes.	Replace or allow recharge vent main battery.	Resets when battery has ≥ 5 minutes of operational time remaining or when AC power is restored.
LOW BATTERY	High	Compressor battery operational time <5 minutes.	Replace or allow recharge compressor battery.	Resets when compressor battery has ≥ 5 minutes of operational time remaining or when AC power is restored

Table 6-5. Non-technical Alarm Summary (Continued)

Base message	Priority	Analysis message	Remedy message	Comments
LOW BATTERY	High	Vent main battery operational time <5 minutes and compressor battery operational time < 5 minutes.	Replace or allow recharge vent main battery and compressor battery.	Resets when main battery or compressor battery has ≥5 minutes of operational time remaining or when AC power is restored
↓V _{TE MAND} (patient data alarm)	Low	Last 2 mand breaths ≤ set limit.	Check for leaks, changes in patient's R & C.	Exhaled mandatory tidal volume≤ set limit. Alarm updated whenever exhaled mandatory tidal volume is recalculated. Possible dependent alarms: ↓V _{E TOT} , ↑f _{TOT} .
	Medium	Last 4 mand breaths ≤ set limit.		
	High	Last 10 or more mand breaths ≤ set limit.		
↓V _{TE SPONT} (patient data alarm)	Low	Last 4 spont breaths ≤ set limit	Check patient & settings.	Exhaled spontaneous tidal volume ≤ set limit. Alarm updated whenever exhaled spontaneous tidal volume is recalculated. Possible dependent alarms: ↓V _{E TOT} , ↑f _{TOT} .
	Medium	Last 7 spont breaths ≤ set limit		
	High	Last 10 or more spont breaths ≤ set limit		
↑V _{TI} (patient data alarm)	Low	Last spont breath ≥ set limit.	In TC, VS, or PAV+:	Delivered inspiratory volume ≥ inspiratory limit. Ventilator transitions to exhalation. Possible dependent alarms: ↓V _{TE SPONT} , ↓V _{E TOT} , ↑f _{TOT} . Corrective action: Check for leaks. Check for the correct tube type. Check the V _{T SUPP} or % Supp setting. In PAV+, check for patient agitation, which can cause miscalculation of R _{PAV} and C _{PAV} . Consider reducing% Supp setting. Check ↑V _{TI} .
	Medium	Last 3 spont breaths ≥ set limit.	Check patient and settings.	
	High	Last 4 or more spont breaths ≥ set limit.		

Table 6-5. Non-technical Alarm Summary (Continued)

Base message	Priority	Analysis message	Remedy message	Comments
$\downarrow \dot{V}_{E\text{TOT}}$ (patient data alarm)	Low	$\dot{V}_{E\text{TOT}} \leq \text{set limit for } \leq 30 \text{ s.}$	Check patient & settings.	Total minute volume $\leq$ set limit. Alarm updated whenever exhaled minute volume is recalculated. Possible dependent alarms: $\downarrow V_{TE}$ MAND, $\downarrow V_{TE\text{ SPONT}}$, $\uparrow f_{TOT}$.
	Medium	$\dot{V}_{E\text{TOT}} \leq \text{set limit for } > 30 \text{ s.}$		
	High	$\dot{V}_{E\text{TOT}} \leq \text{set limit for } > 120 \text{ s.}$		
VOLUME NOT DELIVERED (not adjustable) (patient data alarm)	Low	Last 2 spont (or mand) breaths pressure $>$ max allowable level.	Check patient & setting for $\uparrow P_{PEAK}$.	Insp target pressure $>$ ($P_{PEAK} - PEEP - 3 \text{ cmH}_2\text{O}$), when spontaneous type is VS or mandatory type is VC+. Ventilator cannot deliver target volume. Possible dependent alarms: For VC+ breaths: $\downarrow V_{TE\text{ MAND}}$, $\downarrow \dot{V}_{E\text{TOT}}$, $\uparrow f_{TOT}$. For VS breaths: $\downarrow V_{TE\text{ SPONT}}$, $\downarrow \dot{V}_{E\text{TOT}}$, $\uparrow f_{TOT}$. Corrective action: Check patient and settings.
	Medium	Last 10 or more spont (or mand) breaths, pressure $>$ max allowable level.		
NO AIR SUPPLY	Low	Compressor inoperative. Ventilation continues as set. Only O_2 available.	Check air source.	Ventilator delivers 100% O_2 . Air supply pressure ≤ 17 psig. Resets if air supply pressure ≥ 35 psig is connected.
NO AIR SUPPLY	High	Compressor inoperative. Ventilation continues as set, except $O_2 = 100$.	Check patient & air source.	
NO AIR SUPPLY	High	Ventilation continues as set except $O_2 = 100$.	Check patient & air source.	

Table 6-5. Non-technical Alarm Summary (Continued)

Base message	Priority	Analysis message	Remedy message	Comments
NO O ₂ SUPPLY	Low	Ventilation continues as set. Only air available.	Check O ₂ source.	Operator-set O ₂ % equals 21%. Resets if O ₂ supply connected.
	High	Ventilation continues as set, except O ₂ % = 21.	Check patient & O ₂ source.	Ventilator delivers 21% O ₂ instead of set O ₂ %. Resets if oxygen supply connected.
PROCEDURE ERROR	High	Patient connected before setup complete.	Provide alternate ventilation. Complete setup process.	Ventilator begins safety ventilation. Resets when ventilator startup procedure is complete.
SEVERE OCCLUSION	High	Little/no ventilation.	Check patient. Provide alternate ventilation. Clear occlusions; drain circuit.	Ventilator enters occlusion status cycling (OSC). Patient data displays are blanked and GUI screen displays elapsed time without ventilator support.
PROX INOPERATIVE (if Proximal Flow Sensor is in use)	Low	Data from Proximal Flow Sensor are not being used.	Check proximal flow sensor connections and tubes for occlusions or leaks.	Data obtained from the proximal flow sensor are invalid, non-existent, or unreasonable based on current ventilator settings or purge lines are occluded. Alarm resets when condition is corrected. Data for real time waveforms and monitored volumes are obtained from internal sensors.
INADVERTENT POWER OFF	High	Ventilator switched OFF with patient connected to breathing circuit.	Return power switch to on position and disconnect patient before turning power off.	User must acknowledge turning the power OFF by touching Power Off on the GUI.

Table 6-6. Non-Technical Alarms and Suggested Responses

Alarm message	Meaning	Response
AC POWER LOSS	The ventilator or compressor is running on battery power.	Monitor the battery charge level to ensure there is enough power remaining to operate the ventilator or compressor.
APNEA (patient data alarm)	The time between patient breaths exceeds the set apnea interval.	Check patient and settings.
CIRCUIT DISCONNECT	The patient circuit has become disconnected or there is a large leak in the patient circuit.	Re-connect the patient circuit, or eliminate the leak.
Compliance limited V_T (patient data alarm)	Compliance volume required to compensate delivery of a VC, VC+, or VS breath exceeds the maximum allowed for three consecutive breaths.	Check patient and circuit type. Inspired volume may be less than set.
COMPRESSOR INOPERATIVE	Air pressure not detected in the compressor's accumulator. Status display indicates the compressor is inoperative.	Service or replace compressor.
$\uparrow P_{PEAK}$ (patient data alarm)	The measured airway pressure is $\geq$ set limit. Reduced tidal volume likely.	• Check the patient. • Check the patient circuit. • Check the endotracheal tube.
$\downarrow P_{PEAK}$ (patient data alarm)	The peak inspiratory pressure in the patient circuit $\leq$ alarm setting. This alarm is only available when NIV is the selected ventilation type or when VC+ is the selected mandatory type during invasive ventilation.*	Check for leaks in the patient circuit and VBS.
* Because the VC+ pressure control algorithm does not allow the target inspiratory pressure to fall below $PEEP+3 \text{ cmH}_2\text{O}$, attempting to set the $\downarrow P_{PEAK}$ alarm setting at or below this level will turn the alarm off.		
$\uparrow O_2\%$ (patient data alarm)	The $O_2\%$ measured during any phase of a breath cycle is 7% (12% during the first hour of operation) or more above the $O_2\%$ parameter for at least 30 seconds. The percentage window increases by 5% for 4 minutes after increasing the set $O_2\%$ value.	Check the patient, the air and oxygen supplies, the oxygen analyzer, and the ventilator.

Table 6-6. Non-Technical Alarms and Suggested Responses (Continued)

Alarm message	Meaning	Response
↓O ₂ % (patient data alarm)	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 % parameter for at least 30 seconds. The percentage window increases by 5% for 4 minutes after increasing the set O ₂ % value.	• Check the patient, the air and oxygen supplies, the oxygen analyzer and the ventilator. • Calibrate the oxygen sensor. See Oxygen Sensor Calibration (4.10.2) on page 4-31 for details regarding calibrating the oxygen sensor. • Use an external O₂ monitor and disable the O₂ sensor.
↑V _{TE} (patient data alarm)	Exhaled tidal volume ≥ alarm setting for the last two breaths.	• Check patient settings. • Check for changes in patient's resistance and compliance.
↑ $\dot{V}_{E\text{TOT}}$ (patient data alarm)	Minute volume ≥ alarm setting.	Check patient settings.
↑f _{TOT} (patient data alarm)	The breath rate from all breaths is ≥ alarm setting.	Check the patient and the ventilator settings.
↑P _{VENT} (patient data alarm)	The inspiratory pressure transducer has measured a pressure >110 cmH ₂ O in VC, TC, or PAV+. The ventilator transitions to exhalation. A reduced tidal volume is likely.	• Check the patient, the patient circuit (including filters), and the endotracheal tub. Ensure that the ET tube ID is the correct size. • Check the ventilator flow and volume settings. • Rerun SST. • Obtain and alternate ventilation source. • Remove the ventilator from clinical use and obtain service.
INOPERATIVE BATTERY	The battery charge is inadequate after 6 hours of attempted charge time or the battery system is non-functional.	Replace the battery or install an extended battery.
INSPIRATION TOO LONG (patient data alarm)	The PBW-based inspiratory time for the last two spontaneous breaths exceeds the ventilator-set limit. Active only when ventilation type is invasive.	• Check the patient. • Check the patient circuit for leaks. • Check rise time% and E_{SENS} settings.
LOSS OF POWER	The ventilator power switch is on, but there is insufficient power from the mains AC and the battery. There may not be a visual indicator for this alarm, but an independent audio alarm (immediate priority) sounds for at least 120 seconds.	• Check the integrity of the AC power and battery connections. • Obtain alternate ventilation, if necessary. • Use an extended battery. If the loss of power event has been resolved, turn the power switch off and back on again to reset the alarm.

Table 6-6. Non-Technical Alarms and Suggested Responses (Continued)

Alarm message	Meaning	Response
LOW BATTERY	Medium priority alarm indicating <10 minutes of battery power remaining to operate the ventilator or compressor. High priority alarm indicating <5 minutes of battery power remain to operate the ventilator or compressor.	Recharge the battery, by plugging the ventilator into AC power or replace the battery, or install an extended battery.
$\downarrow V_{TE\ MAND}$ (patient data alarm)	The patient's exhaled mandatory tidal volume is $\leq$ alarm setting for the last two mandatory breaths.	• Check the patient. • Check for leaks in the patient circuit. • Check for changes in the patient's resistance and compliance.
$\downarrow V_{TE\ SPONT}$ (patient data alarm)	The patient's exhaled spontaneous tidal volume is $\leq$ alarm setting for the last two spontaneous breaths.	• Check the patient. • Check the ventilator settings.
$\downarrow \dot{V}_{E\ TOT}$ (patient data alarm)	The minute volume for all breaths is $\leq$ alarm setting.	• Check the patient. • Check the ventilator settings.
NO AIR SUPPLY	The air supply pressure is less than the minimum pressure required for correct ventilator operation. The ventilator delivers 100% O ₂ if available. If an oxygen supply is not available, the safety valve opens. The ventilator displays the elapsed time without ventilator support. This alarm cannot be set or disabled.	• Check the patient. • Check the air and oxygen sources. • Obtain alternate ventilation, if necessary.
NO O ₂ SUPPLY	The oxygen supply pressure is less than the minimum pressure required for correct ventilator operation. The ventilator delivers 100% air if available. If an air supply is not available, the safety valve opens. The ventilator displays the elapsed time without ventilatory support. This alarm cannot be set or disabled.	• Check the patient. • Check the air and oxygen sources. • Obtain alternate ventilation, if necessary.
$\uparrow P_{COMP}$	Target pressure $\geq (\uparrow P_{PEAK} - 5$ cmH ₂ O	In TC: Check for leaks and tube type/ID setting. In PAV+: Limit target pressure to $\uparrow P_{PEAK} - 5$ cmH₂O.

Table 6-6. Non-Technical Alarms and Suggested Responses (Continued)

Alarm message	Meaning	Response
PROCEDURE ERROR	The patient is attached before ventilator startup is complete. Safety ventilation is active.	• Provide alternate ventilation, if necessary. • Complete ventilator startup procedure.
SEVERE OCCLUSION	The patient circuit is severely occluded. The ventilator enters occlusion status cycling. The elapsed time without ventilatory support appears.	• Check the patient. • Obtain alternate ventilation, if necessary. • Check patient circuit for bulk liquid, crimps, blocked filter. • If problem persists, remove ventilator from use and obtain service.
$\uparrow V_{Tl}$ (patient data alarm)	Delivered inspiratory volume $\geq$ high inspiratory volume limit	• Check patient and ventilator settings. • Check for leaks, tube type/ID, and % Supp settings, and patient agitation. • Ventilator transitions to exhalation.
VOLUME NOT DELIVERED (patient data alarm)	Insp target pressure $>$ ($P_{PEAK} - PEEP - 3 \text{ cmH}_2\text{O}$), when spontaneous type is VS or when mandatory type is VC+.	Check patient and $\uparrow P_{PEAK}$ setting
PAV STARTUP TOO LONG (occurs only if PAV+ function is in use)	Unable to assess resistance or compliance during PAV+ startup.	Check for leaks, shallow breathing, and settings for $\uparrow V_{Tl}$ and $\uparrow P_{PEAK}$.
PAV R & C NOT ASSESSED (occurs only if PAV+ function is in use)	Unable to assess resistance or compliance during PAV+ steady-state.	Check for leaks, shallow breathing, and settings for tube ID, $\uparrow V_{Tl}$ and $\uparrow P_{PEAK}$.
PROX INOPERATIVE	A malfunction occurred with the proximal flow sensor or the pneumatic lines are occluded.	Replace the proximal flow sensor or purge its pneumatic lines. Does not affect data from the ventilator's delivery or exhalation flow sensors.

The next sections provide detailed descriptions of selected alarms.

6.5.9 AC POWER LOSS Alarm

The AC POWER LOSS alarm indicates the ventilator power switch is on and the ventilator is being powered by the battery and an alternate power source may soon be required to sustain normal ventilator operation. The ventilator annunciates a medium-priority LOW BATTERY alarm when the ventilator has less than 10 minutes of battery power remaining. The ventilator annunciates a high-priority LOW BATTERY alarm when less than 5 minutes of battery power are estimated available.

The compressor is a DC device, in which AC power is converted to DC power, and it has its own primary and extended batteries (if the extended battery was purchased). If AC power is lost, there is no conversion to DC power for the compressor as in normal operation, but the compressor supplies air, providing the charge level of its batteries is sufficient.

6.5.10 APNEA Alarm

The APNEA alarm indicates neither the ventilator nor the patient has triggered a breath for the operator-selected apnea interval (T_A). T_A is measured from the start of an inspiration to the start of the next inspiration and is based on the ventilator's inspiratory detection criteria. T_A can only be set via the apnea ventilation settings.

The APNEA alarm autoresets after the patient initiates two successive breaths, and is intended to establish the patient's inspiratory drive is reliable enough to resume normal ventilation. To ensure the breaths are patient-initiated (and not due to autotriggering), exhaled volumes must be at least half the inspired V_T . (This avoids returning to normal ventilation if there is a disconnect.)

6.5.11 CIRCUIT DISCONNECT Alarm

The CIRCUIT DISCONNECT alarm indicates the patient circuit is disconnected at the ventilator or the patient side of the patient wye, or a large leak is present. The methods by which circuit disconnects are detected vary depending on breath type. Time, pressure, flow, delivered volume, exhaled volume, and the D_{SENS} setting may be used in the circuit disconnect detection algorithms. See [Disconnect \(10.13.2\)](#) on page 10-38 for a complete discussion of the CIRCUIT DISCONNECT detection methods.

The CIRCUIT DISCONNECT alarm sensitivity is adjusted via the D_{SENS} setting. During a CIRCUIT DISCONNECT condition, the ventilator enters an idle state and delivers a base flow of oxygen to detect a reconnection.

When the ventilator determines the patient circuit is reconnected, the CIRCUIT DISCONNECT alarm autoresets and normal ventilation resumes without having to manually reset the alarm (for example, following suctioning).

A disconnected patient circuit interrupts gas delivery and patient monitoring. Notification of a patient circuit disconnect is crucial, particularly when the patient cannot breathe spontaneously. The ventilator does not enter apnea ventilation when a disconnect is detected to avoid changing modes during a routine suctioning procedure.



Note:

When utilizing a closed-suction catheter system, the suctioning procedure can be executed using existing mode, breath type and settings. To reduce potential for hypoxemia during the procedure, elevate the oxygen concentration using the Elevate O_2 control. See [To adjust the amount of elevated \$O_2\$ delivered for 2 minutes](#), page 3-36.

6.5.12 LOSS OF POWER Alarm

This alarm alerts the operator that there is insufficient battery power and no AC power to support ventilator or compressor operation. The alarm annunciates as long as the ventilator's power switch is in the on position, and lasts for at least 120 seconds.

6.5.13 DEVICE ALERT Alarm

A DEVICE ALERT alarm indicates a background test or power on self test (POST) has failed. Depending on which test failed, the ventilator either continues to ventilate according to current settings, or ventilates with modified settings, or enters the ventilator inoperative state. The DEVICE ALERT alarm relies on the ventilator's self-testing and notifies the clinician of an abnormal condition requiring service. See [Background Diagnostic System \(10.16.4\)](#) on page 10-61.

6.5.14 HIGH CIRCUIT PRESSURE ($\uparrow P_{PEAK}$) Alarm

The $\uparrow P_{PEAK}$ alarm indicates the currently measured airway pressure is equal to or greater than the set limit. The $\uparrow P_{PEAK}$ limit is active during all breath types and phases to provide redundant patient protection (for example, to detect air flow restrictions downstream of the pressure-sensing device). The $\uparrow P_{PEAK}$ limit is active in all normal ventilation modes. The $\uparrow P_{PEAK}$ alarm new patient default values are separately configurable for neonatal, pediatric, and adult patients. The $\uparrow P_{PEAK}$ limit is not active during a SEVERE OCCLUSION alarm.

The $\uparrow P_{PEAK}$ alarm truncates inspiration and transitions the ventilator into the expiratory phase. The limit cannot be set less than:

- $PEEP + 7 \text{ cmH}_2\text{O}$
- $PEEP + P_I + 2 \text{ cmH}_2\text{O}$
- $PEEP + P_{SUPP} + 2 \text{ cmH}_2\text{O}$
- $\downarrow P_{PEAK}$

The $\uparrow P_{PEAK}$ limit cannot be disabled. The ventilator phases in changes to the $\uparrow P_{PEAK}$ limit immediately to allow prompt notification of a high circuit pressure condition.

The minimum $\uparrow P_{PEAK}$ limit (7 cmH₂O) corresponds to the lowest peak pressures not due to auto-triggering anticipated during a mandatory breath. The maximum $\uparrow P_{PEAK}$ limit (100 cmH₂O) was selected because it is the maximum pressure required to inflate very low-compliance lungs.

The ventilator allows circuit pressure to rise according to a computed triggering profile for the initial phase of PC and PS breaths without activating the $\uparrow P_{PEAK}$ alarm. This triggering profile helps avoid nuisance alarms due to possible transient pressure overshoot in the airway when aggressive values of rise time% are selected. A brief pressure overshoot measured in the patient circuit is unlikely to be present at the carina.

6.5.15 HIGH DELIVERED O₂% (↑O₂%) Alarm

The ↑O₂% alarm indicates the measured O₂% is at or above the error percentage above the O₂% setting for at least 30 seconds to eliminate transient O₂% delivery variation nuisance alarms. The ↑O₂% alarm detects malfunctions in ventilator gas delivery or oxygen monitor. The ventilator declares a ↑O₂% alarm after 30 seconds. Although the ventilator automatically sets the ↑O₂% alarm limits, the oxygen sensor can be disabled. (The error percentage is 12% above setting for the first hour of ventilator operation, 7% above the setting after the first hour of operation, and an additional 5% above the setting for the first 4 minutes following a decrease in the setting.)

The ventilator automatically adjusts the ↑O₂% alarm limit when O₂% changes due to 100% O₂, apnea ventilation, occlusion, circuit disconnect, or a NO AIR SUPPLY or NO O₂ SUPPLY alarm. The ventilator checks the ↑O₂% alarm limit against the measured oxygen percentage at 1-second intervals.

6.5.16 HIGH EXHALED MINUTE VOLUME (↑ $\dot{V}_{E\text{TOT}}$) Alarm

The ↑ $\dot{V}_{E\text{TOT}}$ alarm indicates the measured exhaled total minute volume for spontaneous and mandatory breaths is equal to or greater than the alarm setting. The ↑ $\dot{V}_{E\text{TOT}}$ alarm is effective immediately upon changing the setting, to ensure prompt notification of prolonged high tidal volumes.

The ↑ $\dot{V}_{E\text{TOT}}$ alarm can be used to detect a change in a patient's breathing pattern, or a change in compliance or resistance. The ↑ $\dot{V}_{E\text{TOT}}$ alarm can also detect too-large tidal volumes, which could lead to hyperventilation and hypocarbia.

6.5.17 HIGH EXHALED TIDAL VOLUME (↑V_{TE}) Alarm

The ↑V_{TE} alarm indicates the measured exhaled tidal volume for spontaneous and mandatory breaths is equal to or greater than the set $\bar{V}_{TE}$ alarm. The ↑V_{TE} alarm is updated whenever a new measured value is available.

The ↑V_{TE} alarm can detect increased exhaled tidal volume (due to greater compliance and lower resistance) and prevent hyperventilation during pressure control ventilation or pressure support. Turn the ↑V_{TE} alarm OFF to avoid nuisance alarms. (Hyperventilation due to increased compliance is not a concern during volume-based ventilation, because the tidal volume is fixed by the clinician's choice and the ventilator's compliance-compensation algorithm.)

6.5.18 HIGH INSPIRED TIDAL VOLUME (↑V_{TI}) Alarm

The ↑V_{TI} alarm indicates the patient's inspired volume exceeds the set limit. When this condition occurs, the breath terminates and the alarm sounds. The ventilator displays monitored inspired tidal volume values in the patient data area on the GUI screen. When ventilation type is NIV, there

is no high inspired tidal volume alarm or setting available, but the monitored inspired tidal volume (V_{Ti}) may appear in the patient data area on the GUI screen.

6.5.19 HIGH RESPIRATORY RATE ($\uparrow f_{TOT}$) Alarm

The $\uparrow f_{TOT}$ alarm indicates the measured breath rate is greater than or equal to the $\uparrow f_{TOT}$ alarm setting. The $\uparrow f_{TOT}$ alarm is updated whenever a new total measured respiratory rate is available.

The $\uparrow f_{TOT}$ alarm can detect tachypnea, which could indicate the tidal volume is too low or the patient's work of breathing has increased. The ventilator phases in changes to the $\uparrow f_{TOT}$ limit immediately to ensure prompt notification of a high respiratory rate condition.

6.5.20 INSPIRATION TOO LONG Alarm

The INSPIRATION TOO LONG alarm, active only when ventilation type is invasive, indicates the inspiratory time of a spontaneous breath exceeds the following time limit:

- $(1.99 + 0.02 \times PBW)$ seconds (adult and pediatric circuits)
- $(1.00 + 0.10 \times PBW)$ seconds (neonatal circuits)

where PBW is the current setting for predicted body weight in kg.

When the ventilator declares an INSPIRATION TOO LONG alarm, the ventilator terminates inspiration and transitions to exhalation. The INSPIRATION TOO LONG alarm applies only to spontaneous breaths and cannot be set or disabled.

Because leaks (in the patient circuit, around the endotracheal tube cuff, or through chest tubes) and patient-ventilator mismatch can affect accurate exhalation detection, the INSPIRATION TOO LONG alarm can act as a backup method of safely terminating inspiration. If the INSPIRATION TOO LONG alarm occurs frequently, check for leaks and ensure E_{SENS} and rise time% are properly set.

6.5.21 LOW CIRCUIT PRESSURE ($\downarrow P_{PEAK}$) Alarm



WARNING:

Because the VC+ pressure control algorithm does not allow the target inspiratory pressure to fall below PEEP+3 cmH₂O, attempting to set the $\downarrow P_{PEAK}$ alarm limit at or below this level will turn the alarm off.

The $\downarrow P_{PEAK}$ alarm indicates the measured maximum airway pressure during the current breath is less than or equal to the set alarm level during a non-invasive inspiration or during a VC+ inspiration.

The $\downarrow P_{PEAK}$ alarm is active for mandatory and spontaneous breaths, and is present only when ventilation type is NIV or mandatory type is VC+. During VC+, the $\downarrow P_{PEAK}$ alarm can be turned off. The

$\downarrow P_{PEAK}$ alarm can always be turned off during NIV. The $\downarrow P_{PEAK}$ alarm limit cannot be set to a value greater than or equal to the $\uparrow P_{PEAK}$ alarm limit.

In VC+, whenever PEEP is changed, $\downarrow P_{PEAK}$ is set automatically to its new patient value, PEEP+4 cmH₂O when PEEP $\geq$ 16 cmH₂O, or PEEP+3.5 cmH₂O when PEEP < 16 cmH₂O.

There are no alarms dependent upon $\downarrow P_{PEAK}$ and the $\downarrow P_{PEAK}$ alarm does not depend on other alarms.

6.5.22 LOW DELIVERED O₂% ($\downarrow O_2\%$) Alarm

The $\downarrow O_2\%$ alarm indicates the measured O₂% during any phase of a breath is at or below the error percentage below the O₂% setting, or less than or equal to 18%, for at least 30 seconds. Although the ventilator automatically sets the $\downarrow O_2\%$ alarm, replace (if necessary) or disable the oxygen sensor to avoid nuisance alarms. (The error percentage is 12% below setting for the first hour of ventilator operation following a reset, 7% below setting after the first hour of operation, and an additional 5% below setting for the first 4 minutes following an increase in the setting.)

The ventilator automatically adjusts the $\downarrow O_2\%$ alarm limit when O₂% changes due to apnea ventilation, circuit disconnect, or a NO O₂ SUPPLY or NO AIR SUPPLY alarm. The $\downarrow O_2\%$ alarm is disabled during a safety valve open (SVO) condition. The ventilator checks the $\downarrow O_2\%$ alarm against the measured oxygen percentage at 1-second intervals.

The $\downarrow O_2\%$ alarm can detect malfunctions in ventilator gas delivery or the oxygen monitor, and can ensure the patient is adequately oxygenated. The ventilator declares a $\downarrow O_2\%$ alarm after 30 seconds to eliminate nuisance alarms from transient O₂% delivery variations. The O₂% measured by the oxygen sensor is shown in the patient data area. See [Vital Patient Data](#), page 3-37 to include O₂% if it is not displayed.

6.5.23 LOW EXHALED MANDATORY TIDAL VOLUME ($\downarrow V_{TE\ MAND}$) Alarm

The alarm indicates the measured exhaled mandatory tidal volume is less than or equal to the $\downarrow V_{TE\ MAND}$ alarm setting. The $\downarrow V_{TE\ MAND}$ alarm updates when a new measured value of exhaled mandatory tidal volume is available.

The $\downarrow V_{TE\ MAND}$ alarm can detect an obstruction, a leak during volume ventilation, or a change in compliance or resistance during pressure-based ventilation (that is, when the same pressure is achieved but tidal volume decreases). There are separate alarms for mandatory and spontaneous exhaled tidal volumes for use during SIMV, SPONT, and BiLevel. The ventilator phases in a change to the $\downarrow V_{TE\ MAND}$ alarm immediately to ensure prompt notification of a low exhaled tidal volume condition.

6.5.24 LOW EXHALED SPONTANEOUS TIDAL VOLUME ($\downarrow V_{TE\ SPONT}$) Alarm

The $\downarrow V_{TE\ SPONT}$ alarm indicates the measured exhaled spontaneous tidal volume is less than or equal to the $\downarrow V_{TE\ SPONT}$ alarm setting. The alarm updates when a new measured value of exhaled spontaneous tidal volume is available.

The $\downarrow V_{TE\ SPONT}$ alarm can detect a leak in the patient circuit or a change in the patient's respiratory drive during a single breath. The $\downarrow V_{TE\ SPONT}$ alarm is based on the current breath rather than on an average to detect changes as quickly as possible. There are separate alarms for mandatory and spontaneous exhaled tidal volumes for use during SIMV and BiLevel. The ventilator phases in a change to the $\downarrow V_{TE\ SPONT}$ alarm limit immediately to ensure prompt notification of a low exhaled tidal volume condition.

6.5.25 LOW EXHALED TOTAL MINUTE VOLUME ($\downarrow \dot{V}_{E\ TOT}$) Alarm

The $\downarrow \dot{V}_{E\ TOT}$ alarm indicates the measured minute volume (for mandatory and spontaneous breaths) is less than or equal to the $\downarrow \dot{V}_{E\ TOT}$ alarm setting. The $\downarrow \dot{V}_{E\ TOT}$ alarm updates with each new calculation for exhaled minute volume.

The $\downarrow \dot{V}_{E\ TOT}$ alarm can detect a leak or obstruction in the patient circuit, a change in compliance or resistance, or a change in the patient's breathing pattern. The $\downarrow \dot{V}_{E\ TOT}$ alarm can also detect too-small tidal volumes, which could lead to hypoventilation and hypoxia (oxygen desaturation).

The ventilator phases in changes to the $\downarrow \dot{V}_{E\ TOT}$ alarm limit immediately to ensure prompt notification of prolonged low tidal volumes.

6.5.26 PROCEDURE ERROR Alarm

The ventilator declares a PROCEDURE ERROR alarm if it is powered up (either by turning on the power switch or if power is regained following a power loss of at least 5 minutes) and the ventilator detects a patient attached before Ventilator Startup is complete. Until confirmation of the ventilator settings, the ventilator annunciates a high-priority alarm and enters Safety PCV. See [Table 10-10](#) on page 10-60.

The PROCEDURE ERROR alarm requires confirmation of ventilator settings after restoration of ventilator power, in case a new patient is attached to the ventilator. Safety PCV is an emergency mode of ventilation providing ventilation according to displayed settings until settings confirmation, and is not intended for long-term patient ventilation.

6.5.27 SEVERE OCCLUSION Alarm

A severe occlusion alarm occurs when gas flow in the ventilator breathing system is severely restricted. The ventilator enters Occlusion Status Cycling (OSC) where the ventilator periodically attempts to deliver a pressure-based breath while monitoring inspiratory and expiratory breath

phases for a severe occlusion. If an occlusion is not detected, the ventilator considers the occlusion condition reset, clears the occlusion alarm, and continues ventilation with the settings in use before the occlusion occurred. The ventilator indicates an occlusion was detected.

6.6 Monitored Patient Data

Monitored patient data appear in the Patient Data Banner at the top of the GUI screen above the waveforms display. See [Figure 4-1](#) on page 4-3.

See [Vital Patient Data](#), page 3-37 to change the displayed patient data parameters or the order in which they are displayed.

If any patient data values are displayed continuously blinking, it means their values are shown clipped to what has been defined as their absolute limits. If the values are displayed in parentheses "()", it means they are clipped to their variable limits. Variable limits are calculated values derived from the set PBW and ventilator settings. Displayed patient data values that have been clipped should be viewed as suspect.

Dashes (--) are displayed if the patient data value is not applicable based on mode or breath type combinations.



Note:

If no value is displayed, then the ventilator is in a state where the value cannot be measured.



Note:

All displayed patient volume data represent lung volumes expressed under BTPS conditions.

The following sections contain descriptions of all patient data parameters shown in the patient data displays.

6.6.1 Total Exhaled Minute Volume ($\dot{V}_{E\text{ TOT}}$)

The BTPS and compliance compensated sum of exhaled gas volumes from both mandatory and spontaneous breaths for the previous 1-minute interval.

6.6.2 Exhaled Spontaneous Minute Volume ($\dot{V}_{E\text{ SPONT}}$)

The BTPS- and compliance-compensated sum of exhaled spontaneous volumes for the previous minute.

6.6.3 Exhaled Tidal Volume (V_{TE})

The volume of the patient's exhaled gas for the previous mandatory or spontaneous breath. Displayed V_{TE} is both compliance- and BTPS compensated, and updates at the next inspiration.

6.6.4 Proximal Exhaled Minute Volume ($\dot{V}_{E\text{ TOTY}}$)

The BTPS- and compliance-compensated sum of exhaled spontaneous volumes for the previous minute, measured by the proximal flow sensor (for neonatal patients, only).

6.6.5 Proximal Exhaled Tidal Volume (V_{TEY})

The exhaled tidal volume for the previous breath measured by the proximal flow sensor (for neonatal patients, only). V_{TEY} is updated at the beginning of the next inspiration.

6.6.6 Exhaled Spontaneous Tidal Volume ($V_{TE\text{ SPONT}}$)

The exhaled volume of the last spontaneous breath, updated at the beginning of the next inspiration following a spontaneous breath.

6.6.7 Exhaled Mandatory Tidal Volume ($V_{TE\text{ MAND}}$)

The exhaled volume of the last mandatory breath, updated at the beginning of the next inspiration following a mandatory breath. If the mode is SPONT and the ventilator has not delivered mandatory breaths in a time period of greater than 2 minutes (for example via a manual inspiration), the $V_{TE\text{ MAND}}$ patient data indicator becomes hidden. The indicator reappears when the value updates.

6.6.8 Exhaled mL/kg Volume

The patient's exhaled volume displayed in mL/kg PBW.

6.6.9 Inspired Tidal Volume (V_{TI})

Inspired tidal volume (V_{TI}) is the BTPS- and compliance-compensated volume of inspired gas for all pressure-based or NIV breaths, updated at the beginning of the following expiratory phase. V_{TI} is displayed when data are available.

6.6.10 Proximal Inspired Tidal Volume (V_{TIY})

Proximal inspired tidal volume (V_{TIY}) is the inspired tidal volume for a mandatory or spontaneous breath measured by the proximal flow sensor (for neonatal patients, only). V_{TIY} is updated at the beginning of the following expiratory phase and is displayed when data are available.

6.6.11 Delivered mL/kg Volume

The delivered gas volume in mL/kg PBW.

6.6.12 I:E Ratio

I:E ratio is the ratio of inspiratory time to expiratory time for the previous breath, regardless of breath type, updated at the beginning of the next inspiration. When I:E ratio is $\geq 1:1$, it is displayed as XX:1. Otherwise it is displayed as 1:XX.



Note:

Due to limitations in setting the I:E ratio in PC ventilation, the monitored data display may not exactly match the I:E ratio setting.

6.6.13 Mean Circuit Pressure (P_{MEAN})

Mean circuit pressure (P_{MEAN}) is the average circuit pressure for a complete breath period, including both inspiratory and expiratory phases whether mandatory or spontaneous. The displayed value can be either positive or negative.

6.6.14 Peak Circuit Pressure (P_{PEAK})

Peak circuit pressure (P_{PEAK}) is the maximum circuit pressure at the patient wye during the previous breath, including both inspiratory and expiratory phases.

6.6.15 End Inspiratory Pressure ($P_{\text{I END}}$)

End inspiratory pressure ($P_{\text{I END}}$) is the pressure at the end of the inspiratory phase of the current breath.

6.6.16 End Expiratory Pressure (PEEP)

End expiratory pressure (PEEP) is the pressure at the end of the expiratory phase of the previous breath, updated at the beginning of the next inspiration. During an expiratory pause maneuver, the displayed value includes any active lung PEEP.

6.6.17 Intrinsic PEEP (PEEP_I)

Intrinsic PEEP (PEEP_I) is an estimate of the pressure above the PEEP level at the end of an exhalation. PEEP_I is determined during an expiratory pause maneuver.

6.6.18 PAV-based Intrinsic PEEP ($PEEP_{I\text{PAV}}$)

PAV-based intrinsic PEEP ($PEEP_{I\text{PAV}}$) is an estimate of intrinsic PEEP, updated at the end of a spontaneous PAV+ breath.

6.6.19 Total PEEP ($PEEP_{TOT}$)

Total PEEP ($PEEP_{TOT}$) is the estimated pressure at the circuit wye during the expiratory pause maneuver.

6.6.20 Plateau Pressure (P_{PL})

Plateau pressure (P_{PL}) is the pressure measured and displayed during an inspiratory pause maneuver.

6.6.21 Total Respiratory Rate (f_{TOT})

Total respiratory rate (f_{TOT}) is the total number of mandatory and spontaneous breaths per minute delivered to the patient.

6.6.22 PAV-based Lung Compliance (C_{PAV})

For a PAV+ breath, C_{PAV} is the change in pulmonary volume for an applied change in patient airway pressure, measured under zero-flow conditions and updated upon successful completion of each calculation. C_{PAV} is displayed on the waveform screen.

6.6.23 PAV-based Patient Resistance (R_{PAV})

For a PAV+ breath, R_{PAV} is the change in pulmonary pressure for an applied change in patient lung flow and updated upon successful completion of each calculation. R_{PAV} is displayed on the waveform screen.

6.6.24 PAV-based Lung Elastance (E_{PAV})

For a PAV+ breath, E_{PAV} is the inverse of C_{PAV} and is updated upon successful completion of each calculation.

6.6.25 Spontaneous Rapid Shallow Breathing Index (f/V_T)

Spontaneous rapid shallow breathing index (f/V_T) is an indication of the patient's ability to breathe spontaneously. High values generally mean the patient is breathing rapidly, but with low tidal volumes. Low values generally indicate the inverse.

6.6.26 Spontaneous Inspiratory Time Ratio (T_I/T_{TOT})

In SPONT mode, spontaneous inspiratory time ratio (T_I/T_{TOT}) is the percentage of a spontaneous breath consumed by the inspiratory phase. Updated at the successful completion of a spontaneous breath.

6.6.27 Spontaneous Inspiratory Time ($T_{I\text{ SPONT}}$)

Spontaneous inspiratory time ($T_{I\text{ SPONT}}$) is the duration of the inspiratory phase of a spontaneous breath and updated at the end of each spontaneous breath. $T_{I\text{ SPONT}}$ is only calculated when the breathing mode allows spontaneous breaths and the breaths are patient-initiated.

6.6.28 PAV-based Total Airway Resistance (R_{TOT})

For a PAV+ breath, R_{TOT} is the change in pulmonary pressure for an applied change in total airway flow and updated upon the successful completion of each calculation. If the R_{PAV} value appears in parentheses as described at the beginning of this section, the R_{TOT} value also appears in parentheses.

6.6.29 Static Compliance (C_{STAT}) and Static Resistance (R_{STAT})

C_{STAT} is an estimate of the elasticity of the patient's lungs, expressed in mL/cmH₂O. It is computed during a mandatory breath.

R_{STAT} is the total inspiratory resistance across the artificial airway and respiratory system, displayed at the start of the next inspiration after the inspiratory pause maneuver. It is an estimate of how restrictive the patient's airway is, based on the pressure drop at a given flow, expressed in cmH₂O/L/s. R_{STAT} is computed during a VC mandatory breath with a square flow waveform.

C_{STAT} is calculated using this equation:

$$C_{STAT} = \frac{V_{pt}}{P_{ckt} - PEEP} - C_{ckt}$$

C_{STAT}	Static compliance	P_{ckt}	The pressure in the patient circuit measured at the end of the 100 ms interval defining the pause-mechanics plateau
V_{pt}	Total expiratory volume (patient and breathing circuit)	$PEEP$	The pressure in the patient circuit measured at the end of expiration
C_{ckt}	Compliance of the breathing circuit during the pause maneuver (derived from SST)		

R_{STAT} is calculated using this equation after C_{STAT} is computed and assuming a VC breath type with a square waveform:

$$R_{STAT} = \frac{\left[1 + \frac{C_{ckt}}{C_{STAT}}\right] \langle P_{PEAK} - P_{PL} \rangle}{\dot{V}_{pt}}$$

R_{STAT}	Static resistance	C_{STAT}	Static compliance
C_{ckt}	Compliance of the breathing circuit during the pause maneuver (derived from SST)	P_{PL}	Mean pressure in the patient circuit over the 100 ms interval defining the pause mechanics plateau
$\dot{V}_{pt}$	Flow into the patient during the last 100 ms of the waveform	P_{PEAK}	Peak circuit pressure

During the pause, the most recently selected graphics are displayed and frozen, to determine when inspiratory pressure stabilizes. C_{STAT} and R_{STAT} are displayed at the start of the next inspiration following the inspiratory pause and take this format:

C_{STAT} xxx

or

R_{STAT} yyy

Special formatting is applied if the software determines variables in the equations or the resulting C_{STAT} or R_{STAT} values are out of bounds:

- Parentheses () signify questionable C_{STAT} or R_{STAT} values, derived from questionable variables.
- Flashing C_{STAT} or R_{STAT} values are out of bounds.

- R_{STAT} ----- means resistance could not be computed, because the breath was not of a mandatory, VC type with square flow waveform.

6.6.30 Dynamic Compliance (C_{DYN})

C_{DYN} is a dynamic estimate of static compliance for each mandatory breath delivered.

6.6.31 Dynamic Resistance (R_{DYN})

R_{DYN} is a dynamic estimate of static resistance for each mandatory breath delivered.

6.6.32 C_{20}/C

C_{20}/C is the ratio of compliance of the last 20% of inspiration to the compliance of the entire inspiration.

6.6.33 End Expiratory Flow (EEF)

End expiratory flow (EEF) is a measurement of the end expiratory flow for an applicable breath.

6.6.34 Peak Spontaneous Flow (PSF)

Peak spontaneous flow is a measurement of the maximum inspiratory spontaneous flow for an applicable spontaneous breath

6.6.35 Displayed $O_2\%$

Displayed $O_2\%$ is the percentage of oxygen in the gas delivered to the patient, measured at the ventilator's outlet, upstream of the inspiratory filter. It is intended to provide a check against the set $O_2\%$ for alarm determination, and not as a measurement of oxygen delivered to the patient. $O_2\%$ data can be displayed as long as the O_2 monitor is enabled. If the monitor is disabled, dashes (--) are displayed. If a device alert occurs related to the O_2 monitor, a blinking 0 is displayed.

6.6.36 Inspiratory Time Constant ($3\tau_i$)

The $3\tau_i$ parameter is three times the product of the patient's resistance and compliance, and is used to determine the adequacy of the set inspiratory time (pressure ventilation), or the inspiratory time determined by the flow pattern, tidal volume, (V_T), peak flow ($\dot{V}_{MAX}$), and plateau time (T_{PL}) settings (volume ventilation).

7 Preventive Maintenance

7.1 Overview

This chapter contains information on maintenance of the Puritan Bennett™ 980 Series Ventilator. It includes:

- How to perform routine preventive maintenance procedures, including frequency
- How to clean, disinfect, or sterilize the ventilator and its main components
- How to store the ventilator for extended periods
- How to dispose of used parts

7.2 Ventilator Operational Time

The ventilator contains an hour meter that records the number of operational hours since the ventilator was manufactured. An additional timer tracks the number of hours since the last preventive maintenance activity was performed. Both the GUI and the status display show the number of hours before the next preventive maintenance is due.

7.3 Preventive Maintenance Intervals



WARNING:

To ensure proper ventilator operation, perform Preventive Maintenance intervals as specified in [Table 7-1.](#) on page 7-2 and [Table 7-4.](#) on page 7-15.

Table 7-1. Operator Preventive Maintenance Frequency

Part	Frequency	Maintenance
Patient circuit: inspiratory and expiratory limbs	Several times a day or as required by the institution's policy.	• Check both limbs for water accumulation. • Empty and clean.
Condensate vial (disposable), water trap	Several times a day or as required by the institution's policy.	Check and empty as needed.
Oxygen sensor calibration	Daily or as necessary	From the ventilator setup screen, touch the More Settings tab. To calibrate the oxygen sensor, touch Calibrate in the oxygen sensor area of the screen. See <i>Oxygen Sensor Calibration Testing (4.10.3)</i> on page 4-31 for information on testing the oxygen sensor calibration.
Inlet air filter bowl	• Replace bowl if it is cracked. • If any sign of moisture is visible, remove ventilator from use and contact service personnel.	
Disposable drain bag and tubing (single unit)	Discard when filled to capacity or when changing the patient circuit.	N/A
Disposable patient circuit tubing	Discard.	Discard per the institution's protocol.
Disposable exhalation filter	• After each patient use • After 15 days of continuous use	Replace with a new filter. Discard used filter according to the institution's protocol.
Drain bag clamp	After each patient use	Wipe clean with a cloth dampened with one of the cleaning agents listed in <i>Table 7-2</i> .
	Replace if the clamp is damaged.	
Drain bag tubing	When the drain bag is filled to capacity or when changing the patient circuit	Discard.
Neonatal door/adaptor	When gas pathway surfaces are visibly soiled or per institutional guidelines.	Disinfect per <i>Table 7-3</i> .
	When exterior surfaces of door are soiled.	Surface clean per <i>Surface Cleaning of Exterior Surfaces (7.4)</i> .
Battery	When transferring battery to or from another ventilator	Disinfect by wiping with a damp cloth using one of the solutions listed. See <i>Table 7-2</i> on page 7-4 for approved cleaning agents.
Battery	Every 3 years	Replace.

Table 7-1. Operator Preventive Maintenance Frequency (Continued)

Part	Frequency	Maintenance
Exhalation flow sensor assembly (EVQ)	Per institutional guidelines, or if SST flow sensor cross check fails. DO NOT STERILIZE the exhalation flow sensor assembly.	Disinfect. See <i>Component Cleaning and Disinfection (7.5)</i> on page 7-4 and <i>Exhalation Flow Sensor Assembly (EVQ) Disinfection (7.5.1)</i> on page 7-6. Run flow sensor calibration and SST.
	Every 100 disinfection cycles. A disinfection cycle is defined as one disinfection event as described in <i>Exhalation Flow Sensor Assembly (EVQ) Disinfection (7.5.1)</i> on page 7-6.	Replace. Discard used flow sensor according to the institution's protocol. Run flow sensor calibration and SST.
Compressor inlet air filter	Every 250 hours	Wash in mild soapy water and rinse thoroughly. Let air dry.

**Note:**

If problems occur after exhalation flow sensor replacement, reseal or readjust the flow sensor, and check the patient circuit integrity. If the problem persists, replace the flow sensor.

**Caution:**

Use specified cleaning and disinfecting agents and procedures for the appropriate part as instructed. Follow cleaning procedures outlined in *Surface Cleaning of Exterior Surfaces (7.4)* through *Exhalation Flow Sensor Assembly (EVQ) Disinfection (7.5.1)*.

7.4 Surface Cleaning of Exterior Surfaces

External surfaces of the GUI, BDU, and standard or compressor base may become soiled and should be cleaned periodically.

To clean the GUI, BDU, and base surfaces

1. Moisten a soft cloth with one of the surface cleaning agents listed or use Sani-Cloths (PDI, Inc.). See *Table 7-2.* on page 7-4.
2. Wipe the GUI, BDU, and base, removing any dirt or foreign substances.
3. Dry all components thoroughly.
4. If necessary, vacuum any cooling vents on the GUI and BDU with an electrostatic discharge (ESD)-safe vacuum to remove any dust.

Table 7-2. Surface Cleaning Agents

Part	Procedure	Comments/cautions
Ventilator exterior (including touch screen and flex arm)	Wipe clean with a cloth dampened with one of the cleaning agents listed below or equivalent. Use a damp cloth and water to rinse off chemical residue as necessary. • Mild dish washing detergent solution • Isopropyl alcohol (70% solution) • Bleach (10% solution) • Window cleaning solution (isopropyl alcohol and ammonia) • Ammonia (15% solution) • Hydrogen peroxide (3% solution) • Formula 409TM cleaner (Clorox Company) • CaviCideTM surface disinfectant (Metrex Research Corporation) • Control IIITM germicide (Maril Products, Inc.) • Mr. Muscle Window & Glass (SC Johnson) • Sani Cloths (PDI, Inc.) • [Propan-2-ol, Isopropanol, Isopropyl Alcohol]¹	• Do not allow liquid or sprays to penetrate the ventilator openings or cable connections. • Do not attempt to sterilize the ventilator by exposure to ethylene oxide (ETO) gas. • Do not use pressurized air to clean or dry the ventilator, including the GUI cooling vents. • Do not submerge the ventilator or pour cleaning solutions over or into the ventilator.
Ventilator cooling vents	Vacuum the vents at the back of the GUI and BDU to remove dust.	N/A

¹ Chemicals stated are the generic equivalents of Mr. Muscle Window & Glass

7.5 Component Cleaning and Disinfection



WARNING:

To avoid microbial contamination and potential performance problems, do not clean, disinfect, or reuse single-use or disposable components. Discard per local or institutional regulations.

Risks associated with reuse of single-patient use items include but are not limited to microbial cross-contamination, leaks, loss of part integrity, and increased pressure drop. When cleaning reusable components, do not use hard brushes or implements that could damage surfaces.

Table 7-3. Component Cleaning Agents and Disinfection Procedures

Part	Cleaning agent/procedure	Comments/cautions
EVQ	Before disinfection, presoak in EMpower™ Dual Enzymatic Solution (Metrex Inc.). Perform high level disinfection using liquid chemical disinfectant with any of the following agents: • Cidex™ (2.5%) (ASP¹) • Cidex™ OPA (0.55%) ASP¹ • Sporox™ II (Sultan) See <i>Exhalation Flow Sensor Assembly (EVQ) Disinfection (7.5.1)</i> on page 7-6 for specific instructions.	Do not drop the EVQ or handle roughly during disinfection or storage.
Neonatal door/adapter	Before disinfection, presoak in EMpower™ Dual Enzymatic Solution (Metrex Inc.). Perform high-level disinfection using liquid chemical disinfectant with any of the following agents: • Cidex™ (2.5%) (ASP¹) • Cidex™ OPA (0.55%) ASP¹ Follow the manufacturer's instructions.	N/A
Reusable patient circuit tubing	Disinfect per manufacturer's instructions for use.	• Inspect for nicks and cuts and replace if damaged. • Run SST to check for leaks when reinstalling the circuit or when installing a new circuit.
Breathing circuit in-line water traps	Disinfect per manufacturer's instructions for use.	• Inspect water traps for cracks and replace if damaged. • Run SST to check for leaks when reinstalling the circuit or when installing a new circuit.
Breathing circuit components	Disinfect per manufacturer's instructions for use.	• Inspect components for nicks and cuts and replace if damaged. • Run SST to check for leaks when reinstalling the circuit or when installing a new circuit.
Inlet air filter bowl	Wash the bowl with mild soap solution, if needed.	• Avoid exposing the inlet air filter bowl to aromatic solvents, especially ketones. • Replace if cracks or crazing are visible.
Battery	Wipe with a damp cloth using one of the cleaning agents listed. See <i>Table 7-2.</i> on page 7-4.	Do not immerse the battery or get the contacts wet.

Table 7-3. Component Cleaning Agents and Disinfection Procedures (Continued)

Part	Cleaning agent/procedure	Comments/cautions
Cooling fan filter	Clean every 250 hours or as necessary.	Wash in mild soap solution, rinse, and air dry.
Other accessories	Follow manufacturer's instructions for use.	N/A

1 Advanced Sterilization Products.

To clean and disinfect parts

1. Wash parts in warm water using a mild soap solution.
2. Thoroughly rinse parts in clean, warm water (tap water is acceptable) and wipe dry.
3. Clean or disinfect ventilator surfaces and component parts per the procedures listed for each component. See [Table 7-2.](#) and [Table 7-3.](#) on pages 7-4 and 7-5 for lists of acceptable cleaning and disinfecting agents.
4. Visually inspect the components for cracks or other damage prior to use.
5. Dispose of damaged parts according to the institution's policy.



Note:

Steps 1 through 3 above do not apply to the EVQ. See [Exhalation Flow Sensor Assembly \(EVQ\) Disinfection \(7.5.1\)](#) for disinfection instructions.

Whenever replacing or reinstalling a component, run SST before ventilating a patient.

7.5.1 Exhalation Flow Sensor Assembly (EVQ) Disinfection



Note:

Follow the institution's infection control protocol for handling, storage, and disposal of potentially bio-contaminated waste.



Caution:

To avoid damaging the hot film wire, do not insert fingers or objects into the center port when disinfecting the EVQ.

The EVQ contains the exhalation flow sensor electronics, exhalation valve diaphragm, exhalation filter seal, and pressure sensor filter. The exhalation flow sensor electronics consist of the hot film wire and the thermistor.

**Caution:**

To avoid damage to the exhalation flow sensor element:

- Do not touch the hot film wire or thermistor in the center port.
- Do not vigorously agitate fluid through the center port while immersed.
- Do not forcefully blow compressed air or any fluid into the center cavity.
- Do not drop or handle roughly during disinfection, replacement, or storage.

**WARNING:**

Damaging the flow sensor's hot film wire or thermistor in the center port can cause the ventilator's spirometry system to malfunction.

Figure 7-1. EVQ

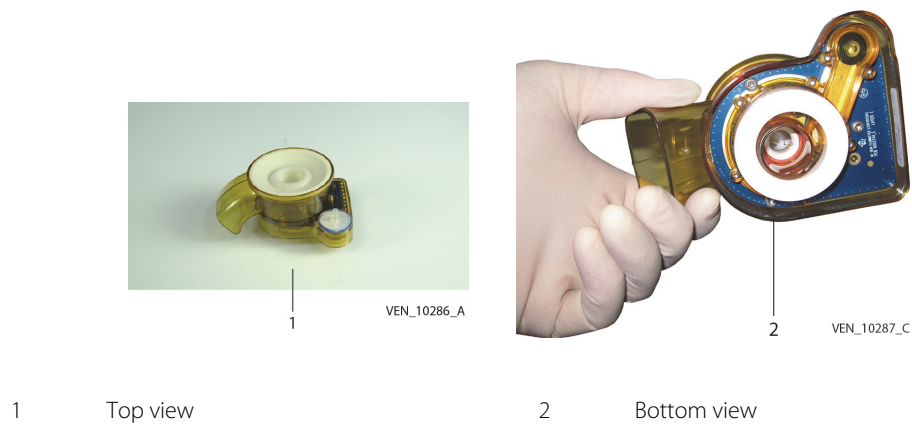
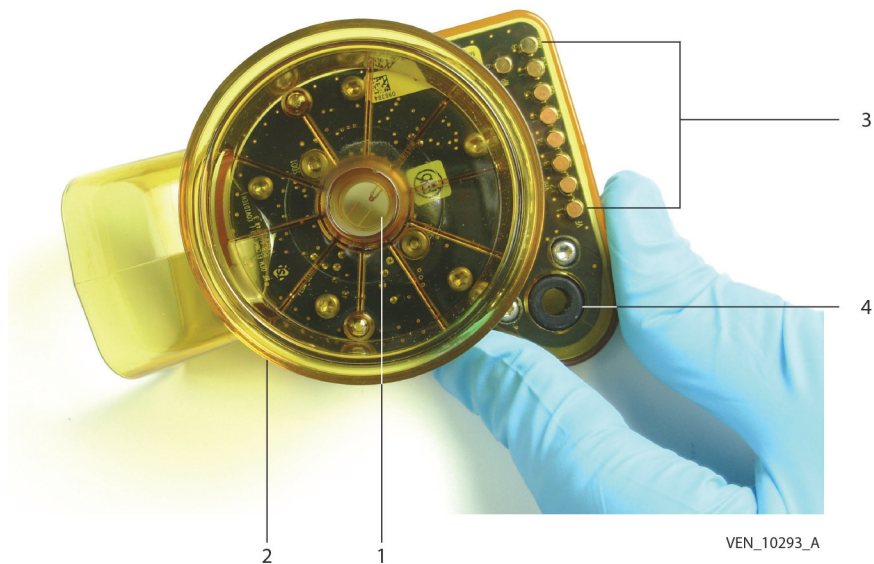


Figure 7-2. EVQ Components



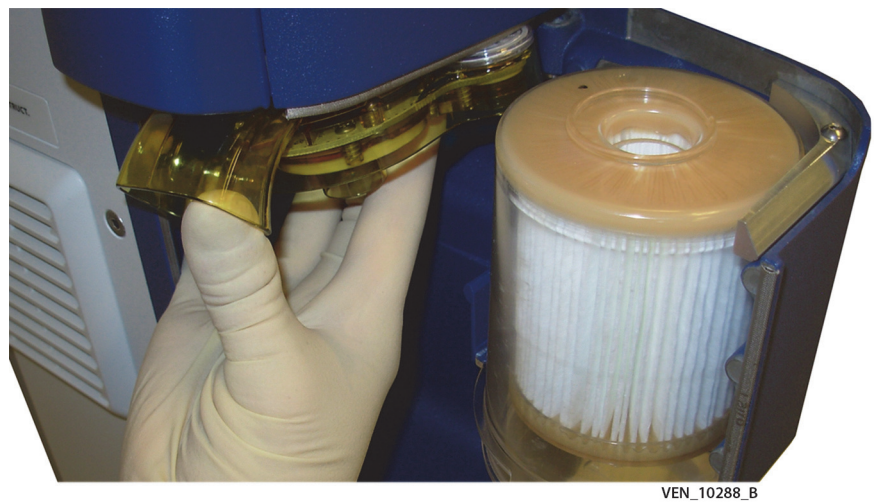
- | | | | |
|---|------------------------------|---|---------------------|
| 1 | Hot film wire and thermistor | 3 | Electrical contacts |
| 2 | Diaphragm sealing surface | 4 | Filter grommet |

Removal

To remove the EVQ

1. Lift up on the exhalation filter latch and open the exhalation filter door.
2. With thumb inserted into the plastic exhalation port and four fingers under the EVQ, pull it down until it snaps out. **To avoid damaging the flow sensor element, do not insert fingers into the center port.**

Figure 7-3. EVQ Removal



**WARNING:**

Prior to cleaning and disinfection, remove and dispose of the disposable components of the exhalation flow sensor assembly. See [To reassemble the EVQ components](#), page 7-12 for re-assembly instructions.

To remove disposable components of the EVQ

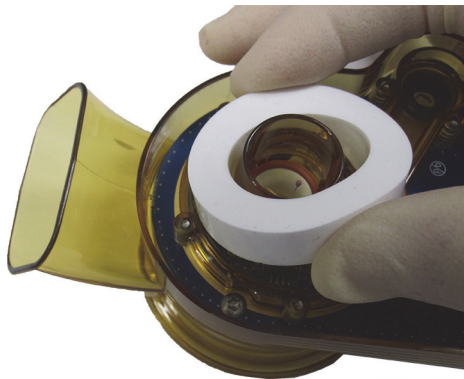
1. Remove and discard the exhalation valve diaphragm, the exhalation filter seal, and the pressure sensor filter. Lift the exhalation filter seal out of the exhalation flow sensor to remove it.

Figure 7-4. Exhalation Valve Diaphragm Removal



VEN_10289_A

Figure 7-5. Exhalation Filter Seal Removal



VEN_10290_B

Figure 7-6. Pressure Sensor Filter Removal

VEN_10291_A

2. Dispose of removed items according to the institution's protocol. Follow local governing ordinances regarding disposal of potentially biocontaminated waste.

Disinfection

**WARNING:**

Do not steam autoclave the EVQ or sterilize with ethylene oxide gas. Either process could cause the ventilator's spirometry system to malfunction when reinstalled in the ventilator.

**WARNING:**

Use only the disinfectants described. See [Table 7-3](#), on page 7-5. Using disinfectants not recommended by Covidien may damage the plastic enclosure or electronic sensor components, resulting in malfunction of the ventilator's spirometry system.

**WARNING:**

Follow disinfectant manufacturer's recommendations for personal protection (such as gloves, fume hood, etc.) to avoid potential injury.

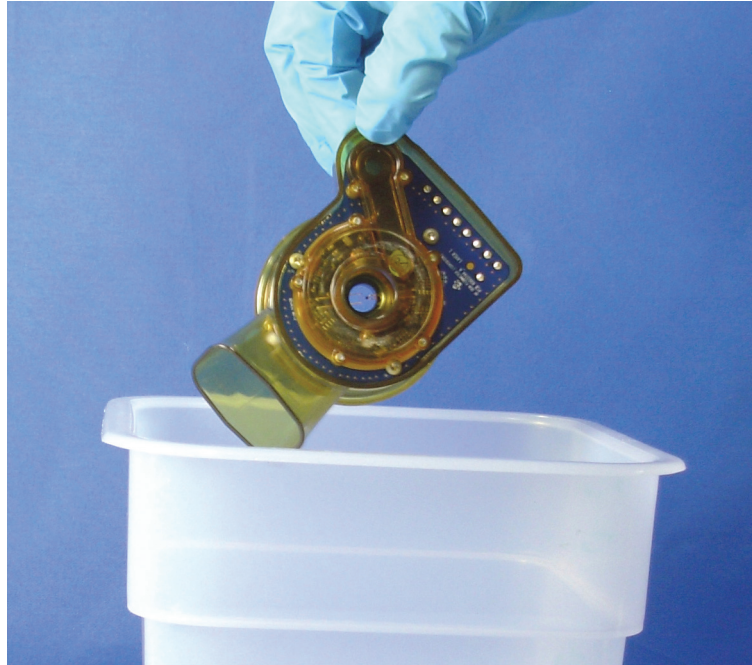
1. Presoak the EVQ in the enzymatic solution. See [Table 7-1](#), on page 7-2. The purpose for this presoak is to break down any biofilm that may be present. Follow manufacturer's instructions regarding duration of soak process.

**Caution:**

Do not use any type of brush to scrub the EVQ, as damage to the flow sensing element could occur.

2. Rinse in clean, deionized water.
3. Prepare the chemical disinfectant according to the manufacturer's instructions or as noted in the institution's protocol. See [Table 7-3](#), on page 7-5 for the proper disinfecting agents.
4. Immerse the exhalation flow sensor in the disinfectant solution, oriented as shown in [Figure 7-7](#), and rotate to remove trapped air bubbles in the its cavities. Keep immersed for the minimum time period by the manufacturer or as noted in the institution's protocol.

Figure 7-7. Immersion Method



5. At the end of the disinfecting immersion period, remove and drain all disinfectant. Ensure all cavities are completely drained.

Rinsing

1. Rinse the EVQ using clean, deionized water in the same manner used for the disinfection step.
2. Drain and **repeat rinsing three times** with clean, deionized water.



WARNING:

Rinse according to manufacturer's instructions. Avoid skin contact with disinfecting agents to prevent possible injury.

3. After rinsing in deionized water, immerse in a clean isopropyl alcohol bath for approximately 15 seconds. Slowly agitate and rotate to empty air pockets.

Drying

1. Dry in a low temperature warm air cabinet designed for this purpose. Covidien recommends a convective drying oven for this process, with temperature not exceeding 60°C (140°F).



Caution:

Exercise care in placement and handling in a dryer to prevent damage to the assembly's flow sensor element.

Inspection

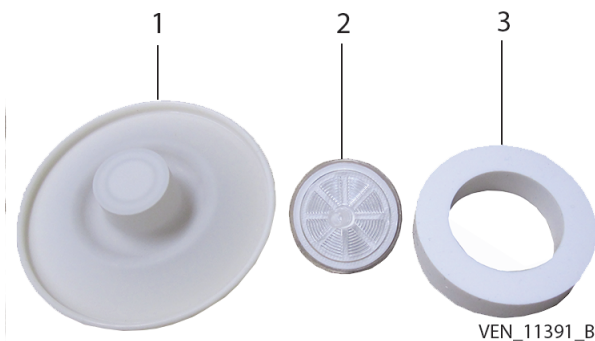
See [Figure 7-2.](#) on page 7-8 while inspecting the EVQ.

1. Inspect the plastic body, diaphragm sealing surface, filter grommet and the seal groove on the bottom side for any visible damage, degradation, or contamination.
2. Inspect electrical contacts for contaminating film or material. Wipe clean with a soft cloth if necessary.
3. Inspect the hot film wire and thermistor in the center port for damage and for contamination. **DO NOT ATTEMPT TO CLEAN EITHER OF THESE.** If contamination exists, rinse again with deionized water. If rinsing is unsuccessful or hot film wire or thermistor is damaged, replace the EVQ.

7.5.2 EVQ Reassembly

[Figure 7-8.](#) shows the reprocessing kit:

Figure 7-8. EVQ Reprocessing Kit



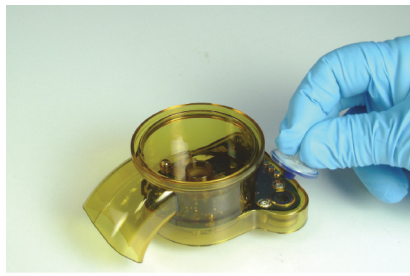
1 Diaphragm

3 Exhalation filter seal

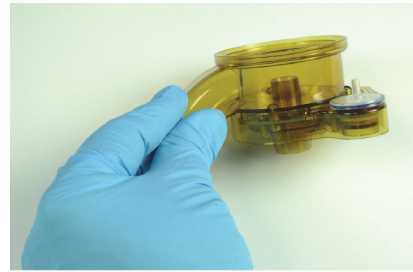
2 Pressure sensor filter

To reassemble the EVQ components

1. After drying the EVQ, remove the pressure sensor filter from the reprocessing kit and install its large diameter into the filter grommet with a twisting motion until flush with the plastic valve body, as shown. The narrow end faces out.

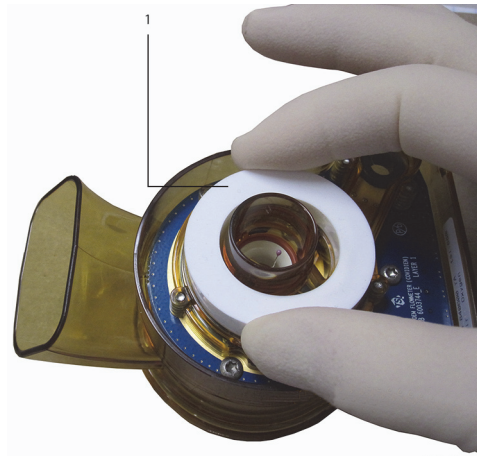
Figure 7-9. Installing the Pressure Sensor Filter

VEN_10295_A



VEN_10294_A

2. Remove the exhalation filter seal from the kit and turn the assembly so its bottom is facing up.
3. Install the seal into the exhalation flow sensor as shown in [Figure 7-10](#). Ensure that the seal fits completely within the recess and sits flat.

Figure 7-10. Installing the Exhalation Filter Seal

1 Exhalation filter seal

4. Remove the diaphragm from the kit and install it. See [Figure 7-11](#).

Figure 7-11. Installing the Diaphragm

1 Diaphragm bead located in the EVQ's groove.

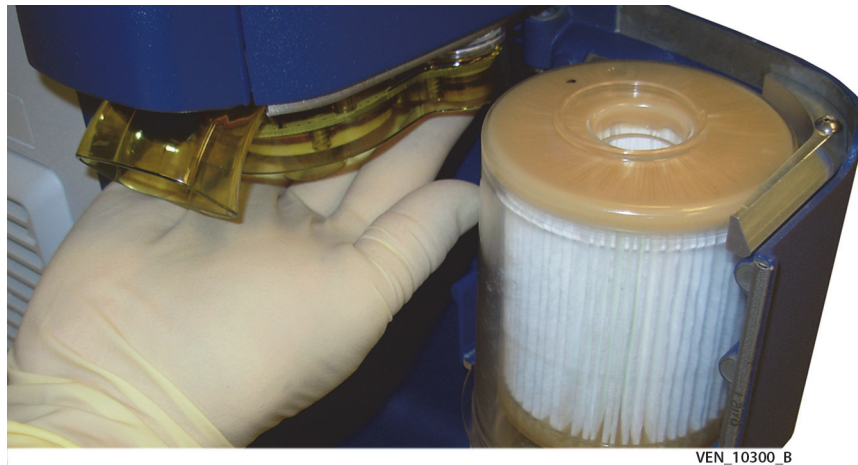
5. Carefully inspect component placement and the complete assembly.

7.5.3 EVQ Replacement

1. Replace the EVQ any time if cracked or damaged in use. If a malfunction occurs during SST or EST, first readjust or reseal the exhalation flow sensor. If SST or EST errors still occur, replace the exhalation flow sensor.
2. Replace the assembly if damage to the hot film wire or thermistor in the center port is noted.
3. Perform required calibrations. See [Table 7-1.](#) on page [7-2.](#)

To install the EVQ into the ventilator

1. With the exhalation filter door open, insert the assembly directly under the exhalation valve and push straight up until it snaps into place. See [Figure 7-12.](#) To avoid damaging the hot film wire, do not insert fingers into any opening.
2. Install the exhalation filter by sliding it onto the tracks in the door, and orienting the filter's **from patient** port through the hole in the door.
3. Close the exhalation filter door and lower the exhalation filter latch.

Figure 7-12. Installing the EVQ

VEN_10300_B

4. Run flow sensor calibration and SST after EVQ reinstallation.

7.5.4 Storage

1. Pretest the EVQ before storage by installing it into the ventilator and running SST to test the integrity of the breathing system. See *To run SST*, page 3-43.
2. After performing SST, remove the assembly and place it into a protective bag or similar covered container.

7.6 Service Personnel Preventive Maintenance

Covidien recommends only qualified service personnel perform preventive maintenance activities. Complete details are described in the *Puritan Bennett™ 980 Series Ventilator Service Manual*.

At ventilator startup, and in Service mode, the GUI and status display indicate when there are 500 hours or less before preventive maintenance is due.

Table 7-4. Service Preventive Maintenance Frequency

Frequency	Part	Maintenance
Every 12 months	Entire ventilator	• Run extended self test (EST). Test alarm system. See Alarm Testing (6.5.5) on page 6-8. • Perform electrical safety test and inspect ventilator for mechanical damage and for label illegibility.
	Primary and extended batteries	Perform battery test (as part of EST in Service mode).

Table 7-4. Service Preventive Maintenance Frequency (Continued)

Frequency	Part	Maintenance
When ventilator location changes by 1000 feet of altitude	Atmospheric pressure transducer	Perform atmospheric pressure transducer calibration.
Every 3 years, or when battery test fails, or when EST indicates battery life has been exhausted	Primary battery	Replace primary batteries (ventilator and compressor). Actual battery life depends on the history of use and ambient conditions.
	Extended batteries	Replace extended batteries (ventilator and compressor). Actual battery life depends on the history of use and ambient conditions.
Every 10 000 operational hours	Internal inspiratory filter	Replace. Do not attempt to autoclave or reuse.
	BDU 10K PM kit, p/n 10097275	Replace the components included in the 10K PM kit. Fill out the PM label and attach to the device. See the <i>Puritan Bennett™ 980 Series Ventilator Service Manual</i> , Table 7-1 for information on tests required after installation of the BDU 10K PM Kit.
Every year from date of installation, or sooner as needed.	Oxygen sensor	• Replace the oxygen sensor as needed. • Calibrate after replacement. • Actual sensor life depends on operating environment. Operation at higher temperature or O₂% levels will result in shorter sensor life.

7.7 Safety Checks

Qualified service personnel should perform extended self test (EST) on the ventilator after servicing it at the intervals specified in [Table 7-4](#). See the *Puritan Bennett™ 980 Series Ventilator Service Manual* for details on performing EST.

7.8 Inspection and Calibration

Ventilator inspection and calibration should be performed by qualified service personnel at the intervals specified in [Table 7-4](#).

7.9 Documentation

Qualified service personnel should manually enter the service date, time, and nature of repair/preventive maintenance performed into the log using a keyboard on the GUI.

To manually document a service or preventive maintenance activity

1. Enter Service Mode.
2. Touch the Logs tab.
3. Touch the Service Log tab.
4. Touch Add Entry, and using the buttons to the right of each line, complete the entry.
5. Touch Accept when complete.

7.10 Storage for Extended Periods

To store the ventilator

1. Clean the unit thoroughly.
2. Remove any batteries and accessories.

To return the ventilator to service

1. Replace batteries.
2. Recharge batteries prior to patient ventilation. If batteries are older than 3 years, use new batteries.
3. Perform EST and SST prior to patient ventilation.

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8 Troubleshooting

8.1 Overview

This chapter contains information regarding ventilator logs on the Puritan Bennett™ 980 Series Ventilator.



WARNING:

To avoid a potential electrical shock, do not attempt to correct any electrical problem with the ventilator while it is connected to AC power.

8.2 Problem Categories

For the *Puritan Bennett™ 980 Series Ventilator Operator's Manual*, troubleshooting is limited to responding to ventilator alarms and reviewing various ventilator logs. For detailed alarm information, including how to respond to alarms, see Chapter 6 to address individual alarms that may occur during ventilator use. Qualified service personnel who have attended the Covidien training class for Puritan Bennett™ 980 Series Ventilators should consult the *Puritan Bennett™ 980 Series Ventilator Service Manual* for detailed repair information and an interpretation of ventilator diagnostic codes.

8.3 How to Obtain Ventilator Service

To obtain service for the ventilator, call Covidien Customer Service at 1 800 635 5267 and follow the prompts.

8.4 Used Part Disposal

Follow local governing ordinances and recycling plans regarding disposal or recycling of device components. Discard all damaged parts removed from the ventilator during the maintenance procedures according to your institution's protocol. Sterilize contaminated parts before nondestructive disposal.

8.5 Ventilator Logs



The ventilator uses various logs to store event information for later retrieval when managing a patient's treatment. Some of the logs are accessible during ventilation and some logs are only available to Covidien personnel when the ventilator is in Service mode. The *Puritan Bennett™ 980 Series Ventilator Service Manual* gives more details regarding logs available to qualified service personnel.

When New Patient is selected during ventilator setup, patient data, ventilator settings, and alarm logs are cleared, but this information is available for service personnel review following New Patient selection when the ventilator is set up.



- **Alarms Log** — The alarm log records up to 1000 alarms that have occurred, whether they have been reset or autoreset, the priority level, and their analysis messages. The alarm log is accessible during normal ventilation and in Service mode. A date- and time-stamped entry is made in the log whenever an alarm is detected, escalated, reset or auto-reset. An entry is also made when an audio paused interval begins, ends, or is canceled. If one or more alarms have occurred since the last time the alarm log was viewed, a triangular icon appears on the GUI indicating there are unread items. The alarm log is stored in non-volatile memory (NVRAM) and may be re-displayed after the ventilator's power is cycled. If the ventilator enters backup ventilation (BUV) for any reason, this is also entered into the alarm log. The alarm log is cleared by setting the ventilator up for a new patient.
- **Settings Log** — The settings log records changes to ventilator settings for retrospective analysis of ventilator-patient management. The time and date, old and new settings, and alarm resets are recorded. A maximum of 500 settings changes can be stored in the log. The settings log is cleared when the ventilator is set up for a new patient. The settings log is accessible in normal ventilation mode and Service mode.
- **Patient Data Log** — This log records every minute (up to 4320 patient data entries) consisting of date and time of the entry, patient data name, and the patient data value during ventilator operation. It is cleared when the ventilator is set up for a new patient. Three tabs are contained in the patient data log:
 - **Vital Patient data** — The log contains the same information that the clinician has configured in the patient data banner at the top of the GUI. If the patient data parameters in the banner are changed, these changes are reflected the next time the patient data log is viewed.
 - **Additional Patient Data – 1** — This log corresponds to the patient data parameters set on page one of the additional patient data banner. A total of 15 parameters are stored here, consisting of date and time of the entry (recorded every minute), patient data name, and the patient data value during ventilator operation.
 - **Additional Patient Data – 2** — This log corresponds to the patient data parameters set on page two of the additional patient data banner. A total of 10 parameters are stored here, consisting of date and time of the entry (recorded every minute), patient data name, and the patient data value during ventilator operation.
- **Diagnostic Log** — The Diagnostic Log is accessible during normal ventilation and Service modes and contains tabs for the System Diagnostic Log (default), the System Communication Log, and the EST/SST Diagnostic Log. The diagnostic log contains tabs for the following:

- **System Diagnostic Log** — The System Diagnostic Log contains the date and time when an event occurred, the type of event, the diagnostic codes associated with each fault or error that occurred, the type of error that occurred, and any notes. The diagnostic log is not cleared when the ventilator is set up for a new patient.
- **System Communication Log** — This log contains information generated by the ventilator's communication software. See the *Puritan Bennett™ 980 Series Ventilator Service Manual*, 10128204, for a description of information contained in the System Communication Log.
- **EST/SST Diagnostic Log** — The EST/SST diagnostic log displays the time, date, test/event, system code, type, and notes.
- **EST/SST Status Log** — The EST and SST status log displays the time, date, test, test status (passed or failed).
- **General Event Log** — The general event log contains ventilator-related information not found in any other logs. It includes date and time of compressor on and off, changes in alarm volume, when the ventilator entered and exited Stand-By, GUI key presses, respiratory mechanics maneuvers, O₂ calibration, patient connection, elevate O₂, and warning notifications. The General event log can display up to 256 entries and is not cleared upon new patient setup.
- **Service Log** — The service log is accessible during normal ventilation and Service modes and contains the nature and type of the service, reference numbers specific to the service event (for example, sensor and actuator ID numbers), manual and automatic serial number input, and the time and date when the service event occurred. It is not cleared upon new patient setup.

To view ventilator logs



1. Touch the clipboard icon in the constant access icon area of the GUI. The log screen appears with tabs for the various logs.
2. Touch the tab of the log desired.
3. View the information for each parameter desired.

Figure 8-1. Log Screen



VEN_11360_D

- 1 Individual logs tabs
- 2 Pages contained in the log being viewed

Ventilator logs can be saved by entering Service mode, and downloading them via the Ethernet port. See the *Puritan Bennett™ 980 Series Ventilator Service Manual* for instructions on downloading ventilator logs.

8.6 Diagnostic Codes

Refer to the diagnostic log for the codes generated during patient ventilation. For more information on the diagnostic codes, contact Covidien Technical Support.

9 Accessories

9.1 Overview

This chapter includes accessories that can be used with the Puritan Bennett™ 980 Series Ventilator. See [Table 9-1](#) on page 9-3 for part numbers of any items available through Covidien.

The following commonly available accessories from the listed manufacturers can be used with the ventilator system:

- **Filters**—DAR/Covidien, Puritan Bennett
- **Heated Humidification Systems**—Hudson RCI/Teleflex, Fisher & Paykel
- **Patient Circuits**—commonly available breathing circuits with standard ISO 15 mm/22 mm connection for neonatal, pediatric, and adult patients. Manufacturers include Fisher & Paykel, DAR, and Hudson RCI/Teleflex.
- **Masks**—ResMed, Respironics, Fisher & Paykel
- **Patient Monitoring Systems**—See [Connectivity to External Systems \(5.9\)](#) on page 5-19 for information on systems that can be used with the ventilator
- **Nasal Interfaces**—Hudson RCI/Teleflex, Fisher & Paykel, Argyle
- **Compressed air filter and water trap**—Covidien



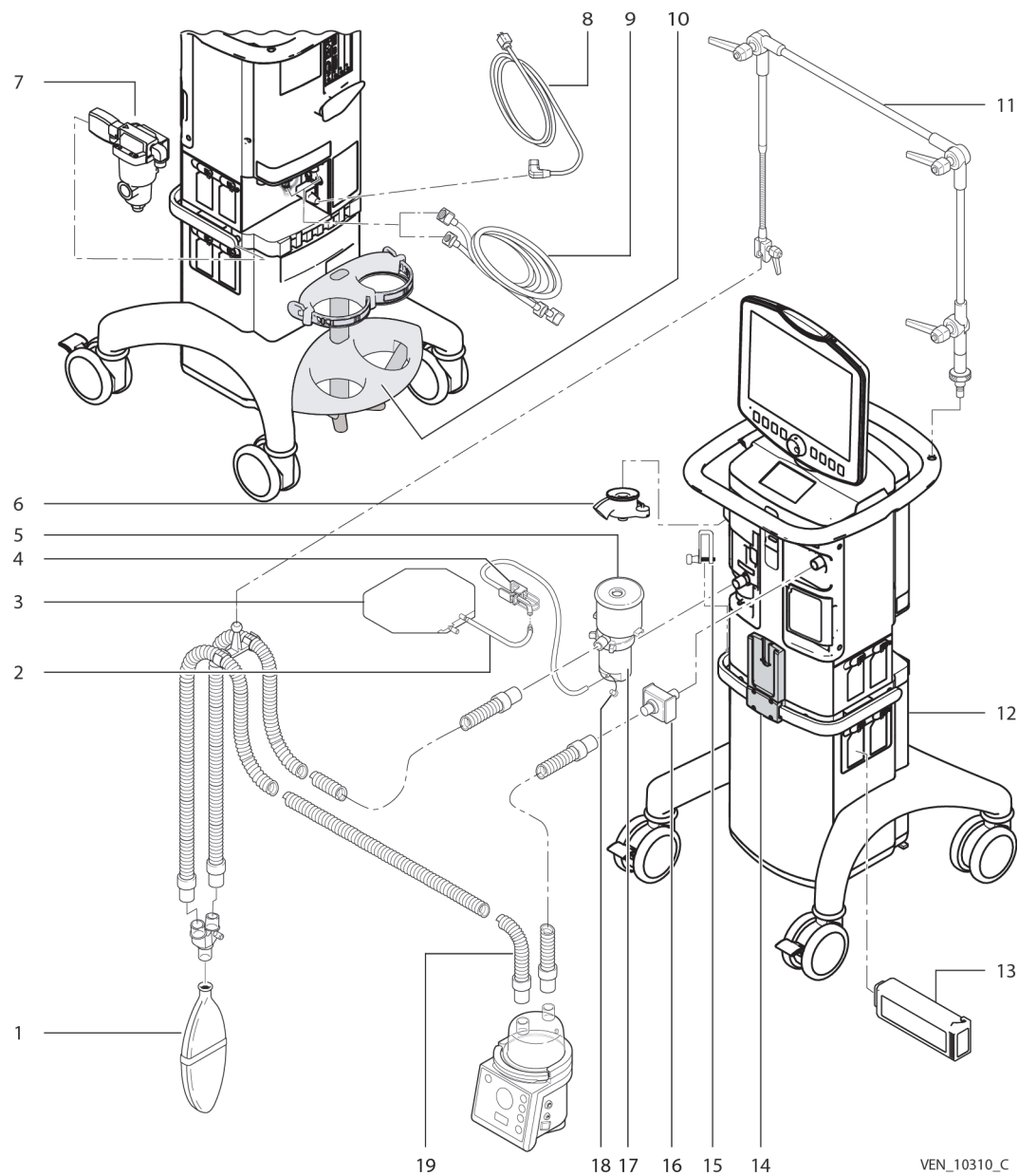
WARNING:

The Puritan Bennett™ 980 Series Ventilator contains phthalates. When used as indicated, very limited exposure to trace amounts of phthalates may occur. There is no clear clinical evidence that this degree of exposure increases clinical risk. However, to minimize risk of phthalate exposure in children and nursing or pregnant women, this product should only be used as directed.

9.2 General Accessory Information

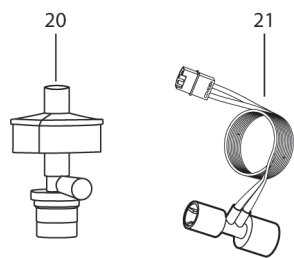
The patient circuit support arm (flex arm) can be fastened to the ventilator handle on either the right or left side. Flex arms used on the Puritan Bennett™ 840 Ventilator System can also be used on the Puritan Bennett™ 980 Series Ventilator System.

Figure 9-1. Ventilator with Accessories



VEN_10310_C

Figure 9-2. Additional Accessories



VEN_11712_B

See [Figure 9-1.](#) on page 9-2 and [Figure 9-2.](#) for the parts listed in the following table:



Note:

Occasionally, part numbers change. If in doubt about a part number, contact your local Covidien representative.



Note:

The ventilator is designed with a semi-automated short self test (SST) procedure that, in addition to other tests, measures compliance, resistance, and leak for the ventilator breathing circuit assembly (inspiratory filter, breathing circuit, humidifier chamber (as applicable), exhalation filter, and exhalation flow sensor). Reference [SST \(Short Self Test\)](#), page 3-41.

When SST is performed according to the instructions provided in [SST \(Short Self Test\) \(3.9.1\)](#), a ventilator breathing circuit assembly that passes SST for a particular patient type (adult, pediatric, or neonatal) will allow the ventilator to operate within specification for that same patient type. Refer to [Table 11-4.](#) for acceptable compliance and resistance ranges.

Table 9-1. Accessories and Options

Item number	Accessory or option description	Part number
1	Test lung	10005490
2	Drain bag tubing (package of 10)	4-048493-00
3	Drain bag (package of 25)	4-048491-00
4	Drain bag tubing clamp, reusable (package of 5)	4-048492-00
5	Pediatric–adult exhalation filtration system (carton of 12), disposable	10043551
6	980 FRU, exhalation flow sensor	10097468
7	Wall air water trap	10086051
8	Power cord, 10A, RA, USA	10081056
9	Air hose assembly; United States	4-006541-00
	Oxygen hose assembly; United States	4-001474-00
10	Cylinder mount for compressed air and O ₂ gas	10086050
11	Flex arm assembly	10005187
12	FRU, caster base assembly	980CASBAS
13	Rechargeable lithium-ion battery	10086042
14	Humidifier bracket	10086049
15	Drain bag clip	10087137
16	Inspiratory bacterial filter, disposable, (carton of 50) (DAR)	351U5856
17	Condensate vial, permanently attached to disposable exhalation filter	--

Table 9-1. Accessories and Options (Continued)

Item number	Accessory or option description	Part number
18	Condensate vial drain cap	4-074613-00
19	Assy, patient circuit, adult dual heated wire, disposable, for F&P MR850 (Medtronic/DAR) Adapter cable: 111/1149	304S14300
	Assy, patient circuit, single heated wire, adult, disposable, for F&P MR850 (Medtronic/DAR) Adapter cable: 111/1146	304S14402Z
	Ventilator breathing circuit, adult, dual heated system, disposable (Fisher & Paykel) ¹	RT280
	Ventilator breathing circuit, adult, dual heated, no water traps, disposable (Hudson RCI/Teleflex) ¹	870-35 KIT
	Assy, patient circuit, with single water trap, heated insp. limb, pediatric, disposable, F&P MR850 (Medtronic/DAR) Adapter cable: 111/1146	306S8987
	Assy, patient circuit, dual heated wire, pediatric, disposable, F&P MR850 (Intersurgical) ¹	550S850
	Ventilator breathing circuit, pediatric, dual heated, disposable (Hudson RCI/ Teleflex) ¹	780-24
	Assy, patient circuit, neonatal, single heated wire, disposable, incubator use, for F&P MR850 (Medtronic/DAR) Adapter cable: 111/1146	307S9910
	Assy, patient circuit, neonatal, single heated wire, disposable, not for incubator use, for F&P MR850 (Medtronic/DAR) Adapter cable: 111/1146	307/8682
	Ventilator breathing circuit, neonatal, heated insp tube, disposable (Hudson RCI/Teleflex) ¹	780-06
	Ventilator breathing circuit, neonatal, dual heated system, dual water traps, disposable (Hudson RCI/Teleflex) ¹	780-15
	Ventilator breathing circuit, neonatal, dual heated system, disposable (Fisher & Paykel) ¹	RT265
20	Neonatal exhalation filtration system, disposable, with condensate vial	4-076900-00
21	Proximal Flow monitoring sensor (disposable, 10/box)	10047078
Not shown	Exhalation valve module reprocessing kit (6/carton)	10086048
Not shown	Gold standard test circuit, 21 inch (for performing EST)	4-018506-00
Hardware options		
Not shown	Proximal Flow monitoring option	10084331
Not shown	980, USB flash drive	PT00011076

Table 9-1. Accessories and Options (Continued)

Item number	Accessory or option description	Part number
Not shown	End tidal CO ₂ monitoring option	10084332
Software options		
Not shown	NeoMode 2.0 software	10086743
Not shown	NeoMode 2.0 software upgrade	10096526

- ¹ The part numbers listed reflect the breathing circuit manufacturer part numbers and are subject to change. Refer to breathing circuit manufacturer for exact circuit details regarding ordering information.

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10 Theory of Operations

10.1 Overview

This chapter provides specific details on breath delivery functions of the Puritan Bennett™ 980 Series Ventilator. The chapter is organized as shown below.

Section number	Title	Page
10.1	<i>Overview</i>	<i>10-1</i>
10.2	<i>Theoretical Principles</i>	<i>10-3</i>
10.3	<i>Applicable Technology</i>	<i>10-3</i>
10.4	<i>Inspiration—Detection and Initiation</i>	<i>10-4</i>
10.5	<i>Exhalation—Detection and Initiation</i>	<i>10-7</i>
10.6	<i>Compliance and BTPS Compensation</i>	<i>10-10</i>
10.7	<i>Mandatory Breath Delivery</i>	<i>10-13</i>
10.8	<i>Spontaneous Breath Delivery</i>	<i>10-18</i>
10.9	<i>A/C Mode</i>	<i>10-25</i>
10.10	<i>SIMV Mode</i>	<i>10-28</i>
10.11	<i>Spontaneous (SPONT) Mode</i>	<i>10-32</i>
10.12	<i>Apnea Ventilation</i>	<i>10-33</i>
10.13	<i>Detecting Occlusion and Disconnect</i>	<i>10-37</i>
10.14	<i>Respiratory Mechanics</i>	<i>10-40</i>
10.15	<i>Ventilator Settings</i>	<i>10-46</i>
10.16	<i>Safety Net</i>	<i>10-59</i>
10.17	<i>Power On Self Test (POST)</i>	<i>10-63</i>
10.18	<i>Short Self Test (SST)</i>	<i>10-63</i>
10.19	<i>Extended Self Test (EST)</i>	<i>10-64</i>

**WARNING:**

The ventilator offers a variety of breath delivery options. Throughout the patient's treatment, the clinician should carefully select the ventilation mode and settings to use for that patient based on clinical judgment, the condition and needs of the patient, and the benefits, limitations, and characteristics of the breath delivery options. As the patient's condition changes over time, periodically assess the chosen modes and settings to determine whether or not those are best for the patient's current needs.

The gas supplies to which the ventilator are connected must be capable of delivering 200 L/min flow with the supply pressure between 241.8 kPa to 599.8 kPa (35 psig and 87 psig). These supplies may be compressed air from an external source (wall or bottled) air or oxygen. (An optional compressor is available to be used as an external air source.)

Air and oxygen hoses connect directly to fittings at the rear of the breath delivery unit (BDU). The flow of each gas is metered by a proportional solenoid (PSOL) valve to achieve the desired mix in the mix module. The flow through each PSOL is monitored by separate flow sensors to ensure the accuracy of the mix. The mixed gases then flow to the inspiratory module.

The blended gas in the inspiratory module is metered by the breath delivery PSOL and monitored by the breath delivery flow sensor to ensure that the gas is delivered to the patient according to the settings specified by the operator. Delivered tidal volumes are corrected to standard respiratory conditions (BTPS) to ensure consistent interpretation by the clinician. The inspiratory module also incorporates the safety valve, which opens to vent excess pressure and allows the patient to breathe room air (if able to do so) in the event of a serious malfunction.

An optional compressor, capable of delivering flows of 140 L/min (BTPS) and minute volumes of up to 40 L/min (BTPS), can be connected to the ventilator. Gas mixing occurs in the accumulator, protected by a relief valve. A one-way valve allows a maximum reverse flow into the gas supply system up to 100 mL/min under normal conditions.

Air and O₂ gases travel through PSOLs, flow sensors, and one-way valves, and are mixed in the mix module (according to the operator-set O₂ concentration), which also has a pressure-relief valve. From here, the gas flows through another PSOL, to the inspiratory pneumatic system, where it passes by a safety valve, then through a one-way valve, an internal bacteria filter, an external bacteria filter, through the humidifier, if used, and then to the patient via the connected breathing circuit.

During exhalation, the gas flows through the expiratory limb of the breathing circuit, through a condensate vial, a bacteria filter, through the exhalation flow sensor, through the exhalation valve, and out the **exhaust** port. The exhalation valve actively controls PEEP while minimizing pressure overshoots and relieving excess pressures.

Pressure transducers in the inspiratory pneumatic system (**PI**) and exhalation compartment (**PE**) monitor pressures for accurately controlling breath delivery.

10.2 Theoretical Principles

This theory of operations is described mainly from a clinical standpoint, discussing how the ventilator responds to various patient inputs, but also including a general description of the ventilator's components and how they work together to manage breath delivery.

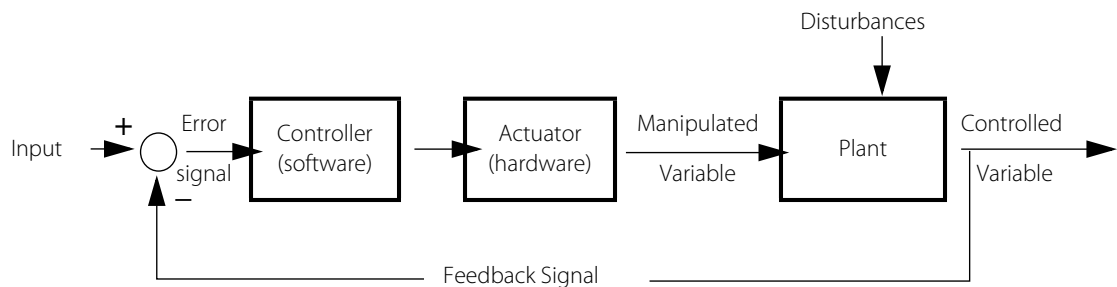
10.3 Applicable Technology

The ventilator's control is provided by breath delivery (BD) and graphical user interface (GUI) central processing units (CPUs). The BD CPU manages all breath delivery functions and provides background checks on the subsystems required for breath delivery. The GUI CPU controls the primary display, operator input devices, and the alarm system. The status display, a small, non-interactive LCD display located on the breath delivery unit (BDU) is controlled by its own processor. See [Status Display](#), page 2-25 for more information.

USB, Ethernet, and HDMI interfaces are provided on the ventilator. The USB interface supports items such as transferring data to an external monitor via a serial -over-USB protocol and saving screen captures to a memory storage device or flash drive. See [To configure Comm ports](#), page 5-4 for information on serial-over-USB data transfer. The Ethernet interface is used by qualified service personnel for accessing ventilator logs and performing software options installation, and the HDMI interface provides the ability to display the GUI screen on an external video display device.

Pressure and flow sensors in the inspiratory and expiratory modules to manage breath delivery processes. Sensor signals are used as feedback to the breath delivery PSOL and exhalation valve controllers. Additional flow and pressure sensors are used in the mix module to control the breathing gas composition. In addition, gas temperature is measured for temperature compensation of flow readings. Atmospheric pressure is measured in the inspiratory module and used for BTPS compensation. The sensor signals are filtered using anti-aliasing filters and sampled with A/D converters. Additional low-pass filters precondition the signals, the signals are then used for controls and display purposes.

Closed-loop control is used to maintain consistent pressure and flow waveforms in the face of changing patient/system conditions. This is accomplished by using the output as a feedback signal that is compared to the operator-set input. The difference between the two is used to drive the system toward the desired output. For example, pressure-control modes use airway pressure as the feedback signal to control gas flow from the ventilator. See the figure below. This diagram shows a schematic drawing of a general feedback control system. The input is a reference value (e.g., operator preset inspiratory pressure) that is compared to the actual output value (e.g., instantaneous value of airway pressure). The difference between those two values is the error signal. The error signal is passed to the controller (e.g., the software control algorithm). The controller converts the error signal into a signal that can drive the actuator (e.g., the hardware drivers and valves) to cause a change in the manipulated variable (e.g., inspiratory flow).

**Note:**

In the diagram above, the “plant” is the patient and the connected breathing circuit.

10.4 Inspiration—Detection and Initiation

When ventilator inspiration occurs, it is called triggering. Breaths are delivered to the patient based on ventilator settings the practitioner has entered and are determined by pressure, flow, or time measurements, or operator action. The ventilator uses the following methods to trigger an inspiration:

- Pressure triggering (P-Trig)
- Flow triggering ($\dot{V}$ -Trig)
- Time-triggering
- Operator-initiated

If the ventilator detects a drop in pressure at the circuit wye or when there is a decrease in base flow measured at the exhalation valve, the patient is said to trigger the breath. Mandatory breaths triggered by the patient are referred to as **PIM** or patient-initiated mandatory breaths.

All spontaneous breaths are patient-initiated, and are also triggered by a decrease in circuit pressure or measured base flow indicating the patient is initiating an inspiration.

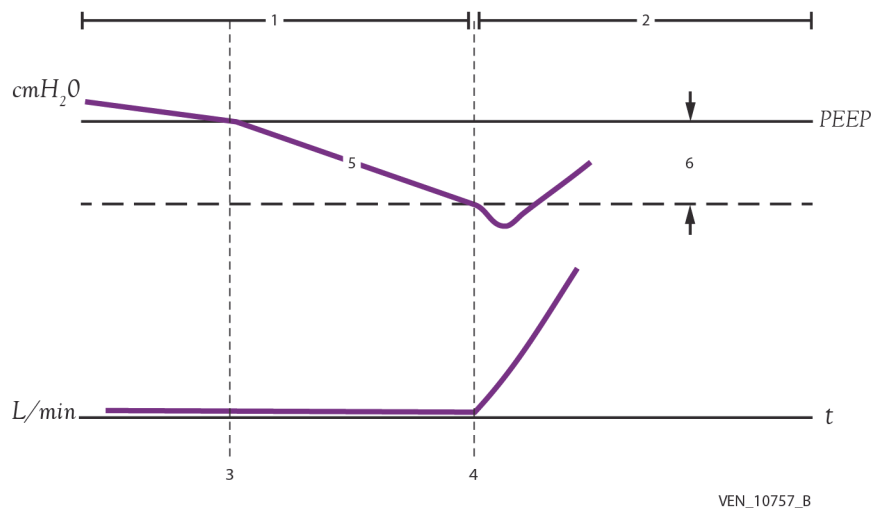
Another term, **autotriggering**, is used to describe a condition where the ventilator triggers a breath in the absence of the patient’s breathing effort. Autotriggering can be caused by inappropriate ventilator sensitivity settings, water in the patient circuit, or gas leaks in the patient circuit.

10.4.1 Pressure Triggering

If pressure triggering (P-Trig) is selected, the ventilator transitions into inspiration when the pressure at the patient circuit wye drops below positive end expiratory pressure (PEEP) minus the operator-set sensitivity level (P_{SENS}). See [Figure 10-1](#). As the patient begins the inspiratory effort and breathes gas from the circuit (event 5, the A-B interval), pressure decreases below PEEP. When the pressure drops below PEEP minus P_{SENS} (event 6), the ventilator delivers a PIM breath. The

pressure-decline time interval between events A and B determines how aggressive the patient's inspiratory effort is. A short time interval signifies an aggressive breathing effort. The A-B interval is also affected by P_{SENS} . A smaller P_{SENS} setting means a shorter A-B time interval. (The minimum P_{SENS} setting is limited by autotriggering, and the triggering criteria include filtering algorithms that minimize the probability of autotriggering.)

Figure 10-1. Inspiration Using Pressure Sensitivity



1	Exhalation	4	Event B: Patient-triggered inspiration begins
2	Inspiration	5	A-B interval
3	Event A: (patient inspires)	6	Operator-set pressure sensitivity

10.4.2 Flow Triggering

If flow triggering ($\dot{V}$ -Trig) is selected the BDU provides a constant gas flow through the ventilator breathing circuit (called base flow) during exhalation. The base flow is 1.5 L/min greater than the value selected for flow sensitivity ($\dot{V}_{\text{SENS}}$). See [Figure 10-2](#), on page 10-6 where the top graphic represents expiratory flow and the bottom graphic represents inspiratory flow.]

The ventilator's breath delivery flow sensor measures the base flow delivered to the circuit and the exhalation flow sensor measures the flow entering the exhalation valve. The ventilator monitors patient flow by measuring the difference between the inspiratory and exhaled flow measurements. If the patient is not inspiring, any difference in measured flows is due to leaks in the breathing system or flow sensor inaccuracy. The clinician can compensate for leaks in the breathing system by increasing $\dot{V}_{\text{SENS}}$ to a value equal to desired $\dot{V}_{\text{SENS}}$ + leak flow.

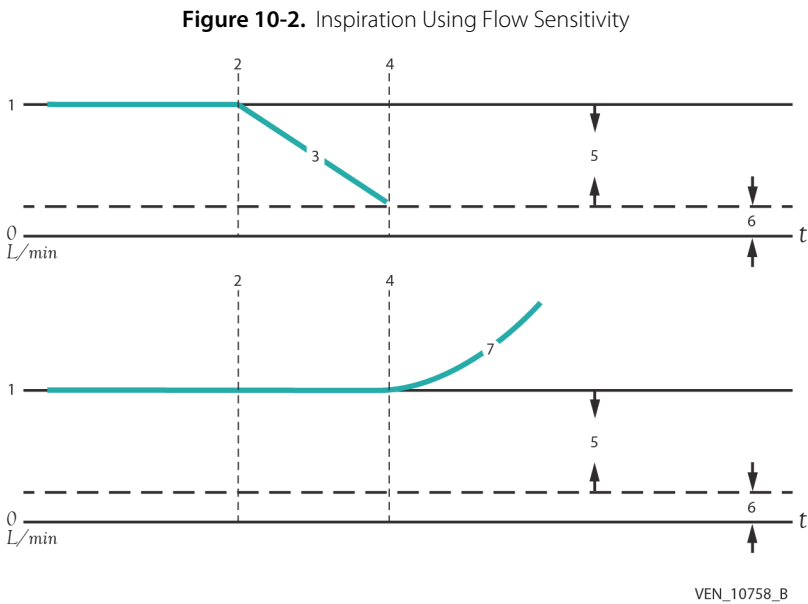
As the patient begins the inspiratory effort and inspires from the base flow, less exhaled flow is measured, while the delivered flow remains constant. See [Figure 10-2](#), (event A). As the patient continues to inspire, the difference between the delivery and exhalation flow sensor measure-

ments increases. The ventilator initiates an inspiration when the difference between the two flow measurements is greater than or equal to the operator-set flow sensitivity value. See [Figure 10-2.](#) , (event B).

As with pressure triggering, the time delay between onset of the patient’s effort and actual gas delivery depends on:

- How quickly the exhaled flow declines (that is, the aggressiveness of the inspiratory effort). The more aggressive the inspiratory effort, the shorter the interval.
- The flow sensitivity value. The smaller the value, the shorter the delay.

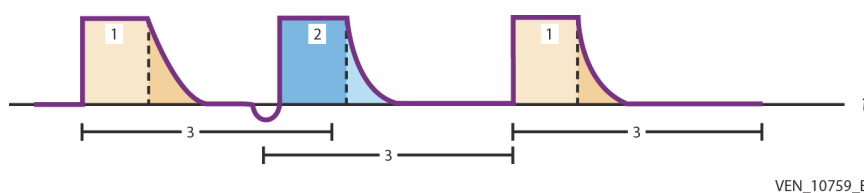
During flow triggering, a backup pressure sensitivity of 2 cmH₂O is present to detect a breath trigger in the event that the flow trigger fails.



1	Software-set base flow (L/min)	5	Operator-set flow sensitivity
2	Start of patient effort	6	1.5 L/min
3	Event A: flow is decreasing	7	Flow delivered to patient
4	Event B: Gas delivery begins		

10.4.3 Time Triggers

The ventilator measures the time interval for each breath and breath phase. If the ventilator is in Assist/Control (A/C) mode (where the ventilator delivers breaths based on the breath rate setting), a **VIM** or ventilator initiated mandatory breath is delivered after the appropriate time interval. The duration of the breath in seconds (T_B) is $60/f$.

Figure 10-3. Breath Activity During Time-triggered Inspiration

- | | | | |
|---|-----------------------|---|--------------------------------|
| 1 | Breath activity (VIM) | 3 | Time period (T_b) = $60/f$ |
| 2 | Breath activity (PIM) | | |

10.4.4 Operator-initiated Triggers

If the operator presses the manual inspiration key, an **OIM** (operator-initiated mandatory) breath is delivered. The ventilator will not deliver an OIM under the following conditions:

- During an active inspiration, whether mandatory or spontaneous
- During the restricted phase of exhalation
- During circuit disconnect and occlusion status cycling (OSC) conditions

See [Manual Inspiration \(10.7.5\)](#) later in this chapter for information on the restricted phase of exhalation.

10.5 Exhalation—Detection and Initiation

When exhalation occurs, it is called cycling. Mandatory breaths can be volume-cycled or time-cycled by the ventilator or pressure cycled by the patient. Spontaneous breaths can be flow-cycled or pressure-cycled by the patient or time-cycled by the ventilator. A patient-cycled exhalation relies on measurements such as inspiratory flow rate or airway pressure. The ventilator uses the three methods described below to detect exhalation:

- Airway pressure method (spontaneous breaths)
- Percent peak flow method (spontaneous breaths)
- Time-cycling method (mandatory breaths)

10.5.1 Airway Pressure Method

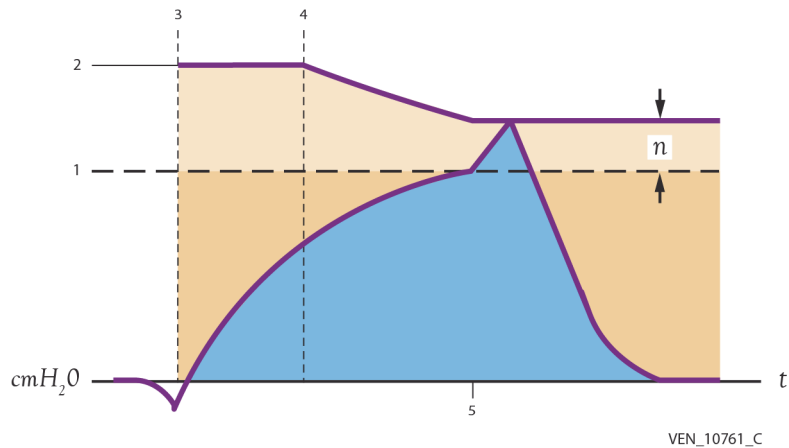
If expiratory sensitivity (E_{SENS}) is set to a value too low for the patient-ventilator combination, a forceful expiratory effort could cause circuit pressure (P_{PEAK}) to rise to its limit. The ventilator monitors circuit pressure throughout the inspiratory phase, and initiates an exhalation when the pressure equals the inspiratory pressure (P_i) target value + an incremental value. This transition to exhalation occurs during spontaneous pressure-based ventilation and in volume support (VS).



Note:

The allowable incremental value above the target pressure is 1.5 cmH₂O once a portion of inspiration time (T_n) has elapsed. Before T_n, the incremental value is higher to allow for transient pressure overshoots. For the first 200 ms of inspiration, the incremental pressure is 10% of the target pressure, up or 8 cmH₂O, whichever is greater. From 200 ms to T_n, the incremental pressure decreases in a linear fashion from the initial value to 1.5 cmH₂O.

Figure 10-4. Exhalation via the Airway Pressure Method

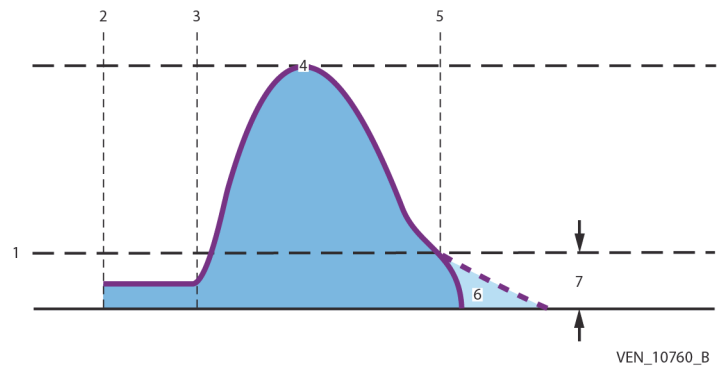


1	Pressure target	4	200 ms
2	Pressure target +incremental value (n)	5	Tn
3	Start breath		

10.5.2 Percent Peak Flow Method

For spontaneous breath types including PS (pressure supported), TC (tube compensated), and VS (volume supported, the ventilator captures the value of the delivered peak inspiratory flow, then monitors the inspiratory flow decline until the value of current flow to peak flow (expressed as a percentage) is less than or equal to the set E_{SENS} value. The ventilator then cycles from inspiration into exhalation.

See [Figure 10-5](#). for an example of exhalation using this method.

Figure 10-5. Exhalation via the Percent Peak Flow Method

1	Inspiratory flow (0 L/min)	5	Event B: Ventilator initiates exhalation
2	Inspiration	6	Inspiratory flow (L/min) without expiratory trigger
3	Trigger	7	$\dot{V}_{MAX} \times E_{SENS} / 100$
4	Event A: delivered flow begins to decrease ($\dot{V}_{MAX}$)		

**Note:**

PAV+ uses a flow-based cycling method, also called E_{SENS} , but it is expressed in L/min rather than in % of $\dot{V}_{MAX}$

10.5.3 Time-cycling Method

In pressure ventilation, the set inspiratory time (T_I) defines the duration of the inspiratory phase. In volume ventilation, T_I depends on the tidal volume (V_T) setting, peak flow ($\dot{V}_{MAX}$), flow pattern, and plateau time (T_{PL}). The ventilator cycles into exhalation when the set T_I (pressure ventilation) or computed T_I (volume ventilation) lapses.

10.5.4 Backup Methods

There are four backup methods for preventing excessive duration or pressure during inspiration:

- **Time limit** — For adult and pediatric patients, the time limit method ends inspiration and begins exhalation when the duration of a spontaneous inspiration is greater than or equal to $[1.99 \text{ s} + 0.02 \times \text{PBW (kg)}] \text{ s}$.
- **High circuit pressure limit** — During any type of inspiration, inspiration ends and exhalation begins when the monitored airway pressure (P_{CIRC}) is greater than or equal to the set high circuit pressure limit.

- **High ventilator pressure limit** — The ventilator transitions from inspiration to exhalation if the high ventilator pressure ($\bar{P}_{VENT}$) limit of 110 cmH₂O is reached.
- **High inspired tidal volume limit** — The high inspired tidal volume limit terminates inspiration and commences exhalation during VC+, VS, tube compensated (TC), or proportionally assisted (PAV+) breaths if the delivered volume is greater than or equal to $\bar{V}_{TI}$.



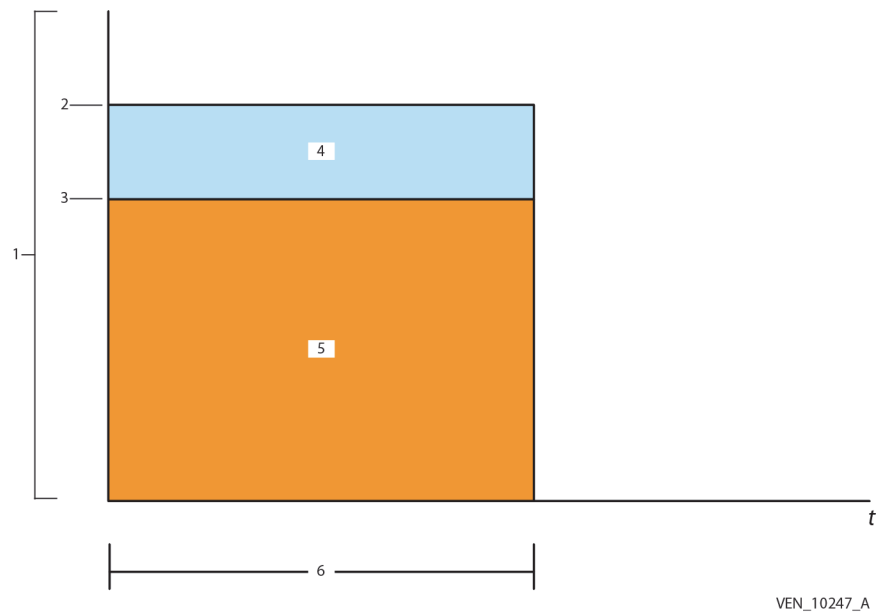
Note:
The ventilator does not generate subatmospheric airway pressures during exhalation.

10.6 Compliance and BTPS Compensation

10.6.1 Compliance Compensation in Volume-based Breaths

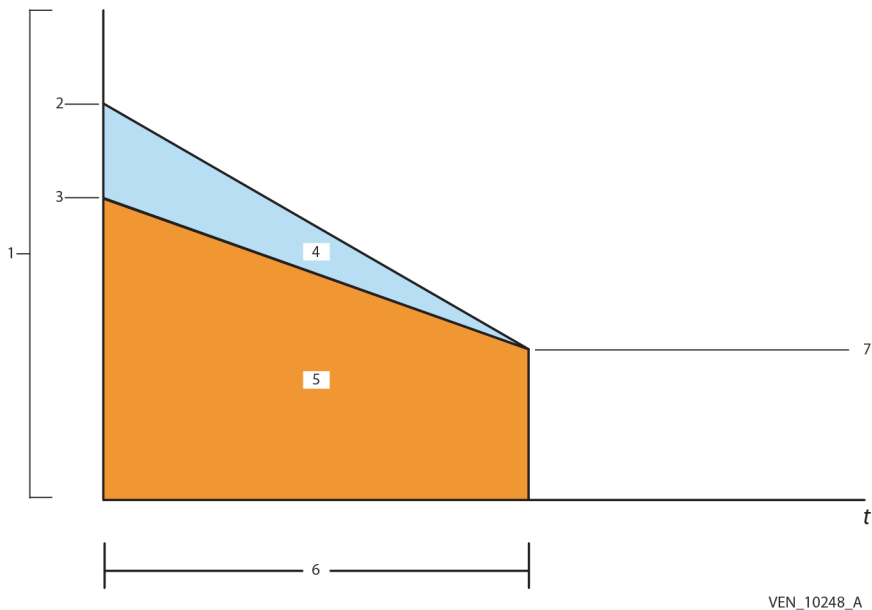
Compliance compensation accounts for the gas volume not actually delivered to the patient during inspiration. This gas is known as the compliance volume, VC. VC is the gas lost to pressurizing the breathing circuit and includes the volumes of the patient circuit, any accessories such as a humidifier and water traps, and internal ventilator gas passages.

Figure 10-6. Square Flow Pattern



1	Flow (y-axis)	4	Compliance volume (VC)
2	Actual $\dot{V}_{MAX}$	5	Set V_T
3	Set $\dot{V}_{MAX}$	6	T_I

Figure 10-7. Descending Ramp Flow Pattern



1	Flow (y-axis)	5	Set V_T
2	Actual $\dot{V}_{MAX}$	6	T_I
3	Set $\dot{V}_{MAX}$	7	Minimum $\dot{V}_{MAX}$
4	Compliance volume (VC)		

In the ventilator, an iterative algorithm automatically computes the compliance volume. There is a maximum tubing to- patient compliance ratio to reduce the potential for over-inflation due to an erroneous patient compliance estimation. The maximum ratio is determined by the selected patient circuit type and predicted body weight (PBW):

$$Factor = \frac{C_{pt\ ckt}}{C_{pt}}$$

$Factor$	Compliance volume factor	C_{pt}	Compliance of the patient
$C_{pt\ ckt}$	Compliance of the patient circuit		

The compliance volume is calculated as

$$V_C = C_{pt\ ckt}(P_{wye} - P)$$

V_C	Compliance volume	P_{wye}	Pressure at the patient wye at the end of the current inspiration
$C_{pt\ ckt}$	Compliance of the patient circuit	P	Pressure at the end of the current exhalation

Without automated compliance compensation, practitioners would have to compute V_C to estimate the loss of volume in the patient circuit, then increase the V_T setting by that amount. Increasing the tidal volume by a single increment to compensate for compliance volume provides only partial compensation, and requires extra effort and understanding by the practitioner. Additionally, P_{wye} and P can change with time.

An iterative algorithm in the ventilator automatically computes the compliance volume and compensates for it. Compliance compensation does not change inspiratory time (T_I). It is achieved by increasing flow (increasing the amplitude of the selected flow pattern). Keeping T_I constant maintains the original I:E ratio.

There is a maximum compliance volume to reduce the potential for overinflation due to an erroneous compliance volume calculation. The maximum compliance volume is determined by the selected patient circuit type and predicted body weight (PBW), and is summarized by this equation:

$$V_{comp,max} = \text{Factor} \times \text{Tidal volume}$$

where:

$$V_{comp,max} = \text{maximum compliance volume}$$

Factor = linear interpolation of the values in [Table 10-1](#). for adult, pediatric, and neonatal circuit types. Factor is calculated as:

$$\text{MIN}(10, \text{MAX}(2.5, 1.0 + (2.0 / 0.3 \times \text{kg PBW})))$$

Table 10-1. Compliance Volume Factors

Adult patient circuit type		Pediatric patient circuit type		Neonatal patient circuit type	
PBW (kg)	Factor	PBW (kg)	Factor	PBW (kg)	Factor
≤10	5	≤10	5	≤0.7	10
15	4.6	11	3.5	1	7.67
30	3.4	12.5	2.9	2	4.33
60	2.75	15	2.7	3	3.22
≥150	2.5	30	2.5	≥4.5	2.5

**Note:**

Compliance compensation calculations are also in effect during exhalation to ensure spirometry accuracy.

If the patient's compliance decreases beyond the limits of compliance compensation, the ventilator relies on the $\uparrow P_{PEAK}$ alarm setting to truncate the breath and switch to exhalation.

10.6.2 BTPS Compensation in Volume-based Breaths

Volumes and flows are BTPS-compensated, that is, they are reported by the ventilator at existing barometric pressure, 37°C (98.6°F), and fully saturated with water vapor.

10.7 Mandatory Breath Delivery

Three mandatory breath types are offered in the ventilator—volume control (VC) which bases breath delivery on the delivered inspiratory tidal volume, pressure control (PC), which bases breath delivery on achieving and sustaining a pressure target for a set period of time, and volume control plus (VC+) which is a pressure-controlled breath based on a target tidal volume. VC+ can be used in situations where a patient's lungs become more compliant due to treatment as it reduces the target pressure (lessening the forces on the alveoli) to achieve the target tidal volume.

Mandatory breaths are delivered by the ventilator, are either assisted (if patient initiated or PIM), or controlled (if ventilator-initiated or VIM), or initiated by the operator (OIM). In A/C mode, the breath period (T_b) is calculated using the breath rate (f) according to the equation

$$T_b = 60 / f$$

If, during T_b , patient effort is detected, a PIM breath is initiated and a new breath period starts. If no patient effort is detected before T_b lapses, the next breath delivered is a VIM, and a new breath period starts.

See [Table 11-9](#). on page [11-7](#) for details on the following VC+ settings:

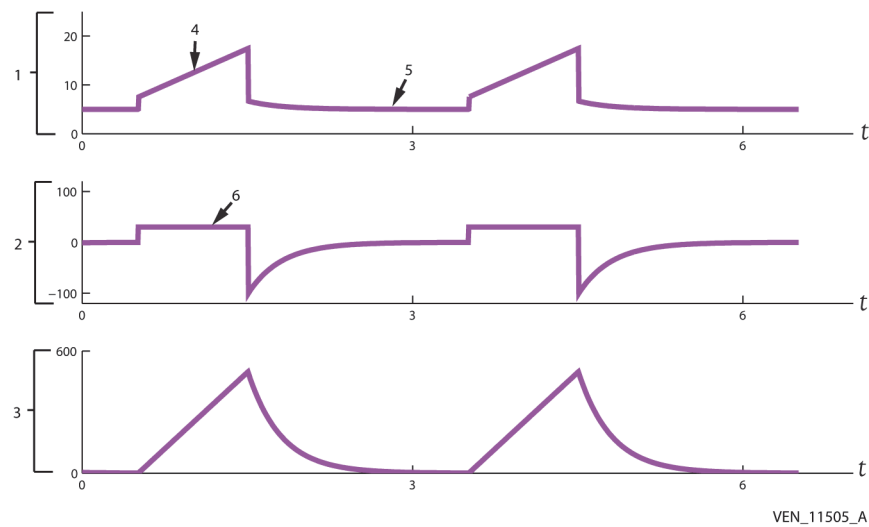
- Expiratory time (T_E)
- I:E ratio
- Inspiratory time (T_I)
- Rise time%
- Target or tidal volume (V_T)

VC and PC breath types require no initialization. A VC breath is based on meeting a delivered volume target and a PC breath is based on meeting a specific pressure target. VC+ breaths, however, go through a startup routine.

10.7.1 **Volume Control (VC)**

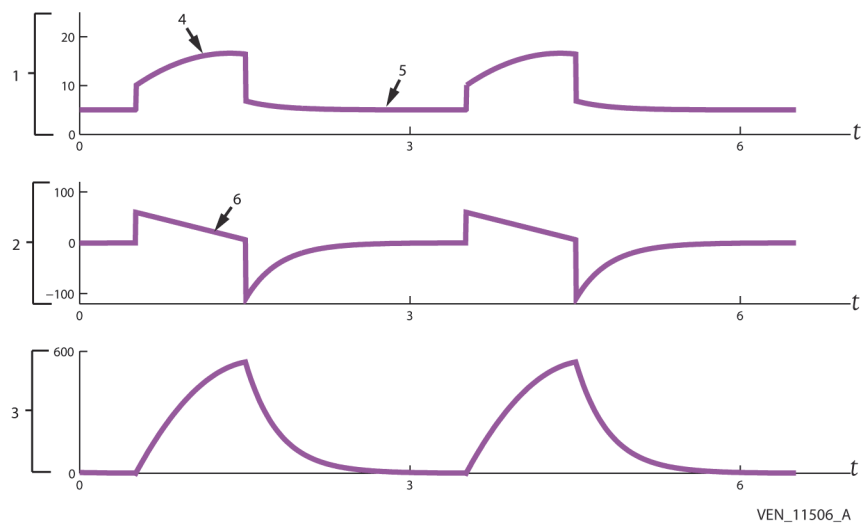
Volume Control is the control scheme that controls the flow with for the purpose of supplying a predetermined volume (set by the practitioner) to the patient. There are two basic flow wave forms to administer this volume: the **square** waveform that guarantees a constant flow during the inspiration time, or the **descending ramp** waveform whose slope and initial value are determined to provide the required volume target. See [Figure 10-8](#). and [Figure 10-9](#). The inspiration time is determined indirectly by the characteristics of the selected flow wave.

Figure 10-8. Ideal Waveform Using Square Flow Pattern



1	Pressure (cmH ₂ O)	4	Inspiratory phase
2	Flow (L/min)	5	Expiratory phase
3	Volume (mL)	6	Constant flow

Figure 10-9. Ideal Waveform Using Descending Ramp Flow Pattern

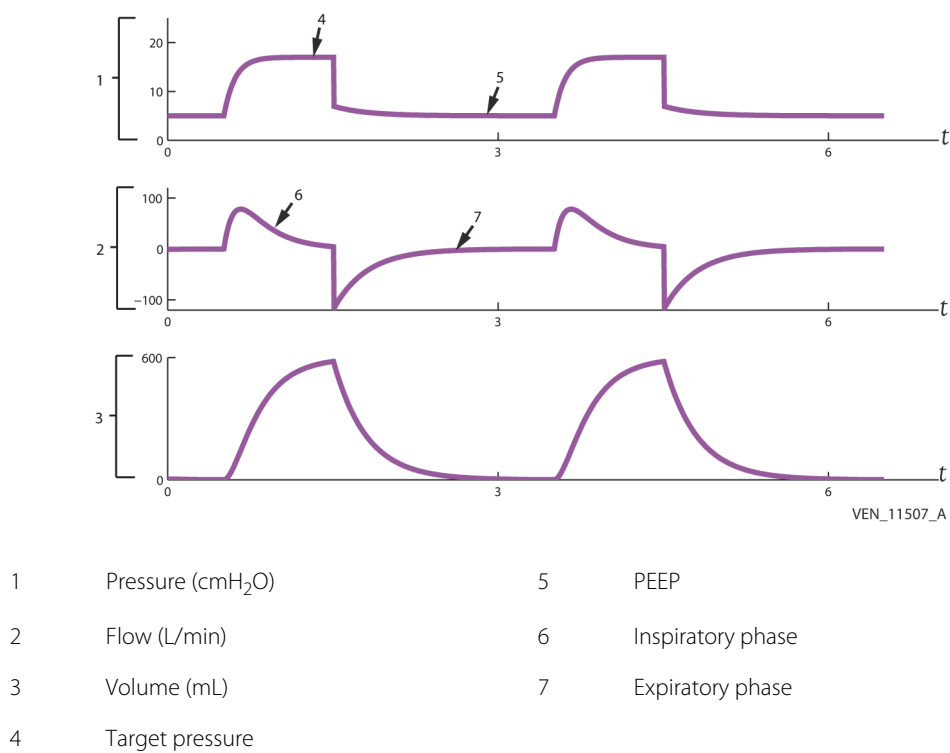


1	Pressure (cmH ₂ O)	4	Inspiratory phase
2	Flow (L/min)	5	Expiratory phase
3	Volume (mL)	6	Descending ramp

10.7.2 Pressure Control (PC)

Pressure Control is the control scheme by which the pressure is controlled at the circuit wye to reach a constant level (set by the practitioner) during inspiration, and a PEEP level during exhalation. See [Figure 10-10](#). on page 10-16. This level is maintained for a time given by the set inspiration time, following followed by an exhalation regulated by the exhalation valve until the PEEP level is reached. As flow is not predetermined, the supplied volume varies depending on the patient's pulmonary response.

Figure 10-10. Ideal Waveform Using Pressure Control Ventilation



10.7.3 VC+

VC+ breaths require initialization and must go through a startup routine.

VC+ Startup

Up to three test breaths are delivered prior to ventilating the patient with VC+ breaths. The delivered VC+ test breaths are volume control (VC) breaths (if Leak Sync is disabled) using the VC+ settings for V_T and inspiratory time and a ramp flow pattern. Delivered peak flows are calculated based on SST tubing compliance, assuming an end-inspiratory pressure of 15 cmH₂O above PEEP. After each test breath, the measured delivered volume and the end-inspiratory pressure and end-expiratory pressure are used to estimate the patient’s lung compliance to determine the VC+ pressure target to achieve the set V_T .

In VC+, if pressure and volume measurements from the test breaths are not valid, then a PC breath is delivered with P_I of 15 cmH₂O for pediatric and adult patients or 10 cmH₂O for neonatal patients using the T_I and rise time% settings in VC+.



Note:
To allow for optimal function of startup and operation of VC+ in the ventilator it is important not to block the tubing while the patient is undergoing suctioning or other treatment that requires disconnection from

the ventilator. The ventilator has a disconnect detection algorithm that suspends ventilation while the patient is disconnected.

After VC+ startup, the ventilator will make adjustments to the target pressure to deliver the set volume (V_T). To reach the desired volume promptly, the maximum allowed pressure adjustments for an adult or pediatric patient will be greatest during the first five breaths following startup or a change in V_T or $V_{T SUPP}$. The values of the maximum pressure adjustments for each patient type are summarized in [Table 10-2](#).

Table 10-2. Maximum Pressure Adjustments

Conditions	Maximum change in target pressure		
	PBW $\geq$ 25 kg	15 kg $\leq$ PBW < 25 kg	PBW < 15 kg
Less than five breaths after: VC+ startup or change in V_T	± 10.0 cmH ₂ O	± 6.0 cmH ₂ O	± 3.0 cmH ₂ O
Five breaths or more after VC+ startup	± 3.0 cmH ₂ O	± 3.0 cmH ₂ O	± 3.0 cmH ₂ O

See [Table 6-5](#), on page 6-16 for details on the following VC+ alarms:

- VOLUME NOT DELIVERED
- HIGH INSPIRED TIDAL VOLUME ($\uparrow V_T$)
- LOW CIRCUIT PRESSURE ($\downarrow P_{PEAK}$)
- COMPLIANCE LIMITED V_T

During VC+, inspiratory target pressure cannot be lower than PEEP+3 cmH₂O and cannot exceed $\uparrow P_{PEAK} - 3$ cmH₂O.

10.7.4 Rise time%

If PC or VC+ is selected as the mandatory type, adjust rise time% for optimum flow delivery into the lungs. Patients with high impedance (low compliance, high resistance) may benefit from a lower rise time% whereas patients with low impedance may better tolerate a more aggressive rise time setting. The rise time% setting specifies the speed at which the inspiratory pressure reaches 95% of the target pressure. The rise time setting applies to PS (including a setting of 0 cmH₂O), PC, VC+, or BiLevel breaths.

To match the flow demand of an actively breathing patient, observe simultaneous pressure-time and flow-time curves, and adjust the rise time% to maintain a smooth rise of pressure to the target value. A rise time% setting reaching the target value well before the end of inspiration can cause the ventilator to supply excess flow to the patient. Whether this oversupply is clinically beneficial must be evaluated for each patient. Generally, the optimum rise time% for gently breathing

patients is less than or equal to the default (50%), while optimum rise time% for more aggressively breathing patients can be 50% or higher.

**WARNING:**

Under certain clinical circumstances (such as stiff lungs, or a small patient with a weak inspiratory drive), a rise time% setting above 50% could cause a transient pressure overshoot and premature transition to exhalation, or pressure oscillations during inspiration. Carefully evaluate the patient's condition before setting the rise time% above the default setting of 50%.



10.7.5 Manual Inspiration

When pressed, the manual inspiration key delivers one OIM breath to the patient, using set breath delivery parameters. The ventilator will not allow a manual inspiration during the restricted phase of exhalation or when the ventilator is in the process of delivering a breath (whether mandatory or spontaneous). All manual inspiration attempts are logged in the General Event log.

The **restricted phase of exhalation** is the time period during the expiratory phase where an inspiration trigger is not allowed. The restricted phase of exhalation is defined as the first 200 ms of exhalation **or** the time it takes for expiratory flow to drop to $\leq 50\%$ of the peak expiratory flow, **or** the time it takes for the expiratory flow to drop to ≤ 0.5 L/min (whichever is longest). The restricted phase of exhalation will end after 5 seconds of exhalation have elapsed regardless of the measured expiratory flow rate.

10.8 Spontaneous Breath Delivery

The modes allowing spontaneous breaths are SIMV, SPONT, and BiLevel.

The spontaneous breath type setting determines the type of pressure-assist that will be applied to the patient's spontaneous breaths (PS, TC, VS, or PAV+).

After selecting the spontaneous breath type, choose the level of pressure support (P_{SUPP}) for PS, Support volume ($V_{T SUPP}$) for VS or percent support for TC and PAV+ and specify the rise time% and E_{SENS} , where available. Changes to the spontaneous breath type setting phase in at the start of the next inspiration.

**Note:**

In any delivered spontaneous breath, either invasive or NIV, there is always a target inspiratory pressure of at least 1.5 cmH₂O applied.

During spontaneous breathing, the patient's respiratory control center rhythmically activates the inspiratory muscles. The support type setting allows selection of pressure-assist to supplement the patient's pressure-generating capability.

Table 10-3. Spontaneous Breath Delivery Characteristics

Characteristic	Implementation										
Inspiratory detection	P_{SENS} or $\dot{V}_{\text{SENS}}$ depending on the trigger type selected.										
Pressure or flow during inspiration Spontaneous type =PS and $P_{\text{SUPP}} < 5 \text{ cmH}_2\text{O}$	Pressure rises according to the selected rise time% and PBW setting, with target pressure equal to the effective pressure +PEEP: P_{SUPP} Effective pressure (cmH ₂ O) <table> <tr><td>0</td><td>1.5</td></tr> <tr><td>1</td><td>2.2</td></tr> <tr><td>2</td><td>2.9</td></tr> <tr><td>3</td><td>3.6</td></tr> <tr><td>4</td><td>4.3</td></tr> </table>	0	1.5	1	2.2	2	2.9	3	3.6	4	4.3
0	1.5										
1	2.2										
2	2.9										
3	3.6										
4	4.3										
Pressure or flow during inspiration Spontaneous type =PS and $P_{\text{SUPP}} \geq 5 \text{ cmH}_2\text{O}$	Pressure rises according to the selected rise time% and PBW setting, and target pressure equals $P_{\text{SUPP}} + \text{PEEP}$.										
Pressure or flow during inspiration Spontaneous type =VS	Pressure rises according to the selected rise time% and PBW setting, and target pressure equals the pressure determined during the test breath or pressure target determined from assessment of delivered volume from the previous breath. For more information on VS, see Volume Support (VS) (10.8.2) on page 10-20.										
Tube compensation (TC)	Tube compensation provides programmable, inspiratory pressure assistance during otherwise unsupported spontaneous breaths. This assists the patient in overcoming the flow resistance of the artificial airway. Pressure is programmed to help the patient overcome part or all of the resistance of the artificial airway. The ventilator continuously calculates the pressure differential based on tube type and tube ID and adjusts the compensation pressure accordingly. For more information regarding TC, see Tube Compensation (10.8.3) on page 10-22.										
Inspiratory flow profile	The inspiratory flow profile is determined by patient demand and the rise time% setting. As the rise time% setting is increased from minimum to maximum, the time to achieve the pressure target decreases. The maximum available flow is up to 30 L/min for neonatal circuit types, 80 L/min for pediatric circuit types, and up to 200 L/min for adult circuit types without Leak Sync.										
Exhalation valve during inspiration	Adjusts to minimize pressure overshoot and maintain the target pressure.										
Inspiratory valve during inspiration	Adjust to maintain target pressure. Because the exhalation valve acts as a relief valve venting any excess flow, inspiratory flow can be delivered aggressively and allows reduced work of breathing.										

Table 10-3. Spontaneous Breath Delivery Characteristics (Continued)

Characteristic	Implementation
Expiratory detection	The end-inspiratory flow or airway pressure method, whichever detects exhalation first. Time backup and the $\uparrow P_{PEAK}$ alarm are also available as backup strategies.
Pressure or flow during exhalation	Pressure is controlled to PEEP. For pressure triggering: set to deliver a bias flow of 1 L/min. For flow triggering: set to deliver base flow.
Inspiratory valves during exhalation	For pressure triggering: set to deliver a bias flow of 1 L/min. For flow triggering: set to deliver base flow near the end of expiratory flow.
Exhalation valve during exhalation	Adjusts to maintain the operator-selected value for PEEP.

10.8.1 Pressure Support (PS)

Pressure Support is a type of spontaneous breath, similar to PC, by which the pressure is controlled to reach a constant value, preset by the practitioner, once an inspiratory effort is detected. This target value is held until the detection of end of inspiration. Subsequently, the exhalation valve control initiates the exhalation, driving the pressure to the PEEP level.

10.8.2 Volume Support (VS)

Volume support is a pressure-supported spontaneous breath type available when SPONT is selected as the mode. The target support volume (V_{T_SUPP}) is the target volume for pressure supported breaths.

See [Table 11-9](#) on page 11-7 for details regarding the following VS settings:

- Expiratory sensitivity (E_{SENS})
- Rise time%
- Target support volume (V_{T_SUPP})

Technical Description

Volume Support (VS) breaths are patient-triggered, pressure-supported spontaneous breaths. The VS algorithm varies the inspiratory pressure of each breath to deliver the operator-set target tidal volume (V_{T_SUPP}). If the delivered volume for a breath is above or below the set target volume, VS adjusts the target pressure for the next breath up or down, as necessary, to deliver more or less volume. As the patient's condition improves allowing more patient control over spontaneous ventilation, the VS algorithm decreases the amount of inspiratory pressure necessary to deliver

the target volume. Conversely, VS increases inspiratory pressure if the patient's respiratory drive becomes compromised.

In the absence of leaks or changes in patient resistance or compliance, Volume Support achieves and maintains a steady, breath-to-breath tidal volume within five breaths of VS initiation or start-up.

During VS, the inspiratory pressure target cannot be lower than $PEEP + 1.5 \text{ cmH}_2\text{O}$, and cannot exceed $\bar{P}_{PEAK} - 3 \text{ cmH}_2\text{O}$.

VS Startup

Test breaths are delivered prior to ventilating the patient with VS breaths. The delivered VS test breaths are pressure support breaths using a P_{SUPP} value of $15 \text{ cmH}_2\text{O}$ for pediatric and adult patients or $10 \text{ cmH}_2\text{O}$ for neonatal patients. The test breaths use the E_{SENS} and rise time% settings in VS. After each test breath, the measured delivered volume and the end-inspiratory pressure and end-expiratory pressure are used to estimate the patient's lung compliance to determine the VS pressure target to achieve the set V_T .

In VS, if pressure and volume measurements from test breaths are not valid, VS startup continues delivering test breaths until the pressure and volume measurements are valid.



Note:

To allow for optimal function of startup and operation of VS in the ventilator it is important not to block the tubing while the patient is undergoing suctioning or other treatment that requires disconnection from the ventilator. The ventilator has a disconnect detection algorithm that suspends ventilation while the patient is disconnected.

After VS startup, the ventilator makes adjustments to the target pressure in order to deliver the set volume ($V_{T SUPP}$). To reach the desired volume promptly, the maximum allowed pressure adjustments for an adult or pediatric patient will be greatest during the first five breaths following startup or a change in $V_{T SUPP}$. The values of the maximum pressure adjustments for each patient type are summarized in [Table 10-4](#).

Table 10-4. Maximum Pressure Adjustments

Conditions	Maximum change in target pressure		
	PBW $\geq$ 25 kg	15 kg $\leq$ PBW < 25 kg	PBW < 15 kg
Less than five breaths after: VS startup or change in $V_{T SUPP}$	$\pm 10.0 \text{ cmH}_2\text{O}$	$\pm 6.0 \text{ cmH}_2\text{O}$	$\pm 3.0 \text{ cmH}_2\text{O}$
Five breaths or more after VS startup	$\pm 3.0 \text{ cmH}_2\text{O}$	$\pm 3.0 \text{ cmH}_2\text{O}$	$\pm 3.0 \text{ cmH}_2\text{O}$

See [Table 6-5](#), on page [6-16](#) for details on the following VS alarms:

- VOLUME NOT DELIVERED
- COMPLIANCE LIMITED V_T
- HIGH INSPIRED TIDAL VOLUME ($\uparrow V_{TI}$)

Monitored Patient Data

For details on the spontaneous inspired tidal volume patient data parameter available during VS breaths, see [Table 11-9](#), on page [11-7](#).

10.8.3 Tube Compensation

Tube compensation (TC) is a pressure-supported spontaneous breath type available in SIMV, SPONT and BiLevel modes. When TC is enabled, the patient's respiratory muscles are not required to work as hard to draw gases into the lungs as they would in the absence of the pressure assistance provided by the TC feature. This is particularly important for patients whose respiratory systems are already functioning poorly, and would have to exert even greater muscular effort to overcome the increased resistance to flow through the artificial airway.

TC provides programmable, inspiratory pressure assistance during otherwise unsupported spontaneous breaths. This assists the patient in overcoming the flow resistance of the artificial airway. Pressure is programmed to vary in accordance with the resistance to flow of the artificial airway. The ventilator continuously calculates the pressure differential and adjusts the compensation pressure accordingly.

TC also includes safety protection, safety checks, and logic checks that prevent the operator from entering certain incompatible settings, such as a large airway size paired with a small predicted body weight.

If the type of humidifier has been changed after running SST with TC, the volume can be adjusted at the same time to avoid a reduction in compensation compliance accuracy.

Technical Description

TC is a spontaneous mode enhancement that assists patients' spontaneous breaths not already supported by specific pressure-based breath types (such as PS, VS, and PAV+) by delivering positive pressure proportional to the flow-based, resistive pressure developed across the artificial airway. TC causes the sensation of breathing through an artificial airway to diminish because the TC algorithm instructs the ventilator to develop just the correct amount of forward pressure to offset (cancel) the back pressure developed across the artificial airway during the inspiratory phase. The degree of cancellation can be set by the clinician and is adjustable between 10% and 100% in increments of 5%.

TC can support all unsupported spontaneous breaths for patients with predicted body weights ≥ 7.0 kg (15.4 lb), and for endotracheal/tracheostomy tubes with an inside diameter (ID) of ≥ 4.5

mm. TC can be used within SPONT, BiLevel or SIMV, all of which permit unsupported spontaneous breaths. With BiLevel selected, TC supports spontaneous breaths at both pressure levels.

TC checks the flow rate every 5 ms, using an internal lookup table that contains the flow-to-pressure relationship of the selected artificial airway, and is used to calculate the amount of pressure needed to overcome all or part of the resistance of the artificial airway. Based on the TC setting and the instantaneous flow measurement, the ventilator's PSOL valves are continually adjusted, adjusting the circuit pressure to match the changing tube-pressure compensation requirements.

Tube Compensation Alarms

For details of the $\uparrow P_{\text{COMP}}$, $\uparrow P_{\text{VENT}}$, and $\uparrow V_{\text{TI}}$ alarms associated with TC, see [Table 6-5](#) on page 6-16.

Monitored Patient Data

For details of the inspired tidal volume (V_{TI}) monitored patient data parameter associated with TC, see [Table 11-11](#) on page 11-17.

Tube Inside Diameter (ID)

The ventilator uses soft bound and hard bound values for estimated tube inside diameter (ID) based on PBW. Soft bounds are ventilator settings that have reached their recommended high or low limits. When adjusting the tube size, if the inside diameter does not align with a valid predicted body weight, a Continue button appears. Setting the ventilator beyond these soft bounds requires the operator to acknowledge the prompt by touching the Continue button before continuing to adjust the tube size. The limit beyond which the tube ID cannot be adjusted is called a hard bound, and the ventilator emits an invalid entry tone when a hard bound is reached.



WARNING:

Greater than expected ventilatory support, leading to unknown harm, can result if the specified tube type or tube ID is smaller than the actual tube type or tube ID.

Ventilator Settings/Guidelines

The estimation of settings to use with TC is aided by an understanding of: the ventilator settings, the data used for determination of the compensation values, and the specified performance or accuracy of the TC function.

The setting for $\bar{P}_{\text{PEAK}}$ must take the estimated tube compensation into consideration. The target pressure (compensation) at the patient wye is derived from the knowledge of the approximate airway resistance of the ET or tracheostomy tube being used. The compensation pressure in cmH₂O for available tube sizes and gas flows is shown. See [Figure 10-11](#) on page 10-24 and [Figure 10-12](#) on page 10-25. The estimated compensation must be added to the value of PEEP for calculation and setting of $\bar{P}_{\text{PEAK}}$.

Specified Performance

Performance using TC is specified to be $\pm(0.5+10\%$ of actual) joules/liter (residual work during inspiration at the 100% support (% Supp) level). Work is computed over the entire inspiratory interval. In terms of ventilation, resistive work is given by the following equation:

$$W = \frac{k \times \int (P_{E\ END} - P_{TR}) \times \dot{V} dt}{\dot{V} dt}$$

W	Work [J/L]	P _{TR}	Tracheal pressure
P _{E END}	End expiratory pressure	k	Conversion constant (0.098) [J/cmH ₂ O × L]

Figure 10-11. and Figure 10-12. indicate pressures at steady-state flows for ET tubes and tracheostomy tubes, respectively, at 100% support at the wye for sizes between 4.5 mm and 10 mm.

Figure 10-11. ET Tube Target Pressure vs. Flow

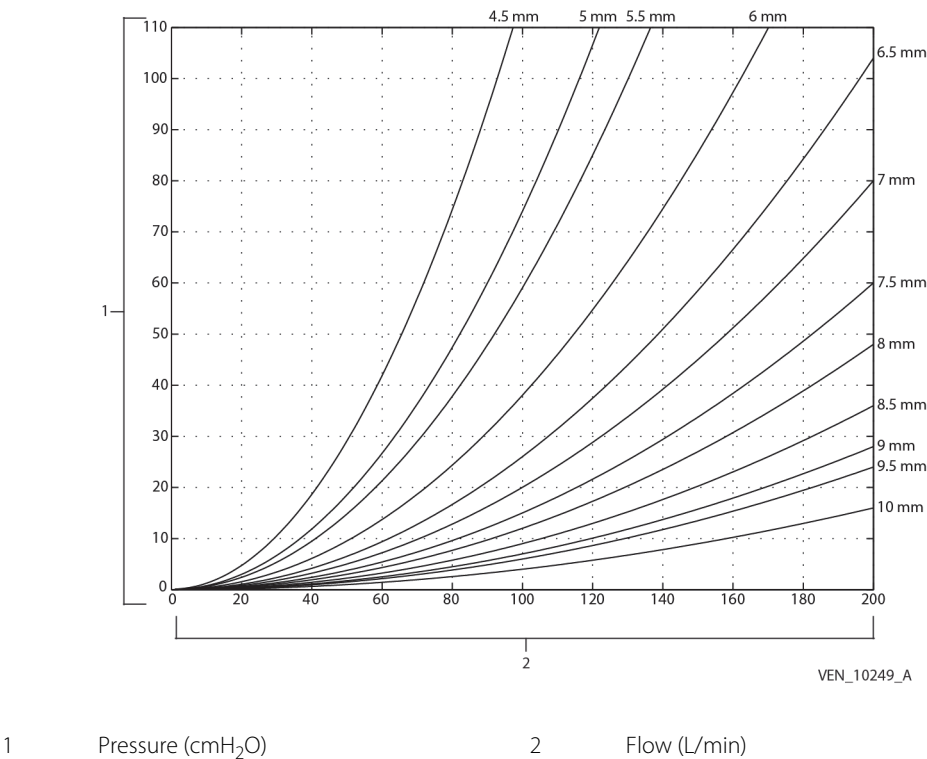
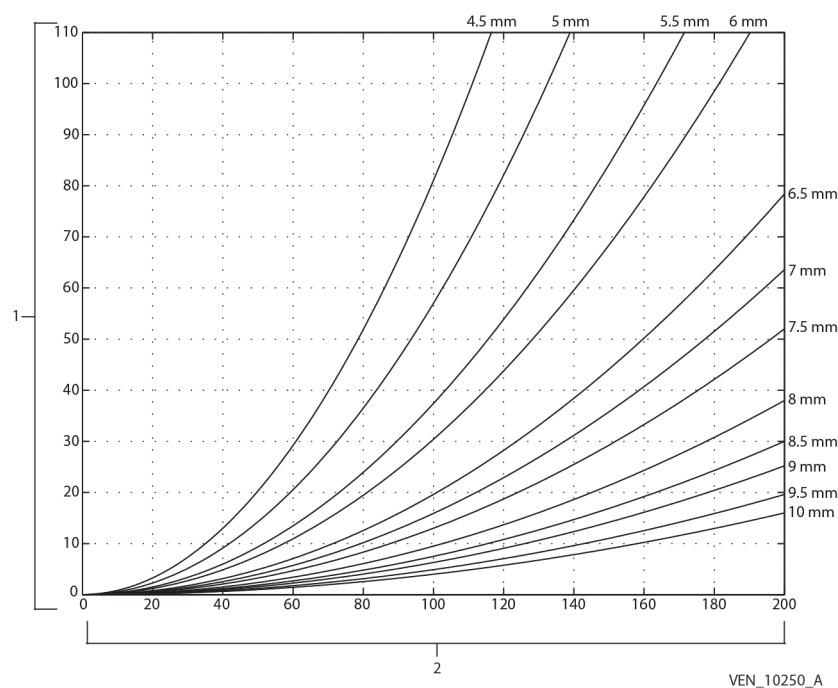


Figure 10-12. Tracheostomy Tube Target Pressure vs. Flow1 Pressure (cmH₂O)

2 Flow (L/min)

10.8.4 Proportional Assist Ventilation (PAV™+)

PAV+ is another available type of spontaneous breath. For detailed description of the operating theory, see Appendix C.

10.9 A/C Mode

When the ventilator is in **assist-control (A/C)** mode, only mandatory breaths are delivered. These mandatory breaths can be PC, VC, or VC+ breaths. See [Mandatory Breath Delivery \(10.7\)](#) on page 10-13 for a more detailed explanation of VC+ breaths. As for any mandatory breath, the triggering methods can be P-Trig, $\dot{V}$ -Trig, time-triggered, or operator initiated. If the ventilator senses the patient initiating the breath, a PIM or **assist breath** is delivered. Otherwise, VIM breaths (**control breaths**) are delivered based on the set respiratory rate. The length of the breath period is defined as:

$$Tb = 60/f$$

where:

Tb = breath period (seconds)

f = set respiratory rate (breaths per minute)

The inspiratory phase length is determined by the current breath delivery settings. At the end of the inspiratory phase, the ventilator enters the expiratory phase as determined by the following equation:

$$T_E = Tb - T_I$$

where:

T_E = length of the expiratory phase (seconds)

T_I = length of inspiratory phase including plateau time, T_{pL} (seconds)

Figure 10-13. illustrates A/C breath delivery when there is no patient inspiratory effort detected (all inspirations are VIMs).

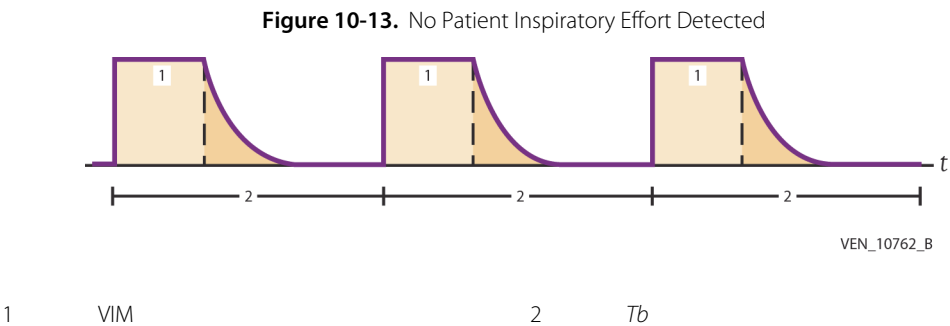


Figure 10-14. shows A/C breath delivery when patient inspiratory effort is detected. The ventilator allows PIM breaths to be delivered at a rate greater than or equal to the set respiratory rate.

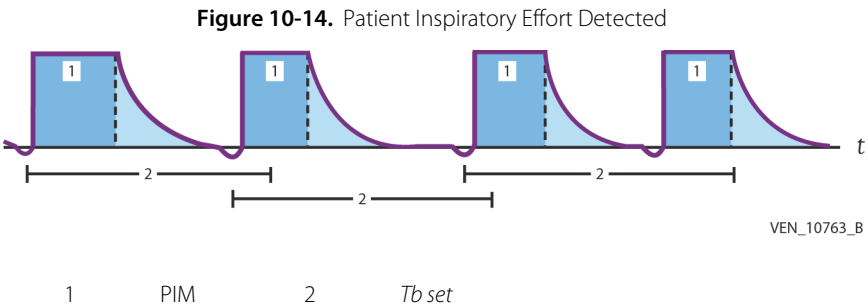
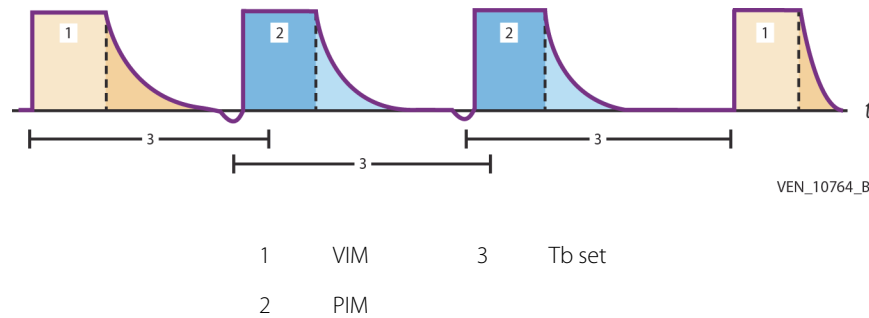


Figure 10-15. illustrates A/C breath delivery when there are both PIM and VIM breaths. delivered.

Figure 10-15. Combined VIM and PIM Breaths

If changes to the respiratory rate are made, they are phased in during exhalation only. The new breath period depends on the new respiratory rate, is based on the start of the current breath, and follows these rules:

- The current breath's inspiratory time is not changed.
- A new inspiration is not delivered until at least 200 ms of exhalation have elapsed.
- The maximum time t until the first VIM for the new respiratory rate is delivered is 3.5 times the current inspiratory time or the length of the new breath period (whichever is longer), but t is no longer than the old breath period.
- If the patient generates a PIM after the ventilator recognizes the rate change and before time t , the new rate begins with the PIM.

10.9.1 Changing to A/C Mode

Switching to A/C mode from any other mode causes the ventilator to phase in a VIM and set the start time for the beginning of the next A/C breath period. Following this VIM, and before the next A/C period begins, the ventilator responds to the patient's inspiratory efforts by delivering mandatory breaths.

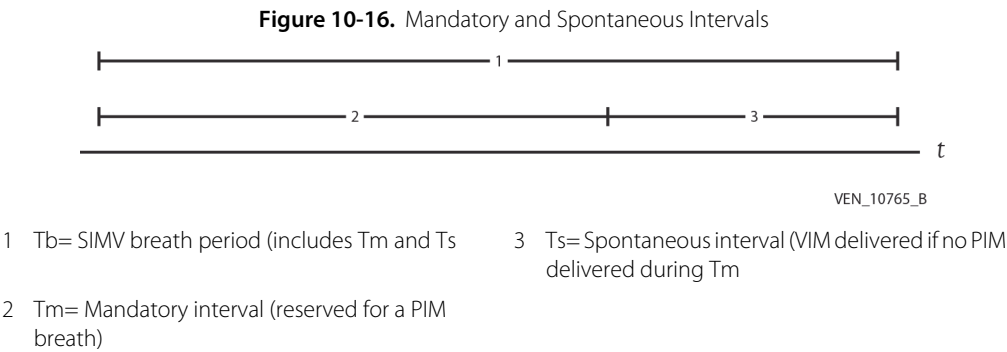
The first A/C breath (VIM breath) is phased in while following these rules:

- The breath is not delivered during an inspiration.
- The breath is not delivered during the restricted phase of exhalation.
- The ventilator ensures the apnea interval elapses at least 5 seconds after the beginning of exhalation.
- Any other specially scheduled event (for example, a respiratory mechanics maneuver or any pause maneuver) is canceled and rescheduled at the next interval.

When the first VIM of the new A/C mode is delivered depends on the mode and breath type active when the mode change is requested.

10.10 SIMV Mode

Synchronized Intermittent Mandatory Ventilation (SIMV) mode is a mixed ventilation mode allowing both mandatory and spontaneous breaths using pressure- or flow-triggering. The mandatory breaths can be PC, VC, or VC+, and the spontaneous breaths are pressure-assisted with either PS or TC. SIMV guarantees one mandatory breath per SIMV breath period, which is either a PIM or VIM. OIM breaths are allowed in SIMV and are delivered at the setting selected for mandatory type. *Figure 10-16.* shows the two parts of the SIMV breath period.



The first part of the period is the mandatory interval (Tm) which is reserved for a PIM. If a PIM is delivered, the Tm interval ends and the ventilator switches to the second part of the period, the spontaneous interval (Ts), which is reserved for spontaneous breathing for the remainder of the breath period. At the end of an SIMV breath period, the cycle repeats. If a PIM is not delivered during the mandatory interval, the ventilator delivers a VIM at the end of the mandatory interval, then switches to the spontaneous interval. *Figure 10-17.* shows an SIMV breath period where a PIM is delivered within the mandatory interval. Any subsequent trigger efforts during Ts yield spontaneous breaths. As shown, Tm transitions to Ts when a PIM is delivered.

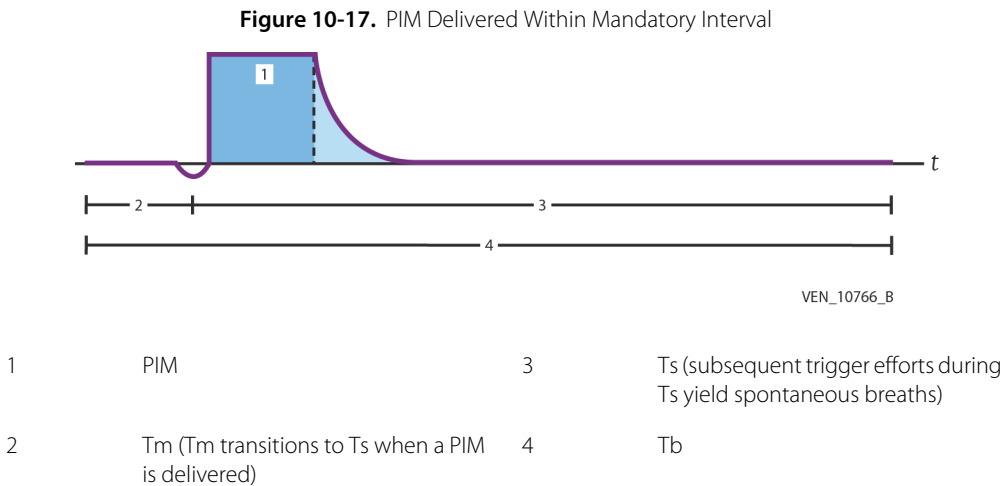
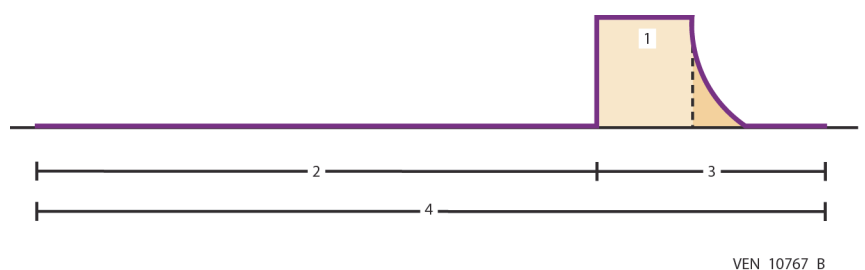


Figure 10-18. shows an SIMV breath period where a PIM is not delivered within the mandatory interval.

Figure 10-18. PIM Not Delivered Within Mandatory Interval



1	VIM	3	Ts
2	Tm (VIM delivered at end of Tm if no PIM delivered during Tm)	4	Tb

In SIMV, mandatory breaths are identical to those in A/C mode if the ventilator's respiratory rate setting is greater than the patient's natural respiratory rate. Spontaneous breaths are identical to those in SPONT mode if the ventilator setting for respiratory rate is significantly below the patient's natural respiratory rate. Patient triggering must meet the requirements for pressure and flow sensitivity.

The procedure for setting the respiratory rate in SIMV is the same as in A/C mode. Once the respiratory rate (f) is set, the SIMV interval period Tb in seconds is:

$$Tb = 60/f$$

During the mandatory interval, if the patient triggers a breath according to the current setting for pressure or flow sensitivity, the ventilator delivers a PIM. Once a mandatory breath is triggered, Tm ends, Ts begins, and any further trigger efforts yield spontaneous breaths. During the spontaneous interval, the patient can take as many spontaneous breaths as allowed. If no PIM or OIM is delivered by the end of the mandatory interval, the ventilator delivers a VIM and transitions to the spontaneous interval at the beginning of the VIM.

The SIMV breathing algorithm delivers one mandatory breath each period interval, regardless of the patient's ability to breathe spontaneously. Once a PIM or VIM is delivered, all successful patient efforts yield spontaneous breaths until the cycle interval ends. The ventilator delivers one mandatory breath during the mandatory interval, regardless of the number of successful patient efforts detected during the spontaneous interval. (An OIM delivered during the mandatory interval satisfies the mandatory breath requirement, and causes Tm to transition to Ts .)

The maximum mandatory interval for any valid respiratory rate setting in SIMV is defined as the lesser of:

- 0.6x the SIMV interval period (Tb)
- 10 s

There is no minimum value for T_m .

In SIMV, the interval from mandatory breath to mandatory breath can be as long as 1.6 times the SIMV period interval (but no longer than the period interval + 10 s. At high respiratory rates and too-large tidal volumes, **breath stacking** (the delivery of a second inspiration before the first exhalation is complete) is likely. In volume ventilation, breath stacking during inspiration and early exhalation leads to hyperinflation and increased airway and lung pressures, which can be detected by a high pressure limit alarm. In pressure control ventilation (with inspiratory pressure remaining constant), breath stacking leads to reduced tidal volumes, which can be detected by the low tidal volume and minute ventilation alarms.

In SIMV mode it is possible for the respiratory rate to drop temporarily below the f setting (unlike A/C mode, in which f_{TOT} is always greater than or equal to the f setting). If the patient triggers a breath at the beginning of a breath period, then does not trigger another breath until the maximum mandatory interval for the following breath has elapsed, a monitored respiratory rate less than the respiratory rate setting can result.

If a spontaneous breath occurs toward the end of the spontaneous interval, inspiration or exhalation can still be in progress when the SIMV interval ends. No VIM, PIM, or OIM is allowed during the restricted phase of exhalation. In the extreme, one or more expected mandatory breaths could be omitted. When the expiratory phase of the spontaneous breath ends, the ventilator reverts to its normal criteria for delivering mandatory breaths.

If an OIM is detected during the mandatory interval, the ventilator delivers the currently specified mandatory breath then closes T_m and transitions to T_s . If an OIM is detected during the spontaneous interval, the ventilator delivers the currently specified mandatory breath, but the SIMV cycle timing does not restart if OIM breaths are delivered during T_s .

10.10.1 Changing to SIMV Mode

Switching the ventilator to SIMV from any other mode, causes the ventilator to phase in a VIM and set the start time for the next SIMV period. Following this VIM, but before the next SIMV period begins, the ventilator responds to successful patient inspiratory efforts by delivering spontaneous breaths. The first SIMV VIM breath is phased in according to the following rules:

- The VIM breath is not delivered during an inspiration or during the restricted phase of exhalation.
- If the current mode is A/C, the first SIMV VIM is delivered after the restricted phase of exhalation plus the shortest of the following intervals, referenced to the beginning of the last or current inspiration: $3.5 \times T_I$, current T_A , or the length of the current breath period.
- If the current mode is SPONT, and the current or last breath type was spontaneous or OIM, the first SIMV VIM is delivered after the restricted phase of exhalation plus the shortest of the following intervals, referenced to the beginning of the last or current inspiration: $3.5 \times T_I$, or current T_A .
- If the current mode is BiLevel in the P_H state and the current breath is mandatory, the PEEP level will be reduced to P_L once the expiratory phase is detected.

The time t until the first VIM of the new A/C mode is the lesser of:

- PEEP transition time +2.5× the duration of the active gas delivery phase
- The length of the apnea interval (T_A)
- The length of the current breath cycle
- If the current mode is BiLevel in the P_H state and the current breath is spontaneous:
 - The PEEP level will be reduced once the expiratory phase is detected.

The time t until the first VIM of the new A/C mode is the lesser of:

- PEEP transition time +2.5× the duration of the spontaneous inspiration
- The start time of the spontaneous breath + the length of the apnea interval (T_A)
- If the current mode is BiLevel in the P_L state and the current breath is mandatory, the time t until the first VIM of the new A/C mode is the lesser of:
 - PEEP transition time +2.5× the duration of the active gas delivery phase
 - The length of the apnea interval (T_A)
 - The length of the current breath cycle
- If the current mode is BiLevel in the P_L state and the current breath is spontaneous and the spontaneous start time has occurred during P_L , the time t until the first VIM of the new A/C mode is the lesser of:
 - 3.5× the duration of the spontaneous inspiration
 - The length of the apnea interval (T_A)
 - The length of the current breath cycle
- If the current mode is BiLevel in the P_L state and the current breath is spontaneous and the spontaneous start time has occurred during P_H , the time t until the first VIM of the new A/C mode is the lesser of:
 - PEEP transition time +2.5× the duration of the spontaneous inspiration
 - The start time of the spontaneous breath + the length of the apnea interval (T_A)

If the command to change to SIMV occurs after the restricted phase of exhalation has ended, and before a next breath or the apnea interval has elapsed, the ventilator delivers the first SIMV VIM at the moment the command is recognized.

The point at which the new rate is phased in depends on the current phase of the SIMV interval and when the rate change command is accepted. If the rate change occurs during the mandatory interval, the maximum mandatory interval is that for the new or old rate, whichever is less. If the

patient generates a successful inspiratory effort during the spontaneous interval, the ventilator responds by delivering a spontaneous breath.

Respiratory rate changes are phased in during exhalation only. The new SIMV interval is determined by the new respiratory rate and is referenced to the start of the current SIMV period interval, following these rules:

- Inspiratory time (T_i) of current breath is neither truncated nor extended.
- The new inspiration is not delivered until 200 ms of exhalation have elapsed.

The time until the new SIMV interval begins is:

- Whichever is greater: the new SIMV period interval or $3.5 \times$ the last or current T_i
- Not greater than the current SIMV period interval.

10.11 Spontaneous (SPONT) Mode

In SPONT mode, the patient initiates inspiration according to the trigger type in effect, but OIM breaths are allowed and are delivered with the currently specified mandatory breath parameters. The following spontaneous breath types are available in SPONT mode:

- PS
- VS
- TC
- PAV+

The inspiratory phase begins when the ventilator detects patient effort during the ventilator's expiratory phase. Breath delivery during the inspiratory phase is determined by the settings for pressure support, PEEP, rise time%, and expiratory sensitivity, unless the breath is an OIM breath.

If TC or PAV+ is selected as the spontaneous type, breath delivery during the inspiratory phase is determined by the settings for% support (% Supp), expiratory sensitivity, tube ID, and tube type.



Note:

Given the current ventilator settings, if PAV+ would be an allowable spontaneous type (except that tube ID <6 mm) then PAV+ becomes selectable. If selected, tube ID is set to its New Patient default value based on the PBW entered. An attention icon for tube ID appears.



If volume support (VS) is selected as the spontaneous type, breath delivery during the inspiratory phase is determined by rise time%, volume support level ($V_{T\text{ SUPP}}$), expiratory sensitivity, and PEEP.

Inspiratory pause maneuvers are only possible during OIM breaths, and expiratory pause maneuvers are not allowed during SPONT.

Expiratory trigger methods include:

- E_{SENS} (% flow deceleration from peak inspiratory flow)
- PBW based time limit (T_I too long)
- $\uparrow P_{PEAK}$
- Inspiratory tidal volume limit (for VS only)
- Airway pressure cycling method

10.11.1 Changing to SPONT Mode

If the operator changes to SPONT mode during an A/C or SIMV inspiration (mandatory or spontaneous), the inspiration is completed, unaffected by the mode change. Because SPONT mode has no special breath timing requirements, the ventilator then enters the expiratory phase and waits for the detection of patient inspiratory effort, a manual inspiration, or apnea detection.

10.12 Apnea Ventilation

When a patient stops breathing or is no longer being ventilated, it is called apnea. When apnea is detected by the ventilator, the ventilator alarms and delivers apnea ventilation according to the current apnea ventilation settings.

10.12.1 Apnea Detection

The ventilator declares apnea when no breath has been delivered by the time the operator-selected apnea interval elapses, plus a small increment of time (350 ms). This increment allows time for a patient who has begun to initiate a breath to trigger inspiration and prevent the ventilator from declaring apnea when the apnea interval is equal to the breath period.

The apnea timer resets whenever an inspiration begins, regardless of whether the inspiration is patient-triggered, ventilator-triggered, or operator-initiated. The ventilator then sets a new apnea interval beginning from the start of the current inspiration. To hold off apnea ventilation, another inspiration must be delivered before (the current apnea interval + 350 ms) elapses. Apnea detection is suspended during a disconnect, occlusion, or safety valve open (SVO) state.

Apnea is not declared when the apnea interval setting equals or exceeds the breath period. For example, if the respiratory rate setting is 4/min, an apnea interval of 15 seconds or more means apnea cannot be detected. The ventilator bases apnea detection on inspiratory (not expiratory) flow, and allows detection of a disconnect or occlusion during apnea ventilation. Apnea detection is designed to accommodate interruptions to the typical breathing pattern due to other ventilator features that temporarily extend the inspiratory or expiratory intervals (rate changes, for example) but still detect a true apnea event.

Figure 10-19. shows an apnea breath where T_A equals the breath period.

Figure 10-19. Apnea Interval Equals Breath Period

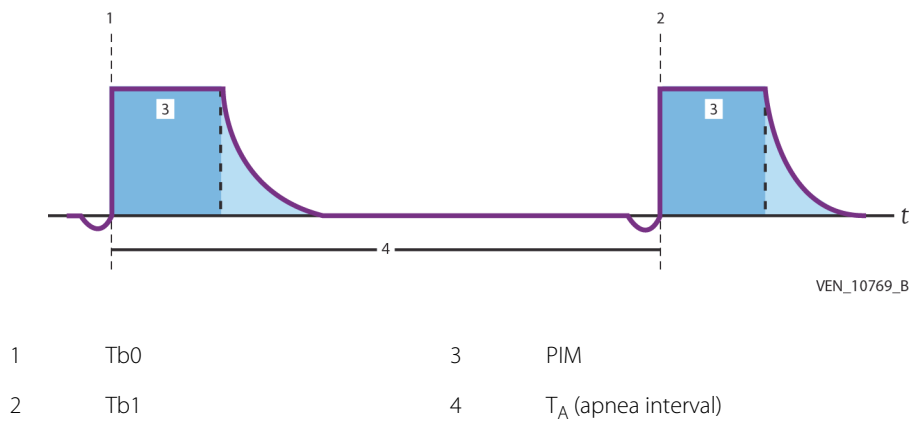


Figure 10-20. shows an apnea breath with T_A greater than the breath period.

Figure 10-20. Apnea Interval Greater Than Breath Period

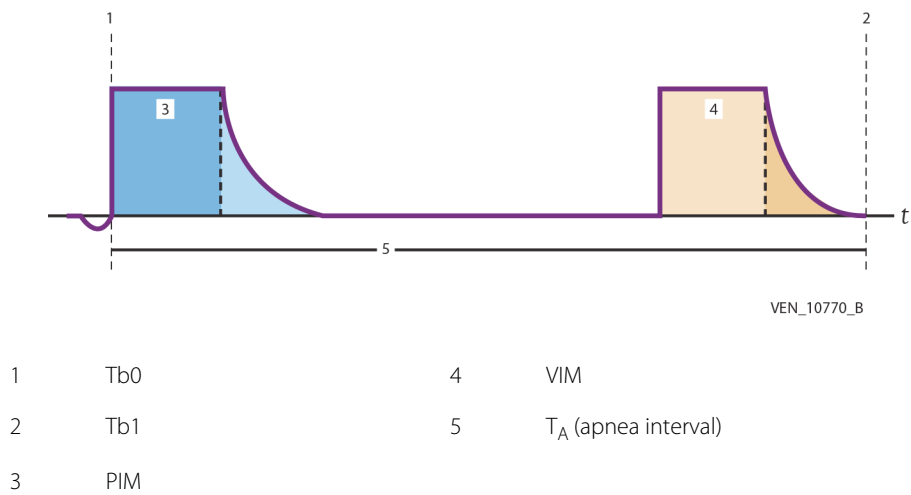
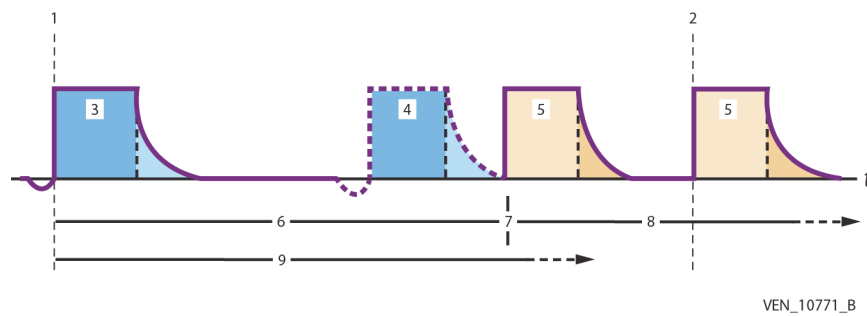


Figure 10-21. shows an apnea breath with T_A less than the breath period.

Figure 10-21. Apnea Interval Less Than Breath Period



1	Tb0	6	Apnea interval
2	Tb1	7	Apnea Tb0
3	PIM	8	Apnea ventilation
4	Dashed line indicates a PIM to avoid apnea	9	Tb ($T_A < T_b$)
5	Apnea VIM		

10.12.2 Transition to Apnea Ventilation

When apnea is declared, the ventilator delivers apnea ventilation according to the current apnea ventilation settings and displays the apnea settings on the graphical user interface (GUI). Regardless of the apnea interval setting, apnea ventilation cannot begin until inspiration of the current breath is complete and the restricted phase of exhalation has elapsed.

10.12.3 Settings Changes During Apnea Ventilation

All apnea and non-apnea settings remain active on the GUI during apnea ventilation. Both non-apnea and apnea settings changes are phased in according to the applicable rules. If apnea ventilation is active, new settings are accepted but not implemented until non-apnea ventilation begins. Allowing key entries after apnea detection allows adjustment of the apnea interval at setup, regardless of whether apnea has been detected. During apnea ventilation, the manual inspiration key is active, but expiratory pause and inspiratory pause keys are not active. The increase O_2 control is active during apnea ventilation, because apnea detection is likely during suctioning.

The apnea respiratory rate must be $\geq 60/T_A$. Additionally, apnea settings cannot result in an I:E ratio $> 1.00:1$.

10.12.4 Resetting Apnea Ventilation

Apnea ventilation is intended as an auxiliary mode of ventilation when there is insufficient breath delivery to the patient over a specified period of time. Apnea ventilation can be reset to normal ventilation by the operator (by pressing the alarm reset key) or the patient (autoreset). It is also reset when a rate change is made that renders apnea ventilation inapplicable.

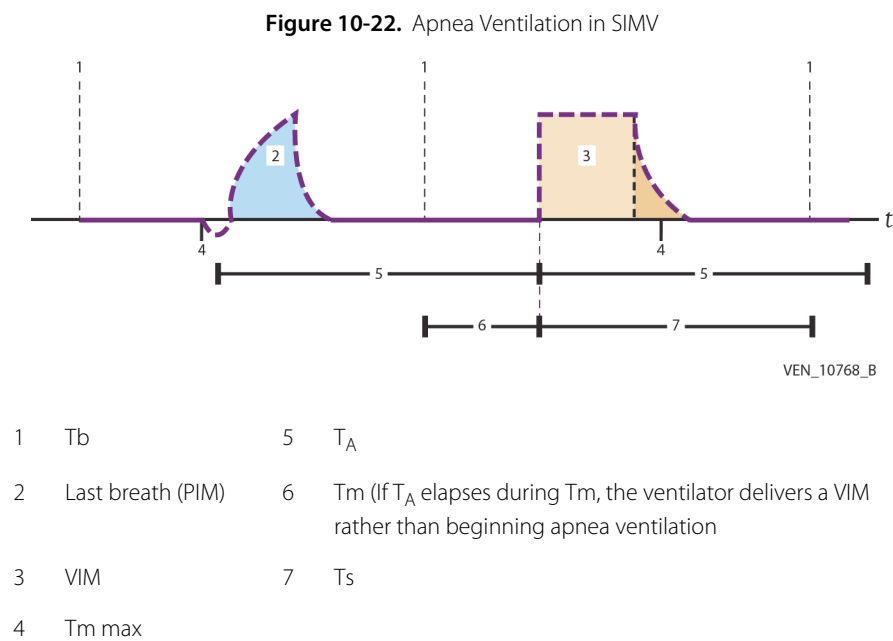
If the patient regains inspiratory control, the ventilator returns to the operator-selected mode of non-apnea ventilation. The ventilator determines whether the patient has regained respiratory control by monitoring triggered inspirations and exhaled volume. If the patient triggers two consecutive inspirations, and the exhaled volume is equal to or greater than 50% of the delivered volume (including any compliance volume), the ventilator resets to non-apnea ventilation. Exhaled volume is monitored to avoid resetting due to autotriggering caused by large leaks in the patient circuit.

10.12.5 Apnea Ventilation in SIMV

The following strategy is designed to allow SIMV to avoid triggering apnea ventilation if a VIM breath can be delivered instead:

- If the apnea interval (T_A) elapses at any time during the mandatory interval, the ventilator delivers a VIM rather than beginning apnea ventilation.
- If T_A elapses during the spontaneous interval, apnea ventilation begins.

Figure 10-22. shows an illustration of how SIMV is designed to deliver a VIM rather than trigger apnea ventilation, when possible.



10.12.6 Phasing in New Apnea Intervals

How a new apnea interval is phased in depends on whether or not apnea ventilation is active. If apnea ventilation is active, the ventilator accepts and implements the new setting immediately. During normal ventilation (that is, apnea ventilation is not active), these rules apply

- If the new apnea interval setting is shorter than the current (or temporarily extended) apnea interval, the new value is implemented at the next inspiration.
- If the new apnea interval setting is longer than the current (or temporarily extended) apnea interval, the old interval is extended to match the new interval immediately.

10.13 Detecting Occlusion and Disconnect

10.13.1 Occlusion

The ventilator detects severe patient circuit occlusions to protect the patient from excessive airway pressures, or from receiving little or no gas. Occlusions require immediate attention to remedy.

The ventilator detects a severe occlusion if:

- The inspiratory or expiratory limb of the breathing circuit is partially or completely occluded (condensate or secretions collected in a gravity-dependent loop, kinked or crimped tubing, etc.).
- The ventilator **exhaust** port is blocked or resistance through the port is too high.
- The exhalation valve fails in the closed position (occlusion detection at the **from patient** port begins after 195 ms of exhalation has passed).

The ventilator does not detect a severe occlusion if:

- The pressure difference between the inspiratory and the expiratory transducers is less than or equal to 5 cmH₂O.
- The exhalation valve fails in the closed position and the pressure in the exhalation limb is less than 2 cmH₂O.
- Silicone tubing is attached to the **exhaust** port of the ventilator (i.e., for metabolic monitoring purposes).

The ventilator checks the patient circuit for occlusions during all modes of breathing (except Stand-By state and safety valve open) at delivery of every breath. 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 during disconnect and safety valve open). Once the **exhaust** port check begins, the ventilator detects a severe occlusion within 100 ms following the first 200 ms of exhalation. All occlusion checking is disabled during pressure sensor autozeroing.

When an occlusion is detected, an alarm sounds, the ventilator enters the OSC (occlusion status cycling) state and displays a message indicating the length of time the patient has gone without ventilation (how long the ventilator has been in OSC). This alarm has the capability to autoreset, as occlusions such as those due to patient activity (for example, crimped or kinked tubing) can correct themselves.

Once a severe occlusion is detected, the ventilator acts to minimize airway pressure. Because any severe occlusion places the patient at risk, the ventilator minimizes the risk while displaying the length of time the patient has been without ventilatory support. Severe occlusion is detected regardless of what mode or triggering strategy is in effect. When a severe occlusion is detected, the ventilator terminates normal ventilation, terminates any active audio paused interval, annunciates an occlusion alarm, and enters the safe state (exhalation and inspiratory valve deenergized and safety valve open) for 15 seconds or until inspiratory pressure drops to 5 cmH₂O or less, whichever comes first.

During a severe occlusion, the ventilator enters OSC, in which it periodically attempts to deliver a pressure-based breath while monitoring the inspiratory and expiratory phases for the existence of a severe occlusion. If the severe occlusion is corrected, the ventilator detects the corrected condition after two complete OSC breath periods during which no occlusion is detected. When the ventilator delivers an OSC breath, it closes the safety valve and waits 500 ms for the safety valve to close completely, delivers a breath with a target pressure of 15 cmH₂O for 2000 ms, then cycles to exhalation. This breath is followed by a mandatory breath according to the current settings, but with PEEP = 0 and O₂% equal to 100% for adult/pediatric circuit types or 40% for neonatal circuits. During OSC (and only during OSC), the $\bar{P}_{PEAK}$ (high circuit pressure) alarm limit is disabled to ensure it does not interfere with the ability of the ventilator to detect a corrected occlusion. When the ventilator does not detect a severe occlusion, it resets the occlusion alarm, reestablishes PEEP, and reinstates breath delivery according to current settings.

Inspiratory and expiratory pause maneuvers, and manual inspirations are suspended during a severe occlusion. Pause maneuvers are canceled by a severe occlusion. During a severe occlusion, ventilator settings changes are possible. Severe occlusions are not detected when the ventilator is in the safety valve open (SVO) state.

A corrected occlusion is detected within 15 seconds.

10.13.2 Disconnect

A circuit disconnect condition is detected when the ventilator cannot ensure that a patient is receiving sufficient tidal volume (due to a large leak or disconnected patient circuit). This discussion applies when Leak Sync is disabled.

When a disconnect is detected, an alarm sounds, the ventilator indicates that a disconnect has been detected, and displays a message indicating the length of time the patient has gone without ventilation.

Patient data are not displayed during a circuit disconnect condition.

The ventilator monitors the expiratory pressure and flow, delivered volume, and exhaled volume to declare a disconnect using any of these methods

- The ventilator detects a disconnect when the expiratory pressure transducer measures no circuit pressure and no exhaled flow during the first 200 ms of exhalation. The ventilator postpones declaring a disconnect for another 100 ms to allow an occlusion (if detected) to be declared first, because it is possible for an occlusion to match the disconnect detection criteria.
- Despite many possible variations of circuit disconnections or large leaks, it is possible for a patient to generate some exhaled flow and pressure. The ventilator then uses the disconnect sensitivity (D_{SENS} , the percentage of delivered volume lost during the expiratory phase of the same breath to declare a disconnect) setting to detect a disconnect.
- If the disconnect occurs during a spontaneous breath, a disconnect is declared when the inspiration is terminated by maximum inspiratory time (or the $\uparrow T_{\text{I SPONT}}$ limit setting when ventilation type is non-invasive [NIV]) and the ventilator detects inspiratory flow rising to the maximum allowable.
- If the disconnect occurs at the endotracheal tube, the exhaled volume will be much less than the delivered volume for the previous inspiration. The ventilator declares a disconnect if the exhaled volume is lower than the D_{SENS} setting for three consecutive breaths. The D_{SENS} setting helps avoid false detections due to leaks in the circuit or the patient's lungs, and the three-consecutive-breaths requirement helps avoid false detections due to a patient out-drawing the ventilator during volume control (VC) breaths.
- Flow less than a value determined using the D_{SENS} setting and pressure less than 0.5 cmH₂O detected for 10 consecutive seconds during exhalation.



WARNING:

When ventilation type is NIV, and D_{SENS} setting is turned OFF, the system may not sound an alarm for leaks and some disconnect conditions.

Once the ventilator detects a patient circuit disconnect, the ventilator declares a high-priority alarm and discontinues breath delivery, regardless of what mode (including apnea) was active when the disconnect was detected. If there is an active audio paused interval when the disconnect occurs, the audio paused interval is **not** canceled. The ventilator displays the length of time the patient has been without ventilatory support. During the disconnect, the exhalation valve closes, idle flow (10 L/min flow at 100% O₂% or 40% O₂ in NeoMode, if available with Leak Sync disabled and 20 L/min with Leak Sync enabled) begins, and breath triggering is disabled. A message appears identifying how long the patient has gone without ventilatory support.

The ventilator monitors both expiratory flow and circuit pressures to detect reconnection. The ventilator declares a reconnect if any of the following criteria are met for the applicable time interval:

- Exhaled idle flow within the reconnect threshold is detected.
- Inspiratory and expiratory pressures are both above or both below reconnect threshold levels or,
- Inspiratory pressure rises to a reconnect level.

If the disconnect condition is corrected, the ventilator detects the corrected condition within 1 second.

Ventilator triggering, apnea detection, expiratory and inspiratory pause maneuvers, manual inspirations, and programmed maneuvers or one-time events are suspended during a patient circuit disconnect condition. Spirometry is not monitored during a disconnect, and all alarms based on spirometry values are disabled. During a disconnect condition, ventilator settings changes are possible.

If the disconnect alarm is autoreset or manually reset, the ventilator reestablishes PEEP. Once PEEP is reestablished, the ventilator reinstates breath delivery according to settings in effect before the disconnect was detected.

Circuit disconnect detection is not active during OSC, SVO, or prior to patient connection.

10.13.3 Annunciating Occlusion and Disconnect Alarms

Occlusion and disconnection cannot be declared at the same time. Therefore, the ventilator annunciates only the first event to be declared.

10.14 Respiratory Mechanics

See [Respiratory Mechanics Maneuvers \(4.9\)](#) on page 4-26 for instructions on how to perform these maneuvers.

In addition to inspiratory pause and expiratory pause maneuvers, the ventilator can provide other respiratory maneuvers, including negative inspiratory force (NIF), occlusion pressure ($P_{0.1}$) and vital capacity (VC), as well as automatic calculations of lung function and performance, such as dynamic compliance (C_{DYN}) and dynamic resistance (R_{DYN}), peak expiratory flow (PEF), end expiratory flow (EEF), C_{20}/C , and peak spontaneous flow (PSF).

Respiratory maneuvers can be performed in all breathing modes (except as noted below) but are not available during the following conditions:

- Apnea ventilation
- Safety PCV
- Occlusion status cycling (OSC)
- Non-invasive ventilation (NIV)
- When the circuit type is neonatal
- SVO
- Ventilator is in Stand-By state
- When any other respiratory maneuver has already taken place during the same breath

The GUI also displays any maneuver request, distinguishing between requests that are accepted or rejected, and any maneuver that has begun, ended, or has been canceled.

When a maneuver is selected, a GUI information panel is opened, displaying the maneuver name, user prompts and controls, and recent calculated results.

Any maneuver is canceled automatically upon declaration of any of the following alarms:

- $\uparrow P_{PEAK}$ alarm
- $\uparrow P_{VENT}$ alarm
- $\uparrow V_{TI}$

The following respiratory mechanics maneuvers are not available in BiLevel ventilation:

- $P_{0.1}$ —Occlusion pressure
- NIF —Negative inspiratory force
- VC—Vital capacity

10.14.1 Inspiratory Pause



Note:

Inspiratory pause and expiratory pause maneuvers can be performed directly by pressing the respective keys on the GUI or by swiping the Menu tab on the left side of the GUI. For more information on how to perform respiratory mechanics maneuvers from the Menu tab, see [Respiratory Mechanics Maneuvers \(4.9\)](#) on page 4-26.

An inspiratory pause maneuver extends the inspiratory phase of a single mandatory breath for the purpose of measuring end inspiratory circuit pressure which is used to calculate static compliance of the patient's lungs and thorax (C_{STAT}), static resistance of the respiratory system (R_{STAT}), and inspiratory plateau pressure (P_{PL}). To calculate these pressures, the inspiratory and exhalation valves are closed, allowing pressures on both sides of the artificial airway to equalize, revealing the actual lung inflation pressure during a no-flow condition. An inspiratory pause maneuver can be either automatically or manually administered, and is only available during the next mandatory breath in A/C, SIMV, BiLevel or SPONT modes. In BiLevel, an inspiratory pause maneuver is scheduled for the next inspiration prior to a transition from P_H to P_L . Only one inspiratory pause maneuver is allowed per breath. An inspiratory pause maneuver cannot occur during apnea ventilation, safety PCV, stand-by state, occlusion, and SVO.

An **automatic** inspiratory pause maneuver begins when the inspiratory pause key is pressed momentarily or the maneuver is started from the GUI screen. See [Respiratory Mechanics Maneuvers \(4.9\)](#) on page 4-26 for more information on performing respiratory mechanics maneuvers from the Menu tab on the GUI rather than using the keys on the GUI. The pause lasts at least 0.5 second but no longer than 3 seconds. A **manual** inspiratory pause maneuver starts by pressing and

holding the inspiratory pause key. The pause lasts for the duration of the key press (up to 7 seconds).

An active **manual** inspiratory pause maneuver is considered complete if any of the following occur:

- The inspiratory pause key is released and at least 2 seconds of the inspiratory pause maneuver have elapsed or pressure stability conditions have been detected for not less than 0.5 second.
- Pause duration reaches 7 seconds.

A **manual** inspiratory pause maneuver request (if the maneuver is not yet active) will be canceled if any of events 1 through 10 in [Table 10-5](#) occur.

Table 10-5. Inspiratory and Expiratory Pause Events

Event identifier	Event
1	There is a loss of communications with the GUI
2	High Ventilator pressure limit ($\uparrow P_{\text{VENT}}$) is reached
3	High circuit pressure limit ($\uparrow P_{\text{PEAK}}$) is reached
4	A disconnect is detected
5	Occlusion is detected
6	Apnea is detected
7	72 seconds have elapsed without an inspiratory pause after one has been requested
8	INSPIRATION TOO LONG alarm is detected
9	High inspired tidal volume ($\uparrow V_{\text{T}}$) alarm is detected
10	High compensation pressure ($\uparrow P_{\text{COMP}}$) alarm is detected
11	Cancel is touched if maneuver is initiated from the GUI screen.
12	Safety valve open (SVO) is detected
13	Patient trigger effort causes circuit pressure to go below sensitivity. The sensitivity level is the setting value for pressure trigger or the backup pressure value for flow trigger
14	BUV is entered
15	Expiratory pause key is pressed (inspiratory pause key if maneuver is an expiratory pause)

During a **manual** inspiratory pause maneuver, the maneuver is terminated if any of events 1, 3, 5, 6, 12, or 13 occur.

An inspiratory pause maneuver is ignored if the ventilator is in apnea ventilation, safety PCV, OSC, SVO, BUV, or Stand-By state.

An active **automatic** inspiratory pause maneuver is terminated and exhalation begun if any of events 1 through 12, or 14 occur.

The active **automatic** inspiratory pause maneuver is considered complete if the pause duration reaches 3 seconds or pressure stability conditions have been detected for not less than 0.5 second.

An **automatic** inspiratory pause maneuver request (if the maneuver is not yet active) will be canceled if any of events 1 through 9, 11, 12, 14, or 15 occur.

Other characteristics of inspiratory pause maneuvers include:

- During an inspiratory pause maneuver, the apnea interval (T_A) is extended by the duration of the inspiratory pause maneuver.
- If the ventilator is in SIMV, the breath period during which the next scheduled VIM occurs will also be extended by the amount of time the inspiratory pause maneuver is active.
- All activations of the inspiratory pause control are logged in the Patient Data log.
- Severe occlusion detection is suspended.
- When calculating I:E ratio, the inspiratory pause maneuver is considered part of the inspiratory phase.
- The expiratory time remains unchanged, and will result in a change in the I:E ratio for the breath that includes the inspiratory phase.

Once the inspiratory pause maneuver is completed the operator can review the quality of the maneuver waveform and accept or reject the maneuver data.

10.14.2 Expiratory Pause

An expiratory pause maneuver extends the expiratory phase of a single breath to measure end expiratory lung pressure ($PEEP_{TOT}$) and allows intrinsic PEEP ($PEEP_I$) to be calculated as $PEEP_{TOT}$ minus set PEEP. The pressures on either side of the artificial airway are allowed to equalize by closing the inspiratory and exhalation valves. Expiratory pause maneuvers are available in A/C, SIMV, and BiLevel modes. For A/C and SIMV, the expiratory pause maneuver is scheduled for the next end-of-exhalation prior to a mandatory breath. In BiLevel, the expiratory pause maneuver occurs at the next end-of-exhalation prior to a transition from P_L to P_H . Only one expiratory pause maneuver per breath is allowed, and the expiratory pause maneuver request is rejected if an inspiratory pause maneuver has already taken place during the same breath.

A request for an expiratory pause maneuver is ignored in apnea ventilation, safety PCV, SPONT, OSC, BUV, and Stand-By. See [To access respiratory mechanics maneuvers](#), page 4-26 for more information on performing these maneuvers from the GUI screen rather than using the keys on the GUI.

Either **manual** or **automatic** expiratory pause maneuvers can occur. A momentary press of the expiratory pause key begins an automatic expiratory pause maneuver, which lasts at least 0.5 second, but no longer than 3.0 seconds. A **manual** expiratory pause maneuver starts by pressing

and holding the expiratory pause key and lasts for the duration of the key-press (up to 15 seconds).

An active **manual** expiratory pause maneuver is terminated if any of events 1 through 12 occur (see [Table 10-5](#) on page 10-42).

An active **manual** expiratory pause maneuver is complete if the expiratory pause key is released and at least 3 seconds of the expiratory pause maneuver have elapsed, pressure stability conditions have been detected for ≥ 0.5 second, or pause duration lasts 15 seconds.

An active **automatic** expiratory pause maneuver is terminated if any of events 1, 3, or 11 through 13 in [Table 10-5](#) occur.

An active **automatic** expiratory pause maneuver is complete if pause duration reaches 3 seconds or pressure stability conditions have been detected for ≥ 0.5 second, or pause duration lasts 15 seconds.

The **automatic** expiratory pause maneuver request (the maneuver is not yet active) is canceled if events 1 through 9, 11, 12, or 15 in [Table 10-5](#) occur.

The **automatic** expiratory pause maneuver is terminated and inspiration begun if any of events 1, 3, or 11 through 13 in [Table 10-5](#) occur.

Other characteristics of expiratory pause maneuvers include:

- During an active manual expiratory pause maneuver, severe occlusion detection is suspended.
- When calculating I:E ratio, the expiratory pause maneuver is considered part of the expiratory phase.
- During the expiratory pause maneuver, the inspiratory time remains unchanged, so the I:E ratio is changed for the breath that includes the expiratory pause maneuver.
- All activations of the expiratory pause control are logged in the Patient Data log.

Once the expiratory pause maneuver is completed the operator can review the quality of the maneuver waveform and accept or reject the maneuver data.

10.14.3 Negative Inspiratory Force (NIF) Maneuver

The negative inspiratory force (NIF) maneuver is a coached maneuver where the patient is prompted to draw a maximum inspiration against an occluded airway (the inspiratory and exhalation valves are fully closed).

A NIF maneuver is canceled if:

- Disconnect is detected.
- Occlusion is detected.
- SVO is detected.
- $\uparrow P_{PEAK}$ alarm is declared.

- $\uparrow P_{\text{VENT}}$ alarm is declared.
- $\uparrow V_{\text{Tl}}$ alarm is declared.
- Communications with the GUI is lost.
- The maneuver has been active for 30 seconds and an inspiration is not detected.
- INSPIRATION TOO LONG alarm is declared.
- A manual inspiration is requested.

When a NIF maneuver is activated, a single pressure-time waveform grid is automatically displayed. During a NIF maneuver, the circuit pressure displays on the waveforms screen and is regularly updated, producing a real-time display.

When an active NIF maneuver ends successfully, the calculated NIF result appears on the waveforms screen and on the maneuver panel. The NIF value displayed represents the maximum negative pressure from PEEP.

When a NIF maneuver ends, a PEEP restoration breath is delivered to the patient, then normal breath delivery resumes.

10.14.4 **$P_{0.1}$ Maneuver (Occlusion Pressure)**

$P_{0.1}$ is the negative airway pressure (delta pressure change) generated during the first 100 ms of an occluded inspiration. It is an estimate of the neuromuscular drive to breathe.

When a $P_{0.1}$ maneuver ends successfully, the calculated airway pressure displays on the waveforms screen and on the maneuver panel. A $P_{0.1}$ maneuver is terminated if 7 seconds elapse and a trigger has not been detected to activate the maneuver.

A $P_{0.1}$ maneuver is canceled if:

- Disconnect is detected.
- Occlusion is detected.
- SVO is detected.
- $\uparrow P_{\text{PEAK}}$ alarm is declared.
- $\uparrow P_{\text{VENT}}$ alarm is declared.
- $\uparrow V_{\text{Tl}}$ alarm is declared.
- INSPIRATION TOO LONG alarm is declared.
- Communications with the GUI is lost.
- A manual inspiration is requested.

10.14.5 Vital Capacity (VC) Maneuver

The vital capacity (VC) maneuver is a coached maneuver where the patient is prompted to draw a maximum inspiration (regardless of the current settings) and then to slowly and fully exhale.

When the vital capacity maneuver becomes active, the ventilator delivers a spontaneous inspiration in response to patient effort (with $P_{SUPP}=0$, Rise time% =50, and $E_{SENS}=0$), and then allows for a full exhalation effort.

When a vital capacity maneuver is requested, a single volume-time waveform grid is automatically displayed. A vital capacity maneuver is canceled if:

- Disconnect is detected.
- Occlusion is detected.
- SVO is detected.
- $\uparrow P_{PEAK}$ alarm is declared.
- $\uparrow P_{PEAK}$ alarm is declared.
- $\uparrow V_{TI}$ alarm is declared.
- INSPIRATION TOO LONG alarm is declared.
- Communications with the GUI is lost.
- A manual inspiration is requested.
- The maneuver has been active for 15 seconds and inspiration is not detected.
- Cancel is touched.

When an active VC maneuver ends successfully, the calculated expiratory volume displays on the waveforms screen and on the maneuver panel and a PEEP restoration breath is delivered.

10.15 Ventilator Settings

10.15.1 Apnea Ventilation

Apnea ventilation is a backup mode and starts if the patient fails to breathe within the apnea interval (T_A) set by the operator. T_A defines the maximum allowable length of time between the start of inspiration and the start of the next inspiration. Available settings include mandatory type (PC or VC). For PC breaths the allowable settings are:

- Apnea interval (T_A)
- Inspiratory pressure (P_I)

- Inspiratory time (T_I)
- Respiratory rate (f)

For VC breaths, the allowable settings are:

- Apnea interval (T_A)
- Flow pattern
- $O_2\%$
- Peak inspiratory flow ($\dot{V}_{MAX}$)
- Respiratory rate (f)
- Tidal volume (V_T)

During apnea ventilation with PC selected as the mandatory type, rise time% is fixed at 50%, and the constant parameter during a rate change is inspiratory time (T_I).

If apnea is possible (that is, if $(60/f) > T_A$) increasing the non-apnea $O_2\%$ setting automatically changes apnea ventilation $O_2\%$ if it is not already set higher than the new non-apnea $O_2\%$. Apnea ventilation $O_2\%$ does not automatically change by decreasing the non-apnea $O_2\%$. Whenever there is an automatic change to an apnea setting, a message appears on the GUI, and the apnea settings screen appears.

During apnea ventilation, changes to all non-apnea ventilation settings are allowed, but the new settings do not take effect until the ventilator resumes normal ventilation. Being able to change T_A during apnea ventilation can avoid immediately re-entering apnea ventilation once normal ventilation resumes.

Because the minimum value for T_A is 10 seconds, apnea ventilation cannot take place when non-apnea f is greater than or equal to 5.8/min. The ventilator does not enter apnea ventilation if T_A is equal to the breath period interval. Set T_A to a value less than the expected or current breath period interval as a way of allowing the patient to initiate breaths while protecting the patient from the consequences of apnea.

10.15.2 Circuit Type and Predicted Body Weight (PBW)

Together, circuit type and PBW (displayed in lb or kg) provide the basis for new patient values and absolute limits on various ventilator settings such as tidal volume V_T and Peak flow ($\dot{V}_{MAX}$). Run SST to change the circuit type. [Table 10-6](#) gives the minimum, maximum, and new patient default values for V_T based on circuit type.

Table 10-6. Values for V_T Based on Circuit Type

Circuit type	New patient default	Minimum V_T	Maximum V_T
Neonatal	When mandatory type is VC+, MAX {2 mL, (mL/kg Ratio $\times$ PBW)} mL; When mandatory type is VC, MAX {3 mL, (mL/kg Ratio $\times$ PBW)} mL	2 mL if NeoMode 2.0 software option is installed	315 mL
Pediatric	mL/kg ratio $\times$ PBW mL	25 mL	1590 mL
Adult	mL/kg ratio $\times$ PBW mL	25 mL	2500 mL

For more information on V_T calculations based on PBW and circuit type, see [Table 11-9](#) on page 11-7, V_T setting.

Table 10-7. Peak Flow and Circuit Type (Leak Sync Disabled)

Circuit type	Maximum peak flow ($\dot{V}_{MAX}$) setting
Neonatal	30 L/min
Pediatric	60 L/min
Adult	150 L/min

PBW determines constants for breath delivery algorithms, some user-settable alarms, the high spontaneous inspiratory time limit setting ($\bar{T}_{I\ SPONT}$) in NIV, and the non-settable INSPIRATION TOO LONG alarm.

10.15.3 Ventilation Type

There are two ventilation type choices—invasive and NIV (non-invasive). Invasive ventilation is conventional ventilation used with endotracheal or tracheostomy tubes. All installed software options, breathing modes, breath types, and trigger types are available during invasive ventilation.

NIV interfaces include non-vented full-faced or nasal masks or nasal prongs. See [NIV Breathing Interfaces \(4.7.2\)](#) on page 4-20 for a list of interfaces that have been successfully tested with NIV).

NIV enables the ventilator to handle large system leaks associated with these interfaces by providing pressure-based disconnect alarms, minimizing false disconnect alarms, and replacing the INSPIRATION TOO LONG alarm with a high spontaneous inspiratory time limit ($\bar{T}_{I\ SPONT}$) setting and visual indicator.

The following list shows the subset of invasive settings active during NIV:

- **Mode** — A/C, SIMV, SPONT. (BiLevel is not available during NIV.)
- **Mandatory Type** — PC or VC. (VC+ is not available during NIV.)
- **Spontaneous Type** — PS (TC and VS are not available during NIV.)

During NIV alarm setup, the clinician may set alarms to OFF and must determine if doing so is appropriate for the patient's condition.

10.15.4 Mode and Breath Type

Specifying the mode defines the types and sequences of breaths allowed for both invasive and NIV ventilation types.

Table 10-8. Modes and Breath Types

Mode	Mandatory breath type	Spontaneous breath type	Sequence
A/C	Invasive: VC, VC+, or PC NIV: VC or PC	Not allowed	All mandatory (patient-, ventilator-, or operator-initiated)
SIMV	Invasive: PC, VC, or VC+ NIV: VC or PC	Pressure supported (PS) or TC.	Each new breath begins with a mandatory interval, during which a patient effort yields a synchronized mandatory breath. If no patient effort is detected during the mandatory interval, the ventilator delivers a mandatory breath. Subsequent patient efforts before the end of the breath yield spontaneous breaths.
SPONT	Not allowed (PC or VC allowed only for manual inspirations).	Invasive: Pressure supported (PS), Tube compensated (TC), Volume supported (VS), Proportionally assisted (PAV+) NIV: PS	All spontaneous (except for manual inspirations).
BiLevel (invasive ventilation type only)	PC	PS, TC	Combines mandatory and spontaneous breathing modes. See Appendix A for more information on BiLevel ventilation.
CPAP	VC or PC (allowed only for OIM breaths)	N/A	All spontaneous (except for manual inspirations). See Appendix D for more information on CPAP.

Breath types must be defined before settings can be specified. There are only two categories of breath type: mandatory and spontaneous. Mandatory breaths are volume controlled (VC) or pressure controlled (PC or VC+). The ventilator currently offers spontaneous breaths that are pressure supported (PS) volume supported (VS), tube compensated (TC), or proportionally assisted (PAV+). [Table 10-9](#) shows the modes and breath types available on the ventilator.

Table 10-9. Illustrated Modes and Breath Types

A/C, SIMV, SPONT, BiLevel							
Mandatory				Spontaneous			
PC	VC	VC+		PS	TC	VS	PAV+

The mode setting defines the interaction between the ventilator and the patient.

- Assist/control (A/C) mode allows the ventilator to control ventilation within boundaries specified by the practitioner. All breaths are mandatory, and can be PC, VC, or VC+
- Spontaneous (SPONT) mode allows the patient to control ventilation. The patient must be able to breathe independently, and exert the effort to trigger ventilator support.
- Synchronized Intermittent Mandatory Ventilation (SIMV) is a mixed mode that allows a combination of mandatory and spontaneous interactions. In SIMV, the breaths can be spontaneous or mandatory, mandatory breaths are synchronized with the patient's inspiratory efforts, and breath delivery is determined by the f setting.
- BiLevel is a mixed mode that combines both mandatory and spontaneous breath types. Breathes are delivered in a manner similar to SIMV mode with PC selected, but providing two levels of pressure. The patient is free to initiate spontaneous breaths at either pressure level during BiLevel.

Changes to the mode are phased in at the start of inspiration. Mandatory and spontaneous breaths can be flow or pressure triggered.

The ventilator automatically links the mandatory type setting to the mode setting. During A/C or SIMV modes, once the operator has specified volume or pressure, the ventilator displays the appropriate breath parameters. Changes in the mandatory type are phased in at the start of inspiration.

10.15.5 Respiratory Rate (f)

The f setting determines the minimum number of mandatory breaths per minute for ventilator-initiated mandatory breaths in A/C, SIMV, and BiLevel modes. If the mode is A/C or SIMV and VC is the breath type, specifying $\dot{V}_{MAX}$ and flow pattern determines T_I , T_E , and I:E. In PC breaths, specifying T_I automatically determines the other timing variables. See [Inspiratory Time \(\$T_I\$ \) \(10.15.13\)](#) on page 10-53 for an explanation of the interdependencies of f, T_I , T_E , and I:E. Changes to the f setting are phased in at the start of inspiration.

The ventilator does not accept a proposed f setting if it would cause the new T_I or T_E to be ≤ 0.2 second, the T_I to be ≥ 8 seconds, or I:E ratio $\geq 4.00:1$. The ventilator also applies these restrictions to a proposed change to the apnea respiratory rate, except that apnea I:E cannot exceed 1.00:1. An exception to this rule occurs in BiLevel ventilation where the proposed f setting will allow the I:E ratio to be $\geq 4.00:1$ only until the minimum T_I is reached.

10.15.6 Tidal Volume (V_T)

The V_T setting determines the volume of gas delivered to the patient during a VC mandatory breath. The delivered V_T is compensated for BTPS and patient circuit compliance. Changes to the V_T setting are phased in at the start of inspiration. The V_T setting only affects the delivery of mandatory breaths.

When proposing a change to the V_T setting, the ventilator compares the new value with the settings for f , $\dot{V}_{MAX}$, flow pattern, and T_{PL} . If the proposed setting would result in an I:E ratio that exceeds 4.00:1 or a $T_I \geq 8$ seconds or ≤ 0.2 second, or a $T_E \leq 0.2$ second, the ventilator disallows the change.

10.15.7 Peak Inspiratory Flow ($\dot{V}_{MAX}$)

The $\dot{V}_{MAX}$ setting determines the maximum rate of delivery of tidal volume to the patient during mandatory VC breaths, only. Changes to $\dot{V}_{MAX}$ are phased in at the start of inspiration. Mandatory breaths are compliance compensated, even at the maximum $\dot{V}_{MAX}$ setting. Circuit compliance compensation does not cause the ventilator to exceed the ventilator's maximum flow capability.

When proposing a change to the $\dot{V}_{MAX}$ setting, the ventilator compares the new value with the settings for V_T , f , flow pattern, and T_{PL} . It is impossible to set a new $\dot{V}_{MAX}$ that would result in an I:E ratio that exceeds 4.00:1, or a $T_I \geq 8.0$ seconds or ≤ 0.2 second, or a $T_E \leq 0.2$ second.

10.15.8 Plateau Time (T_{PL})

The T_{PL} setting determines the amount of time inspiration is held in the patient's airway after inspiratory flow has ceased. T_{PL} is available only during VC mandatory breaths (for A/C and SIMV mode, and operator-initiated mandatory breaths). T_{PL} is not available for PC mandatory breaths. Changes to the T_{PL} setting are phased in at the start of inspiration.

When proposing a change to the T_{PL} setting, the ventilator computes the new I:E ratio and T_I , given the current settings for V_T , f , $\dot{V}_{MAX}$, and flow pattern. It is impossible to set a new T_{PL} that would result in an I:E ratio that exceeds 4.00:1, or a $T_I \geq 8$ seconds or ≤ 0.2 second, or a $T_E \leq 0.2$ second. For the I:E ratio calculation, T_{PL} is considered part of the inspiratory phase.

10.15.9 Flow Pattern

The flow pattern setting defines the gas flow pattern of volume-controlled (VC) mandatory breaths only. The selected values for V_T and $\dot{V}_{MAX}$ apply to both the square or descending ramp flow patterns. If V_T and $\dot{V}_{MAX}$ are held constant, T_I approximately halves when the flow pattern changes from descending ramp to square (and approximately doubles when flow pattern

changes from square to descending ramp), and corresponding changes to the I:E ratio also occur. Changes in flow pattern are phased in at the start of inspiration.

The settings for flow pattern, V_T , f , T_{PL} , and $\dot{V}_{MAX}$ are interrelated. If any setting change would cause any of the following, the ventilator does not allow that change

- I:E ratio >4:1
- $T_I > 8.0$ s or $T_I < 0.2$ s
- $T_E < 0.2$ s

10.15.10 Flow Sensitivity ($\dot{V}_{SENS}$)

The $\dot{V}_{SENS}$ setting defines the rate of flow inspired by a patient that triggers the ventilator to deliver a mandatory or spontaneous breath. When $\dot{V}$ -Trig is selected, a base flow of gas (1.5 L/min) travels through the patient circuit during the ventilator's expiratory phase. Once a value for flow sensitivity is selected, the ventilator delivers a base flow equal to $\dot{V}_{SENS} + 1.5$ L/min (base flow is not user-selectable). When the patient inhales and their inspiratory flow exceeds the $\dot{V}_{SENS}$ setting, a trigger occurs and the ventilator delivers a breath. Reductions to $\dot{V}_{SENS}$ are phased in immediately, while increases are phased in at the start of exhalation.

When $\dot{V}_{SENS}$ is active, it replaces pressure sensitivity (P_{SENS}). The $\dot{V}_{SENS}$ setting has no effect on the P_{SENS} setting. $\dot{V}_{SENS}$ can be active in any ventilation mode (including pressure supported, volume controlled, pressure controlled, and apnea ventilation). When $\dot{V}_{SENS}$ is active, a backup P_{SENS} setting of 2 cmH₂O is in effect to detect the patient's inspiratory effort, even if the flow sensors do not detect flow.

Although the minimum $\dot{V}_{SENS}$ setting of 0.2 L/min (adult/pediatric circuit types) or 0.1 L/min (neonatal circuit type) can result in autotriggering, it can be appropriate for very weak patients. The maximum setting of 20 L/min (adult/pediatric circuit types) or 10 L/min (neonatal circuit type) is intended to avoid autotriggering when there are significant leaks in the patient circuit.

10.15.11 Pressure Sensitivity (P_{SENS})

The P_{SENS} setting selects the pressure drop below baseline (PEEP) required to begin a patient-initiated breath (either mandatory or spontaneous). Changes to P_{SENS} are phased in immediately. The P_{SENS} setting has no effect on the $\dot{V}_{SENS}$ setting and is active only if the trigger type is P-Trig.

Lower P_{SENS} settings provide greater patient comfort and require less patient effort to initiate a breath. However, fluctuations in system pressure can cause autotriggering at very low settings. The maximum P_{SENS} setting avoids autotriggering under worst-case conditions if patient circuit leakage is within specified limits.

10.15.12 Inspiratory Pressure (P_I)

The P_I setting determines the pressure at which the ventilator delivers gas to the patient during a PC mandatory breath. The P_I setting only affects the delivery of PC mandatory breaths. The selected P_I is the pressure above PEEP. (For example, if PEEP is set to 5 cmH₂O, and P_I is 20 cmH₂O, the ventilator delivers gas to the patient at 25 cmH₂O.) Changes to the P_I setting are phased in at the start of inspiration.

The sum of PEEP+ P_I +2 cmH₂O cannot exceed the high circuit pressure ($\uparrow P_{PEAK}$) limit. To increase this sum of pressures, first raise the $\uparrow P_{PEAK}$ limit before increasing the settings for PEEP or P_I . The minimum value for P_I is 5 cmH₂O and the maximum value is 90 cmH₂O.

10.15.13 Inspiratory Time (T_I)

The T_I setting determines the time during which an inspiration is delivered to the patient for PC mandatory breaths. The ventilator accepts a setting as long as the resulting I:E ratio and T_E settings are valid. Changes to T_I phase in at the start of inspiration. Directly setting T_I in VC mandatory breaths is not allowed.

The ventilator rejects settings that result in an I:E ratio $\geq 4.00:1$, a $T_I \geq 8$ seconds or ≤ 0.2 second, or a $T_E \leq 0.2$ second to ensure the patient has adequate time for exhalation.

Setting f and T_I automatically determines the value for I:E and T_E .

$$60/f - T_I = T_E$$

This equation summarizes the relationship between T_I , I:E, T_E , and breath period time

$$T_I = \left(\frac{60}{f}\right)((I:E)/(1 + I:E))$$

If the f setting remains constant, any one of the three variables (T_I , I:E, or T_E) can define the inspiratory and expiratory intervals. If the f setting is low (and additional spontaneous patient efforts are expected), T_I can be a more useful variable to set than I:E. As the f setting increases (and the fewer patient-triggered breaths are expected), the I:E setting becomes more relevant. Regardless of which variable is chosen, a breath timing bar always shows the interrelationship between T_I , I:E, T_E , and f .

10.15.14 Expiratory Time (T_E)

The T_E setting defines the duration of exhalation for PC and VC+ mandatory breaths, only. Changes to the T_E setting are phased in at the start of exhalation. Setting f and T_E automatically determines the value for I:E ratio and T_I . See [Inspiratory Time \(\$T_I\$ \) \(10.15.13\)](#) on page 10-53 for an explanation of the interdependencies of f , T_I , T_E , and I:E.

10.15.15 I:E Ratio

The I:E ratio setting is available when I:E is selected as the constant during rate change. The I:E setting determines the ratio of inspiratory time to expiratory time for mandatory PC breaths. The ventilator accepts the specified range of direct I:E ratio settings as long as the resulting T_I and T_E settings are within the ranges established for mandatory breaths. Changes to the I:E ratio phase in at the start of inspiration. Directly setting the I:E ratio in VC mandatory breaths is not allowed. See [Inspiratory Time \(\$T_I\$ \) \(10.15.13\)](#) on page 10-53 for an explanation of the interdependencies of f , T_I , T_E , and I:E.

Setting f and I:E automatically determine the values for T_I and T_E . The maximum I:E ratio setting of 4.00:1 is the maximum that allows adequate time for exhalation and is intended for inverse ratio pressure control ventilation.

10.15.16 High Pressure (P_H) in BiLevel

The pressure level entered by the operator for the inspiratory phase of the mandatory breath in BiLevel ventilation.

10.15.17 Low Pressure (P_L) in BiLevel

The pressure level entered by the operator for the expiratory phase of the mandatory breath in BiLevel ventilation.

10.15.18 High Time (T_H) in BiLevel

The duration of time (in seconds) the ventilator maintains the set high pressure level in BiLevel ventilation.

10.15.19 Low Time (T_L) in BiLevel

The duration of time (in seconds) the ventilator maintains the set low pressure level in BiLevel ventilation.

10.15.20 $T_H:T_L$ Ratio in BiLevel

The ratio of T_H to T_L in BiLevel ventilation, similar to I:E ratio when ventilating a patient without BiLevel.

10.15.21 PEEP

This setting defines the positive end-expiratory pressure (PEEP), also called baseline airway pressure. PEEP is the positive pressure maintained in the patient circuit during exhalation. Changes to the PEEP setting are phased in at the start of exhalation.

The sum of

- PEEP+7 cmH₂O
- PEEP+ P_I +2 cmH₂O (if PC is active)
- PEEP+ P_{SUPP} +2 cmH₂O (if PS is in use)

cannot exceed the $\uparrow P_{PEAK}$ limit. To increase the sum of pressures, first raise the $\uparrow P_{PEAK}$ limit before increasing the settings for PEEP, P_I , or P_{SUPP} .

If there is a loss of PEEP from occlusion, disconnect, safety valve open, or loss of power conditions, PEEP is reestablished (when the condition is corrected) by the ventilator delivering a PEEP restoration breath. The PEEP restoration breath is a 1.5 cmH₂O pressure-supported breath with exhalation sensitivity of 25%, and rise time% of 50%. A PEEP restoration breath is also delivered at the conclusion of vent startup. After PEEP is restored, the ventilator resumes breath delivery at the current settings.



Note:

PEEP restoration breath parameters are not user adjustable.

10.15.22 Pressure Support (P_{SUPP})

The P_{SUPP} setting determines the level of positive pressure above PEEP applied to the patient's airway during a spontaneous breath. P_{SUPP} is only available in SIMV, SPONT, and BiLevel, in which spontaneous breaths are allowed. The P_{SUPP} setting is maintained as long as the patient inspires, and patient demand determines the flow rate. Changes to the P_{SUPP} setting are phased in at the start of inspiration. The pressure support setting affects only spontaneous breaths.

The sum of PEEP+ P_{SUPP} +2 cmH₂O cannot exceed the $\uparrow P_{PEAK}$ limit. To increase the sum of pressures, first raise the $\uparrow P_{PEAK}$ limit before increasing the settings for PEEP or P_{SUPP} . As the $\uparrow P_{PEAK}$ limit is the highest pressure considered safe for the patient, a P_{SUPP} setting that would cause a $\uparrow P_{PEAK}$ alarm requires reevaluating the maximum safe circuit pressure.

10.15.23 Volume Support ($V_{T\text{ SUPP}}$)

Volume support ($V_{T\text{ SUPP}}$) is defined as the volume of gas delivered to the patient during spontaneous VS breaths. Changes to the $V_{T\text{ SUPP}}$ setting are phased in at the start of inspiration.

10.15.24 % Supp in TC

In TC, the % Supp setting represents the amount of the imposed resistance of the artificial airway the TC breath type will eliminate by applying added pressure at the patient circuit wye. For example, if the % Supp setting is 100%, TC eliminates 100% of the extra work imposed by the airway. At 50%, TC eliminates 50% of the added work from the airway. TC is also used with BiLevel, and is available during both P_H and P_L phases.

10.15.25 % Supp in PAV+

In PAV+, the % Supp setting represents the percentage of the total work of breathing (WOB) provided by the ventilator. Higher inspiratory demand yields greater support from the ventilator. The patient performs the remaining work. If the total WOB changes (resulting from a change to resistance or compliance) the percent support remains constant.

10.15.26 Rise Time%

The rise time% setting allows adjustment of the speed at which the inspiratory pressure reaches 95% of the target pressure. Rise time settings apply to PS (including a setting of 0 cmH₂O), VS, PC, VC+, or BiLevel breaths. The higher the value of rise time%, the more aggressive (and hence, the more rapid) the rise of inspiratory pressure to the target (which equals PEEP+ P_I (or P_{SUPP})). The rise time% setting only appears when pressure-based breaths are available. The range of rise time% is 1% to 100%. A setting of 50% takes approximately half the time to reach 95% of the target pressure as a setting of 1.

- For mandatory PC, VC+, or BiLevel breaths, a rise time setting of 1 produces a pressure trajectory reaching 95% of the inspiratory target pressure (PEEP + P_I) in 2 seconds or 2/3 of the T_I , whichever is shortest.
- For spontaneous breaths (VS, or PS), a rise time setting of 1 produces a pressure trajectory reaching 95% of the inspiratory target (PEEP+ P_{SUPP}) in (0.4×PBW-based T_I TOO LONG ×2/3) seconds.
- When both PC and PS breaths are active, the slopes and thus the pressure trajectories can appear to be different. Changes to T_I and P_I cause PC pressure trajectories to change. Changes in rise time% are phased in at the start of inspiration.
- When $P_{\text{SUPP}}=0$, the rise time% setting determines how quickly the ventilator drives circuit pressure to PEEP+1.5 cmH₂O.

10.15.27 Expiratory Sensitivity (E_{SENS})

The E_{SENS} setting defines the percentage of the measured peak inspiratory flow at which the ventilator cycles from inspiration to exhalation in all spontaneous breath types. When inspiratory flow falls to the level defined by E_{SENS} , exhalation begins. E_{SENS} is a primary setting and is accessible from the GUI screen. Changes to E_{SENS} are phased in at the next patient-initiated spontaneous inspiration.

E_{SENS} complements rise time%. Rise time% should be adjusted first to match the patient's inspiratory drive, and then the E_{SENS} setting should cause ventilator exhalation to occur at a point most appropriate for the patient. The higher the E_{SENS} setting, the shorter the inspiratory time. Generally, the most appropriate E_{SENS} is compatible with the patient's condition, neither extending nor shortening the patient's intrinsic inspiratory phase.

E_{SENS} in a PAV+ breath is expressed in L/min instead of percent.

10.15.28 Disconnect Sensitivity (D_{SENS})

Leak Sync disabled: Disconnect sensitivity (D_{SENS}) is defined as the percentage of returned volume lost due to declaring a leak, above which the ventilator declares a CIRCUIT DISCONNECT alarm. When D_{SENS} is set to its lowest value (20%) it has the highest sensitivity for detecting a leak or disconnect. Conversely, when D_{SENS} is set to its highest value (95%), the ventilator is least sensitive to declaring a leak or disconnect, because greater than 95% of the returned volume must be lost before the alarm annunciates. During NIV, the D_{SENS} value is automatically set to OFF, which means that returned volume loss is not considered and the alarm will not sound.

Leak Sync enabled: Disconnect sensitivity (D_{SENS}) is defined as the leak at PEEP value in L/min above which the ventilator declares a CIRCUIT DISCONNECT alarm. The lowest setting is most sensitive to detecting and declaring a disconnect and vice versa.

To set D_{SENS} with NIV interfaces when Leak Sync is enabled

1. After adjusting the patient settings, start ventilation.
2. Ensure that Leak Sync is enabled.
3. With the NIV interface open to ambient (not connected to the patient), use the patient data leak value to quantify the leak in L/min.
4. Set the D_{SENS} (in L/min) below the leak rate (in L/min).
5. Periodically assess the leak rate, especially with PEEP changes, and adjust the D_{SENS} setting as needed.
6. Always use alternative methods of monitoring during NIV.

**Note:**

If D_{SENS} is set to OFF during NIV, the ventilator is still capable of declaring a CIRCUIT DISCONNECT alarm.

**Note:**

D_{SENS} cannot be turned OFF if Leak Sync is enabled.

Changes to D_{SENS} are phased in at the start of inspiration.

10.15.29 High Spontaneous Inspiratory Time Limit ($\uparrow T_{\text{I SPONT}}$)

The high spontaneous inspiratory time limit setting ($\uparrow T_{\text{I SPONT}}$) is available only in SIMV or SPONT modes during NIV, and provides a means for setting a maximum inspiratory time after which the ventilator automatically transitions to exhalation. The default $\uparrow T_{\text{I SPONT}}$ setting is based upon circuit type and PBW.

For pediatric/adult circuit types, the new patient default value is $(1.99 + (0.02 \times \text{PBW}))$ s.

For neonatal circuit types, the new patient default value is $((1.00 + (0.10 \times \text{PBW}))$ s.

The $\uparrow T_{\text{I SPONT}}$ indicator appears on the primary display at the beginning of a ventilator-initiated exhalation and remains visible for as long as the ventilator truncates breaths in response to the $\uparrow T_{\text{I SPONT}}$ setting. The $\uparrow T_{\text{I SPONT}}$ indicator disappears when the patient's inspiratory time returns to less than the $\uparrow T_{\text{I SPONT}}$ setting, or after 15 seconds has elapsed after the beginning of exhalation of the last truncated breath. Changes to $\uparrow T_{\text{I SPONT}}$ are phased in at the start of inspiration.

10.15.30 Humidification Type

The humidification type setting sets the type of humidification system (heated expiratory tube, non-heated expiratory tube, or heat-moisture exchanger (HME) used on the ventilator and can be changed during normal ventilation or short self test (SST). Changes in humidification type phase in at the start of inspiration.

SST calibrates spirometry partly based on the humidification type. Changing the humidification type without rerunning SST can affect the accuracy of spirometry and delivery.

The accuracy of the exhalation flow sensor varies depending on the water vapor content of the expiratory gas, which depends on the type of humidification system in use. Because the temperature and humidity of gas entering the exhalation filter differ based on the humidification type being used, spirometry calculations also differ according to humidification type. For optimum accuracy, rerun SST to change the humidification type.

10.15.31 Humidifier Volume

The dry, compressible volume in mL of the humidification chamber for the humidification type entered during SST. Humidifier volume is only entered if a humidifier is used.

10.16 Safety Net

While the ventilator is designed to be as safe and as reliable as possible, Covidien recognizes the potential for problems to arise during mechanical ventilation, either due to user error, patient-ventilator interactions, or because of problems with the ventilator itself. Safety net is a broad term that includes strategies for handling problems that arise in the patient-ventilator system (patient problems) as well as strategies to minimize the impact of system faults on patient safety. In these scenarios, the ventilator is designed to alarm and to provide the highest level of ventilation support possible in case of ventilator malfunction. If the ventilator is not capable of ventilatory support, it opens the patient circuit and allows the patient to breathe from room air if able to do so (this emergency state is called **Safety Valve Open (SVO)**). Safety mechanisms are designed to be verified periodically or to have redundancy. The ventilator is designed to ensure that a single-point failure does not cause a safety hazard or affect its ability to annunciate a high-priority audible alarm.

10.16.1 User Error

The ventilator is designed to prevent the operator from implementing settings that are clearly inappropriate for the patient's predicted body weight (PBW). Each setting has either soft bounds (can be overridden) or hard bounds (no override allowed) that alert the operator to the fact that the settings may be inappropriate for the patient. In the event that the patient is connected without any parameters being specified, the ventilator enters Safety PCV, a safe mode of ventilation regardless of the circuit type in use (neonatal, pediatric, or adult) or patient's PBW. Safety PCV is entered after POST, if a patient connection is made prior to settings confirmation. Safety PCV uses new patient default settings with exceptions shown in [Table 10-10](#).

Table 10-10. Safety PCV Settings

Parameter	Safety PCV value
PBW	Neonatal: 3 kg Pediatric: 15 kg Adult: 50 kg
Mode	A/C
Mandatory type	PC
f_{TOT} (total respiratory rate)	Neonatal: 25 1/min Pediatric: 16 1/min Adult: 16 1/min
T_I	Neonatal: 0.3 s Pediatric: 0.7 s Adult: 1 s
P_I	15 cmH ₂ O
O ₂ %	Neonatal: 40% Pediatric: 100% Adult: 100%
PEEP	3 cmH ₂ O
Trigger type	Neonatal: $\dot{V}$ -Trig Pediatric: P-Trig Adult: P-Trig
P_{SENS}	2 cmH ₂ O
$\dot{V}_{SENS}$	1.0 L/min
$\uparrow P_{PEAK}$	20 cmH ₂ O
$\uparrow \dot{V}_{E\ TOT}$ alarm	OFF
$\downarrow \dot{V}_{E\ TOT}$ alarm	0.05 L/min
$\uparrow V_{TE}$ alarm	OFF
$\downarrow V_{TE\ MAND}$ alarm	OFF
$\downarrow V_{TE\ SPONT}$ alarm	OFF
Circuit type	Last set value, or adult if none available
Humidification type	Set value, or non-heated exp tube if none available
Humidifier volume	Last set value

**Note:**

In Safety PCV, expiratory pause maneuvers are not allowed.

10.16.2 Patient Related Problems

In case of patient problems, the ventilator remains fully operative and annunciates the appropriate alarm. The detection, response, and priority of each patient-related alarm is determined by the actual patient problem. See [Alarms \(6.5\)](#) on page 6-4 for a comprehensive description of the patient alarm system.

10.16.3 System Related Problems

The ventilator is designed to prevent system faults. Its modular design allows the breath delivery unit (BDU) to operate independently of the graphical user interface (GUI) and several modules of the breath delivery sub-system have redundancy that, if certain faults occur, provides for ventilatory support using settings that do not depend on the suspect hardware. System faults include the following:

- Hardware faults (those that originate inside the ventilator and affect its performance)
- Soft faults (faults momentarily introduced into the ventilator that interfere with normal operation)
- Inadequate supply (AC power or external gas pressure)
- Patient circuit integrity (occluded or disconnected circuit)

10.16.4 Background Diagnostic System

The ventilator has an extensive system of continuous testing processes. If an error is detected in the background diagnostic system, the ventilator notifies the operator by posting an entry in the diagnostic log. If the ventilator experiences an anomaly that causes an unintended reset, the ventilator will recover from that reset and deliver a breath within 3 seconds without any operator intervention. After recovering from a reset, the ventilator uses the same settings that were in effect before the reset occurred.

The background test process compares monitored values of ventilator functions with expected values of ventilator sensors under normal conditions regardless of whether the ventilator is in Stand-By or is ventilating a patient. The ventilator will continue to ventilate the patient with the highest level of support possible, and may revert to one of the states described. See [Ventilator Protection Strategies \(4.11\)](#) on page 4-31.

Background tests include

- Periodically initiated tests performed at intervals of a specific number of machine cycles. These tests check hardware components directly affecting breath delivery, safety mechanisms, and the GUI, and detect and correct corruption of control variable data.
- Boundary checks performed at every analog measurement. These checks verify measurement circuitry, including sensors.

Ventilation Assurance is a safety net feature invoked if the background diagnostics detect a problem with certain components in either the gas mix subsystem, the inspiratory subsystem, or

the expiratory subsystem. Each subsystem has a backup ventilation strategy that allows ventilation to continue by bypassing the suspect components giving the operator time to replace the ventilator.

Mix backup ventilation (BUV) is invoked if the measured gas mix is significantly different from the set mix, if the accumulator pressure is out of range or if a fault is indicated in the mix PSOLs or flow sensors. During Mix BUV, the normal mix controller is bypassed and ventilation continues as set, except that the gas mix reverts to 100% oxygen or air, depending on where the fault indication was detected. Backup circuits then control the pressure in the accumulator to keep it in the proper range for the Inspiratory Module.

Inspiratory BUV is invoked if background diagnostics detect a problem in the inspiratory module (PSOL or flow sensor signal out of range). In Inspiratory BUV, ventilation continues with the settings listed in [Table 10-11](#).

Table 10-11. Inspiratory Backup Ventilation Settings

Backup ventilation parameter	Setting
PBW	Previously used setting during Vent Startup
Mode	A/C
Mandatory type	PC
f	Neonatal: 25 1/min Pediatric: 16 1/min Adult: 16 1/min
T _I	Neonatal: 0.3 s Pediatric: 0.7 s Adult: 1 s
P _I	15 cmH ₂ O above PEEP
O ₂ %	100% (21% if O ₂ not available)
PEEP	3 cmH ₂ O
T _{PL}	0 s
Trigger type	V-Trig; 2 L/min (adult/pediatric), 1.5 L/min (neonatal)
Gas flow	Controlled by pressure in the mix accumulator

During Inspiratory BUV, the delivery PSOL is disabled, but gas delivery is achieved via an inspiratory BUV solenoid valve, the gas flow being created by pressure in the mix accumulator.

Exhalation BUV is invoked if problems with the exhalation valve driver are detected. A backup analog circuit is enabled to control the exhalation valve though the more advanced control features (active exhalation valve control) are not functional.



Note:

During Mix and Inspiratory BUV, gas supply to installed options is disabled.

Entry into BUV is logged in the alarm log and system diagnostic log, and the status display provides an indicator that the ventilator is in BUV and which subsystem is affected.

When in BUV, a high priority alarm is annunciated, and the GUI displays an alarm banner indicating BUV, displays blank fields for patient data, and displays a pressure waveform.

If the ventilator cannot provide any degree of reliable ventilatory support and fault monitoring, then the ventilator sounds an alarm and enters the safety valve open (SVO) emergency state. During SVO, the ventilator deenergizes the safety valve, exhalation, and inspiratory valves, annunciates a high-priority alarm, and turns on the SVO indicator. During SVO, a patient can spontaneously inspire room air (if able to do so) and exhale. Check valves on the inspiratory and expiratory sides minimize rebreathing of exhaled gas during SVO. During SVO the ventilator:

- Displays the elapsed time without ventilatory support
- Does not display patient data (including waveforms)
- Does not detect patient circuit occlusion or disconnect conditions

Visible indicators on the ventilator's GUI and status display illuminate when the ventilator is in the SVO state. Other safeguards built into the ventilator include a one-way valve (check valve) in the inspiratory pneumatic circuit allowing the patient to inhale through the safety valve with limited resistance. This check valve also limits exhaled flow from entering the inspiratory limb to reduce the possibility of rebreathing exhaled CO₂ gas.

10.17 Power On Self Test (POST)

Every time the ventilator is powered on or resets and at the beginning of short self test (SST) and extended self test (EST) it performs power on self test (POST). POST checks the integrity of the GUI and breath delivery subsystems and communication channels without operator intervention and takes approximately 15 seconds to complete.

If POST detects a major fault, qualified service personnel must correct the problem and successfully pass EST. See the *Puritan Bennett™ 980 Series Ventilator Service Manual* for more details on POST.

10.18 Short Self Test (SST)

SST is a short (about 6 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 resistance of the exhalation filter. SST, in normal mode, can only be performed at start up, prior to initiation of ventilation. Covidien recommends running SST every 15 days, between patients, and when changing the patient circuit or its configuration (including changing circuit type, adding or removing in-line water traps, or using a different type or style of patient circuit). See [To run SST](#), page 3-43. The ventilator does not allow access to SST if it senses a patient is connected.

10.19 Extended Self Test (EST)

EST verifies the integrity of the ventilator's subsystems using operator participation. EST requires a "gold standard" test circuit and a stopper to block the patient wye. All test resources, including the software code to run EST, exist in the ventilator. EST testing, excluding tests of optional equipment (such as the compressor and extended battery) takes about 10 minutes. If the compressor is used as the air source for EST and optional equipment is tested, then EST takes approximately 15 minutes. See [Extended Self Test \(EST\) \(3.9.3\)](#) on page 3-50.

**WARNING:**

Do not enter Service mode with a patient attached to the ventilator. Serious injury could result.

11 Specifications

11.1 Overview

This chapter contains the following specifications for the Puritan Bennett™ 980 Series Ventilator:

- Physical
- Electrical
- Interface
- Environmental
- Performance (ranges, resolution, and accuracies for ventilator settings, alarm settings, and patient data)
- EMC compliance information



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 <345 kPa (50 psi) are employed.

11.2 Measurement Uncertainty

Measurement uncertainties and the manner in which they are applied are listed in [Table 11-1](#).

Table 11-1. Performance Verification Equipment Uncertainty

Measured parameter	Offset	Gain
Flow	0.1001 SLPM	2.7642% reading
Pressure	0.121594 cmH ₂ O	0.195756% reading
Oxygen concentration	0.0168% O ₂	0.0973% reading
Temperature	0.886041°C	0.128726% reading
Atmospheric Pressure	1.76 cmH ₂ O	-

During breath delivery performance verification for flow and pressure based measurements, the equipment inaccuracy is subtracted from the acceptance specification as follows:

- Net acceptance gain = requirement specification gain – measurement uncertainty gain
- Net acceptance offset = requirement specification offset – measurement uncertainty offset
- Acceptance limit = $\pm[(\text{net acceptance offset}) + (\text{net acceptance gain}) \times (\text{setting})]$
- $(\text{setting} - \text{acceptance limit}) \leq \text{measurement} \leq (\text{setting} + \text{acceptance limit})$

For derived parameters, such as volume, compliance, etc., the individual sensor uncertainties are combined and applied as applicable to determine the acceptance limits.

11.3 Physical Characteristics

Table 11-2. Physical Characteristics

Weight	Ventilator: 51.26 kg (113 lb) including BDU, GUI, standard base, and primary battery BDU only: 31.3 kg (69 lb) Ventilator and compressor: 71.2 kg (157 lb) including BDU, GUI, ventilator and compressor primary batteries, base assembly, and compressor Compressor: 40.4 kg (89 lb) including base assembly BDU only: 31.3 kg (69 lb) Pendant configuration: 34.5 kg (76 lb) including BDU, GUI, primary battery Pendant configuration, BDU only: 27.2 kg (60 lb) Pendant configuration, GUI only: 5.7 kg (12.6 lb)
Dimensions	Ventilator: 32 cm by 30 cm by 111 cm (12.5 in. width by 11.5 in. depth by 43.5 in. height) (not including GUI screen) Ventilator: 32 cm by 30 cm by 148 cm (including GUI screen) (12.5 in. width by 11.5 in. depth by 58 in. height) Standard base: 58 cm by 66 cm (22.5 in. width by 26 in. depth)
A-weighted sound pressure level, ventilator	At a distance of 1 meter, does not exceed 48 dBA at 5 L/min
A-weighted sound pressure level, ventilator and compressor	At a distance of 1 meter does not exceed 54 dBA at 5 L/min
A-weighted sound power level, ventilator	Does not exceed 61 dBA at 5 L/min
A-weighted sound power level, ventilator and compressor	Does not exceed 63 dBA at 5 L/min
Connectors	Inspiratory and expiratory limb connectors are 22 mm OD conical fittings compliant with ISO 5356-1
Inspiratory/ exhalation filters	See filter instructions for use for complete specifications

Table 11-2. Physical Characteristics

Pressure units (chosen by operator)	Hectopascal (hPa) centimeters of water (cmH ₂ O)
Displayed weight units	Kilograms (kg) or Pounds (lb) (user selectable)
Displayed length units	Centimeters (cm) or Inches (in) (user selectable)

Table 11-3. Pneumatic Specifications

Oxygen and air inlet supplies	Pressure: 241 kPa to 600 kPa (35 psi to 87 psi) Flow: Maximum of 200 L/min
Oxygen sensor life	Up to 1 year. Operating life varies depending on oxygen usage and ambient temperature.
Gas mixing system	Range of flow from the mixing system: Up to 150 L/min for adult patients. Additional flow is available (peak flow to 200 L/min) for compliance compensation Up to 80 L/min for pediatric circuit type Up to 30 L/min for neonatal circuit type Leakage from one gas system to another: Meets IEC 80601-2-12 standard Operating pressure range: 241 kPa to 600 kPa (35 psi to 87 psi)

Table 11-4. Technical Specifications

Maximum limited pressure ($P_{LIM\ max}$)	A fixed pressure limit to the safety valve limits circuit pressure to <125 cmH ₂ O (123 hPa) at the patient wye.
Maximum working pressure ($P_{W\ max}$)	$P_{W\ max}$ is ensured by the high pressure limit ($\bar{P}_{PEAK}$) when P_I is <100 cmH ₂ O (98.07 hPa).
Response time to change in FiO ₂ setting from 21% to 90% O ₂ (measured at the patient wye)	<18 s for volumes >150 mL <19 s for volumes ≥30 mL but ≤150 mL <50 s for volumes ≥2 mL but <30 mL
Measuring devices	Pressure measurements: Type: Solid stated differential pressure transducer Sensing position: Inspiratory module; expiratory module Volume measurements: Type: Hot film anemometer Sensing position: Inspiratory module; expiratory module Oxygen measurement: Type: Galvanic cell Sensing position: Inspiratory module
Minute volume ($\dot{V}_{E\ TOT}$) capability, ventilator	Up to 75 L/min
Minute volume ($\dot{V}_{E\ TOT}$) capability, compressor	Up to 40 L/min BTPS, including compliance compensation

Table 11-4. Technical Specifications (Continued)

Results of ventilator testing using circuits identified for use with the ventilator system	
Internal inspiratory filter bacterial/viral filtration efficiency	>99.999%
Internal inspiratory filter particle filtration efficiency	>99.97% retention of particles 0.3 μm nominal at 100 L/min flow
Internal inspiratory filter resistance	0.2 cmH_2O < resistance <2.2 cmH_2O at 30 L/min flow 0.2 cmH_2O < resistance <1.7 cmH_2O at 15 L/min flow
Combined inspiratory limb resistance	0.2 cmH_2O < resistance <5.5 cmH_2O at 30 L/min flow 0.2 cmH_2O < resistance <1.7 cmH_2O at 15 L/min flow
Exhalation filter resistance (pediatric/adult, disposable)	< 2.0 cmH_2O at 30 L/min when new < 1.7 cmH_2O at 15 L/min when new
Exhalation filter particle filtration efficiency, pediatric/adult, disposable	Maximum of 0.03% penetration of particles 0.3 μm nominal at 30 L/min flow
Exhalation filter bacterial/viral filtration efficiency (neonatal, disposable)	>99.999% bacterial filtration efficiency/99.99% viral filtration efficiency
Exhalation filter particle filtration efficiency (neonatal, disposable)	> 99.70% retention of particles 0.3 μm nominal at 30 L/min flow
Exhalation filter resistance (neonatal, disposable)	< 0.58 cmH_2O at 2.5 L/min when new
Circuit compliance (acceptable ranges of VBS compliance for each patient type)	ADULT: 1.3 mL/ cmH_2O to 4.2 mL/ cmH_2O PEDIATRIC: 0.9 mL/ cmH_2O to 3.0 mL/ cmH_2O NEONATAL: 0.4 mL/ cmH_2O to 1.5 mL/ cmH_2O
Inspiratory limb circuit resistance (acceptable ranges of VBS inspiratory limb resistance for each patient type)	ADULT (at 60 L/min): 1.15 cmH_2O to 11.0 cmH_2O PEDIATRIC (at 30 L/min): 0.46 cmH_2O to 4.5 cmH_2O NEONATAL (at 10 L/min): 0.37 cmH_2O to 4.5 cmH_2O (6.0 cmH_2O for Prox)
Expiratory limb circuit resistance (acceptable ranges of VBS expiratory limb resistance for each patient type)	ADULT (at 60 L/min): 1.15 cmH_2O to 11.0 cmH_2O PEDIATRIC (at 30 L/min): 0.46 cmH_2O to 4.5 cmH_2O NEONATAL (at 10 L/min): 0.37 cmH_2O to 4.5 cmH_2O (6.0 cmH_2O for Prox)
Alarm volume (primary) Measurement uncertainty: ± 3 dBA	Range: High priority alarm volume range (dBA): 58 (volume setting 1) to 86 (volume setting 10) Medium priority alarm volume range (dBA): 52 (volume setting 1) to 78 (volume setting 10) Low priority alarm volume range (dBA): 50 (volume setting 1) to 76 (volume setting 10) Measured 1 m from front, rear, and sides of ventilator See Alarm Volume Key (6.5.4) on page 6-8 for alarm volume behavior during an alarm condition. Resolution: 1
Alarm volume (secondary) Measurement uncertainty: ± 3 dBA	Minimum 64 dBA measured 1 m from front, rear, and sides of ventilator.

11.4 Electrical Specifications

Table 11-5. Electrical Specifications

Electrical ratings, ventilator	100 V ~, 50–60 Hz, 2.25 A 120 V ~, 50–60 Hz 1.5 A 220–240 V ~, 50–60 Hz, 0.75 A
Electrical ratings, ventilator and compressor	100 V~, 50–60 Hz, 8.25 A 120 V~, 50–60 Hz, 6.0 A 220–240 V~, 50–60 Hz, 3.0 A
Mains overcurrent release	CB1: 4 A CB2: 6 A
Earth leakage current	Meets requirements of IEC 60601-1, type BF applied part
Touch current	Meets requirements of IEC 60601-1, type BF applied part
Patient leakage current	Meets requirements of IEC 60601-1, type BF applied part

11.5 Interface Requirements

The pinout for the RS-232 interface is as follows:

Table 11-6. RS-232 Pinout

Pin	Signal	Name
1	N/C	Not connected
2	RxD	Receive data
3	TxD	Transmit data
4	N/C	Not connected
5	GND	Ground
6	N/C	Not connected
7	RTS	Request to send
8	CTS	Clear to send
9	N/C	Not connected

The pinout for the nurse call interface is as follows:

Table 11-7. Nurse Call Pinout

Pin	Configuration
1	Normally closed (NC)
2	Relay common
3	Normally open (NO)
4	Not connected

11.6 Environmental Specifications

Table 11-8. Environmental Specifications

Specification	Operation	Storage
Temperature	10°C to 40°C (50°F to 104°F) Ventilator 10°C to 35°C (50°F to 95°F) Internal Battery Charger	–20°C to 70°C (–68°F to 158°F)
Atmospheric Pressure	70 kPa to 106 kPa (10.15 psi to 15.37 psi)	50 kPa to 106 kPa (7.25 psi to 15.37 psi)
Altitude	–411.5 m to 3048 m (–1350 ft to 10 000 ft)	6096 m max (20 000 ft max)

Table 11-8. Environmental Specifications

Specification	Operation	Storage
Relative Humidity	10% to 95% non-condensing	10% to 95% non-condensing

**Note:**

When using the compressor, reduced dryer performance may be expected if relative humidity exceeds 50% when temperature is 40°C.

When using the compressor, reduced dryer performance may be expected if temperature exceeds 32.8°C when relative humidity is 95%.

**Note:**

The limits marked on the device label represent out-of-box storage conditions as follows:

- Temperature: 10°C to 40°C (50°F to 104°F)
- Pressure: 70 kPa to 106 kPa (10.15 psi to 15.37 psi)
- Relative humidity: 10% to 95% non-condensing

11.7 Performance Specifications

11.7.1 Ranges and Resolutions

See [Table 11-9](#) for ranges and resolutions for ventilator settings. See [Table 11-10](#) on page 11-14 for alarm settings, and [Table 11-11](#) on page 11-17 for displayed patient data parameters.

Table 11-9. Ventilator Settings Range and Resolution

Setting	Description	Range and resolution
Apnea ventilation	A safety mode of ventilation that starts if the patient does not receive a breath for an elapsed time exceeding the apnea interval.	See individual apnea settings.
Apnea expiratory time (T_E)	For mandatory PC apnea breaths, the time interval between the end of inspiration and the beginning of the next inspiration.	Range: 0.20 s to 59.8 s Resolution: 0.01 s
Apnea I:E ratio	In PC breath types, specifies the ratio of apnea inspiratory time to apnea expiratory time.	Range: I:E $\leq 1.00:1$ Resolution: 0.01 for values $>1:10.0$; 0.1 for values $\leq 1:10$ and $>1:100$; 1 for values $\leq 1:100$

Table 11-9. Ventilator Settings Range and Resolution (Continued)

Setting	Description	Range and resolution
Apnea flow pattern	The flow shape of the delivered mandatory volume-based (VC) apnea breath.	Range: square, descending ramp
Apnea inspiratory pressure (P_I)	The pressure above PEEP at which gas is delivered to the patient during mandatory PC apnea breaths.	Range: 5 cmH ₂ O to 90–PEEP cmH ₂ O Resolution: 1 cmH ₂ O
Apnea inspiratory time (T_I)	Same as inspiratory time for non-apnea ventilation	Range: 0.20 s to 8 s Resolution: 0.01 s in PC or VC+, 0.02 s in VC
Apnea interval (T_A)	The time after which the ventilator transitions to apnea ventilation $T_A \geq 60/f_A$	Range: 10 s to 60 s or OFF in CPAP Resolution: 1 s
Apnea O ₂ %	Determines the oxygen concentration in a standard mixture of air and oxygen	Range: 21% O ₂ to 100% O ₂ Resolution: 1%
Apnea peak inspiratory flow ($\dot{V}_{MAX}$)	The maximum rate of tidal volume delivery during mandatory volume-based apnea breaths.	Range: When mandatory type is VC: NEONATAL: 1 L/min to 30 L/min PEDIATRIC: 3.0 L/min to 60 L/min ADULT: 3.0 L/min to 150 L/min Resolution: 0.1 L/min for flows <20 L/min (BTPS); 1 L/min for flows ≥ 20 L/min (BTPS)
Apnea respiratory rate (f_A)	Sets the number of volume- or pressure-based breaths per minute for ventilator initiated mandatory (VIM) apnea breaths	Range: 2.0 1/min to 40 1/min Resolution: 0.1 1/min for 2.0 1/min to 9.9 1/min; 1 1/min for 10 1/min to 40 1/min
Apnea tidal volume (V_T)	Sets the volume of gas delivered to the patient's lungs during a mandatory, volume-controlled apnea breath. Apnea tidal volume is compensated for body temperature and pressure, saturated (BTPS) and the compliance of the patient circuit.	Range: NEONATAL: 3 mL to 315 mL PEDIATRIC/ADULT: ≥ 25 mL to 2500 mL Resolution: 0.1 mL for values <20 mL; 0.5 mL for values ≥ 20 mL and <25 mL; 1 mL for values ≥ 25 mL and <100 mL; 5 mL for values ≥ 100 mL and <400 mL; 10 mL for values ≥ 400 mL
Apnea constant during rate change	Specifies which of the three operator-adjustable breath timing variables remains constant when respiratory rate is changed during apnea ventilation.	Range: T_I

Table 11-9. Ventilator Settings Range and Resolution (Continued)

Setting	Description	Range and resolution
Apnea mandatory type	The type of mandatory breath delivered during apnea ventilation	Range: PC, VC
Circuit type	Specifies the circuit for which compliance and resistance values during SST have been calculated	Range: NEONATAL, PEDIATRIC, ADULT
Constant during rate change	Specifies which of the three operator-adjustable breath timing variables remains constant when respiratory rate is changed.	Range: I:E ratio, T_I , T_E for PC or VC+ breaths; T_H : T_L ratio, T_H , T_L in BiLevel
Disconnect sensitivity (D_{SENS})	Leak Sync disabled: The percentage of returned volume lost, above which the ventilator declares a CIRCUIT DISCONNECT alarm. Leak Sync enabled: The leak at PEEP value in L/min above which the ventilator declares a CIRCUIT DISCONNECT alarm.	Range: (Leak Sync disabled): 20% to 95% or OFF Range: (Leak Sync enabled): NEONATAL: 1 L/min to 15 L/min PEDIATRIC: 1 L/min to 40 L/min ADULT: 1 L/min to 65 L/min Resolution: (Leak Sync disabled): 1% Resolution: (Leak Sync enabled) 0.5 L/min for values < 10 L/min; 1 L/min for values ≥ 10 L/min
Expiratory sensitivity (E_{SENS})	The percentage of $\dot{V}_{MAX}$ that, when reached, causes the ventilator to cycle from inspiration to exhalation during spontaneous, pressure-based breaths	Range: 1% to 80% when spontaneous type is PS or VS 1 L/min to 10 L/min when spontaneous type is PAV+ Resolution: 1% when spontaneous type is PS, TC, or VS; 1 L/min when spontaneous type is PAV+. NOTE: Default value is not expected to need adjustment. Only adjust after becoming experienced with PAV+ and only if it is suspected that the ventilator is not cycling at the patient's end-of-inspiration.
Expiratory time (T_E)	For PC or VC+ breaths, the time interval between the end of inspiration and the beginning of the next inspiration. The end of the expiratory phase is considered to be when the flow rate at the patient wye remains less than 0.5 L/min above the base flow.	Range: ≥ 0.20 s Resolution: 0.01 s
Flow pattern	The flow shape of the delivered mandatory or VC breath	Range: square, descending ramp

Table 11-9. Ventilator Settings Range and Resolution (Continued)

Setting	Description	Range and resolution
Flow sensitivity ($\dot{V}_{\text{SENS}}$)	For flow triggered breaths, determines the volume of flow (below the base flow) required to begin a mandatory or spontaneous patient initiated breath.	Range: NEONATAL: 0.1 L/min to 10 L/min PEDIATRIC/ADULT: 0.2 L/min to 20.0 L/min Resolution: 0.1 L/min
Gender	The patient's gender	Range: Male or Female
Height	The patient's height	Range: 19.5 cm to 280 cm; 7.5 in. to 110 in. Resolution: 0.5 cm for heights <35 cm; 1 cm for heights <254 cm; 2 cm for heights ≥254 cm; 0.25 in. for heights <14 in.; 0.5 in. for heights <100 in.; 1 in. for heights ≥100 in. <i>See Predicted Body Weight (PBW) Calculation (4.6) on page 4-19.</i>
High spontaneous inspiratory time limit ($\uparrow T_{\text{I SPONT}}$)	Active in NIV only, allows the operator to select the maximum spontaneous inspiratory time.	Range: NEONATAL: 0.2 s to 1.7 s PEDIATRIC/ADULT: 0.4 s to 5 s
Humidification type	The type of humidification system used on the ventilator	Range: HME, non-heated expiratory tube, heated expiratory tube
Humidifier volume	The empty fluid volume of the currently installed humidifier.	Range: 100 mL to 1000 mL Resolution: 10 mL
Elevate O ₂	The percentage of O ₂ to be added to the current air/O ₂ mixture for 2 minutes	Range: 1% to 100% Resolution: 1% between 1% and 10%; 5% between 5% and 75%; jumps to 100% when increased above 75%
I:E ratio	In PC and VC+ breath types, specifies the ratio of inspiratory time to expiratory time.	Range: 1:299 to 149:1 Resolution: 0.01 for values >1:10; 0.1 for values ≤1:10.0 and >1:100.0; 1 for values ≤1:100 Displayed as XX:1 when I:E ≥ 1; displayed as 1:XX when I:E < 1
Inspiratory pressure (P _i)	The pressure above PEEP at which gas is delivered to the patient during mandatory PC breaths.	Range: 5 cmH ₂ O to 90 cmH ₂ O Resolution: 1 cmH ₂ O
Inspiratory time (T _i)	The time during which an inspiration is delivered to the patient during mandatory PC or VC+ breaths.	Range: 0.2 s to 8 s for mandatory PC, and VC+ breaths, (T _{PL} +0.2 s to 8 s in VC) Resolution: 0.01 s for PC or VC+ breaths; 0.02 s for VC breaths

Table 11-9. Ventilator Settings Range and Resolution (Continued)

Setting	Description	Range and resolution
Leak Sync (leak compensation)	Compensates for leaks during invasive or non-invasive (NIV) ventilation.	Range: Enabled or Disabled
Mandatory type	The type of mandatory breath delivered in A/C, SPONT or SIMV modes. SPONT mode allows mandatory type selection for operator initiated mandatory (OIM) breaths.	Range: PC, VC, VC+
mL/kg ratio	The default tidal volume/PBW ratio (only adjustable in Service Mode)	Range: 5.0 mL/kg to 10 mL/kg Resolution: 0.5 mL/kg
Mode	The ventilation mode. The mode determines the allowable breath types: A/C—assist/control—a mandatory mode allowing volume controlled (VC), pressure controlled (PC), or VC+ breath types. SPONT—allows the patient to initiate the breath. Applicable SPONT breath types are pressure support (PS), volume support (VS), tube compensated (TC) or PAV+. SIMV—Synchronized Intermittent Mandatory Ventilation—a mixed ventilatory mode providing mandatory breaths and allowing a patient spontaneous breaths during the breath cycle. BiLevel—a mixed ventilatory mode combining the attributes of both mandatory and spontaneous breaths incorporating two pressure levels, P_H and P_L .	Range: A/C, SPONT, SIMV, BiLevel but not available when ventilation type is NIV; CPAP (only available when circuit type is NEONATAL and ventilation type is NIV))
O ₂ % (delivered)	Percentage of delivered oxygen in the gas mixture	Range: 21% to 100% Resolution: 1%
Peak inspiratory flow ($\dot{V}_{MAX}$)	The maximum rate of tidal volume delivery during mandatory volume-based breaths.	Range: When mandatory type is VC: NEONATAL: 1 L/min to 30 L/min PEDIATRIC: 3.0 L/min to 60 L/min ADULT: 3.0 L/min to 150 L/min Resolution: 0.1 L/min for values <20 L/min (BTPS); 1 L/min for values ≥20 L/min (BTPS)

Table 11-9. Ventilator Settings Range and Resolution (Continued)

Setting	Description	Range and resolution
PEEP	Sets the positive end-expiratory pressure, defined as the pressure targeted in the patient circuit during exhalation.	Range: 0 cmH ₂ O to 45 cmH ₂ O Resolution: 0.5 cmH ₂ O from 0.0 cmH ₂ O to 19.5 cmH ₂ O; 1 cmH ₂ O from 20 cmH ₂ O to 45 cmH ₂ O
P _H	The positive pressure during the insufflation phase in BiLevel ventilation.	Range: 5 cmH ₂ O to 90 cmH ₂ O Resolution: 1 cmH ₂ O
P _L	The positive pressure in the patient circuit during the expiratory phase of BiLevel ventilation.	Range: 0 cmH ₂ O to 45 cmH ₂ O Resolution: 0.5 cmH ₂ O from 0.0 cmH ₂ O to 19.5 cmH ₂ O; 1 cmH ₂ O from 20 cmH ₂ O to 45 cmH ₂ O
Plateau time (T _{PL})	The amount of time inspiration is held in the patient's lungs after inspiratory flow ceases for mandatory volume-based breaths. Considered part of the inspiratory phase for I:E ratio calculations.	Range: 0s to 2 s Resolution: 0.1 s
Predicted Body Weight (PBW)	Indicates an approximation of the patient's body weight based upon their gender and height (or length for neonatal patients). PBW determines default limits and limits for breath delivery parameters.	Range: NEONATAL: 0.3 kg (0.66 lb) to 7.0 kg (15 lb) when NeoMode 2.0 option is installed; PEDIATRIC: 3.5 kg (7.7 lb) to 35 kg (77 lb) ADULT: ≥25 kg (55.12 lb) Resolution: 0.01 kg for weights <1 kg, 0.1 kg for weights ≥1 kg and <10 kg, 1 kg for weights ≥10 kg
Pressure sensitivity (P _{SENS})	For pressure triggered breaths, determines the amount of pressure below PEEP required to begin a mandatory or spontaneous patient initiated breath.	Range: 0.1 cmH ₂ O to 20.0 cmH ₂ O Resolution: 0.1 cmH ₂ O
Pressure support (P _{SUPP}) or PS	The positive pressure above PEEP (or P _L in BiLevel) during a spontaneous breath.	Range: 0 cmH ₂ O to 70 cmH ₂ O Resolution: 1 cmH ₂ O
Respiratory rate (f)	Sets the number of volume- or pressure-based breaths per minute for ventilator initiated mandatory (VIM) breaths in A/C, SIMV, and BiLevel modes	Range: NEONATAL: 1.0 1/min to 150 1/min PEDIATRIC/ADULT: 1.0 1/min to 100 1/min Resolution: 0.1 1/min from 1.0 1/min to 9.9 1/min; 1 1/min from 10 1/min to 150 1/min

Table 11-9. Ventilator Settings Range and Resolution (Continued)

Setting	Description	Range and resolution
Rise time%	Sets the speed at which inspiratory gas delivered to the patient reaches the pressure target in BiLevel, PC, VC+, VS, or PS. Higher percentages of rise time produce inspiratory pressure trajectories with shorter time to the target value.	Range: 1% to 100% Resolution: 1%
Spontaneous type	The breath type for patient initiated spontaneous breaths in SIMV, SPONT, and BiLevel modes.	Range: PS, TC, PAV+, or VS
% Supp	In tube compensation, specifies the additional positive pressure desired to overcome resistance of the artificial airway.	Range: 10% to 100% Resolution: 5%
% Supp	In PAV+, specifies the percentage of total inspiratory work of breathing (WOB) performed by the ventilator.	Range: 5% to 95% Resolution: 5%
T _H (time high)	The duration of the insufflation phase during BiLevel ventilation.	Range: 0.2 s to 30 s Resolution: 0.01 s
T _L (time low)	The duration of the expiratory phase during BiLevel ventilation.	Range: ≥0.20 s Resolution: 0.01 s
T _H :T _L ratio	In BiLevel, specifies the ratio of insufflation time to expiratory time	Range: 1:299 to 4:1; in BiLevel T _H :T _L Resolution: 0.01 for <10.00:1 and >1:10.00; 0.1 for [<100.0:1 and ≥10.0:1] or [≤1:10.0 and >1:100.0]; 1 for <1:100.0 or ≥100:1
Tidal volume (V _T)	The volume of gas delivered to the patient during a mandatory volume-based breath. V _T compensates for body temperature and pressure, saturated (BTPS) and circuit compliance. Applicable for volume-based breaths.	Range: NEONATAL: 2 mL to 315 mL in VC+ NEONATAL: 3 mL to 315 mL in VC PEDIATRIC: 25 mL to 1590 mL ADULT: 25 mL to 2500 mL Resolution: 0.1 mL for values <20 mL; 0.5 mL for values ≥20 mL and <25 mL; 1 mL for values ≥25 mL and <100 mL; 5 mL for values ≥100 mL and <400 mL; 10 mL for values ≥400 mL

Table 11-9. Ventilator Settings Range and Resolution (Continued)

Setting	Description	Range and resolution
Volume support ($V_{T\text{SUPP}}$) or VS	The volume of gas delivered to the patient during spontaneous, volume supported breaths	Range: NEONATAL: 2 mL to 310 mL PEDIATRIC: 25 mL to 1590 mL ADULT: 25 mL to 2500 mL Resolution: 0.1 mL for values <20 mL; 0.5 mL for values ≥ 20 mL and <25 mL; 1 mL for values ≥ 25 mL and <100 mL; 5 mL for values ≥ 100 mL and <400 mL; 10 mL for values ≥ 400 mL
Trigger type	Determines whether flow changes ($\dot{V}$ -Trig, or pressure changes (P-Trig) trigger patient breaths	Range: NEONATAL: $\dot{V}$ -Trig PEDIATRIC/ADULT: $\dot{V}$ -Trig or P-Trig
Tube ID	The internal diameter of the artificial airway used to ventilate the patient.	Range: 4.5 mm to 10 mm when spontaneous type is TC Range: 6 mm to 10 mm when spontaneous type is PAV+ Resolution: 0.5 mm
Tube type	The type of artificial airway used to ventilate the patient.	Range: Endotracheal (ET), tracheal (Trach)
Ventilation type	Invasive or non-invasive (NIV) ventilation type based upon the type of breathing interface used. Invasive: ET or Trach tubes NIV: masks, infant nasal prongs, or uncuffed ET tubes	Range: Invasive, NIV

Table 11-10. Alarm Settings Range and Resolution

Setting	Description	Range and resolution
Alarm volume	Controls the volume of alarm annunciations	Range: 1 (minimum) to 10 (maximum) Resolution: 1
Apnea interval (T_A)	The apnea alarm condition indicates that neither the ventilator nor the patient has triggered a breath for the operator-selected apnea interval (T_A). When the apnea alarm condition is true, the ventilator invokes mandatory ventilation as specified by the operator.	Range: 10 s to 60 s or OFF in CPAP Resolution: 1 s
High circuit pressure setting ($\bar{P}_{\text{PEAK}}$)	The $\bar{P}_{\text{PEAK}}$ alarm indicates the patient's airway pressure $\geq$ the set alarm level	Range: 7 cmH ₂ O to 100 cmH ₂ O Resolution: 1 cmH ₂ O

Table 11-10. Alarm Settings Range and Resolution (Continued)

Setting	Description	Range and resolution
Low circuit pressure setting ($\downarrow P_{PEAK}$)	The $\downarrow P_{PEAK}$ alarm indicates the measured airway pressure $\leq$ the set alarm limit during an NIV or VC+ inspiration.	Range: NIV: OFF or ≥ 0.5 cmH ₂ O to 100 cmH ₂ O VC+: $\geq PEEP + 3.5$ cmH ₂ O (with $PEEP \leq 16$ cmH ₂ O) $\geq PEEP + 4$ cmH ₂ O (with $PEEP > 16$ cmH ₂ O) to 100 cmH ₂ O Resolution: 0.5 cmH ₂ O for values < 20.0 cmH ₂ O; 1 cmH ₂ O for values ≥ 20 cmH ₂ O
High exhaled minute volume alarm setting ($\uparrow \dot{V}_{E\text{TOT}}$)	The $\uparrow \dot{V}_{E\text{TOT}}$ alarm indicates the measured total minute volume $\geq$ the set alarm limit.	Range: OFF and NEONATAL: 0.1 L/min to 10 L/min PEDIATRIC: 0.1 L/min to 30L/min ADULT: 0.1 L/min to 100 L/min Resolution: 0.005 L/min for values < 0.50 L/min; 0.05L/min for values ≥ 0.5 L/min to < 5.0 L/min; 0.5 L/min for values ≥ 5.0 L/min
High exhaled tidal volume alarm setting ($\uparrow V_{TE}$)	The $\uparrow V_{TE}$ alarm indicates that the measured exhaled tidal volume $\geq$ the set alarm limit for spontaneous and mandatory breaths.	Range: OFF and NEONATAL: 5 mL to 500 mL PEDIATRIC: 25 mL to 1500 mL ADULT: 25 mL to 3000 mL Resolution: 1 mL for values < 100 mL; 5 mL for values ≥ 100 mL and < 400 mL; 10 mL for values ≥ 400 mL
High inspired tidal volume alarm limit ($\uparrow V_{TI}$)	The $\uparrow V_{TI}$ alarm indicates the delivered volume of any breath $\geq$ the set alarm limit.	Range: 6 mL to 6000 mL Resolution: 1 mL for values < 100 mL; 5 mL for values ≥ 100 mL to < 400 mL; 10 mL for values ≥ 400 mL
High respiratory rate alarm setting ($\uparrow f_{TOT}$)	The $\uparrow f_{TOT}$ alarm indicates the measured breath rate $\geq$ the set alarm limit.	Range: OFF or NEONATAL: 10 1/min to 170 1/min PEDIATRIC/ADULT: 10 1/min to 110 1/min Resolution: 1 1/min

Table 11-10. Alarm Settings Range and Resolution (Continued)

Setting	Description	Range and resolution
High spontaneous inspiratory time limit ($\uparrow T_{I\text{ SPONT}}$)	The $\uparrow T_{I\text{ SPONT}}$ indicator allows the operator to select the maximum spontaneous inspiratory time of an NIV breath. No alarm is annunciated; only the symbol $\uparrow T_{I\text{ SPONT}}$ appears on the screen near the NIV indicator when inspiration time exceeds the setting. If $\uparrow T_{I\text{ SPONT}}$ is exceeded, the ventilator transitions from inspiration to exhalation.	Range: NEONATAL: 0.2 s to $\leq$ the value of the NIV inspiratory time limit trigger for the patient's PBW and circuit type (in seconds) PEDIATRIC/ADULT: 0.4 s to $\leq$ the value of the NIV inspiratory time limit trigger (in seconds) for the patient's PBW and circuit type Resolution: 0.1 s
Low exhaled mandatory tidal volume alarm setting ($\downarrow V_{TE\text{ MAND}}$)	The $\downarrow V_{TE\text{ MAND}}$ alarm indicates the measured mandatory tidal volume $\leq$ the set alarm limit.	Range: OFF and NEONATAL: 1 mL to 300 mL PEDIATRIC: 1 mL to 1000 mL ADULT: 1 mL to 2500 mL Resolution: 1.0 mL for values <100 mL; 5 mL for values $\geq$ 100 mL and <400 mL; 10 mL for values $\geq$ 400 mL
Low exhaled minute volume alarm setting ($\downarrow \dot{V}_{E\text{ TOT}}$)	The $\downarrow \dot{V}_{E\text{ TOT}}$ alarm indicates the measured exhaled minute volume $\leq$ the set alarm limit for mandatory and spontaneous breaths.	Range: OFF when ventilation type = NIV and NEONATAL: 0.01 L/min to 10 L/min PEDIATRIC: 0.05 L/min to 30 L/min ADULT: 0.05 L/min to 60 L/min Resolution: 0.005 L/min for values <0.50 L/min; 0.05 L/min for values $\geq$ 0.50 L/min and < 5.0 L/min; 0.5 L/min for values >5.0 L/min
Low exhaled spontaneous tidal volume alarm setting ($\downarrow V_{TE\text{ SPONT}}$)	The $\downarrow V_{TE\text{ SPONT}}$ alarm indicates the measured spontaneous tidal volume $\leq$ the set alarm limit.	Range: OFF and NEONATAL: 1 mL to 300 mL PEDIATRIC: 1 mL to 1000 mL ADULT: 1 to 2500 mL Resolution: 1 mL for values <100 mL; 5 mL for values 100 mL to <400 mL; 10 mL for values $\geq$ 400 mL

Table 11-11. Patient Data Range and Resolution

Data value	Description	Range and resolution
Breath phase	The breath phase indicator displays the breath delivery phase (inspiratory or expiratory) currently being delivered to the patient.	Range: Control (C), Assist (A), Spontaneous (S)
Inspired tidal volume (V_{TL}) during Leak Sync	The volume inspired for each breath when Leak Sync is enabled.	Range: 0 mL to 6000 mL Resolution: 0.1 mL for values <10 mL; 1 mL for values 10 mL to 6000 mL
Inspired tidal volume (V_{TI})	The volume inspired for a pressure-based breath	Range: 0 mL to 6000 mL Resolution: 0.01 mL for 0 mL to 9.9 mL, 1 mL for values 10 mL to 6000 mL
Dynamic compliance (C_{DYN})	The result of dividing the delivered tidal volume by the peak airway pressure.	Range: 0 mL/cmH ₂ O to 200 mL/cmH ₂ O Resolution: 0.1 mL/cmH ₂ O for values <10 mL/cmH ₂ O; 1 mL/cmH ₂ O for values ≥10 mL/cmH ₂ O
Dynamic resistance (R_{DYN})	The change in pressure per unit change in flow.	Range: 0.0 cmH ₂ O/L/s to 100 cmH ₂ O/L/s Resolution: 0.1 cmH ₂ O/L/s for values <10 cmH ₂ O/L/s; 1 cmH ₂ O/L/s for values ≥10 cmH ₂ O/L/s
End expiratory flow (EEF)	The rate of expiratory flow occurring at the end of exhalation.	Range: 0 L/min to 150 L/min Resolution: 0.1 L/min for values <20 L/min; 1 L/min for values ≥ 20 L/min
End expiratory pressure (PEEP)	The pressure at the end of the expiratory phase of the previous breath (also applies in BiLevel).	Range: –20.0 cmH ₂ O to 130 cmH ₂ O Resolution: 0.1 cmH ₂ O between –10.0 cmH ₂ O and +10.0 cmH ₂ O; 1 cmH ₂ O for values ≤ –10 cmH ₂ O and ≥10 cmH ₂ O
End inspiratory pressure (P_{IEND})	The pressure at the end of the inspiratory phase of the current breath (also applies in BiLevel).	Range: –20.0 cmH ₂ O to 130 cmH ₂ O Resolution: 0.1 cmH ₂ O for –20.0 cmH ₂ O to 9.9 cmH ₂ O; 1 cmH ₂ O for values 10 cmH ₂ O to 130 cmH ₂ O

Table 11-11. Patient Data Range and Resolution (Continued)

Data value	Description	Range and resolution
Exhaled mandatory tidal volume ($V_{TE\ MAND}$)	The exhaled volume of the last mandatory breath. When the mode is SPONT, and no mandatory breaths have occurred for a time period ≥ 2 minutes, the $V_{TE\ MAND}$ indicator is hidden. Mandatory breaths can occur during SPONT mode via manual inspiration.	Range: 0 mL to 6000 mL Resolution: 0.1 mL for 0 mL to 9.9 mL; 1 mL for 10 mL to 6000 mL
Exhaled minute volume ($\dot{V}_{E\ TOT}$)	A calculated sum of the volumes exhaled by the patient for mandatory and spontaneous breaths for the previous one-minute interval (also applies in BiLevel).	Range: 0.00 L/min to 99.9 L/min Resolution: 0.01 L/min for 0.00 L/min to 9.99 L/min; 0.1 L/min for 10.0 L/min to 99.9 L/min
Exhaled spontaneous minute volume ($\dot{V}_{E\ SPONT}$)	The sum of exhaled spontaneous volumes per minute (also applies in BiLevel)	Range: 0 L/min to 99.9 L/min Resolution: 0.01 L/min for 0.00 L/min to 9.99 L/min; 0.1 L/min for 10.0 L/min to 99.9 L/min
Exhaled spontaneous tidal volume ($V_{TE\ SPONT}$)	The exhaled volume of the last spontaneous breath.	Range: 0 mL to 6000 mL Resolution: 0.1 mL for 0 mL to 9.9 mL; 1 mL for 10 mL to 6000 mL
Exhaled tidal volume (V_{TE})	The volume exhaled by the patient for the previous mandatory or spontaneous breath (also applies in BiLevel).	Range: 0 mL to 6000 mL Resolution: 0.1 mL for 0 mL to 9.9 mL; 1 mL for 10 mL to 6000 mL
Leak Sync exhaled tidal volume (V_{TE})	The volume exhaled by the patient for the previous mandatory or spontaneous breath during Leak Sync (also applies in BiLevel).	Range: 0 mL to 6000 mL Resolution: 0.1 mL for 0 mL to 9.9 mL; 1 mL for 10 mL to 6000 mL
I:E ratio	The ratio of the inspiratory time to expiratory time for the previous breath.	Range: 1:599 to 149:1 Resolution: 0.1 for 9.9:1 to 1:9.9; 1 for 149:1 to 10:1 and 1:10 to 1:599
Inspiratory compliance (C_{20}/C)	The ratio of compliance of the last 20% of inspiration to the compliance of the entire inspiration	Range: 0 to 1.00 Resolution: 0.01
Intrinsic PEEP ($PEEP_i$)	A calculated estimate of the pressure above PEEP at the end of exhalation.	Range: $-20.0\text{ cmH}_2\text{O}$ to $+130\text{ cmH}_2\text{O}$ Resolution: 0.1 cmH_2O between $-9.9\text{ cmH}_2\text{O}$ and $+9.9\text{ cmH}_2\text{O}$; 1 cmH_2O for values $\leq -10\text{ cmH}_2\text{O}$ and $\geq 10\text{ cmH}_2\text{O}$

Table 11-11. Patient Data Range and Resolution (Continued)

Data value	Description	Range and resolution
Mean circuit pressure (P_{MEAN})	The calculated average circuit pressure for an entire breath cycle including both inspiratory and expiratory phases (whether the breath is mandatory or spontaneous).	Range: $-20.0 \text{ cmH}_2\text{O}$ to $100 \text{ cmH}_2\text{O}$ Resolution: $0.1 \text{ cmH}_2\text{O}$ for $-20.0 \text{ cmH}_2\text{O}$ to $9.9 \text{ cmH}_2\text{O}$; $1 \text{ cmH}_2\text{O}$ for $10 \text{ cmH}_2\text{O}$ to $100 \text{ cmH}_2\text{O}$
Negative inspiratory force (NIF)	The negative pressure generated during a maximally forced inspiratory effort against an obstruction to flow.	Range: $\leq 0 \text{ cmH}_2\text{O}$ to $\geq -50 \text{ cmH}_2\text{O}$ Resolution: $1 \text{ cmH}_2\text{O}$ for values $\leq -10 \text{ cmH}_2\text{O}$; $0.1 \text{ cmH}_2\text{O}$ for values $> -10 \text{ cmH}_2\text{O}$
$\text{O}_2\%$ (monitored)	The monitored percentage of oxygen in the gas delivered to the patient, measured at the ventilator outlet upstream of the inspiratory filter.	Range: 0% to 103% Resolution: 1%
$P_{0.1}$	The inspiratory depression of airway pressure after 100 ms of occlusion. $P_{0.1}$ is an indicator of respiratory drive.	Range: $\geq -20 \text{ cmH}_2\text{O}$ to $0 \text{ cmH}_2\text{O}$ Resolution: $1 \text{ cmH}_2\text{O}$ for values $< -10 \text{ cmH}_2\text{O}$; $0.1 \text{ cmH}_2\text{O}$ for values $\geq -10 \text{ cmH}_2\text{O}$
PAV based intrinsic PEEP (PEEP_{PAV})	The estimated intrinsic PEEP during a PAV+ breath. Intrinsic PEEP is an estimate of the pressure above PEEP at the end of every pause exhalation.	Range: $0 \text{ cmH}_2\text{O}$ to $130 \text{ cmH}_2\text{O}$ Resolution: $0.1 \text{ cmH}_2\text{O}$ for values $< 10 \text{ cmH}_2\text{O}$; $1 \text{ cmH}_2\text{O}$ for values $\geq 10 \text{ cmH}_2\text{O}$
PAV-based lung compliance (C_{PAV}) ¹	The calculated change in pulmonary volume for an applied change in patient airway pressure when measured under conditions of zero flow during a PAV+ plateau maneuver. When PAV+ is selected, the ventilator displays the current filtered value for patient compliance, and updates the display at the successful completion of each estimation. C_{PAV} can be displayed in the vital patient data banner. See Vital Patient Data , page 3-37.	Range: $2.5 \text{ mL/cmH}_2\text{O}$ to $200 \text{ mL/cmH}_2\text{O}$ Resolution: $0.1 \text{ mL/cmH}_2\text{O}$ for values $< 10 \text{ mL/cmH}_2\text{O}$; $1 \text{ cmH}_2\text{O}$ for values $\geq 10 \text{ mL/cmH}_2\text{O}$
PAV-based lung elastance (E_{PAV}) ¹	For a PAV+ breath, E_{PAV} is calculated as the inverse of C_{PAV} (see above). E_{PAV} can be displayed in the vital patient data banner. See Vital Patient Data , page 3-37.	Range: $5.0 \text{ cmH}_2\text{O/L}$ to $400 \text{ cmH}_2\text{O/L}$ Resolution: $0.1 \text{ cmH}_2\text{O/L}$ for values $< 10 \text{ cmH}_2\text{O/L}$; $1 \text{ cmH}_2\text{O/L}$ $\geq 10 \text{ cmH}_2\text{O/L}$

Table 11-11. Patient Data Range and Resolution (Continued)

Data value	Description	Range and resolution
PAV-based patient resistance (R_{PAV}) ¹	The difference between estimated total resistance R_{TOT} and the simultaneously estimated resistance of the artificial airway. When PAV+ is selected, the ventilator displays the current filtered value for patient resistance, and updates the display at the successful completion of each estimation. R_{PAV} can be displayed in the vital patient data banner. See Vital Patient Data , page 3-37.	Range: 0.0 cmH ₂ O/L/s to 60 cmH ₂ O/L/s Resolution: 0.1 cmH ₂ O/L/s for values <10 cmH ₂ O/L/s; 1 cmH ₂ O/L/s for values ≥ 10 cmH ₂ O/L/s
PAV-based total airway resistance (R_{TOT}) ¹	R_{TOT} is an estimated value captured just past peak expiratory flow and is equal to the pressure loss across the patient airway plus respiratory system (patient airway + ET tube + expiratory limb of the VBS)/ expiratory flow. This pressure loss is divided by the expiratory flow estimated at the same moment, yielding the estimate for R_{TOT} . The complete operation is orchestrated and monitored by a software algorithm. When PAV+ is selected, the ventilator displays the current filtered value for total resistance, and updates the display at the successful completion of each calculation. R_{TOT} can be displayed in the vital patient data banner. See Vital Patient Data , page 3-37.	Range: 1.0 cmH ₂ O/L/s to 80 cmH ₂ O/L/s Resolution: 0.1 cmH ₂ O/L/s for values <10 cmH ₂ O/L/s; 1 cmH ₂ O/L/s for values ≥10 cmH ₂ O/L/s
PAV-based work of breathing (WOB_{TOT})	The estimated effort needed for patient inspiration including both patient and ventilator.	Range: 1.0 J/L to 10.0 J/L Resolution: 0.1 J/L
Peak expiratory flow (PEF)	The maximum speed of exhalation.	Range: 0 L/min to 150 L/min Resolution: 0.1 L/min for PEF <20 L/min; 1 L/min for PEF ≥20 L/min
Peak circuit pressure (P_{PEAK})	The maximum pressure during the previous breath, relative to the patient wye, including inspiratory and expiratory phases.	Range: –20.0 cmH ₂ O to 130 cmH ₂ O Resolution: 0.1 cmH ₂ O for values –20.0 cmH ₂ O to 9.9 cmH ₂ O; 1 cmH ₂ O for values 10 cmH ₂ O to 130 cmH ₂ O

Table 11-11. Patient Data Range and Resolution (Continued)

Data value	Description	Range and resolution
Peak spontaneous flow (PSF)	The maximum flow rate sampled during a spontaneous inspiration.	Range: 0 L/min to 200 L/min Resolution: 0.1 L/min for values <20 L/min; 1 L/min for values ≥ 20 L/min
Plateau pressure (P_{PL})	The pressure measured during an inspiratory pause maneuver.	Range: -20.0 cmH ₂ O to 130 cmH ₂ O Resolution: 0.1 cmH ₂ O for values -20.0 cmH ₂ O to 9.9 cmH ₂ O; 1 cmH ₂ O for values ≥ 10 cmH ₂ O
Proximal exhaled tidal volume (V_{TEY})	For neonatal patients, the exhaled volume of the previous breath measured by the proximal flow sensor) (if installed).	Range: 0 mL to 500 mL Resolution: 0.1 mL for values 0 mL to 9.9 mL; 1 mL for values 10 mL to 500 mL
Proximal exhaled total minute volume ($\dot{V}_{E\text{ TOTY}}$)	For neonatal patients, the exhaled minute volume measured by the proximal flow sensor) (if installed).	Range: 0.00 L/min to 99.9 L/min Resolution: 0.01 L/min for 0.00 L/min to 9.99 L/min; 0.1 L/min for 10.0 L/min to 99.9 L/min
Proximal inspired tidal volume (V_{TIY})	For neonatal patients, the inspired volume of the previous breath measured by the proximal flow sensor) (if installed).	Range: 0 mL to 500 mL Resolution: 1 mL
Spontaneous inspiratory time ($T_{I\text{ SPONT}}$)	The duration of the inspiratory phase of a spontaneous breath.	Range: 0 s to 10 s Resolution: 0.01 s
Spontaneous inspiratory time ratio (T_I/T_{TOT})	The fraction of the total spontaneous breath time used by inspiration.	Range: 0 to 1 Resolution: 0.01
Spontaneous rapid shallow breathing index (f/V_T)	A calculated value using exhaled spontaneous tidal volume. High values indicate the patient is breathing rapidly, but with little volume/breath. Low values indicate the inverse scenario.	Range: 0.1 1/min-L to 600 1/min-L Resolution: 0.1 1/min-L for values <10 1/min-L; 1 1/min-L; for values ≥ 10 1/min-L
Static compliance (C_{STAT})	An estimate of the patient's lung-thorax static compliance or elasticity.	Range: 0 mL/cmH ₂ O to 500 mL/cmH ₂ O Resolution: 0.1 mL/cmH ₂ O for values <10 mL/cmH ₂ O; 1 mL/cmH ₂ O for values ≥ 10 mL/cmH ₂ O

Table 11-11. Patient Data Range and Resolution (Continued)

Data value	Description	Range and resolution
Static resistance (R_{STAT})	An estimate of the restrictiveness of the patient's lungs and the artificial airway.	Range: 0 cmH ₂ O/L/s to 500 cmH ₂ O /L/s Resolution: 0.1 cmH ₂ O/L/s for values <10 cmH ₂ O/L/s, 1 cmH ₂ O/ L/s for values ≥10 cmH ₂ O/L/s
Total PEEP ($PEEP_{TOT}$)	The estimated pressure at the circuit wye during an expiratory pause maneuver.	Range: -20.0 cmH ₂ O to +130 cmH ₂ O Resolution: 0.1 cmH ₂ O for values <10 cmH ₂ O; 1 cmH ₂ O for values ≤-10 cmH ₂ O and ≥10 cmH ₂ O
Total respiratory rate (f_{TOT})	The number of mandatory or spontaneous breaths/min delivered to the patient.	Range: 1 1/min to 200 1/min Resolution: 0.1 1/min for values <10 1/min; 1 1/min for 10 1/min to 200 1/min
Vital capacity (VC)	The maximum amount of air that can be exhaled after a maximum inhalation.	Range: 0 mL to 6000 mL Resolution: 0.1 mL for values <10 mL; 1 mL for values ≥10 mL
V_{LEAK}	Inspiratory leak volume, the total volume delivered during inspiration to compensate for the leak.	Range: 0 mL to 9000 mL Resolution: 1 mL
%LEAK	Percent leak, the percentage of total delivered volume during inspiration attributed to the leak calculated as (leak volume during inspiration / total delivered inspiratory volume)×100.	Range: 0% to 100% Resolution: 1%
LEAK	Exhalation leak. The leak rate at PEEP during exhalation.	Range: 0 L/min to 200 L/min Resolution: 0.1 L/min
$LEAK_Y$	Exhalation Leak at PEEP during Leak Sync, measured by the proximal flow sensor.	Range: 0 L/min to 50 L/min Resolution: 0.1 L/min

¹ If the estimated value of C_{PAW} , E_{PAW} , R_{PAW} , or R_{TOT} violates expected (PBW-based) limits, parentheses around the value indicate the value is questionable. If the estimated value exceeds its absolute limit, the limit value flashes in parentheses.

Table 11-12. Delivery Accuracy

Parameter	Accuracy	Range
Inspiratory pressure (P_I)	$\pm(3.0+2.5\%$ of setting) cmH_2O	5 cmH_2O to 90 cmH_2O
End expiratory pressure (PEEP)	$\pm(2.0+4\%$ of setting) cmH_2O	0 cmH_2O to 45 cmH_2O
Pressure support (P_{SUPP})	$\pm(3.0+2.5\%$ of setting) cmH_2O	0 cmH_2O to 70 cmH_2O
Tidal volume (V_T)	For adult and pediatric circuit type settings: For $T_I < 600\text{ms}$: $\pm(10+10\%$ of setting $\times 600\text{ ms}/T_I\text{ ms}$) mL For $T_I \geq 600\text{ ms}$: $\pm(10+10\%$ of setting) mL. For neonatal circuit type settings: For setting of 2 mL VC+ only: $\pm(1+10\%$ of setting) mL. For setting of 3 mL to 4 mL: $\pm(2+10\%$ of setting) mL (delivered volume shall be $\geq 1\text{ mL}$). For setting of 5 mL to 20 mL: $\pm(3+15\%$ of setting). For setting of $\geq 20\text{ mL}$: $\pm(4+10\%$ of setting) mL.	For adult and pediatric circuit type settings: 25 mL to 2500 mL For neonatal circuit type settings: 2 mL to 310 mL
$\text{O}_2\%$ (delivered)	$\pm 3\%$	21% to 100%
P_H	$\pm(2.0+4\%$ of setting) cmH_2O	5 cmH_2O to 90 cmH_2O
P_L	$\pm(2.0+4\%$ of setting) cmH_2O	0 cmH_2O to 45 cmH_2O

Table 11-13. Monitoring (Patient Data) Accuracy

Parameter	Accuracy	Range
Peak circuit pressure (P_{PEAK})	$\pm(2+4\%$ of reading) cmH_2O	5 cmH_2O to 90 cmH_2O
Mean circuit pressure (P_{MEAN})	$\pm(2+4\%$ of reading) cmH_2O	3 cmH_2O to 70 cmH_2O
End expiratory pressure (PEEP)	$\pm(2+4\%$ of reading) cmH_2O	0 cmH_2O to 45 cmH_2O
End inspiratory pressure ($P_{\text{I END}}$)	$\pm(2+4\%$ of reading) cmH_2O	5 cmH_2O to 90 cmH_2O
Inspired tidal volume (V_{TI})	$\pm(4\text{ mL}+15\%$ of actual) mL	2 mL to 2500 mL
Exhaled tidal volume (V_{TE})	$\pm(4\text{ mL}+10\%$ of actual) mL	2 mL to 2500 mL

Table 11-13. Monitoring (Patient Data) Accuracy (Continued)

Parameter	Accuracy	Range
Inspired tidal volume during Leak Sync (V_{TL})	For adult and pediatric circuit type settings: For $T_I \leq 600$ ms: $\pm(10+20\% \times 600 \text{ ms}/T_I \text{ ms of reading}) \text{ mL}$. For $T_I > 600$ ms: $\pm(10+20\% \text{ of reading}) \text{ mL}$. For neonatal circuit type setting: $\pm(10+20\% \text{ of reading}) \text{ mL}$. For readings $< 100 \text{ mL}$, the accuracy shall apply when the percentage of inspiratory leak volume is $< 80\%$.	For adult and pediatric circuit type settings: 25 mL to 2500 mL For neonatal circuit type settings: 2 mL to 310 mL
Exhaled tidal volume (V_{TE}) during Leak Sync	For adult and pediatric circuit type settings: For $T_E \leq 600$ ms: $\pm(10+20\% \times 600 \text{ ms}/T_E \text{ ms of reading}) \text{ mL}$. For $T_E > 600$ ms: $\pm(10+20\% \text{ of reading}) \text{ mL}$. For neonatal circuit type setting: $\pm(10+20\% \text{ of reading}) \text{ mL}$. For readings $< 100 \text{ mL}$, the accuracy shall apply when the percentage of inspiratory leak volume is $< 80\%$.	For adult and pediatric circuit type settings: 25 mL to 2500 mL For neonatal circuit type settings: 2 mL to 310 mL
Proximal exhaled tidal volume (V_{TEY})	$\pm(1+10\% \text{ of reading}) \text{ mL}$	2 mL to 310 mL
Proximal inspired tidal volume (V_{TIY})	$\pm(1+10\% \text{ of reading}) \text{ mL}$	2 mL to 310 mL
$O_2\%$ (monitored)	$\pm 3\%$	15% to 100%
Respiratory rate (f_{TOT})	$\pm 0.8 \text{ 1/min}$	1 1/min to 150 1/min

Table 11-14. Computed Value Accuracy

Parameter	Accuracy	Range
PAV-based lung compliance (C_{PAV})	$\pm(1+20\% \text{ of measured value}) \text{ mL/cmH}_2\text{O}$	10 mL/cmH ₂ O to 100 mL/cmH ₂ O
PAV-based total airway resistance (R_{TOT})	$\pm(3+20\% \text{ of measured value}) \text{ cmH}_2\text{O/L/s}$	5.0 cmH ₂ O/L/s to 50 cmH ₂ O/L/s
PAV-based work of breathing (WOB_{TOT})	$\pm(0.5+10\% \text{ of measured work}) \text{ J/L}$ with a percent support setting of 75%	0.7 J/L to 4 J/L

**WARNING:**

The ventilator accuracies listed in this chapter are applicable under the operating conditions identified. See [Table 11-8](#) on page 11-6.

Operation outside specified ranges cannot guarantee the accuracies listed in the tables above, and may supply incorrect information.

11.8 Manufacturer's Declaration

The following tables contain the manufacturer's declarations for the ventilator system electromagnetic emissions, electromagnetic immunity, separation distances between ventilator and portable and mobile RF communications equipment and a list of compliant cables.

**WARNING:**

Portable and mobile RF communications equipment can affect the performance of the ventilator system. Install and use this device according to the information contained in this manual.

**WARNING:**

The ventilator system should not be used adjacent to or stacked with other equipment, except as may be specified elsewhere in this manual. If adjacent or stacked used is necessary, the ventilator system should be observed to verify normal operation in the configurations in which it will be used.

**WARNING:**

Portable RF communications equipment (including peripherals such as antenna cables and external antennas should be used no closer than 30 cm (12 inches) to any part of the ventilator, including cables specified by the manufacturer. Otherwise, degradation of the performance of this equipment could result.

**Caution:**

This equipment is not intended for use in residential environments and may not provide adequate protection to radio communication services in such environments.

**Note:**

The emissions characteristics of this equipment make it suitable for use in industrial areas and hospitals (CISPR 11 class A). If it is used in a residential environment (for which CISPR 11 class B is normally required) this equipment might not offer adequate protection to radio-frequency communication services. The user might need to take mitigation measures, such as relocating or re-orienting the equipment.

Table 11-15. Electromagnetic Emissions

The ventilator is intended for use in the electromagnetic environment specified below. The customer or the operator of the ventilator should assure that it is used in such an environment.		
Emissions test	Compliance	Electromagnetic environment—guidance
Radiated RF emissions CISPR 11	Group 1 Class A	The ventilator uses RF energy only for its internal functions. The ventilator is intended to be used only in hospitals and not be connected to the public mains network.
Conducted emissions CISPR 11		The ventilator is intended to be used only in hospitals and not be connected to the public mains network.
Harmonic emissions IEC 61000-3-2	Class A	The ventilator is intended to be used only in hospitals and not be connected to the public mains network.
Voltage fluctuations/flicker IEC 61000-3-3	Complies	

Table 11-16. Electromagnetic Immunity

The ventilator is intended for use in the electromagnetic environment specified below. The customer or the operator of the ventilator should assure that it is used in such an environment.				
EMC test	Test standard	Test levels	Remarks	Electromagnetic environment—guidance
ESD	IEC 60601-1-2, Edition 3.0:2007 IEC 60601-1-2, Edition 4.0:2014 IEC 61000-4-2	±2,4,6,8 kV contact discharge ±2,4,8, 15kV air discharge	N/A	Floors should be wood, concrete, or ceramic tile. If floors are covered with synthetic material, the relative humidity should be at least 30%.
Radiated immunity	IEC 60601-1-2, Edition 3.0:2007 IEC 61000-4-3	10 V/m	Modulation: 80% AM, 2 Hz	N/A
	IEC 60601-1-2, Edition 4.0:2014 IEC 61000-4-3	3 V/m	Modulation: 80% AM, 1 kHz	

Table 11-16. Electromagnetic Immunity (Continued)

The ventilator is intended for use in the electromagnetic environment specified below. The customer or the operator of the ventilator should assure that it is used in such an environment.				
EMC test	Test standard	Test levels	Remarks	Electromagnetic environment—guidance
EFT/burst	IEC 60601-1-2, Edition 3.0:2007 IEC 61000-4-4	±1 kV (I/O) ±2 kV (AC Mains)	5 kHz pulse repetition rate	Mains power quality should be that of a typical hospital environment.
	IEC 60601-1-2, Edition 4.0:2014 IEC 61000-4-4		100 kHz pulse repetition rate	
Surge	IEC 60601-1-2, Edition 3.0:2007 IEC 60601-1-2, Edition 4.0:2014 IEC 61000-4-5	±0.5 kV, 1 kV line to line ±0.5 kV, 1 kV & 2 kV line to earth	N/A	
Conducted immunity	IEC 60601-1-2, Edition 3.0:2007 IEC 61000-4-6	3 V RMS 10 V RMS in the following frequency ranges (ISM Bands ¹); • 6.765–6.795 MHz • 13.553–13.567 MHz • 26.957–27.283 MHz • 40.66 – 40.70 MHz	Modulation: 80% AM, 2 Hz	Portable and mobile RF communications equipment should be used no closer to any part of the ventilator system, including cables, than the separation distance calculated from the equation applicable to the frequency of the transmitter. See Table 11-19 .
	IEC 60601-1-2, Edition 4.0:2014 IEC 61000-4-6	3 V RMS 6 V RMS in the following frequency ranges (ISM Bands ¹); • 6.765–6.795 MHz • 13.553–13.567 MHz • 26.957 –27.283 MHz • 40.66 – 40.70 MHz	Modulation: 80% AM, 1 kHz	
Magnetic immunity	IEC 60601-1-2, Edition 3.0:2007 IEC 60601-1-2, Edition 4.0:2014 IEC 61000-4-8	30 A/m	N/A	Power frequency magnetic fields should be at levels characteristic of a typical hospital environment.
NOTE: U_T is the AC mains voltage prior to application of the test level.				

Table 11-16. Electromagnetic Immunity (Continued)

The ventilator is intended for use in the electromagnetic environment specified below. The customer or the operator of the ventilator should assure that it is used in such an environment.				
EMC test	Test standard	Test levels	Remarks	Electromagnetic environment—guidance
Voltage dips	IEC 60601-1-2, Edition 3.0:2007 IEC 61000-4-11	• 95% minimum voltage reduction for 0.5 periods (10 ms) • 60% minimum voltage reduction for 5 periods (100 ms) • 30% minimum voltage reduction for 25 periods (500 ms)	N/A	Mains power should be that of a typical hospital environment. If the operator of the ventilator requires continuous operation during power mains interruptions, it is recommended that the ventilator be powered from an uninterruptible power supply or a battery.
	IEC 60601-1-2, Edition 4.0:2014 IEC 61000-4-11	• $U_T=0\%$, 0.5 cycle (0, 45, 90, 135, 180, 225, 270, and 350°) • $U_T=0\%$; 1 cycle • $U_T=70\%$; 25/30 cycles (@0°)		
Interrupts	IEC 60601-1-2, Edition 3.0:2007 IEC 60601-1-2, Edition 4.0:2014 IEC 61000-4-11	• $U_T=0\%$; 250/300 cycles		
Proximity field from RF wireless communication equipment	IEC 60601-1-2, Edition 4.0:2014 IEC 61000-4-3	See <i>Immunity to Proximity Fields RF Wireless Communications Equipment (Table 11-17.)</i> .	Modulation: See <i>Immunity to Proximity Fields RF Wireless Communications Equipment (Table 11-17.)</i> .	N/A
RFID immunity	AIM Standard 7351731 Rev. 2.00 2017 IEC 61000-4-3	See AIM Standard Test Levels (<i>Table 11-18.)</i> .	See section 7 in AIM Standard 7351731 for more details on execution of the different RFID specifications.	N/A
NOTE 1 At 80 MHz and 800 MHz, the higher frequency range applies. NOTE 2 these guidelines may not apply in all situations. Electromagnetic propagation is affected by absorption and reflection from structures, objects and people.				

¹ The ISM (industrial, scientific and medical) bands between 150 kHz and 80 MHz are 6.765 to 6.795 MHz; 13.553 MHz to 13.567 MHz; 26.957 MHz; and 40.66 MHz to 40.70 MHz. The compliance levels in the ISM frequency bands between 150 kHz and 80 MHz and in the frequency range 80 MHz to 2.5 GHz are intended to decrease the likelihood mobile/portable communications equipment could cause interference if it is inadvertently brought into patient areas. For this reason, an additional factor of 10/3 is used in calculating the separation distance for transmitters in these frequency ranges.

Table 11-17. Immunity to Proximity Fields RF Wireless Communications Equipment

Test frequency (MHz)	Band (MHz)	Service	Modulation	Maximum power (W)	Distance (m)	Immunity test level (V/m)
385	380–390	TETRA 400	Pulse modulation 18 Hz	1,8	0,3	27
450	430–470	• GMRS 460 • FRS 460	FM ±5 kHz deviation 1kHz sine	2	0,3	28
710	704–787	LTE Band 13, 17	Pulse modulation 217 Hz	0,2	0,3	9
745						
780						
810	800–960	• GSM 800/900 • TETRA 800 • iDEN 820 • CDMA 850 • LTE Band 5	Pulse modulation 18 Hz	2	0,3	28
870						
930						
1720	1700–1990	• GSM 1800 • CDMA 1900 • GSM 1900 • GSM 1900 DECT • LTE Band 1, 3, 4, 25 • UMTS	Pulse modulation 217 Hz	2	0,3	28
1845						
1970						
2450	2400–2570	• Bluetooth • WLAN, 802.11 b/g/n • RFID 2450 • LTE Band 7	Pulse modulation 217 Hz	2	0,3	28
5240	5100–5800	WLAN 802.11a/n	Pulse modulation 217 Hz	0,2	0,3	9
5500						
5785						

Table 11-18. AIM Standard Test Levels

RFID specification	Frequency	Test level (RMS)
ISO 14223	134.2 kHz	65 A/m
ISO/IEC 14443-3 (Type A)	13.56 MHz	7.5 A/m
ISO/IEC 14443-4 (Type B)	13.56 MHz	7.5 A/m
ISO/IEC 15693 (ISO 18000-3 Mode 1)	13.56 MHz	5 A/m
ISO 18999-3 Mode 3	13.56 MHz	12 A/m
ISO/IEC 18000-7	433 MHz	3 V/m
ISO/IEC 18000-63 Type C	860–960 MHz	54 V/m
ISO/IEC 18000-4 Mode 1	2.45 GHz	54 V/m

Table 11-19. Recommended Separation Distances for RF

The ventilator is intended for use in an electromagnetic environment in which radiated RF disturbances are controlled. The customer or the operator of the ventilator can help prevent electromagnetic interference by maintaining a minimum distance between portable and mobile RF communications equipment (transmitters) and the ventilator as recommended below, according to the maximum output power of the communications equipment.				
Rated maximum output power of transmitter (W)	150 kHz to 80 MHz outside of ISM bands	150 kHz to 80 MHz inside of ISM bands	80MHz to 800 MHz	800 MHz to 2.5 GHz
	$d = 1.17\sqrt{P}$	$d = 1.2\sqrt{P}$	$d = 1.2\sqrt{P}$	$d = 2.3\sqrt{P}$
0.01	0.117	0.12	0.12	0.23
0.1	0.37	0.38	0.38	0.73
1	1.17	1.2	1.2	2.3
10	3.7	3.8	3.8	7.3
100	11.7	12	12	23
For transmitters rated at a maximum output power not listed above, the recommended separation distance d in meters (m)¹ can be estimated using the equation applicable to the frequency of the transmitter where P is the maximum output power rating of the transmitter in watts (W) according to the transmitter manufacturer. NOTE 1 At 80 MHz and 800 MHz, the separation distance for the higher frequency range applies. NOTE 2 These guidelines may not apply in all situations. Electromagnetic propagation is affected by absorption and reflection from structures, objects and people. Field strengths from fixed transmitters, as determined by an electromagnetic site survey², should be less than the compliance level in each frequency range³. Interference may occur in the vicinity of equipment marked with the following symbol: 				

- 1 The compliance levels in the ISM frequency bands between 150 kHz and 80 MHz and in the frequency range 80 MHz to 2.5 GHz are intended to decrease the likelihood mobile/portable communications equipment could cause interference if it is inadvertently brought into patient areas. For this reason, an additional factor of 10/3 is used in calculating the separation distance for transmitters in these frequency ranges.
- 2 Field strengths from fixed transmitters, such as base stations for radio (cellular/cordless) telephones and land mobile radios, amateur radio, AM and FM radio broadcast and TV broadcast cannot be predicted theoretically with accuracy. To assess the electromagnetic environment due to fixed RF transmitters, an electromagnetic site survey should be considered. If the measured field strength in the location in which the 980 Series Ventilator is used exceeds the applicable RF compliance level above, the 980 Series Ventilator should be observed to verify normal operation. If abnormal performance is observed, additional measures may be necessary, such as reorienting or relocating the ventilator.
- 3 Over the frequency range 150 kHz to 80 MHz, field strengths should be less than 10 V/m.



WARNING:

The use of accessories and cables other than those specified with the exception of parts sold by Covidien as replacements for internal components, may result in increased emissions or decreased immunity of the ventilator system.

Table 11-20. Recommended Cables

Part Number and Description	Cable length
10081056, Power cord, 10A, RA, USA	3 m (10 ft)

11.9 Safety Tests

All safety tests should be performed by qualified service personnel at the interval specified. See [Table 7-4](#), on page 7-15.

11.10 Essential Performance Requirements

Per ISO/EN 80601-2-12: 2011, Medical electrical equipment Part 2-12: Particular requirements for basic safety and essential performance of critical care ventilators, the ventilator's essential performance requirements are given in [Table 11-9](#), [Table 11-10](#), and [Table 11-11](#). Alarms, including oxygen level alarms and gas failure alarms, are identified in Chapter 6. AC and battery backup power information is given in Chapter 3, and gas failure cross flow information is given in Chapter 3.

If essential performance is lost or degraded due to exposure of electromagnetic disturbance levels higher than those described in [Table 11-16](#), the following may occur:

- Component failures
- Changes in programmable parameters or settings
- Reset to default settings
- Changes to operating mode
- Initiation of an unintended operation
- Error in delivered volume of individual breaths greater than 35%
- Error in delivered minute volume greater than 25%
- False positive alarm condition
- Failure to Alarm

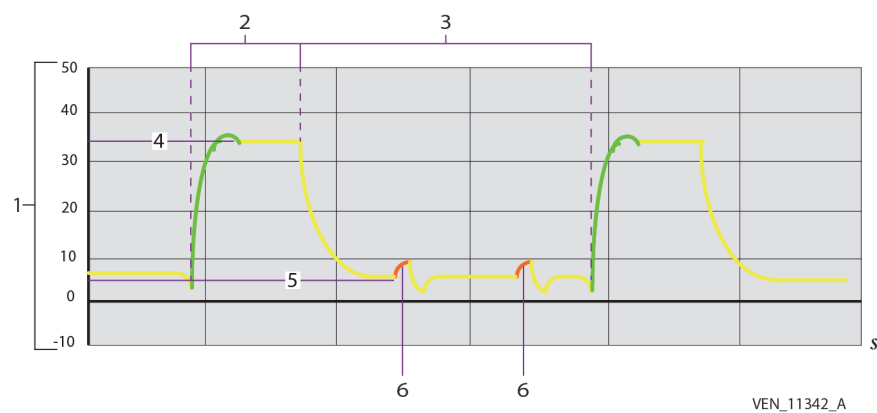
A BiLevel 2.0

A.1 Overview

This appendix describes the operation of the BiLevel 2.0 ventilation mode on the Puritan Bennett™ 980 Series Ventilator.

BiLevel is a mixed mode of ventilation that combines attributes of mandatory and spontaneous breathing, with the breath timing settings determining which breath type is favored. In BiLevel Mode, mandatory breaths are always pressure-controlled, and spontaneous breaths can be pressure-supported (PS) or tube compensated (TC).

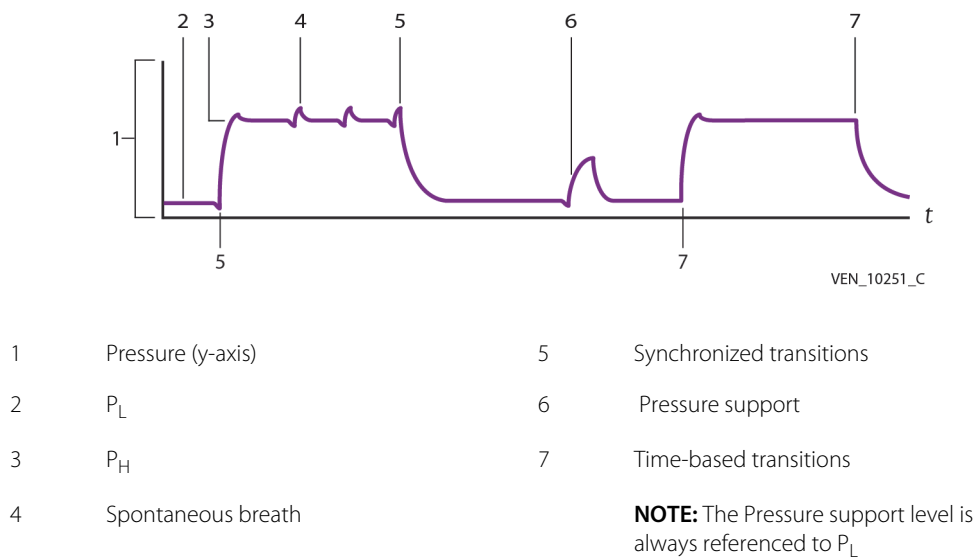
Figure A-1. Spontaneous Breathing at P_L



1	P_{CIRC} (cmH ₂ O)	4	P_H
2	T_H	5	P_L
3	T_L	6	Spontaneous breaths

BiLevel resembles SIMV mode, except that BiLevel establishes two levels of positive airway pressure. Cycling between the two levels can be triggered by BiLevel timing settings or by patient effort.

Figure A-2. BiLevel Mode



The two pressure levels are called low pressure (P_L) and high pressure (P_H). At either pressure level, patients can breathe spontaneously, and spontaneous breaths can be assisted with tube compensation or pressure support. BiLevel monitors mandatory and spontaneous tidal volumes separately.

Inspiratory time and expiratory time in BiLevel become time high (T_H) and time low (T_L), respectively. During these inspiratory and expiratory times, P_H is maintained during T_H and P_L is maintained during T_L .

A.2 Intended Use

BiLevel is intended for adult, pediatric, and neonatal patients.

A.3 Safety Reminder



WARNING:
The ventilator offers a variety of breath delivery options. Throughout the patient's treatment, the clinician should carefully select the ventilation mode and settings to use for that patient based on clinical judgment, the condition and needs of the patient, and the benefits, limitations, and characteristics of the breath delivery options. As the patient's condition changes over time, periodically assess the chosen modes and settings to determine whether or not those are best for the patient's current needs.

A.4 Setting Up BiLevel

BiLevel is a ventilatory mode (along with A/C, SIMV, and SPONT).

To set up BiLevel

1. At the ventilator setup screen, enter PBW or gender and height.
2. Touch BiLevel. After selecting BiLevel mode, the ventilator uses the PC mandatory breath type, which cannot be changed.
3. Choose the spontaneous type (PS or TC).
4. Choose trigger type (P-Trig or $\dot{V}$ -Trig).
5. Select desired ventilator settings. The default settings for BiLevel mode appear. To change a setting, touch its button and turn the knob to set its value. P_H must always be at least 5 cmH₂O greater than P_L .
6. Set T_L , T_H or the ratio of T_H to T_L . To select settings that would result in a $T_H:T_L$ ratio greater than 1:1 or 4:1, you must touch Continue to confirm after reaching the 1:1 and 4:1 limits.

Figure A-3. BiLevel Setup Screen



VEN_11361_D

7. Touch Start.
8. Set apnea and alarm settings by touching their respective tabs at the side of the ventilator settings screen and changing settings appropriately.

**Note:**

The rise time% setting determines the rise time to reach target pressure for transitions from P_L to P_H and for spontaneous breaths, even when pressure support (P_{SUPP})=0. Expiratory sensitivity (E_{SENS}) applies to all spontaneous breaths.

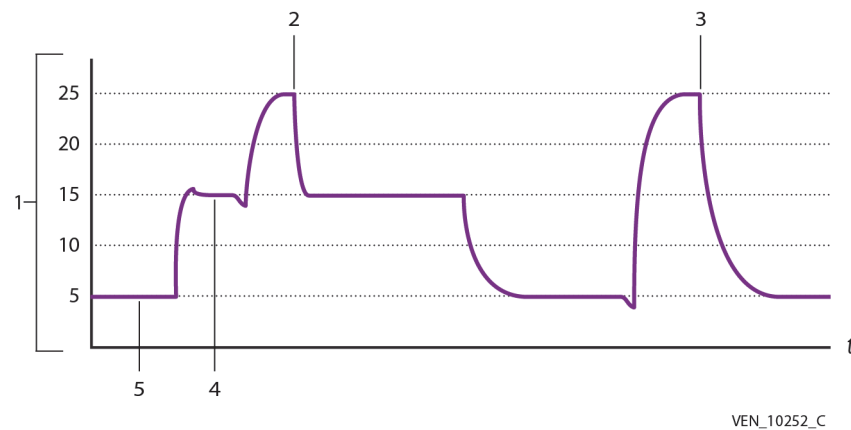
A.5 Using Pressure Support with BiLevel

Spontaneous breaths in BiLevel mode can be assisted with pressure support according to these rules (see [Figure A-4](#), on page [A-5](#)):

- Pressure support (P_{SUPP}) can be used to assist spontaneous breaths at P_L and P_H . P_{SUPP} is always set relative to P_L . Target pressure = $P_L + P_{SUPP}$.
- Spontaneous patient efforts at P_H are not pressure supported unless $P_{SUPP} > (P_H - P_L)$. All spontaneous breaths (whether or not they are pressure supported) are assisted by a pressure of 1.5 cmH₂O.
- If $P_{SUPP} + P_L$ is greater than $P_H + 1.5$ cmH₂O, all spontaneous breaths at P_L are assisted by the P_{SUPP} setting, and all spontaneous breaths at P_H are assisted by $P_{SUPP} - (P_H - P_L)$.
- All spontaneous breaths not supported by PS or TC (for example, a classic CPAP breath) are assisted with an inspiratory pressure of 1.5 cmH₂O.

For example, if $P_L = 5$ cmH₂O, $P_H = 15$ cmH₂O, and $P_{SUPP} = 20$ cmH₂O:

- All spontaneous breaths at P_L are assisted by 20 cmH₂O of pressure support ($P_L + P_{SUPP}$) for a total pressure of 25 cmH₂O, and
- All spontaneous breaths in P_H are assisted by 10 cmH₂O of pressure support ($P_{SUPP} - (P_H - P_L)$) for the same total pressure of 25 cmH₂O.

Figure A-4. BiLevel with Pressure Support

1	Pressure (y-axis)	4	P_H
2	P_H Pressure support =10 cmH ₂ O	5	P_L
3	P_L Pressure support =20 cmH ₂ O		

During spontaneous breaths, the pressure target is calculated with respect to P_L .

A.6 Manual Inspirations in BiLevel Mode



Pressing the manual inspiration key during BiLevel mode causes the ventilator to:

- Cycle to P_H , if the current pressure level is P_L .
- Cycle to P_L , if the current pressure level is P_H .

To avoid breath stacking, the ventilator does not cycle from one pressure level to another during the earliest stage of exhalation.

A.7 Respiratory Mechanics Maneuvers in BiLevel

In BiLevel, respiratory mechanics maneuvers are limited to inspiratory pause and expiratory pause maneuvers.

A.8 Specifications

See [Table 11-9](#), on page 11-7 for the following specifications:

- Low pressure (P_L)
- High pressure (P_H)

- Low time (T_L)
- High time (T_H)
- $T_H:T_L$ ratio
- Respiratory rate (f)
- Rise time%

A.9 Technical Description

BiLevel is a mode of ventilation that alternately cycles between two operator-set pressure levels, P_L and P_H . The pressure durations are defined by operator-set timing variables T_L and T_H . Transitions between the two pressure levels, P_L and P_H , are analogous to breath phase transitions in PC.

At the extreme ranges of T_L and T_H , BiLevel can resemble the single breath type mode A/C - PC, or the more complex breath type mode, an “inverted-like” IMV. If T_H and T_L assume normal values with respect to PBW (for example $T_H:T_L > 1:2$ or $1:3$), then BiLevel assumes a breathing pattern similar to, if not qualitatively identical to A/C - PC. However, as T_L begins to shorten with the $T_H:T_L$ ratio extending beyond 4:1, the breathing pattern assumes a distinctly different shape. In the extreme, the exaggerated time at P_H and abrupt release to P_L would match the pattern patented by John Downs* and defined as APRV.

In between the A/C - PC-like pattern and the APRV-like pattern, there would be patterns with moderately long T_H and T_L intervals, allowing the patient sufficient time to breathe spontaneously at both P_H and P_L . In these types of breathing patterns, (but less so with APRV) BiLevel, like SIMV, can be thought of as providing both mandatory and spontaneous breath types. In this sense, BiLevel and SIMV are classified as mixed modes.

Direct access to any of the three breath timing parameters in BiLevel is accomplished by touching the padlock icon associated with the T_H period, T_L period or the $T_H:T_L$ ratio displayed on the breath timing bar in the setup screen.

While in BiLevel mode, spontaneously triggered breaths at either pressure level can be augmented with higher inspiratory pressures using pressure support (PS) or tube compensation (TC) breath types.

A.9.1 Synchrony in BiLevel

Just as BiLevel attempts to synchronize spontaneous breath delivery with the patient's inspiratory and expiratory efforts, it also attempts to synchronize the transitions between pressure levels with the patient's breathing efforts. This allows T_H to be extended to prevent transitions to P_L during

*. Downs, JB, Stock MC. Airway pressure release ventilation: A new concept in ventilatory support. Crit Care Med 1987;15:459–461

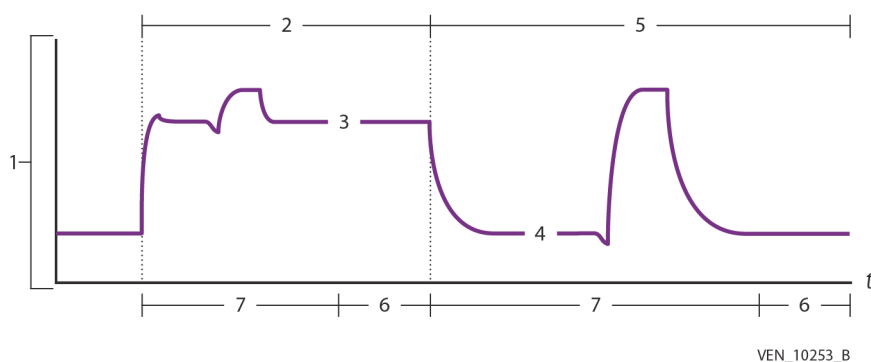
the patient's spontaneous inspiration. Likewise, the T_L interval may be extended to prevent a transition to P_H during the patient's spontaneous exhalation.

The trigger sensitivity setting (P_{SENS} or $\dot{V}_{SENS}$) is used to synchronize the transition from P_L to P_H . The transition from P_H down to P_L is synchronized with the patient's spontaneous expiratory effort. The BiLevel algorithm will vary the T_L and T_H intervals as necessary to synchronize the transitions between P_L and P_H to match the patient's breathing pattern.

The actual durations of T_H and T_L vary according to whether or not the patient makes any spontaneous inspiratory efforts during those periods.

To manage synchrony with the patient's breathing pattern, the BiLevel algorithm partitions the T_H and T_L periods into spontaneous and synchronous intervals as shown in [Figure A-5](#).

Figure A-5. Spontaneous and Synchronous Intervals



1	Pressure (y-axis)	5	T_L
2	T_H	6	Synchronous interval
3	P_H	7	Spontaneous interval
4	P_L		

By partitioning T_H and T_L into **spontaneous** and **synchronous** phases, BiLevel responds to patient efforts (or lack of them) in a predictable pattern:

- During the **spontaneous** interval of each pressure level, successful inspiratory efforts cause the ventilator to deliver spontaneous breaths.
- During T_L **synchronous** intervals, successful inspiratory efforts cause the ventilator to cycle from P_L to P_H . If there is no spontaneous (patient) effort, this transition takes place at the end of the T_L period.
- During T_H **synchronous** intervals, successful expiratory efforts cause the ventilator to cycle from P_H to P_L . If there is no spontaneous exhalation, the transition to the P_L level takes place at the end of the T_H period.

A.9.2 Patient Monitoring in BiLevel

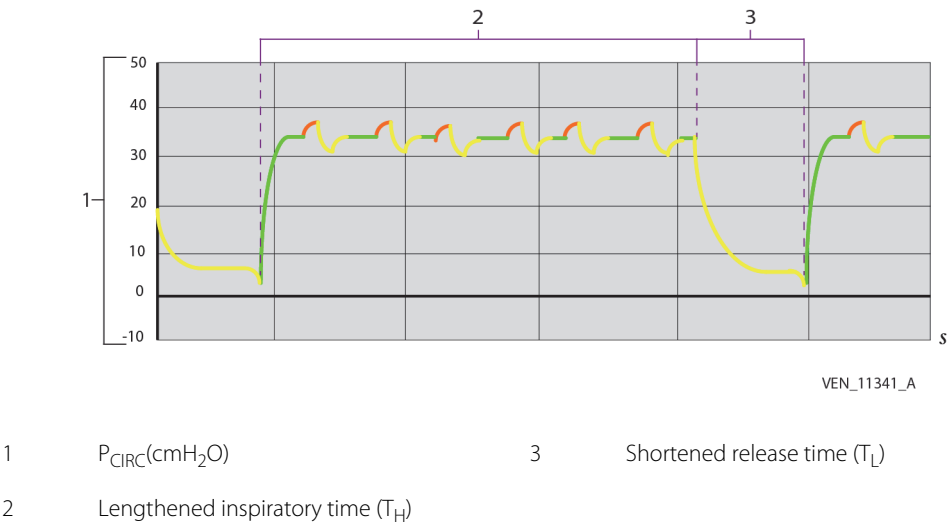
If the patient breathes spontaneously at either pressure level, BiLevel monitors and displays the total respiratory rate, including mandatory and spontaneous breaths. BiLevel also displays the exhaled tidal volume and total exhaled minute volume for both mandatory and spontaneous breaths.

A.9.3 APRV Strategy in BiLevel

Lengthening the T_H period and shortening the T_L period to only allow incomplete exhalation of the mandatory breath volume, results in an inverse $T_H:T_L$ ratio. In this breath timing configuration with $T_H:T_L$ ratios of greater than 4:1, BiLevel becomes **A**irway **P**ressure **R**elease **V**entilation (APRV).

APRV is characterized by longer T_H periods, short T_L periods (usually less than 1 second), and inverse $T_H:T_L$ ratios. Because at these breath timing settings, all of the patient-triggered spontaneous breaths occur during the T_H period, APRV resembles CPAP ventilation with occasional, short periods of incomplete exhalation referred to as “releases”, which are controlled by the f setting.

Figure A-6. APRV With Spontaneous Breathing at P_H



In APRV, the P_H level is set to optimize pulmonary compliance for spontaneous breathing while maintaining an elevated mean airway pressure to promote oxygenation, the P_L level is set, along with the T_L , to control the expiratory release volume of mandatory breaths to help manage CO_2 and alveolar ventilation, and the f setting controls the number of releases per minute which are used to help manage the patient's CO_2 levels. The f setting also impacts the mean airway pressure.

In APRV the operator can configure the BiLevel settings to allow direct control of T_L to assure that changes in the f setting will not inadvertently lengthen the T_L period resulting in destabilization

of end-expiratory alveolar volume. With the T_L period locked, changes in set f will change the T_H period to accommodate the new f setting while maintaining the set T_L period.

A.9.4 Technical Structure of BiLevel

In BiLevel, the ventilator establishes two levels of baseline pressure. One level is essentially the same as the standard PEEP level set for all common modes of ventilation. The second pressure level is the level established at T_H . Both pressure levels permit CPAP, TC and PS breaths. The breath timing settings determine whether the patient can initiate any of these breath types.

A.10 Mode Changes

Changing to BiLevel mode from other modes follows the general guidelines for mode changes:

- The change is made as soon as possible without compromising inspiration or exhalation.
- Breaths are not stacked during inspiration.

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B Leak Sync

B.1 Overview

This appendix describes the operation of the Puritan Bennett™ 980 Series Ventilator Leak Sync function. Leak Sync enables the ventilator to compensate for leaks in the breathing circuit while accurately detecting the patient's effort to trigger and cycle a breath. Because Leak Sync allows the ventilator to differentiate between flow due to leaks and flow due to patient respiratory effort, it provides dynamic compensation and enhances patient-ventilator synchrony. See Chapter 4 for general parameter and operational information.

B.2 Intended Use

Leak Sync is designed to compensate for leaks in the breathing circuit during non-invasive or invasive ventilation. Leak Sync accurately quantifies instantaneous leak rates, therefore detecting patient respiratory phase transitions correctly and may affect work of breathing. Leak Sync is intended for neonatal, pediatric, and adult patients.

B.3 Safety Reminder



WARNING:

The ventilator offers a variety of breath delivery options. Throughout the patient's treatment, the clinician should carefully select the ventilation mode and settings to use for that patient based on clinical judgment, the condition and needs of the patient, and the benefits, limitations, and characteristics of the breath delivery options. As the patient's condition changes over time, periodically assess the chosen modes and settings to determine whether or not those are best for the patient's current needs.

B.4 Leak Sync

Breathing circuit leaks can cause the ventilator to erroneously detect patient inspiratory efforts (called autotriggering) or delay exhalation in pressure support. Patient interfaces such as masks are particularly prone to significant leaks. Inaccurately declaring inspiration or exhalation can result in patient-ventilator dysynchrony and increased work of breathing.

Changing inspiratory or expiratory sensitivity settings can temporarily correct the problem, but requires continued frequent clinical intervention to ensure that sensitivity is adjusted appropriately as conditions change (for example, if the patient moves or the circuit leak changes).

Leak Sync adds flow to the breathing circuit to compensate for leaks. The maximum Leak Sync flow applies to the maximum base flow compensation during exhalation. During pressure-based inspirations, the total delivered flow (leak flow plus inspiratory flow) is limited by the maximum total flow.

Table B-1. shows the maximum leak rates at set PEEP pressure that Leak Sync will compensate based on patient type.

Table B-1. Maximum Leak Compensation Flow Based on Patient Type

Patient type	Maximum leak compensation flow at PEEP	Maximum total flow
Neonatal	15 L/min	50 L/min
Pediatric	40 L/min (25 L/min if compressor is the air source)	120 L/min
Adult	65 L/min (25 L/min if compressor is the air source)	200 L/min



WARNING:
With significant leaks, pressure targets may not be reached due to flow limitations.

B.5 Setting Up Leak Sync

For more information on setting up the ventilator, see Chapter 4.

To enable Leak Sync

1. At the ventilator setup screen, touch the More Settings tab.
2. Touch Enabled in the Leak Sync area.
3. Touch *Accept ALL* to enable Leak Sync.

Figure B-1. Enabling Leak Sync



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**Note:**

The default value for Leak Sync is Disabled when the circuit type is pediatric or adult and the ventilation type is invasive. Otherwise the default value for Leak Sync is Enabled.

**Note:**

Leak Sync is not allowed for tube compensated (TC) and Proportional Assist Ventilation (PAV+) breath types.

B.6 When Leak Sync is Enabled

See [Figure B-2](#) on page [B-4](#) for an example showing the GUI screen when Leak Sync is enabled.

- The vent setup button on the GUI screen indicates Leak Sync is active.
- D_{SENS} is displayed in units of L/min, rather than %.
- If the ventilator detects a leak during a respiratory mechanics maneuver, the message Leak Detected is displayed.
- A new leak or change in leak rate is typically quantified and compensated within three breaths. Monitored patient data stabilizes within a few breaths.
- Select inspiratory and expiratory sensitivity settings as usual. If the ventilator auto-triggers, try increasing flow sensitivity ($\dot{V}_{SENS}$).

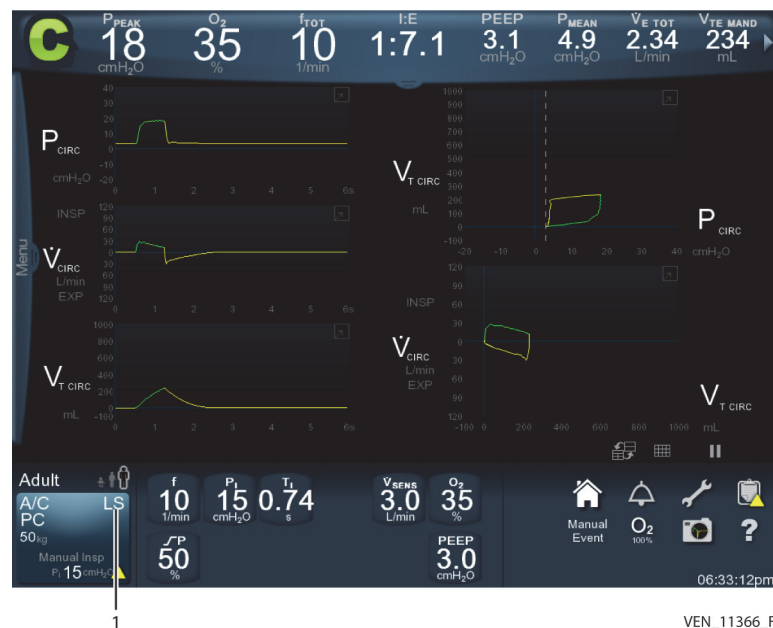
**Note:**

The absence of the Leak Detected message does not mean there is no leak.

**Note:**

Leak Sync is automatically enabled when ventilating a new patient and the circuit type is neonatal, regardless of the ventilation type. If Leak Sync is disabled, it remains disabled when switching between invasive and NIV ventilation types.

Figure B-2. GUI Screen when Leak Sync is Enabled



1 LS appears on vent setup button notifying the operator that Leak Sync is enabled

B.6.1 Adjusting Disconnect Sensitivity (D_{SENS})

When Leak Sync is enabled, the CIRCUIT DISCONNECT alarm becomes active based on the D_{SENS} setting, which is the maximum allowable leak rate at set PEEP.

When Leak Sync is disabled, D_{SENS} is automatically set to 75%.

**WARNING:**

When ventilation type = NIV and Leak Sync is disabled, D_{SENS} is automatically set to OFF.

See Reference [Chapter B-2](#) for a summary of D_{SENS} settings when Leak Sync is enabled. Note that it is possible to set D_{SENS} below maximum Leak Sync flow.

Table B-2. D_{SENS} Settings

Breathing circuit type	D _{SENS} setting	Maximum total flow
Neonatal	Range: 1 L/min to 15 L/min Default: 2 L/min (Invasive Ventilation) 5 L/min (NIV)	50 L/min
Pediatric	Range: 1 L/min to 40 L/min Default: 20 L/min	120 L/min
Adult	Range: 1 L/min to 65 L/min Default: 40 L/min	200 L/min

**WARNING:**

Setting D_{SENS} higher than necessary may prevent timely detection of inadvertent extubation.

B.6.2 Monitored Patient Data

When Leak Sync is enabled, three additional parameters are displayed on the More Patient Data screen and updated for each breath. Display the More Patient Data screen by swiping the tab on the patient data banner. These leak parameters may also be configured on the patient data banner and the large font patient data panel.

Figure B-3. Leak Sync Monitored Patient Data



VEN_11367_F

See [Table 11-11](#), on page [11-17](#) for information regarding the following monitored patient data parameters:

- V_{LEAK}
- % LEAK
- LEAK

Displayed values for exhaled tidal volume (V_{TE}) and inspired tidal volume (V_{TL}) are leak-compensated, and indicate the estimated inspired or exhaled lung volume. The accuracies for V_{TE} and V_{TL} also change when Leak Sync is enabled (see [Technical Discussion \(B.7\)](#) for more information). Graphic displays of flow during Leak Sync indicate estimated lung flows.

B.7 Technical Discussion

Managing breathing circuit leaks is important to ensure appropriate breath triggering and cycling, ventilation adequacy, and valid patient data. Detecting and monitoring leaks can improve treatment, reduce patient work of breathing, and provide more accurate information for clinical assessments.

Leak Sync recognizes that changing pressures lead to varying deflection of interface materials and leak sizes. The Leak Sync leak model includes a rigid leak orifice whose size remains constant under changing pressures, combined with an elastic leak source whose size varies as a function of applied pressure. This algorithm provides a more accurate estimate of instantaneous leak to improve patient-ventilator synchrony under varying airway pressures.

Leak Sync allows the ventilator to determine the leak level and allows the operator to set the flow trigger and peak flow sensitivities to a selected threshold. The base flow during exhalation is set to:

- Flow triggering: 1.5 L/min + estimated leak flow at PEEP+ flow sensitivity
- Pressure triggering: 1.0 L/min + estimated leak flow at PEEP

B.7.1 Inspired Tidal Volume (V_{TL}) Accuracy During Leak Sync

For V_{TL} parameter accuracy, see [Table 11-13](#), on page [11-23](#).

For readings <100 mL, accuracy ranges apply when the percentage of inspiratory leak volume is <80%, where the percentage of leak volume is:

$(\text{Leak volume during inspiration} / \text{total delivered inspiratory volume}) \times 100$

**Note:**

Inspired tidal volume is labeled as V_{TL} when Leak Sync is enabled, and as V_{TI} when Leak Sync is disabled.

B.7.2 Exhaled Tidal Volume (V_{TE}) Accuracy During Leak Sync

For accuracy when Leak Sync is enabled, see [Table 11-13](#) on page 11-23, V_{TE} parameter.

In [Table 11-13](#), T_E = time to exhale 90% of volume actually exhaled by the patient.

For readings <100 mL, accuracy ranges apply when the percentage of inspiratory leak volume is <80%, where the percentage of leak volume is:

(Leak volume during inspiration/total delivered inspiratory volume) $\times 100$

B.7.3 %LEAK Calculation

For %LEAK parameter specifications, see [Table 11-11](#) on page 11-17.

B.7.4 CIRCUIT DISCONNECT Alarm During Leak Sync

The CIRCUIT DISCONNECT alarm is activated if the overall leak volume during the whole breath exceeds the maximum leak volume derived from the D_{SENS} setting. During VC, the CIRCUIT DISCONNECT alarm is also activated if the end-inspiratory pressure falls below (set PEEP+1 cmH₂O) for three consecutive breaths. The screen shows this alarm message:

Figure B-4. Circuit Disconnect During VC



VEN_11368_D

If the compressor is in use and the D_{SENS} setting >25 L/min, a D_{SENS} of 25 L/min is used to determine that the circuit is disconnected. If LEAK >25 L/min, the alarm banner shows the following message:

Check patient. Reconnect circuit. Leak may exceed maximum compensation value for compressor.

Normal operation resumes if the ventilator detects a patient connection.

c.1 Overview

This appendix describes the operation of PAV™+ software for the Puritan Bennett™ 980 Series Ventilator.

Proportional Assist™* Ventilation (PAV+) is designed to improve the work of breathing of a spontaneously breathing patient by reducing the patient's increased work of breathing when pulmonary mechanics are compromised.

The PAV+ breath type differs from the pressure support (PS) breath type in the following way:

PAV+ acts as an inspiratory amplifier; the degree of amplification is set by the % Support setting (% Supp). PAV+ software continuously monitors the patient's instantaneous inspiratory flow and instantaneous lung volume, which are indicators of the patient's inspiratory effort. These signals, together with ongoing estimates of the patient's resistance and compliance, allow the software to instantaneously compute the necessary pressure at the patient wye to assist the patient's inspiratory muscles to the degree selected by the % Supp setting. Higher inspiratory demand yields greater support from the ventilator.

PAV+ software reduces the risk of inadvertent entry of incompatible settings, such as small predicted body weight (PBW) paired with a large airway.

c.2 Intended Use

PAV+ is intended for use in spontaneously breathing adult patients whose ventilator predicted body weight (PBW) setting is at least 25.0 kg (55 lb). Patients must be intubated with either endotracheal (ET) or tracheostomy (Trach) tubes of internal diameter (ID) 6.0 mm to 10.0 mm. Patients must have satisfactory neural-ventilatory coupling, and stable, sustainable inspiratory drive.

*. Proportional Assist and PAV are registered trademarks of The University of Manitoba, Canada. Used under license.

c.3 Safety Information

**WARNING:**

The ventilator offers a variety of breath delivery options. Throughout the patient's treatment, the clinician should carefully select the ventilation mode and settings to use for that patient based on clinical judgment, the condition and needs of the patient, and the benefits, limitations, and characteristics of the breath delivery options. As the patient's condition changes over time, periodically assess the chosen modes and settings to determine whether or not those are best for the patient's current needs.

**WARNING:**

PAV+ is not an available breath type in non-invasive ventilation (NIV). Do not use non-invasive patient interfaces such as masks, nasal prongs, uncuffed ET tubes, etc. as leaks associated with these interfaces may result in over-assist and patient discomfort.

**WARNING:**

Breathing circuit and artificial airway must be free from leaks. Leaks may result in ventilator over-assist and patient discomfort.

**WARNING:**

Ensure high and low tidal volume alarm thresholds are set appropriately because an overestimation of lung compliance could result in an under-support condition resulting in the delivery of smaller than optimal tidal volumes.

c.4 PAV+

**WARNING:**

Ensure that there are no significant leaks in the breathing circuit or around the artificial airway cuff. Significant leaks can affect the performance of PAV+ and the accuracy of resistance (R) and elastance (E) estimates.

**WARNING:**

Do not use silicone breathing circuits with PAV+: the elastic behavior of a silicone circuit at the beginning of exhalation can cause pressure-flow oscillations that result in underestimates of patient resistance.

The act of inspiration requires the patient's inspiratory muscles to develop a pressure gradient between the mouth and the alveoli sufficient to draw in breathing gas and inflate the lungs. Some of this pressure gradient is dissipated as gas travels through the artificial airway and the patient's conducting airways, and some of the pressure gradient is dissipated in the inflation of the lungs and thorax. Each element of pressure dissipation is characterized by a measurable property: the

resistance of the artificial and patient airways, and the compliance (or elastance) of the lung and thorax.

PAV+ software uses specific information, including resistance of the artificial airway, resistance of the patient's airways, lung-thorax compliance, instantaneous inspiratory flow and lung volume, and the % Supp setting to compute the instantaneous pressure to be applied at the patient connection port (patient wye). PAV+ software randomly estimates patient resistance and compliance approximately every four to 10 breaths. Every 5 ms, the software estimates lung flow, based on an estimate of flow at the patient wye, and lung volume, based on the integral of the value of estimated lung flow.

PAV+ begins to assist an inspiration when flow (generated by the patient's inspiratory muscles) appears at the patient wye. If the patient ceases inspiration, the assist also ceases. Once inspiratory flow begins, PAV+ software monitors instantaneous flow and volume every 5 ms and applies the pressure calculated to overcome a proportion (determined by the % Supp setting) of the pressure losses dissipated across the resistances of the artificial and patient airways and lung/thorax compliance.

Because the PAV+ algorithm does not know the patient's mechanics when the PAV+ breath type is selected, the software performs a startup routine to obtain initial data. At startup, PAV+ software delivers four consecutive PAV+ breaths, each of which includes an end-inspiratory pause maneuver that yields estimates of the patient's resistance and compliance. The first breath, however, is delivered using the predicted resistance for the artificial airway and conservative estimates for patient resistance and compliance, based on the patient's PBW.

Each of the next three PAV+ breaths averages stepwise decreased physiologic values with the estimated resistance and compliance values from the previous breath, weighting earlier estimates less with each successive breath, and yielding more reliable estimates for resistance and compliance. The fifth PAV+ breath (the first non-startup breath) is delivered using the final estimates with the clinician-set % Supp setting. Once startup is complete, the PAV+ software randomly applies a maneuver breath every four to 10 breaths after the last maneuver breath to re-estimate patient resistance and compliance. New values are always averaged with former values.

PAV+ graphically displays estimates of patient lung pressure (intrinsic PEEP), patient compliance, patient resistance, total resistance, total work of inspiration, patient work of inspiration, inspiratory elastic work (an indicator of lung-thorax work), and inspiratory resistive work.

The % Supp setting ranges from a minimum of 5% (the ventilator performs 5% of the work of inspiration and the patient performs 95%) to a maximum of 95% (the ventilator performs 95% of the work and the patient performs 5%), adjustable in 5% increments.

PAV+ also includes alarm limits, safety checks, and logic checks that reject non-physiologic values for patient resistance and compliance as well as inappropriate data.

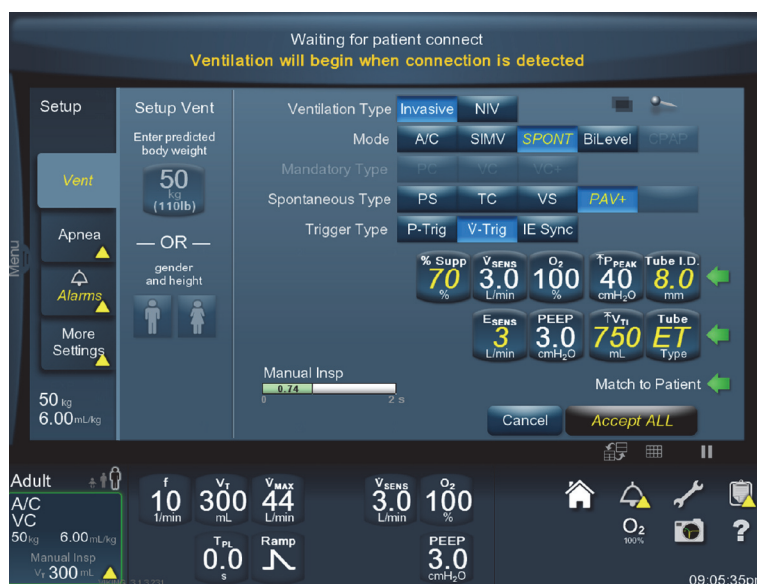
Humidification type and volume can be adjusted after running SST, however the ventilator makes assumptions when calculating resistance and compliance if these changes are made without re-running SST. For optimal breath delivery, run SST after changing humidification type and humidifier volume.

c.4.1 Setting Up PAV+

To set up PAV+

1. At the ventilator setup screen, enter the patient's gender and height or the patient's PBW.
2. Touch invasive ventilation type.
3. Touch SPONT mode.
4. Touch PAV+ to select Spontaneous type.
5. Touch the desired trigger type (P-Trig or $\dot{V}$ -Trig).
6. Select tube type
7. Select the tube ID. Initially, a default value is shown based on the PBW entered at ventilator startup. If this ID is not correct for the airway in use, turn the knob to adjust the ID setting.
8. Continue setting up the ventilator as described in Chapter 4.

Figure C-1. Ventilator Setup Screen



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Note:

If the operator selects an internal diameter that does not correspond to allowable values, touch Continue to override the tube ID setting. If attempts are made to choose a tube ID less than 6.0 mm or greater than 10 mm, a hard bound limit is reached, as PAV+ is not intended for use with tubes smaller than 6.0 mm or larger than 10.0 mm. When touching Dismiss, the setting remains at the last tube ID selected. Touch *Accept* or *Accept ALL* to accept changes, or touch *Cancel* to cancel changes.

**Note:**

If Leak Sync is currently enabled, it becomes disabled when PAV+ is selected.

**Note:**

When the ventilator is used on the same patient previously ventilated using PAV+, the GUI displays an attention icon and the tube type and tube ID previously used, as a reminder to the clinician to review those settings during ventilator setup.



C.4.2 PBW and Tube ID

The ventilator uses soft bound and hard bound values for estimated tube inside diameters based upon PBW. Soft bounds are ventilator settings that have reached their recommended high or low limits. When adjusting the tube size, if the inside diameter does not align with a valid predicted body weight, a Continue button appears. Setting the ventilator beyond these soft bounds requires the operator to acknowledge the prompt by touching Continue before continuing to adjust the tube size. The limit beyond which the tube ID cannot be adjusted is called a hard bound, and the ventilator emits an invalid entry tone when a hard bound is reached.

**WARNING:**

Ensure that the correct artificial airway ID size is entered. Because PAV+ amplifies flow, entering a smaller-than-actual airway ID causes the flow-based pressure assistance to over-support the patient and could lead to transient over-assist at high values of % Supp. Conversely, entering a larger-than-actual ID results in under-support. PAV+ software monitors the settings for the PBW and artificial airway. If the PBW and tube ID settings do not correspond to allowable values, confirm or correct the settings. Confirming or correcting the actual ID size minimizes the likelihood that PAV+ will over-support or under-support.

To apply new settings for the artificial airway follow these steps

1. Touch the vent setup button at the lower left of the GUI screen.
2. Touch Tube Type and turn the knob to select Trach or ET to set the tube type.
3. Touch Tube ID and turn the knob to set the tube ID.
4. Touch *Accept* or *Accept ALL* to apply the new settings, or *Cancel* to cancel.



To apply new humidifier settings

1. Touch the More Settings tab.
2. Touch the appropriate button for Humidification Type.
3. For non-HME humidification types, touch Humidifier Volume, then turn the knob to adjust the (empty) humidifier volume.
4. Touch *Accept ALL* to apply the changes.

**WARNING:**

To ensure the accuracy of PAV+ breaths and spirometry measurements, run SST following any change to the humidification type or humidification volume settings. Ensure that the intended circuit is used with the SST.

c.4.3 Apnea Parameters Adjustment

After accepting the PAV+ settings, touch the Apnea Setup screen. Adjust the Apnea parameters as required.

c.4.4 Alarm Settings Adjustment

PAV+ includes the high inspired tidal volume ($\uparrow V_{TI}$) and low exhaled spontaneous tidal volume alarm ($\downarrow V_{TE\ SPONT}$) alarm limit settings. See [PAV+ Alarms \(C.4.8\)](#) on page C-8.

**Note:**

Because of the breathing variability that PAV+ allows, the $\downarrow V_{TE\ SPONT}$ alarm, by default, is turned OFF to minimize nuisance alarms. To monitor adequate ventilation, use the $\downarrow \dot{V}_{E\ TOT}$ alarm condition instead.

To adjust alarm settings

1. Touch the Alarm tab to view the current alarm settings.
2. Touch the button for each alarm limit requiring a change.
3. Turn the knob to adjust the value of the alarm limit. Proposed values are highlighted. You can change more than one alarm limit before applying the changes.
4. Touch *Accept* or *Accept All* to apply the changes, or *Cancel* to cancel.

c.4.5 PAV+ Ventilator Settings

For a summary of PAV+ ventilator settings for the following parameters, See [Table 11-9](#) on page 11-7:

- % Supp
- Expiratory sensitivity (E_{SENS})
- Tube type
- Tube ID
- Trigger type

C.4.6 PAV+ Alarm Settings

For a summary of the following alarm settings available when PAV+ is active, see [Table 11-10](#) on page [11-14](#):

- High inspired tidal volume limit ($\uparrow V_{TI}$)
- Low exhaled spontaneous tidal volume ($\downarrow V_{TE\ SPONT}$)

C.4.7 Monitored Data

For the following monitored data associated with PAV+, see [Table 11-11](#) on page [11-17](#):

- PAV-based lung compliance (C_{PAV})
- PAV-based lung elastance (E_{PAV})
- PAV-based lung resistance (R_{PAV})
- PAV-based total airway resistance (R_{TOT})
- Inspired tidal volume (V_{TI})

See [Table C-1](#) for monitored data absolute limits.

Table C-1. Absolute limits for PAV+ Monitored Data

PBW (kg)	R_{PAV} (cmH ₂ O/L/s)	C_{PAV} (mL/cmH ₂ O)	E_{PAV} (cmH ₂ O/L)
25	0 to 50	2.5 to 29	34 to 400
35	0 to 44	3.5 to 41	24 to 286
45	0 to 31	4.5 to 52	19 to 222
55	0 to 24	5.5 to 64	16 to 182
65	0 to 20	6.4 to 75	13 to 156
75	0 to 18	7.4 to 87	11 to 135
85	0 to 17	8.4 to 98	10 to 119
95	0 to 16	9.4 to 110	9.1 to 106
105	0 to 15	10 to 121	8.3 to 100
115	0 to 15	11 to 133	7.5 to 91
125	0 to 14	12 to 144	6.9 to 83
135	0 to 14	13 to 156	6.4 to 77
145	0 to 14	14 to 167	6.0 to 71
150	0 to 14	15 to 173	5.8 to 67

c.4.8 PAV+ Alarms

For a summary of the following alarms associated with PAV+, see [Table 6-5](#) on page [6-16](#):

- High circuit pressure ($\uparrow P_{PEAK}$)
- High ventilator pressure ($\uparrow P_{VENT}$)
- PAV STARTUP TOO LONG
- PAV R & C NOT ASSESSED
- High inspired tidal volume ($\uparrow V_{TI}$)

c.5 Ventilator Settings/Guidance



WARNING:

For optimal performance of PAV+, it is important to select the humidification type, tube type, and tube size that match those in use on the patient.

The instantaneous pressure generated at the patient wye during inspiration is a function of the patient effort, % Supp setting, tube type and size, patient resistance and elastance, and the instantaneously measured gas flow and lung volume. Set $\uparrow P_{PEAK}$ to a safe circuit pressure, above which truncation and alarm annunciation are appropriate.



Note:

PAV+ has a built-in high pressure compensation ($\uparrow P_{COMP}$) limit that is determined by the $\uparrow P_{PEAK}$ setting minus 5 cmH₂O or 35 cmH₂O, whichever is less. If the inspiratory pressure at the patient wye (P_{wye}^i) reaches the $\uparrow P_{COMP}$ limit, the inspiration is truncated, and the ventilator transitions to exhalation. See page [C-17](#) for more details regarding $\uparrow P_{COMP}$ and $\uparrow P_{PEAK}$.

c.5.1 Specified Performance

Performance using PAV+ is ± 0.5 Joules/liter (J/L), compared to measured, work during inspiration at the 75% support (% Supp) level. Work is computed over the entire inspiratory interval. In ventilation terms, work (W) is expressed as:

$$W = \frac{k \times \int (P^i \times \dot{V}^i) dt}{\int \dot{V}^i dt}$$

i	ith sample interval (5 ms)	V	Flow [L/s]
W	Work [J/L]	k	conversion constant (0.098) [J/cmH ₂ O × L]
P	Synchronous and combined pressures developed by the ventilator and by the patient (P _{MUS}), [cmH ₂ O]		

c.5.2 Graphics Displays in PAV+

When PAV+ is active (the mode is SPONT and the spontaneous breath type is PAV+), a work of breathing (WOB) graphic is automatically displayed (see [Figure C-2.](#)), which shows:

- An indicator showing the proportion of patient inspiratory work to overcome the elastance (E) of the lung-thorax and the combined resistance (R) of the artificial airway and the patient.
- Estimates of work of breathing relative to normal, subnormal, and above-normal values, including:
 - The estimated work of breathing (in Joules/L) during inspiration (WOB_{PT}).
 - The estimated total work of breathing (in Joules/L) of the patient and ventilator during inspiration (WOB_{TOT}).

Additional information in the graphics screen includes:

- A shadow trace of the estimated lung pressure, shown as a solid area superimposed on the circuit pressure waveform
- PAV-based patient data estimates, including patient resistance (R_{PAV}), lung compliance (C_{PAV}), and intrinsic PEEP (PEEP_{I PAV})



Note:

Graphic displays of lung pressure and patient work of breathing are not actual measurements, and are derived from equations using filtered estimates of pressure and flow.

The WOB graphic is only available when SPONT mode and the PAV+ breath type are selected. The shadow trace can be enabled or disabled when selecting the graphic display, or after a display is paused.

The act of pausing does not affect the WOB graphic, but does store the shadow trace. Once paused, the operator can enable or disable the shadow trace, then view the paused waveform again with or without the shadow trace.

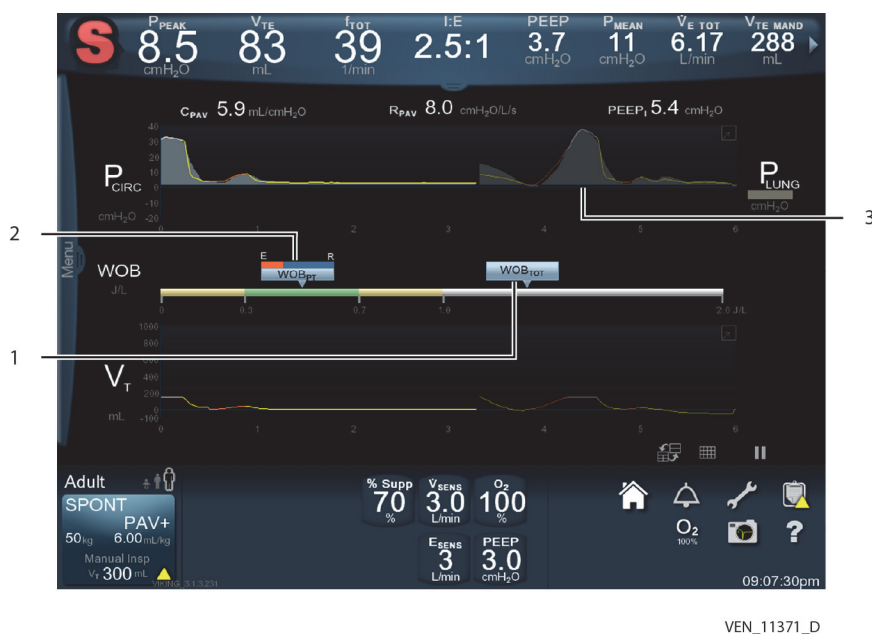
c.5.3 WOB Terms and Definitions

Table C-2. provides a definition and description of each of the work of breathing (WOB) terms.

Table C-2. PAV+ Work of Breathing Terms

WOB term	Definition	Description
WOB_{TOT}	Total work of inspiration	With the PAV+ breath type active, the patient and the ventilator always share the in the work of breathing. The percent WOB_{TOT} performed by the ventilator always equals the % Supp setting and the percent WOB_{TOT} performed by the patient always equals (100 minus the % Supp setting). WOB_{TOT} is the sum of the work to move the breathing gas through the artificial airway and the patient's own airways plus the work to inflate the patient's elastic lung-thorax.
WOB_{PT}	Patient work of breathing	That part of WOB_{TOT} performed by the patient.
$WOB_{PT\ ELASTIC}$	Inspiratory elastic work	That part of WOB_{PT} attributed to inflating the patient's elastic lung-thorax.
$WOB_{PT\ RESISTIVE}$	Inspiratory resistive work	That part of the WOB_{PT} attributed to moving breathing gas through resistive elements in the gas path.

Figure C-2. Graphics displays in PAV+



C.5.4 Technical Description

When PAV+ is selected, the ventilator acts as an inspiratory amplifier, proportionally assisting the pressure generating capability of the inspiratory muscles (P_{MUS}).

Pressure Gradient Equation of Motion

During spontaneous breathing, P_{MUS} generates a pressure gradient that drives breathing gas through the artificial airway and the patient's airways and into the elastic lung-thorax, and is described by the equation of motion:

EQUATION 1

$$P_{MUS} = \dot{V}_L \times R + V_L \times E_{LUNG-THORAX}$$

P_{MUS}	Pressure generating capability of patient's inspiratory muscles	R	Resistance elements (artificial plus patient airways)
$\dot{V}_L$	Flow through the resistance elements and into the lungs	$E_{LUNG-THORAX}$	Elastance of the lung and thorax ($1/C_{LUNG-THORAX}$)
V_L	Insufflation volume of the lung		

Estimates of Patient Resistance and Elastance

If the PAV+ software estimates of patient resistance and elastance (R_{PAV} and E_{PAV}) remain stable, this equation could be rewritten as:

EQUATION 2

$$P_{MUS}^i = \dot{V}_L^i \times R_{airway}^i + \dot{V}_L^i \times K_1 + V_L^i \times K_2$$

i	Instantaneous value of pressure, flow, or airway resistance, R_{airway}^i being a function of flow	K_1	R_{PAV}
K_2	E_{PAV}		

P_{MUS}^i could then be estimated at every control period if $\dot{V}_L^i$, R_{airway}^i , and V_L^i were also known.

Valid Individual Pressure Measurements

Throughout any inspiration, the individual pressure elements that make up P_{MUS} can be expressed as:

EQUATION 3

$$P_{MUS} = P_{ARTIFICIAL\ AIRWAY}^{FLOW} + P_{PATIENT}^{FLOW} + P_{PATIENT}^{VOLUME}$$

P_{MUS}	Pressure generating capability of patient's inspiratory muscles	$p_{PATIENT}^{FLOW}$	Flow based pressure drop across the patient
$p_{ARTIFICIAL\ AIRWAY}^{FLOW}$	Flow based pressure drop across the artificial airway	$p_{PATIENT}^{VOLUME}$	Volume based pressure to overcome the lung-thorax elastance

Equations 2 and 3 provide the structure to explain how PAV+ operates. The clinician enters the type and size of artificial airway in use, and the software uses this information to estimate the resistance of the artificial airway at any lung flow.

Applying a special pause maneuver at the end of selected inspirations provides the information the software needs to estimate patient resistance (R_{PAV}) and compliance (C_{PAV} , which is convert-

ed to elastance, E_{PAV}). Immediately following the end of the pause event, software captures simultaneous values for P_{LUNG} , P_{WYE} , and V_E which yield an estimate for R_{TOT} at the estimated flow.

All raw data are subjected to logic checks, and the estimates of R_{PAV} and C_{PAV} are further subjected to physiologic checks. The estimates of R_{PAV} and C_{PAV} are discarded if any of the logic or physiologic checks fail. If C_{PAV} is rejected, R_{PAV} is also rejected.

Valid estimates of R_{PAV} and C_{PAV} are required for breath delivery, and are constantly updated by averaging new values with previous values. This averaging process smooths data and avoids abrupt changes to breath delivery. If new values for R_{PAV} and C_{PAV} are rejected, the previous values remain active until valid new values are obtained. PAV+ software monitors the update process and generates an escalating alarm condition if the old values do not refresh.

Maneuver Breaths and % Supp

During PAV+, maneuver breaths are randomly performed every four to 10 breaths after the last maneuver breath. A maneuver breath is a normal PAV+ inspiration with a pause at end inspiration. Because muscle activity is delayed for at least 300 ms following the end of neural inspiration, the patient's respiratory control center does not detect the pause. With this approach, maneuver breaths are delivered randomly so that their occurrence is neither consciously recognized nor predictable.

A PAV+ breath begins, after the recognition of a trigger signal, with flow detection at the patient wye. The sample and control cycle of the ventilator (the value of i in Equation 2) is frequent enough to yield essentially constant tracking of patient inspiration. At every i th interval, the software identifies instantaneous lung flow ($\dot{V}_L^i$), which is impeded by the resistances of the artificial airway and patient airways) and integrates this flow to yield an estimate of instantaneous lung volume, (V_L^i), which is impeded by the elastic recoil of the lung and thorax).

Using the values for instantaneous lung flow and lung volume, PAV+ software calculates each of the pressure elements in Equation 2, which gives the value of P_{MUS} at each i th interval.

At this point, Equation 2 and the subsequent analysis identifies that an appropriate patient, supported by PAV+ and with an active P_{MUS} (an absolute requirement) will, within a few breaths, enable the algorithm to obtain reasonable estimates of R_{PAV} and E_{PAV} . Once these physiologic data are captured (and over a relatively brief time as they are improved and stabilized), the PAV+ algorithm mirrors the patient's respiratory mechanics, which then allows the ventilator to harmoniously amplify P_{MUS} . The key point to recognize is that patient's continuous breathing effort "drives" the PAV+ support—no effort, no support.

The % Supp setting specifies the amount of resistance- and elastic-based pressure to be applied at each i th interval at the patient wye.

By taking all of the above information into consideration, EQUATION 2 can be rewritten to include the % Supp setting recognizing that $\dot{V}_L^i$ and V_L^i are driven by the patient, not by the ventilator. (It

is important to note that the ventilator is not amplifying its own flow—only the flow generated by P_{MUS}.)

EQUATION 4

$$P_{wy}^i = S(\dot{V}_L^i \times R_{airway}^i) + S(\dot{V}_L^i \times K_1) + S(V_L^i \times K_2)$$

P_{wy}^i	Pressure generated by the ventilator in response to the instantaneous values of lung flow and lung volume at the wye. This value is the sum of the three individual pressure elements (in parentheses) in Equation 4	S	% Supp setting/100 (ranges from 0.05 to 0.95)
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Resulting Pressure Gradient

The pressure gradient driving breathing gas into the patient’s lungs is given by the sum of P_{wye}ⁱ and the patient’s inspiratory effort, therefore:

EQUATION 5

$$\Delta P_{GRADIENT}^i = P_{wy}^i + P_{MUS}^i$$

$\Delta P_{GRADIENT}^i$	Instantaneous pressure gradient	P_{MUS}^i	Instantaneous pressure generating capability of patient’s inspiratory muscles
P_{wy}^i	Pressure generated by the ventilator in response to the instantaneous values of lung flow and lung volume at the wye		

C.5.5 Protection Against Hazard

PAV+ software is designed to reduce the risk that hyperinflation may occur. The potential for hyperinflation could arise if the software were to overestimate actual patient resistance or under-

estimate actual patient lung-thorax compliance (that is, to overestimate actual elastance). If the software cannot generate valid estimates of R_{PAV} and C_{PAV} , PAV+ cannot start. If, after startup, the values of R_{PAV} and C_{PAV} cannot be updated with valid new values, the previous values become less reliable.

The stability of PAV+ is primarily determined by the relationship between the true lung elastance [E_L (true)] and the true lung volume [V_L (true)]. Although P_{wy}^i (resistive) also plays a part, the following discussion focuses on the elastic component.

At all lung volumes, the true state of the lung and thorax is expressed by:

$$P_{L\ recoil}^i = V_{L\ (true)}^i \times E_{L\ (true)}$$

$P_{L\ recoil}^i$	True lung recoil pressure	E_L (true)	True lung elastance
$V_{L\ (true)}^i$	True instantaneous volume of the lung		

Over-inflation will not occur as long as P_{wy}^i (elastic) < $P_{L\ recoil}^i$, which is equivalent to the inequality:

$$S[V_L^i\ (estimated) \times K_2] < V_L^i\ (true) \times E_L\ (true)$$

where:

$$K_2 = E_{PAV}^{-1}$$

1. see equations 2 and 4

As long as E_{PAV} (estimated) = E_{PAV} (true) and V_L^i (estimated) = V_L^i (true) then $P_{L\ recoil}^i > P_{wy}^i$ even at high values of % Supp (i.e. between 85% and 95%).

This means that if the pressure applied to the lung-thorax is never greater than E_L (true) × V_L , lung volume will collapse if wye flow vanishes. As long as E_{PAV} (estimated) ≤ E_L (true), V_L^i (estimated) ≤ V_L^i (true), and R_{PAV} (estimated) ≤ R_L (true), P_{MUS} is the modulator of P_{wy}^i .

Hyperinflation could occur if the estimated E_{PAV} were greater than the true value of E_L . At a high % Supp setting, P_{wy}^i (elastic) could exceed $P_{L\ recoil}^i$, causing a self-generating flow at the patient wye, which in turn would cause a self-generating inflation of the lungs. This is part of the reason that the % Supp setting is limited to 95%.

Likewise, if the estimated R_{PAV} were to exceed the true value of R_L at a high % Supp setting, P_{wy}^i (resistive) could exceed the value necessary to compensate for pressure dissipation across the

artificial and patient airways, resulting in early hyperinflation of the lungs. As flow declines after the first third of inspiration, however, the hyperinflating effect would most likely disappear.

PAV+ software includes these strategies to minimize the possibility of hyperinflation of the lungs:

1. The maximum % Supp setting is limited to 95%.
2. The raw data for R_{PAV} and C_{PAV} are checked for graph/math logic, and estimated mechanics values are checked against PBW-based physiologic boundaries. These checks reduce the possibility of overestimating patient resistance or underestimating patient compliance, which could lead to potential overinflation.
3. The high inspiratory tidal volume limit ($\bar{V}_{TI}$) places an absolute limit on the integral of lung flow (including leak flow), which equals lung volume. If the value of V_{TI} reaches this limit, the ventilator truncates inspiration and immediately transitions to exhalation.
4. The ($\bar{V}_{TI}$) setting places an upper limit on the value of the $P_{PATIENT}^{VOLUME}$ component of P_{wy}^i (see Equations 3 and 4). At the beginning of each new inspiration, PAV+ software calculates a value for $P_{PATIENT}^{VOLUME}$ as follows:

$$P_{wy}^* \text{ (elastic threshold limit)} = 0.75 \times (V_{TI} \times E_{PAV})$$

where P_{wy}^* is the unique value for the elastic threshold limit of P_{wy}^i that will cause the lung volume to expand to 75% of ($\bar{V}_{TI}$). When $P_{wy}^i \text{ (elastic)} = P_{wy}^* \text{ (elastic threshold limit)}$, the software stops increasing $P_{wy}^i \text{ (elastic)}$. This means that any further increase in lung volume must be accomplished by the patient, which tends to hasten the conclusion of inspiratory effort and avoid truncation due to lung volume reaching the $\bar{V}_{TI}$ limit.

5. The high inspiratory pressure limit ($\bar{P}_{PEAK}$) applies to all breaths, and is used by PAV+ software to detect the high compensation pressure condition ($\uparrow P_{COMP}$):

$$\uparrow P_{COMP} = \bar{P}_{PEAK} - 5 \text{ cmH}_2\text{O or } 35 \text{ cmH}_2\text{O, whichever is less}$$

If the user-adjustable $\bar{P}_{PEAK}$ limit is reached, the ventilator truncates inspiration and immediately transitions to exhalation. If P_{wy}^i (the targeted wye pressure calculated in Equation 4) equals the $\uparrow P_{COMP}$ for 500 ms, the inspiration is truncated and exhalation begins. Further, when $P_{wy}^i = \uparrow P_{COMP}$, P_{wy}^i is limited to $\uparrow P_{COMP}$. Although this freezes the value of P_{wy}^i , patient activity such as coughing could drive P_{wy}^i to $\bar{P}_{PEAK}$, causing inspiration to end.

The rapid rise of P_{wy}^i to the $\uparrow P_{COMP}$ limit would likely occur in the first third of inspiration, and only if R_{PAV} were overestimated and % Supp were set above 85%. The $\uparrow P_{COMP}$ condition guards against overinflation due to overestimation of R_{PAV} .

- 6. The % Supp setting ranges from 5% to 95% in 5% increments. Reducing the level of support decreases the possibility of over-inflation. A significant decrease could produce a sensation of inadequate support, and the patient would absorb the additional work of inspiration or require an increase in the level of support.

A significant increase could cause a surge in the ventilator generated value for P_{wye} , which in turn could cause P_{wye}^i to reach $\bar{P}_{COMP}$ and lead to temporary patient-ventilator disharmony. To minimize this possibility, PAV+ software limits the actual increase in support to increments of 10% every other breath until the new setting is reached.

- 7. Spirometry remains active during PAV+ operation. $\bar{V}_{TI}$ can be set high enough to allow spontaneous sigh breaths, while $\downarrow \dot{V}_{E\,TOT}$ and $\bar{V}_{E\,TOT}$ remain active to reveal changes in minute ventilation.

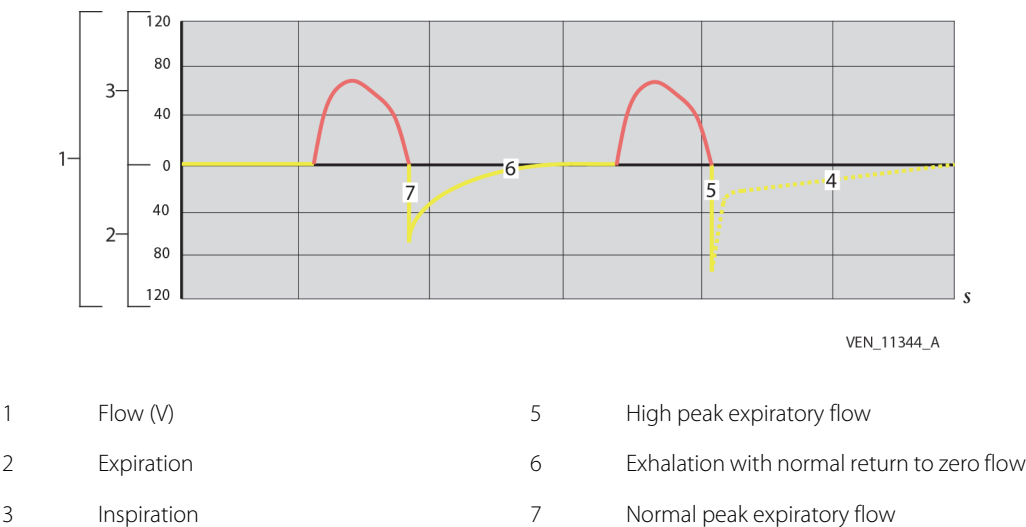
Because PAV+ cannot operate without valid estimates of R_{PAV} and C_{PAV} , and because those values are unknown when PAV+ starts, a startup routine obtains these values during four maneuver breaths that include an end inspiratory pause that provides raw data for R_{PAV} and C_{PAV} , and both estimated values must be valid. If either value is invalid during any of the four startup breaths, the software schedules a substitute maneuver breath at the next breath. See [PAV+ \(C.4\)](#) on page C-2.

A low-priority alarm becomes active if a 45-second interval elapses without valid estimates for R_{PAV} and C_{PAV} . If the condition persists for 90 seconds, the alarm escalates to medium-priority. If the condition persists for 120 seconds, the alarm escalates to high priority. The $\downarrow \dot{V}_{E\,TOT}$ and $\uparrow f_{TOT}$ alarms are also associated with this condition.

Similarly, if R_{PAV} and C_{PAV} cannot be updated with valid values after a successful PAV+ startup, a low-priority alarm is activated if the condition persists for 15 minutes. If the values still cannot be updated with valid values after 30 minutes, the alarm escalates to medium priority.

- 8. If PAV+ estimates a high lung resistance following a sharp spike in the expiratory flow waveform, then a PBW-based resistance value is used. See [Figure C-3.](#) and [Table C-3.](#)

Figure C-3. Use of Default Lung Resistance



- 4 Exhalation with slow, restricted return to zero flow

Table C-3. Default PBW-based Resistance Values

PBW (kg)	Resistance (cmH ₂ O/L/s)	PBW (kg)	Resistance (cmH ₂ O/L/s)	PBW (kg)	Resistance (cmH ₂ O/L/s)	PBW (kg)	Resistance (cmH ₂ O/L/s)
25	18.1	40	14.1	55	11.8	70	10.6
26	17.7	41	13.9	56	11.7	71	10.5
27	17.4	42	13.7	57	11.6	72	10.5
28	17.1	43	13.5	58	11.5	73	10.4
29	16.8	44	13.3	59	11.4	74	10.4
30	16.5	45	13.2	60	11.3	75	10.3
31	16.2	46	13.0	61	11.3	76	10.3
32	15.9	47	12.9	62	11.2	77	10.2
33	15.7	48	12.7	63	11.1	78	10.2
34	15.4	49	12.6	64	11.0	79	10.1
35	15.2	50	12.4	65	10.9	80	10.1
36	14.9	51	12.3	66	10.9	81 to 150	10
37	14.7	52	12.2	67	10.8		
38	14.5	53	12.1	68	10.7		
39	14.3	54	12.0	69	10.7		

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D NeoMode 2.0

D.1 Overview

This appendix describes how to use NeoMode 2.0 software on the Puritan Bennett™ 980 Neonatal Ventilator. NeoMode 2.0 enables the use of the ventilator with neonatal patients and is included with all Puritan Bennett™ 980 Neonatal Ventilators and Puritan Bennett™ 980 Universal Ventilators. For a Puritan Bennett™ 980 Pediatric–Adult ventilator to be used with neonatal patients, the NeoMode 2.0 software option must be installed.

D.2 Intended Use

NeoMode 2.0 is intended to provide respiratory support to neonatal patients with predicted body weights as low as 0.3 kg (0.66 lb). It is intended to cover a wide variety of clinical patient conditions in hospitals and hospital-type facilities, and may be used during intra-hospital and intra-hospital-type facility transport. It supports delivered tidal volumes as low as 2 mL.

D.3 Description

The ventilator determines values for operational variables and allowable settings based on breathing circuit type and predicted body weight (PBW). The PBW range for neonates is 0.3 kg to 7.0 kg (0.66 lb to 15 lb). Software controls prevent inadvertent mismatching of patient size and breathing circuit type. A neonatal breathing circuit connects to a neonatal exhalation filter that must be used with the neonatal adapter door assembly.



Note:

To enable NeoMode 2.0, select the neonatal breathing circuit type in SST. Breathing circuit type can only be changed during SST.

D.4 Safety Information



WARNING:

The Puritan Bennett™ 980 Series Ventilator contains phthalates. When used as indicated, very limited exposure to trace amounts of phthalates may occur. There is no clear clinical evidence

that this degree of exposure increases clinical risk. However, to minimize risk of phthalate exposure in children and nursing or pregnant women, this product should only be used as directed.



WARNING:

The ventilator offers a variety of breath delivery options. Throughout the patient's treatment, the clinician should carefully select the ventilation mode and settings to use for that patient based on clinical judgment, the condition and needs of the patient, and the benefits, limitations, and characteristics of the breath delivery options. As the patient's condition changes over time, periodically assess the chosen modes and settings to determine whether or not those are best for the patient's current needs.



WARNING:

Neonatal patients are at risk for hypercarbia or hypoxemia during $\downarrow \dot{V}_{E\text{TOT}}$ alarm conditions.



WARNING:

Disabling the low exhaled minute volume ($\downarrow \dot{V}_{E\text{TOT}}$) alarm increases the patient's risk of hypercarbia or hypoxemia.



WARNING:

When using NIV, the patient's exhaled tidal volume (V_{TE}) could differ from the ventilator's monitored patient data value for V_{TE} due to leaks around the interface. To avoid this, ensure Leak Sync is enabled.

D.5 Neonatal Door and Filter Installation



WARNING:

Removing the exhalation filter while the patient is connected to the ventilator can cause a loss of circuit pressure, ventilator autotriggering, or direct contact with liquid.



Caution:

Do not pull on the door while the exhalation filter latch is closed, as damage to the ventilator can result.



Note:

See the inspiratory filter and exhalation filter instructions for use for information on filtration efficiency and filter resistance.

To install the neonatal adapter door

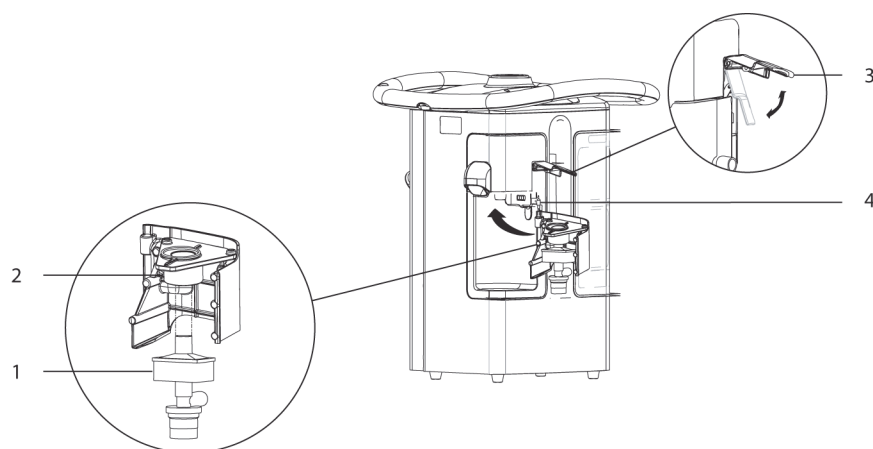
1. Remove the expiratory limb of the patient circuit from the exhalation filter.
2. Lift the exhalation filter latch. See [Figure D-1](#).

3. Remove the existing exhalation filter door by lifting it off of the pivot pins.
4. Fit the neonatal adapter door onto the pivot pins.

To install the neonatal exhalation filter assembly

1. With the door still open, push the neonatal filter straight up into the adapter.
2. Close the door.
3. Lower the exhalation filter latch.
4. Reattach the expiratory limb of the patient circuit to the filter.

Figure D-1. Installing the Neonatal Filter and Door



VEN_11162_A

- | | | | |
|---|----------------------------|---|-------------------------|
| 1 | Neonatal exhalation filter | 3 | Exhalation filter latch |
| 2 | Neonatal adapter door | 4 | Filter door pivot pin |



WARNING:

To ensure all breathing circuit connections are leak-tight, perform a circuit-leak test by running SST every time the filter is installed. The circuit-leak test can be performed as an individual test from the SST startup screen.



WARNING:

Empty the condensate vial before the liquid level reaches the maximum fill line. Condensate vial overflow can enter the filter or the breathing circuit, and can cause increased expiratory flow resistance. Change the filter if it appears to be saturated.



WARNING:

The neonatal exhalation filter and condensate vial is a single unit and is for single-patient use, only. Do not attempt to sterilize the filter assembly.

**WARNING:**

Adding accessories to or removing accessories from the VBS can change the pressure gradient across the VBS and affect ventilator performance. Ensure that any changes to the ventilator circuit configurations do not exceed the specified values for circuit compliance and for inspiratory or expiratory limb total resistance. See [Table 11-4](#), on page 11-3. If adding accessories to or removing accessories from the VBS, always run SST to establish circuit compliance and resistance prior to ventilating the patient.

**Note:**

If the ventilator has not reached operating temperature from recent usage, allow it to warm up for at least 15 minutes before running SST to ensure accurate testing.

**Note:**

Check the inspiratory and expiratory limbs of the breathing circuit and in-line water traps regularly for water buildup. Under certain conditions, they can fill quickly. Empty and clean the in-line water traps as necessary. See the manufacturer's IFU for additional information.

D.6 How to Empty the Condensate Vial

The condensate vial may accumulate liquid, especially if a non-heated wire patient circuit is in use.

**WARNING:**

To avoid liquid entering the ventilator, empty the condensate vial before the liquid level reaches the maximum fill line.

The condensate vial assembly is integrated with the neonatal exhalation filter and does not contain a drain port. Empty the condensate vial when liquid reaches the maximum fill line.

To empty the condensate vial

1. While holding the exhalation filter, twist the condensate vial clockwise approximately one quarter turn to remove it.
2. Remove the condensate vial by carefully lowering the vial all the way down to the base of the exhalation compartment and then sliding it out.
3. Quickly empty the condensate vial.
4. Replace the condensate vial by carefully sliding the vial into position, lifting it upward to the filter assembly, and turning counterclockwise until it reaches the stop.

**Note:**

Condensate vial removal may cause the loss of system pressure and a disconnect alarm to sound.

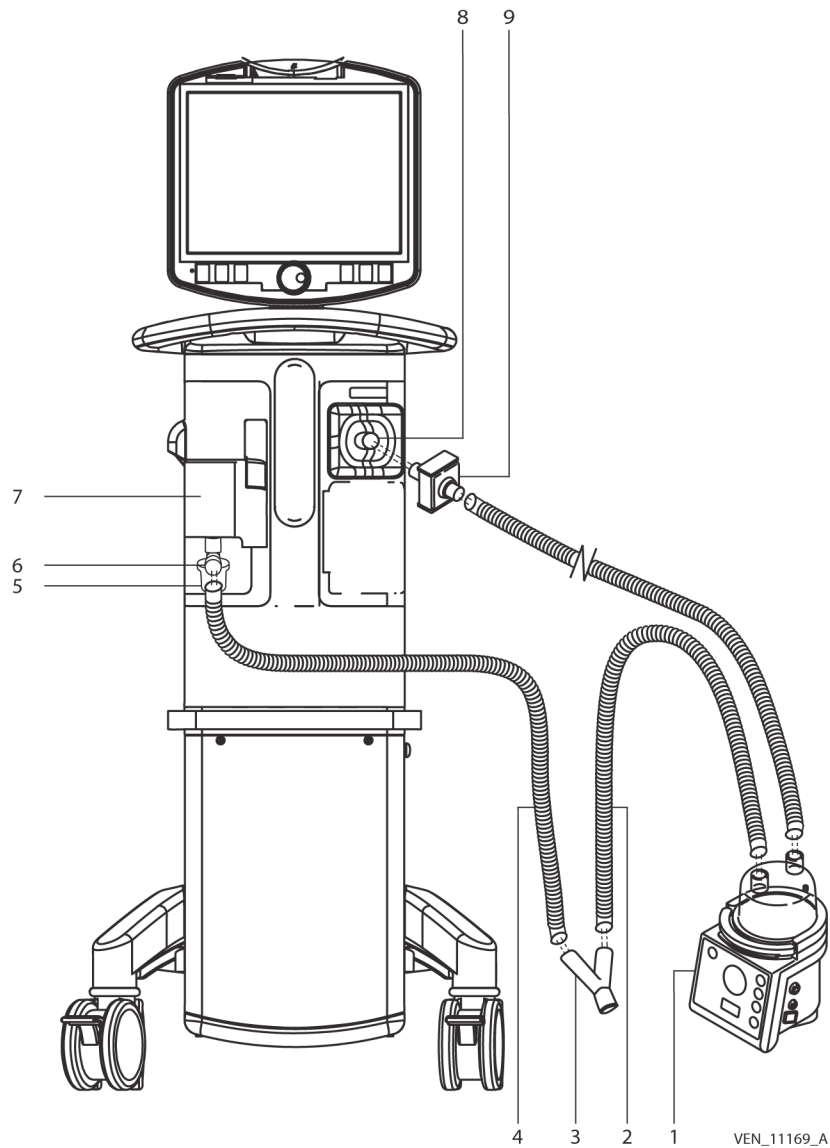
D.7 How to Connect the Breathing Circuit

**WARNING:**

Use one of the ventilator breathing circuits listed. See [Table D-1.](#) on page [D-7](#) or their equivalent. This ensures that maximum pressure and flow values specified by EN794-1 are not exceeded. Using a circuit with a higher resistance does not prevent ventilation, but can cause an SST fault or compromise the patient's ability to breathe through the circuit.

See [Figure D-2.](#) on page [D-6](#) to connect the breathing circuit.

Figure D-2. How to Connect the Breathing Circuit



- | | | | |
|---|----------------------------------|---|--|
| 1 | Humidifier | 6 | From patient port |
| 2 | Patient circuit inspiratory limb | 7 | Neonatal exhalation filter (installed in adapter door) |
| 3 | Patient circuit wye | 8 | To patient port |
| 4 | Patient circuit expiratory limb | 9 | Inspiratory filter |
| 5 | Condensate vial | | |

Table D-1. Recommended Breathing Circuits

Patient circuit	Part number
Ventilator breathing circuit, neonatal disposable, DAR™ (not available in USA)	3078447
Ventilator breathing circuit, neonatal, disposable, Hudson RCI/Teleflex	780-06
Ventilator breathing circuit, neonatal, patient circuit (Evaqua 2) Fisher & Paykel	RT265
Ventilator breathing circuit, neonatal, disposable, Fisher & Paykel	RT235

Table D-2. lists allowable ventilator settings when using NeoMode and ventilating invasively and non-invasively.

Table D-2. Allowable NeoMode Ventilator Settings and Ventilation Type

Ventilation type	Invasive	NIV
Mode	A/C, SIMV, SPONT, BiLevel	A/C, SIMV, SPONT, CPAP
Mandatory type	PC, VC, VC+	PC, VC
Spontaneous type	PS, VS	PS
Trigger type	$\dot{V}$ -Trig	$\dot{V}$ -Trig

D.8 Ventilation Features

Ventilation using NeoMode 2.0 is performed as described in Chapter 4. See *Ventilator Operation (4.5)* on page 4-7. If using a Puritan Bennett™ 980 Neonatal Ventilator, NeoMode 2.0 is already in use and a neonatal patient circuit is the only choice available when performing SST. If using a Puritan Bennett™ 980 Universal Ventilator, the NeoMode 2.0 software option is already installed and SST must be run using a neonatal circuit to use the option. If using a Puritan Bennett™ 980 Pediatric–Adult Ventilator, the NeoMode 2.0 software option must be installed and SST must be run using a neonatal patient circuit.



WARNING:

Always run SST prior to patient ventilation, ensuring that all accessories used during ventilation are in the ventilator breathing system when SST is run. This ensures correct calculation of compliance and resistance. See *SST (Short Self Test) (3.9.1)* on page 3-41 for more information.

D.8.1 Predicted Body Weight (PBW) vs. Patient Length

See *Predicted Body Weight (PBW) Calculation (4.6)* on page 4-19 for references to tables of PBW values associated with patient length in centimeters and inches, respectively.

D.8.2 Elevate O₂



In NeoMode 2.0, the elevate O₂ control works as described in Chapter 3, except when the ventilator is in Stand-By or circuit disconnect states. If the elevate O₂ function is used during these conditions, the value chosen for elevate O₂ applies to the currently delivered oxygen concentration (which is 40% O₂ in these states) and not the set oxygen concentration.

D.8.3 CPAP Mode

When using NeoMode 2.0 and ventilating with non-invasive ventilation (NIV), a separate CPAP mode allows spontaneous breathing with a desired PEEP level. To limit inadvertent alarms associated with the absence of returned volumes in CPAP breathing, CPAP does not make volume alarms available. As some neonates don't trigger breaths, the default apnea interval, T_A, is set to OFF. Also, some settings changes will initiate a PEEP restoration breath before phasing in those changes.



Note:



In CPAP, apnea time, T_A, can be adjusted, if desired. It merely defaults to OFF to avoid inadvertent alarms. The message "APNEA DETECTION DISABLED" is displayed at the bottom of the GUI screen. The attention icons are also displayed.

To set the ventilator for CPAP



1. Select New Patient from the ventilator's startup screen or touch the Vent Setup button.
2. Touch PBW and turn the knob to set the PBW.
3. Select NIV as the ventilation type.
4. Touch CPAP.
5. Touch each ventilator setting and turn the knob to select the appropriate ventilator settings. When finished, touch *START* or *Accept ALL*.
6. Complete the setup by setting the apnea parameters and alarm limits from their respective tabs.

Figure D-3. CPAP Setup Screen



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D.8.4 Entering CPAP From Other Ventilation Modes

Entering CPAP mode from other ventilation modes or ventilation types requires using the NIV ventilation type. *Non-invasive Ventilation (NIV)* (4.7) on page 4-20 explains how the ventilator transitions from invasive to NIV ventilation type.

To enter CPAP mode for an existing patient

1. Touch the Vent Setup button at the lower left of the GUI screen.
2. Touch NIV ventilation type. CPAP is only allowed during NIV.
3. Touch CPAP. The ventilator enters CPAP mode.
4. Set an apnea interval, T_A , if appropriate, as it defaults to OFF in CPAP.



Note:

Exhaled minute volume ($\dot{V}_{E\text{TOT}}$), exhaled tidal volume ($V_{TE\text{SPONT}}$), and inspired tidal volume (V_{TI}) alarms are disabled upon entry into CPAP.

D.8.5 Exiting CPAP Mode

When changing the mode from CPAP to any other mode, several transition rules take effect:

- The $\dot{V}_{E\text{TOT}}$, $V_{TE\text{MAND}}$, $V_{TE\text{SPONT}}$, and V_{TI} alarms are set to their respective new patient defaults.

- The apnea interval T_A changes from OFF to an apnea interval of 10 s and the new setting is phased in immediately.
- The $\dot{V}_{E\text{ TOT}}$, $V_{TE\text{ MAND}}$, $V_{TE\text{ SPONT}}$, and V_{TI} alarm sliders appear in the alarm settings screen according to their applicability to the selected mode.

D.8.6 Compliance Compensation

See [Compliance Compensation in Volume-based Breaths \(10.6.1\)](#) on page 10-10 for a complete discussion of compliance compensation. Compliance compensation in NeoMode 2.0 is implemented as described in the aforementioned reference.



Note:

If the patient's compliance decreases beyond the limits of compliance compensation, the ventilator relies on the $\uparrow P_{PEAK}$ alarm setting to truncate the breath and switch to exhalation.

D.8.7 Settings, Alarms, and Monitored Patient Data



WARNING:

Monitor the patient closely if alarms are disabled. There are no audible or visual annunciations for out-of-range conditions when volume, pressure, or apnea alarms are disabled (turned OFF).

See [Table 11-9](#), [Table 11-10](#), and [Table 11-11](#) for the minimum and maximum ranges for each ventilator setting, alarm setting, or data value. Most settings, however, are also limited by other settings or conditions (for example, a low alarm limit is always limited by the corresponding high alarm limit). Review the prompt area when making settings changes.

Volume accuracy testing in VC+ was conducted to demonstrate performance of delivered and monitored parameters. [Table D-3](#), [Table D-4](#), and [Table D-5](#) provide a summary of the actual results obtained within the range of 2 mL to 25 mL collected during test execution.

The first column (Set tidal volume) represents the desired volume setting in milliliters (mL). The second column represents the total number of test points for test cases executed at that specific setting. The third column is the mean (mean value) of the ventilators and test cases executed for the setting listed. The fourth column represents the standard deviation (SD) of measurements taken for the ventilators and test cases executed at the setting listed.

The measurements were taken using instrumentation located at the patient-connection port. Accessories such as filters and humidifiers were in the circuit during the test. Values were BPTS and compliance compensated. A sample size of five ventilators was used to conduct the testing. Testing was conducted at ambient temperature of $22^{\circ}\text{C} \pm 5^{\circ}\text{C}$.

Table D-3. Delivered Volume Accuracy

Set tidal volume (mL)	Number of test points	Mean value (mL)	SD
2	150	2.061	0.198
5	270	4.853	0.324
15	240	15.108	0.383
25	270	24.608	0.607

Table D-4. Monitored Inspired Volume (V_{TI}) Accuracy

Set tidal volume (mL)	Number of test points	Mean value (mL)	SD
2	150	2.055	0.192
5	270	4.872	0.346
15	240	15.235	0.379
25	270	24.633	0.566

Table D-5. Monitored Exhaled Tidal Volume (V_{TE}) Accuracy

Set tidal volume (mL)	Number of test points	Mean value (mL)	SD
2	150	2.212	0.274
5	270	5.892	0.607
15	240	16.145	0.851
25	270	25.492	0.819

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E Proximal Flow

E.1 Overview

This appendix describes the operation of the Proximal Flow option for the Puritan Bennett™ 980 Series Ventilator. The Proximal Flow option is solely used for monitoring flows, pressures, and tidal volumes and does not control these parameters in any way.

The proximal flow sensor is designed to measure the lower flows, pressures and tidal volumes at the patient wye typically associated with invasively ventilated neonatal patients.

For general parameter and general ventilator setup information, see Chapter 4.

E.2 Intended Use

The Proximal Flow option is used for measuring flows, pressures, and tidal volumes of invasively ventilated neonatal patients with predicted body weights (PBW) of 0.3 kg (0.66 lb) to 7.0 kg (15.4 lb) using ET tube sizes from 2.5 mm to 4.0 mm. The NeoMode 2.0 software option must also be installed on the ventilator.

E.3 Safety Information



WARNING:

The Puritan Bennett™ 980 Series Ventilator contains phthalates. When used as indicated, very limited exposure to trace amounts of phthalates may occur. There is no clear clinical evidence that this degree of exposure increases clinical risk. However, to minimize risk of phthalate exposure in children and nursing or pregnant women, this product should only be used as directed.



WARNING:

The ventilator offers a variety of breath delivery options. Throughout the patient's treatment, the clinician should carefully select the ventilation mode and settings to use for that patient based on clinical judgment, the condition and needs of the patient, and the benefits, limitations, and characteristics of the breath delivery options. As the patient's condition changes over time, periodically assess the chosen modes and settings to determine whether or not those are best for the patient's current needs.

**WARNING:**

Inspect the proximal flow sensor prior to use, and do not use it if the sensor body, tubing, or connector are damaged, occluded, or broken.

**WARNING:**

Do not use the proximal flow sensor if there are kinks in the tubing.

**WARNING:**

Prior to patient ventilation with the Proximal Flow option, run SST with the exact configuration that will be used on the patient. This includes a neonatal patient circuit, proximal flow sensor, and all accessories used with the patient circuit. If SST fails any proximal flow sensor test, check the patient circuit and the proximal flow sensor for leaks or occlusions and replace the flow sensor, if necessary. If SST continues to fail, it may indicate a malfunction or a leak within the proximal flow hardware which could compromise accuracy or increase the likelihood of cross-contamination; thus, replace the Proximal flow hardware.

**WARNING:**

Changing ventilator accessories can change the system resistance and compliance. Do not add or remove accessories after running SST.

**WARNING:**

If the Proximal Flow option fails to respond as described in this appendix, discontinue use until correct operation is verified by qualified personnel.

**WARNING:**

The Proximal flow sensor measures gas flow at the patient wye. The actual volume of gas delivered to the patient may be affected by system leaks between the patient and the proximal flow sensor, such as a leak that could occur from the use of an uncuffed endotracheal tube.

**WARNING:**

Position the proximal flow sensor exactly as described in this appendix or the IFU provided with the sensor.

**WARNING:**

Do not position the Proximal flow sensor cables or tubing in any manner that may cause entanglement, strangulation or extubation which could lead to hypercarbia or hypoxemia. Use the cable management clips supplied to mitigate this risk.

**WARNING:**

To reduce the risk of extubation or disconnection, do not apply tension to or rotate the proximal flow sensor by pulling on the proximal flow sensor's tubing.

**WARNING:**

Do not install the proximal flow sensor in the patient circuit if the sensor is not also connected to the BDU.

**WARNING:**

Excessive moisture in the proximal flow sensor tubing may affect the accuracy of the measurements. Periodically check the sensor and tubing for excessive moisture or secretion build-up.

**WARNING:**

The proximal flow sensor is intended for single use only. Do not re-use the sensor. Attempts to clean or sterilize the sensor may result in bioincompatibility, infection, or product failure risks to the patient.

**WARNING:**

Install the proximal flow sensor as shown. See [Figure E-6](#) on page [E-11](#). Improper orientation of the flow sensor could lead to misinterpretation of data or incorrect ventilator settings.

**Caution:**

Do not use aerosolized medications with the proximal flow sensor. Such medications may damage the sensor.

**Caution:**

To prevent damage to pneumatic lines, use supplied cable management clips.

**Caution:**

Use only Covidien proximal flow sensors with the Proximal Flow option.

E.4 Proximal Flow Option Description

The Proximal Flow option measures pressure, flow, and volume at the patient wye. A printed circuit board assembly (PCBA) containing the electronics and pneumatics for the Proximal Flow option is installed in the ventilator on the option host card. Data measured by the proximal flow sensor are displayed on the GUI for monitoring purposes, not for ventilator control. When the ventilator has a proximal flow sensor installed, both proximal flow and proximal pressure measurements are obtained and displayed on the GUI.

A manual purge control is also provided to clear pneumatic lines for accurate pressure measurements. When a manual purge is requested, the ventilator will not allow another purge for at least 30 seconds. See [Sensor Calibration and Sensor Line Purging \(E.7\)](#) on page [E-6](#) for more information on the purge function.

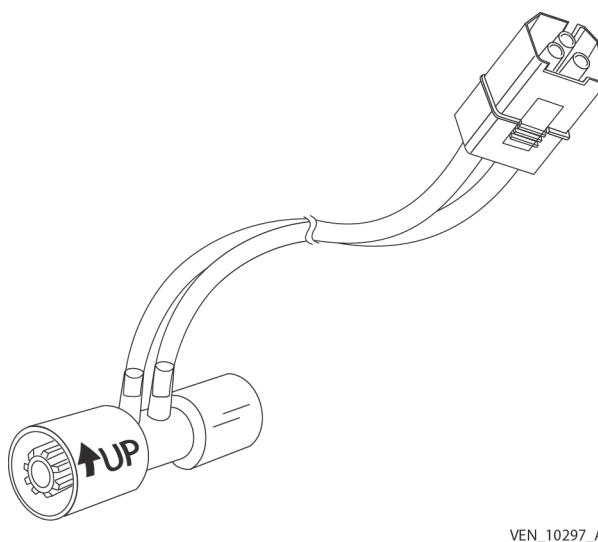
E.4.1 Proximal Flow Option Components

The Proximal Flow option consists of the following components:

Proximal Flow option PCBA — Installed on the option host card in the BDU, this printed circuit board assembly contains a pressure sensor to measure the pressure difference between the flow sensor lines and the interfaces required to convert analog measurements from the proximal flow sensor into digital data displayed by the ventilator. The PCBA also contains valves and an accumulator for purging the sensor lines from blockages.

Proximal flow sensor — The proximal flow sensor is required for use with the Proximal Flow option. The sensor is installed near the patient circuit wye. The other end of the sensor connects to the ventilator's front panel behind a clear door designed to protect the connection point from exposure to spills or from sprayed liquids during cleaning and disinfection. See [Figure E-1](#).

Figure E-1. Proximal Flow Sensor



E.5 Hardware Requirements

The Proximal Flow option requires installation of the Proximal Flow hardware. The NeoMode 2.0 software option or a Puritan Bennett™ 980 Neonatal Ventilator must also be used. Details regarding NeoMode 2.0 can be found in [Appendix D](#).

The following hardware is required:

- Option host card
- Proximal flow sensor

Proximal Flow option hardware installation must be performed by qualified service personnel, using separate installation instructions (part number 10084704).

E.6 On-screen Symbols

When using the Proximal Flow option, flow, pressure, and volume waveform data, along with delivered and exhaled volumes are derived from proximal flow sensor measurements at the patient circuit wye. Proximal flow data are displayed on the waveform plot with a **Y** appearing in inverse video next to the measurement symbol.

Figure E-2. Sample GUI screen Showing Proximal Flow Data



VEN_11428_F

- 1 Data measured using Proximal Flow Sensor
 P_V — Pressure throughout the breath cycle (at the patient circuit wye)
 $\dot{V}_V$ —Flow throughout the breath cycle (at the patient circuit wye)

Inspired and exhaled flows and volumes at the patient wye are measured and identified by the symbols shown below, and correspond to their non-proximal flow equivalents. These values appear in the patient data panel if so configured. See [Vital Patient Data](#), page 3-37, and [Figure E-2](#).

Table E-1. Proximal Flow Option Patient Data Symbols

Data symbol	Description
$V_{T\text{IY}}$	Inspired tidal volume (mandatory or spontaneous at patient circuit wye)
$V_{T\text{EY}}$	Exhaled tidal volume (at patient circuit wye)
$V_{T\text{E SPONTY}}$	Exhaled spontaneous tidal volume (at patient circuit wye)
$V_{T\text{E MANDY}}$	Exhaled mandatory tidal volume (at patient circuit wye)
$\dot{V}_{\text{E TOTY}}$	Exhaled total minute volume (at patient circuit wye)
$\dot{V}_{\text{Y}}$	Flow throughout the breath cycle (at patient circuit wye)
$V_{T\text{LY}}$	Inspired tidal volume (at patient circuit wye with Leak Sync enabled)

**Note:**

In the patient data symbols shown in [Figure E-2](#), the “Y” appears in inverse video, as shown.

**Note:**

When the Proximal Flow and Leak Sync functions are enabled, the following parameters are available for display:

- $V_{T\text{LY}}$ and $V_{T\text{L}}$
- LEAK and LEAK_Y

When only the Proximal Flow option is enabled, $V_{T\text{IY}}$ and $V_{T\text{I}}$ are available for display

When a “Y” appears in the symbol, the data are measured with the proximal flow sensor. When a “Y” is absent from the symbol, the data are measured by the ventilator’s internal flow sensors.

E.7 Sensor Calibration and Sensor Line Purging

To ensure accurate pressure and flow measurements, the ventilator performs an autozero function to calibrate the proximal flow sensor. It does this by periodically opening the pressure sensor on the Proximal Flow option PCBA to atmosphere during exhalation, and uses the resulting measurements as offset corrections.

The purge function is designed to clear the pneumatic lines of fluids that may collect, and is performed periodically by sending a brief flow of air through the sensor lines. Autozero and purge functions are only active during exhalation, limiting the effect of the purge gas on delivered oxygen concentration.

During the autozero or automatic purge processes, the measurement and display of proximal flow data is not shown in real time and a brief message appears on the GUI indicating the purge process is occurring.

During autozero or automatic purge processes, the pressure waveforms, when shown display the current PEEP value and the flow waveform, when shown, displays a value of 0.

Figure E-3. Message During Autozero and Purge Processes



VEN_11429_F

E.8 SST Requirements

SST must be run prior to ventilation and all circuit components and accessories must be installed in the configuration to be used on the patient for the ventilator to calculate the correct compliance and resistance. This includes a neonatal patient circuit, proximal flow sensor, and other accessories used during ventilation. See [To run SST](#), page 3-43. There is also a table listing the SST tests located in that section. See [Table E-2](#) for a listing of the tests when running SST with the Proximal Flow option.



Note:

Failure of the ventilator to pass SST does not prevent ventilation, but will prevent measurement with the proximal flow sensor. The ventilator will use its internal flow sensors for measurement instead of the proximal flow sensor.

Table E-2. Proximal Flow Option SST tests

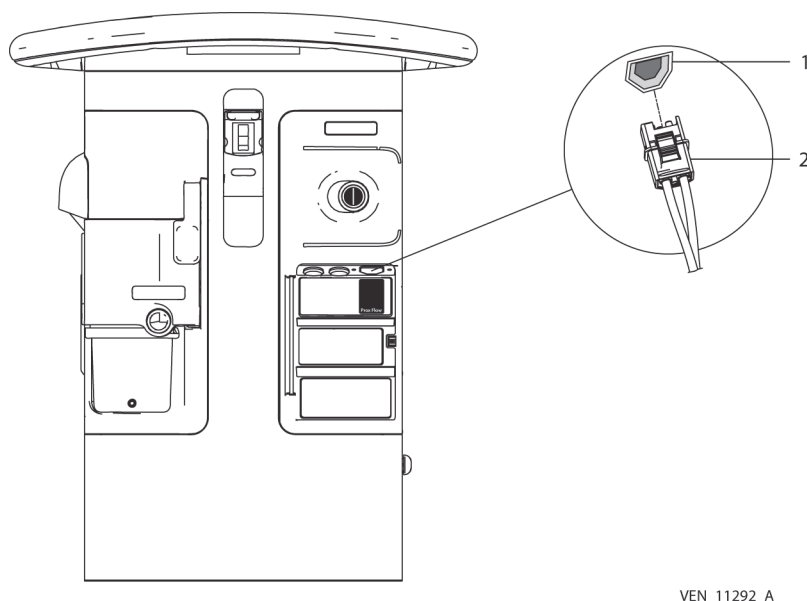
Test step	Function	Comments
SST Flow Sensor Cross Check	Tests O ₂ and air flow sensors	N/A
SST EV Performance	Calibrates the exhalation valve and creates a table for use during calculations.	N/A
SST Circuit Pressure	Exercises delivery PSOL. Checks inspiratory and expiratory autozero solenoids. Cross-checks inspiratory and expiratory pressure transducers at various pressures.	N/A
SST Leak	Tests ventilator breathing system for leaks.	N/A
SST Exhalation Filter	Checks for exhalation filter occlusion and exhalation compartment occlusion.	Ventilator prompts the user to block the proximal flow sensor outlet during the leak test. When prompted to reconnect the patient to the exhalation filter during the exhalation filter test, resume blocking the proximal flow sensor outlet.
SST Circuit Resistance	Checks for inspiratory and expiratory limb occlusions, and calculates and stores the inspiratory and expiratory limb resistance parameters.	N/A
SST Circuit Compliance	Calculates the attached patient circuit compliance.	N/A
SST Prox	Verifies functionality of proximal flow system.	Includes tests of barometric pressure, autozero, purge, and pressure cross check functions

E.8.1 Attaching the Proximal Flow Sensor for SST

During SST the ventilator prompts to attach the proximal flow sensor.

To attach the proximal flow sensor to the patient circuit

1. Verify the proximal flow sensor, pneumatic lines, and connector are not damaged.
2. Open the connector panel door and firmly attach the sensor connector to the receptacle in the BDUs front connector port labeled Prox Flow.

Figure E-4. Attaching Proximal Flow Sensor to Ventilator

VEN_11292_A

- 1 Proximal flow sensor connector insertion port 2 Proximal flow sensor connector

3. When prompted, block the breathing circuit wye.
4. When prompted to attach the proximal flow sensor, unblock the circuit wye and insert the smaller end of the sensor into the wye.
5. When prompted, cap or seal the larger end of the sensor (marked with "UP" and an arrow).
6. Follow the prompts to complete SST.

If SST fails, check the patient circuit and flow sensor connections for leaks or occlusions and replace the proximal flow sensor, if necessary. Replace the Proximal Flow option hardware if SST continues to fail, then repeat SST to determine circuit compliance and resistance. See the *Puritan Bennett™ 980 Series Ventilator Hardware Options Installation Instructions*, p/n 10084704 for instructions on replacing the Proximal Flow option hardware.

E.9 Disabling/Enabling the Proximal Flow Option

The proximal flow sensor can function in the Enabled state only if the circuit type is neonatal. Assuming the Proximal Flow option is available and the ventilation type is invasive, the new patient default value is Enabled.

After SST has been performed, the clinician may disable the Proximal Flow option, if desired.

To disable or enable the Proximal Flow option



1. In the constant access icons area, touch the configure icon. A menu containing tabs appears.

2. Touch the Options tab. A screen appears containing the Installed Options and Prox tabs.
3. Touch Enabled or Disabled to enable or disable the Prox Flow option.

Figure E-5. Enabling/Disabling the Proximal Flow Sensor



VEN_11432_E



Note:

If the Proximal Flow option has been disabled or enabled, SST does not have to be re-run unless the breathing circuit or other breathing system accessories have been changed, removed, or added.

E.10 Using the Proximal Flow Sensor

Review and follow all warnings prior to patient ventilation with the proximal flow sensor. See [Safety Information \(E.3\)](#) on page [E-1](#), and ensure the Proximal Flow option is enabled.

To connect the proximal flow sensor to the ventilator

1. Verify the proximal flow sensor, pneumatic lines, and connector are not damaged in any way.
2. Open the connector panel door and firmly attach the sensor connector to the right-most receptacle in the BDU's front connector port labeled Prox Flow. See [Figure E-4](#). on page [E-9](#).

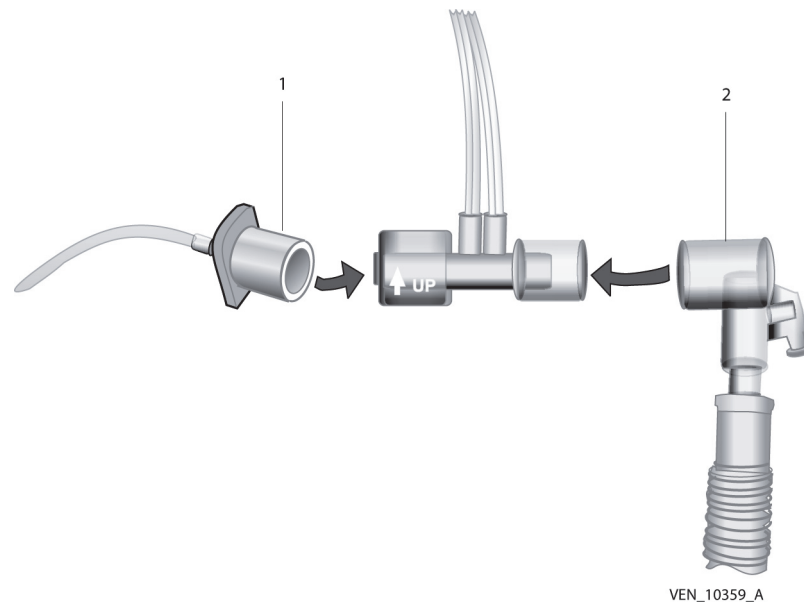
To attach the proximal flow sensor between the endotracheal tube and patient circuit

1. Connect the larger end of the sensor (marked with "UP" and an arrow) to the endotracheal tube. See [Figure E-6](#). Do not force the connection; when the sensor is oriented correctly, insertion requires little effort.

**Note:**

If using a heat-moisture exchanger (HME) on the endotracheal tube, place the proximal flow sensor between the HME and the breathing circuit wye.

Figure E-6. Attaching the Proximal Flow Sensor



1 Endotracheal tube

2 Breathing circuit wye

2. Connect the smaller end of the sensor to the breathing circuit wye.
3. Ensure that the sensor tubing is positioned in an upward direction, as shown in [Figure E-6](#). If the sensor needs repositioning, **DO NOT** rotate it by pulling on the tubing. Reposition as follows:
 - a. Grasp the sensor's plastic body with one hand and the breathing circuit wye with the other hand.
 - b. Rotate the sensor body and wye towards each other until the sensor tubing is upright.
 - c. Confirm a tight connection between the sensor and breathing circuit wye.
4. Use the three cable management clips provided with the sensor to attach the sensor tubing to the breathing circuit tubing. Space the clips evenly along the length of the sensor tubing. Twist the ends of each clip to close.

**Note:**

When the ventilator is set up for Proximal Flow option operation, the proximal flow sensor can be switched as necessary. There is no need to run SST after switching sensors unless the breathing circuit or other ventilator accessories have been changed.

E.10.1 How to Perform a Manual Purge

A manual purge may be performed any time the sensor lines contain excessive condensation, moisture, or secretions.

To perform a manual purge



1. Touch the configure icon on the in the constant access icons area of the GUI.
2. Touch the Options tab. A screen appears containing the Installed Options and Prox tabs.
3. Touch the Prox tab. The Prox Setup screen appears.
4. Touch Start that appears next to the text "Prox Manual Purge: To begin touch the Start button". During the purge, a message appears in the GUI prompt area stating the purge process is being performed. See [Figure E-3](#). on page [E-7](#).

Figure E-7. Manual Purge



VEN_11430_E

E.11 Alarms

If the Proximal Flow option becomes inoperable during ventilation, the ventilator annunciates an alarm and flow sensing reverts to the ventilator's internal delivery and exhalation flow sensors. This switch over may be triggered by any of the following events:

- The proximal flow sensor is not detected.
- Pressure and flow readings are out of range.
- Hardware problems are reported by the Proximal Flow option PCBA.

- There is a communication failure between the ventilator and the Proximal Flow option.

If any of these conditions occur, the GUI displays an alarm message similar the one shown in [Figure E-8](#). Follow the information contained in the remedy message to troubleshoot the alarm.

Figure E-8. Alarm Message—Prox Inoperative



VEN_11431_F

E.12 Ranges, Resolutions, and Accuracies

See [Table 11-11](#), on page [11-17](#) for proximal exhaled tidal volume, proximal inspired tidal volume, proximal exhaled minute volume, and proximal flow patient data parameters.

E.12.1 Proximal Flow Sensor Specifications

Table E-3. Proximal Flow Sensor Volume Accuracy

Measurement	Accuracy ¹
Exhaled tidal volume	$\pm(1.0 \text{ mL} + 10\% \text{ of reading})$
Inspired tidal volume	$\pm(1.0 \text{ mL} + 10\% \text{ of reading})$

1. The sensor is used as described in this appendix or the instructions for use provided with the sensor.

Table E-4. Proximal Flow Sensor Specifications

Parameter	Specification
Weight	6.6 g
Dead space	<1 mL
Pressure drop	1.5 cmH ₂ O at 10 L/min

E.13 Part Numbers

Table E-4. lists the part numbers for the Proximal Flow option kit and individual components.

Table E-5. Proximal Flow Option Component Part Numbers

Item	Part number
Proximal flow option kit Includes: Installation hardware and accessories	10084331
Proximal flow sensor, neonatal (package of 10) NOTE: Includes 3 cable management clips	10047078
Proximal flow sensor module	10087622
Interconnect PCBA	10083941
Purge control cable	10083940
Purge supply line	10083966
PCBA mounting screws	10083963
Proximal Flow option label	10005748

F Trending

F.1 Overview

This appendix describes the operation of the Puritan Bennett™ 980 Series Ventilator Trending function.

Trending is a graphically-based ventilator function allowing a combination of a total of six patient data parameters or ventilator settings to be plotted vs. time. Viewing these data allows the clinician to determine the effectiveness of the patient's therapy.

F.2 Intended Use

The Trending feature is intended to trend a patient's respiratory parameters and ventilator settings over time, to aid physicians in assessing the effectiveness of current therapy. It is not intended to determine the course of treatment.

F.3 Safety Reminder



WARNING:

The ventilator offers a variety of breath delivery options. Throughout the patient's treatment, the clinician should carefully select the ventilation mode and settings to use for that patient based on clinical judgment, the condition and needs of the patient, and the benefits, limitations, and characteristics of the breath delivery options. As the patient's condition changes over time, periodically assess the chosen modes and settings to determine whether or not those are best for the patient's current needs.

F.4 Trending Description

Trending enables a combination of up to six patient data parameters and ventilator settings to be plotted at one time. The user can choose from one of eight time scales.

F.5 Setting Up Trending

To set up trending

1. If a patient is not already being ventilated, set up patient ventilation per the instructions given in Chapter 4.
2. Swipe the Menu tab on the left side of the GUI and touch Trending. The default layout appears with two trended parameters displayed on a 2-hour time scale. Alternatively, touch the layout icon and touch Trending on the Graphs tab. The default layout appears with two trended parameters displayed on a 2-hour time scale.



Figure F-1. Accessing Trending via the Menu Tab



VEN_11536_A

1 Trending button appears after swiping the menu tab

3. Select the parameters to be trended by double-tapping the trended parameter name at the top of the graph or choose Presets, which automatically populates trended items with preset trended parameters. See [Trending Presets \(F.8\)](#) on page F-10. If you desire a different layout than the two-parameter default, touch Custom 2 and a drop-down list appears with layouts for one, two, three, four, or six parameters. Choose the trended parameters for each graph by double-tapping the parameter. A list of buttons appears with arrows to let you know more parameters may be selected. Touch the desired button for the parameter to be trended.

To exit Trending



1. Touch the layout icon, then touch any of the waveform layout buttons (1 through 5). The screen will exit the Trending layout and return to displaying the selected waveforms.

F.6 Trend Parameters

Both ventilator settings and patient data parameters can be trended. Trended ventilator settings are identified with brackets around the setting. For example, if respiratory rate is chosen as a trended ventilator setting, it would appear on the GUI as [f]. Trended patient data parameters are not bracketed. If circuit pressure were trended, its value would appear as P_{PEAK} . [Table F-1](#). and [Table F-2](#). include trended ventilator settings and parameters and are subject to change.

Table F-1. Trended Ventilator Settings

Ventilator setting	Symbol
Expiratory Sensitivity	[E _{SENS}]
Respiratory Rate	[f]
Peak Inspiratory Flow	[$\dot{V}_{MAX}$]
I:E Ratio	[I:E]
Oxygen Percentage	[O ₂ %]
PEEP	[PEEP]
High Pressure (in BiLevel)	[P _H]
Low Pressure (in BiLevel)	[P _L]
Inspiratory Pressure	[P _I]
Pressure Support Level	[P _{SUPP}]
Rise Time%	[ P]
Flow Sensitivity	[$\dot{V}_{SENS}$]
Pressure Sensitivity	[P _{SENS}]
High Time (in BiLevel)	[T _H]
Low Time (in BiLevel)	[T _L]
T _H :T _L Ratio	[T _H :T _L]
Inspiratory Time	[T _I]
Expiratory Time	[T _E]
Tidal Volume (in VC, VC+)	[V _T]
Volume Support	[V _{T SUPP}]
Percent Support - PAV	[% Supp]
Percent Support - TC	[% Supp]
High Spontaneous Inspiratory Time Limit	[$\uparrow T_{I SPONT}$]

Table F-1. Trended Ventilator Settings (Continued)

Ventilator setting	Symbol
Apnea Interval	$[T_A]$
Predicted Body Weight	[PBW]
Alarm Volume	[Alarm Volume]
Expiratory Sensitivity - PAV	$[E_{\text{SENS PAV}}]$
Tube Size	[Tube Size]
Plateau Time	$[T_{PL}]$
Increase $O_2\%$	$[O_2\%]$
IE Sync Trigger Threshold	$[I_{\text{SYNC}}]$
Tidal Volume/PBW Ratio	$[V_T/\text{PBW}]$
Support Volume per kg	$[V_{T \text{ SUPP}}/\text{PBW}]$
Humidifier Volume	[Humid Vol]

Table F-2. Trended Patient Data Parameters

Patient data parameter	Symbol
Dynamic Compliance	C_{DYN}
PAV-based Lung Compliance	C_{PAV}
PAV-based Lung Elastance	C_{STAT}
End Expiratory Flow	E_{PAV}
Peak Expiratory Flow Rate	EEF
Peak Spontaneous Flow Rate	PSF
Total Respiratory Rate	f_{TOT}
I:E Ratio	I:E
Negative Inspiratory Force	NIF
Oxygen Percentage (monitored)	$O_2\%$
Occlusion Pressure	$P_{0.1}$
End Expiratory Pressure	PEEP
Intrinsic PEEP	PEEP_I
PAV-based Intrinsic PEEP	$\text{PEEP}_{I \text{ PAV}}$
Total PEEP	PEEP_{TOT}
Mean Circuit Pressure	P_{MEAN}

Table F-2. Trended Patient Data Parameters (Continued)

Patient data parameter	Symbol
Peak Circuit Pressure	P_{PEAK}
Plateau Pressure	P_{PL}
Spontaneous Rapid Shallow Breathing Index	f/V_T
Dynamic Resistance	R_{DYN}
PAV-based Patient Resistance	R_{STAT}
PAV-based Total Airway Resistance	R_{TOT}
Spontaneous Inspiratory Time	$T_{I\ SPONT}$
Spontaneous Inspiratory Time Ratio	T_I/T_{TOT}
Vital Capacity	VC
Exhaled Total Minute Volume	$\dot{V}_{E\ TOT}$
Exhaled Spontaneous Minute Volume	$\dot{V}_{E\ SPONT}$
Exhaled Tidal Volume	V_{TE}
Exhaled Spontaneous Tidal Volume	$V_{TE\ SPONT}$
Exhaled Mandatory Tidal Volume	$V_{TE\ MAND}$
Inspired Tidal Volume	V_{TI}
Work of Breathing	WOB_{TOT}
Percent Leak	%LEAK
Inspiratory Leak	V_{LEAK}
Exhaled Tidal Volume per kg PBW	V_{TE}/PBW
End Tidal CO_2	$ETCO_2$
Compliance Ratio	C_{20}/C
Inspiratory time constant	$3\tau_{Ii}$
Ineffective Trigger Index	ITI
Estimated Inspiratory volume during Leak Sync	V_{TL}
Leak Rate at PEEP	LEAK
Exhalation leak at PEEP during Leak Sync measured by the proximal flow sensor	$LEAK_Y$
Inspired tidal volume measured by the proximal flow sensor	V_{TIY}
Inspired tidal volume measured by the proximal flow sensor per kg PBW	V_{TIY}/PBW

Table F-2. Trended Patient Data Parameters (Continued)

Patient data parameter	Symbol
Estimated inspiratory volume during Leak Sync per kg PBW	V_{TL}/PBW
Exhaled tidal volume measured by the proximal flow sensor	V_{TEY}
Exhaled tidal volume measured by the proximal flow sensor per kg PBW	V_{TEY}/PBW
Exhaled spontaneous tidal volume measured by the proximal flow sensor	$V_{TE\ SPONTY}$
Exhaled spontaneous minute volume measured by the proximal flow sensor	$\dot{V}_{E\ SPONTY}$
Exhaled mandatory tidal volume when the proximal flow sensor is enabled	$V_{TEY\ MAND}$
Inspiratory tidal volume during Leak Sync measured by the proximal flow sensor	V_{TLY}
Estimated inspiratory volume per kg PBW during Leak Sync measured by the proximal flow sensor	V_{TLY}/PBW
Exhaled minute volume when the proximal flow sensor is enabled	$\dot{V}_{E\ TOTY}$

F.7 Viewing Trended Parameters

The cursor plays an important role when using Trending. Use the cursor to determine the parameter value vs. time and details regarding events. Touch the cursor button and turn the knob to move the cursor. The cursor moves along the waveform with the y-axis displaying the parameter's value and the x-axis showing the time. As the waveform changes, each value is shown surrounded by a highlighted box as the cursor hovers over the waveform.

If the cursor is at its left-most position on the graph, it remains there and the graph displays the earliest time stamp.

If the cursor is in between left- and right-most positions on the graph, the cursor tracks its time stamp as the graph moves and new data arrive.

If the cursor is at its right-most position on the graph, it remains there and the graph displays the latest time stamp.



Note:

If a trend parameter is not selected for a particular graph, the minimum and maximum values appear as dashes (- -).

F.7.1 Time Scales

Eight time scales are available. Time scales of 1, 2, 4, 8, 12, 24, 48, and 72 hours can be viewed. The time scale is indicated by the slider track at the bottom of the Trending screen. The complete slider track represents a 72-hour time interval, and the blue shuttle that slides along the track represents the selected time scale. The selected time scale applies to all displayed trend graphs.

Although data are sampled at periodic intervals, as shown in [Table F-3](#), the GUI screen is refreshed every minute for any time scale selected.

Table F-3. Sampling Periods for Selected Time Scales

Time scale	Sampling period
1 hour	10 seconds
2 hours	20 seconds
4 hours	40 seconds
8 hours	80 seconds
12 hours	2 minutes
24 hours	4 minutes
48 hours	8 minutes
72 hours	12 minutes

To select a time scale

1. Touch the x-axis of the graph. The time values are surrounded by a highlighted box, indicating the time scale is ready to be changed.
2. Turn the knob to select a time scale. Turning the knob clockwise reduces the time scale, and turning it counter-clockwise increases the time scale. The relative size of the shuttle indicates the time interval selected, and the time interval is displayed along the x-axis.
3. When finished, touch the x-axis again to dismiss the box.

After each time scale change, the graphs refresh with updated parameter values for that time scale.

F.7.2 Events

Events are either automatic or manual and appear as vertical tick marks on the trend graph according to their time of occurrence. When the cursor hovers over a tick mark, Event Details changes from unselectable (gray) to a button containing the event ID numbers associated with the tick mark. Touching this button causes a dialog to appear with the event ID and its description. If many IDs are present for a selected time stamp, the user is notified by an ellipsis (...) indicating more IDs are present.

When the operator modifies the real time clock setting, the system places an event marker in the trend log to denote a time or date change. The time stamp of this automatic event will be the new time setting.

**Note:**

The events listed in [Table F-4](#), are subject to change.

Table F-4. Events

Event ID	Description
Manual events	
1	Suction
2	Rx: Bronchodilator
3	Rx: Antihistamine
4	Rx: Steroid
5	Rx: Antibiotic
6	Rx: Muco/Proteolytic
7	Blood Gas
8	Circuit Change
9	Start Weaning
10	Stop Weaning
11	Bronchoscopy ¹
12	X-ray
13	Recruitment maneuver ¹
14	Other 1
15	Other 2
16	Other 3
17	Surfactant administration ²
18	Prone position ²
19	Supine position ²
20	Left side position ²
21	Right side position ²
22	Manual stimulation ²
23	Start transport
24	Stop transport

Table F-4. Events (Continued)

Event ID	Description
25	Start N.O Rx
26	Stop N.O Rx
Automatic events	
51	Changed ventilation type to Invasive
52	Changed ventilation type to NIV
53	Changed mode to A/C
54	Changed mode to SIMV
55	Changed mode to SPONT
56	Changed mode to BiLevel
57	Changed mandatory type to VC
58	Changed mandatory type to VC+
59	Changed mandatory type to PC
60	Changed spontaneous type to PS
61	Changed spontaneous type to VS
63	Changed spontaneous type to PAV+ ³
64	Changed spontaneous type to TC ¹
65	Time (real-time clock) changed by user
66	Same Patient selected
67	Occlusion
68	Circuit Disconnect
69	Apnea Ventilation
70	NIF Accepted
71	P _{0.1} Accepted
72	VC Accepted
73	Inspiratory Pause Maneuver Completed
74	Expiratory Pause Maneuver Completed
75	Changed mode to CPAP ²
76	Elevate O ₂
77	Alarm volume change
78	Proximal Flow Sensor state Enabled ²
79	Proximal Flow Sensor state Disabled ²

Table F-4. Events (Continued)

Event ID	Description
80	Manual Inspiration
81	Leak Sync Enabled
82	Leak Sync Disabled
83	Changed trigger type to Pressure
84	Changed trigger type to Flow
85	Changed trigger type to IE Sync ¹
86	Enter Stand-By Ventilation
87	Exit Stand-By Ventilation
88	Backup Ventilation
89	Changed humidifier type to Heated
90	Changed humidifier type to Non-heated
91	Changed humidifier type to HME

1. Not available for neonatal circuit types.

2. Only for neonatal circuit types.

3. Adult only.

To record a manual event



1. Touch the Manual Event text below the home icon on the GUI screen. The manual event screen appears with arrows allowing scrolling through the available manual events. See [Table 2-6.](#) on page 2-17 and [Figure 4-1.](#) on page 4-3.
2. Touch Accept to confirm the event or Cancel to cancel the action.
3. View the event by hovering the cursor over the vertical tick mark and touching Event Details which now appears as a button containing event IDs. After touching the button, a dialog appears showing the event ID and its description.

F.8 Trending Presets

The trending function enables the clinician to view a combination of up to six patient data parameters and ventilation settings that are plotted over time on a clinician-selected time scale. There are two options for how trended values are selected for display on the trending screen:

- The clinician may select each individual trended value that is displayed on the trending screen.
- The clinician may select a trending preset (a preselected group of trended values) for display.

The ventilator offers presets for adult and pediatric patients and a different set of presets for neonatal patients. The trending presets are intended to aid clinicians in assessing the effectiveness of the current therapy but are not intended to determine the course of treatment.

F.8.1 Adult and Pediatric Trending Presets

Adult and pediatric trending presets include but are not limited to:

Weaning — f/V_T , $P_{0.1}$, NIF, $[V_{T\text{ SUPP}}]$, $[V_{T\text{ SUPP}}]$, C_{STAT}

ARDS — P_{PL} , $[PEEP]$, V_{TE} , R_{STAT} , C_{STAT} , $[V_T]$

COPD — R_{DYN} , EEF , f_{TOT} , $V_{\text{TE SPONT}}$, $\dot{V}_{\text{E TOT}}$, C_{STAT}

VC+ — P_{PEAK} , V_{TE} , C_{STAT} , $[V_T]$, $[T_i]$, R_{STAT}

PAV+ — $[\% \text{ Supp}]$, P_{PEAK} , WOB_{TOT} , f_{TOT} , V_{TE} , R_{PAV}

BiLevel — C_{STAT} , $[P_H]$, $[P_L]$, P_{MEAN} , $PEEP_i$, f_{TOT}

LRM — P_{PEAK} , $PEEP$, C_{DYN} , V_{TE} , C_{STAT} , $[T_i]$.

F.8.2 Neonatal Trending Presets

Neonatal trending presets include but are not limited to:

VCV — P_{PEAK} , $PEEP$, $[V_T]$, P_{MEAN} , V_{TE} , $O_2\%$

PCV — P_{PEAK} , V_{TE} , P_{MEAN} , $[T_i]$, $PEEP$, $O_2\%$

BPD — P_{PEAK} , C_{DYN} , P_{MEAN} , $PEEP$, R_{DYN} , $O_2\%$

SURF — V_{TE} , C_{DYN} , R_{DYN} , P_{MEAN} , $[T_i]$, $O_2\%$

Weaning — f_{TOT} , V_{TE} , C_{DYN} , R_{DYN} , $[f]$, $O_2\%$

N SIMV — f_{TOT} , $[f]$, $[P_i]$, $PEEP$, P_{MEAN} , $O_2\%$

N SPONT — f_{TOT} , $PEEP$, $O_2\%$, I:E ratio, PSF, %LEAK

Leak Sync — %LEAK, LEAK, V_{LEAK} , V_{TL} , V_{TE} , $\dot{V}_{\text{E TOT}}$

To select a trending preset

1. Touch Presets. A dialog appears with available choices. Arrows on the dialog indicate more available choices.
2. Touch the desired trending preset. As all trending presets include six parameters, the trend graph changes to a six-graph layout, populated with the six trended preset parameters described above. The chosen trended preset appears on the Presets button.

**Note:**

If a trended preset is selected, it is not possible to change the trended parameters. You must first select a custom layout, by touching Custom, then double-tapping the parameters you desire to change.

F.9 Data Gaps

Data gaps are shown during Apnea ventilation, occlusion, circuit disconnect, Stand-By ventilation, and backup ventilation. Gaps also appear for trended parameters that are not applicable, such as parameters associated with a non-installed option or those that are not active in the current ventilator settings.

Glossary

Ventilation Terms

analysis message	A message displayed on the GUI screen during an alarm condition, identifying the root cause of the alarm.
assist breath	A mandatory breath triggered by patient inspiratory effort in A/C and SIMV modes.
assist-control A/C mode	A ventilation mode where only mandatory VC, PC, or VC+ breaths are delivered to the patient.
audio paused (alarm silence)	Used interchangeably with the term alarm silence, the 2-minute period that begins after the audio paused (alarm silence) key is pressed, where the audible portion of an alarm is muted.
augmented alarm	The initial cause of an alarm has precipitated one or more related alarms. When an alarm occurs, any subsequent alarm related to the cause of this initial alarm "augments" the initial alarm.
autotriggering	The ventilator delivers repeated, unintended breaths triggered by fluctuating flows or pressures as opposed to patient demand. Patient circuit leaks and low flow or pressure sensitivity settings are common causes of autotriggering.
background checks	Continuously running tests during ventilation that assess the ventilator's electronics and pneumatics hardware.
backup ventilation (BUV)	A safety net feature that is invoked if a system fault in the mix subsystem, inspiratory subsystem, or expiratory subsystem occurs compromising the ventilator's ability to ventilate the patient as set.
base flow	A constant flow of gas through the patient circuit during the latter part of exhalation during flow triggering ($\dot{V}$ -Trig). The value of this base flow is 1.5 L/min greater than the operator selected value for flow sensitivity.
base message	A message given by the ventilator during an alarm condition, identifying the alarm.
batch changes	Changes to multiple settings that go into effect at the same time.
battery back-up system	The system for supplying battery back-up power to a device. The ventilator's battery back-up system consists of a single primary battery to provide up to 1 hour of battery power to the ventilator. An optional extended battery with the same characteristics as the primary battery is available.
BD, BDU	Breath delivery or breath delivery unit. The ventilator component that includes inspiratory and expiratory pneumatics and electronics.

BiLevel mode	A mixed ventilation mode combining mandatory and spontaneous breaths, where two levels of pressure are delivered (P_L and P_H) corresponding to expiratory and inspiratory times T_L and T_H .
BOC	British Oxygen Company. A standard for high pressure gas inlet fittings.
breath stacking	The delivery of a second inspiration before the previous exhalation is complete.
BTPS	Body temperature and pressure, saturated, 37°C, at ambient barometric pressure, at 100% relative humidity.
cmH ₂ O	Centimeters of water. A unit of pressure approximately equal to 1 hPa.
compliance volume	The volume of gas that remains in the patient circuit and does not enter the patient's respiratory system.
compressor	The compressor provides compressed air, which can be used in place of wall or bottled air.
constant during rate change	One of three breath timing variables (inspiratory time, I:E ratio, or expiratory time) the operator can hold constant when the respiratory rate setting changes. Applies only to the pressure control (PC) mandatory breath type (including VC+ and BiLevel).
control breath	A ventilator-initiated mandatory breath delivered in A/C mode
CPU	Central processing unit. The electronic components of the ventilator (BD and GUI) responsible for interpreting and executing instructions entered by the operator.
dependent alarm	An alarm that arises as a result of another primary alarm (also referred to as an augmentation).
D _{SENS}	Disconnect sensitivity. A setting that specifies the allowable loss (percentage) of delivered tidal volume, which if equaled or exceeded, causes the ventilator to declare a DISCONNECT alarm. The greater the setting, the more returned volume must be lost before DISCONNECT is detected. If the Leak Sync function is in use, D _{SENS} is the maximum allowable leak rate and is expressed in terms of L/min.
DISS	Diameter index safety standard. A standard for high pressure gas inlet fittings.
E _{SENS}	Expiratory sensitivity. A setting that determines the percent of peak inspiratory flow (or flow rate expressed in L/min in a PAV breath) at which the ventilator cycles from inspiration to exhalation for spontaneous breaths. Low settings will result in longer spontaneous inspirations.
EST	Extended self test. A comprehensive test of ventilator function, intended to be run by qualified service personnel.
EVQ	The exhalation flow sensor assembly.
expiratory pause	an operator-initiated maneuver that closes the inspiration (proportional solenoid) and exhalation valves during the expiratory phase of a mandatory breath. The maneuver can be used to determine intrinsic (auto) PEEP (PEEP _I).
exhalation valve (EV)	The valve in the expiratory limb of the ventilator breathing system that controls PEEP.

f, f_{TOT}	Respiratory rate, as a setting (f) in A/C, SIMV, and BiLevel the minimum number of mandatory breaths the patient receives per minute. As a monitored value (f_{TOT}), the average total number of breaths delivered to the patient.
Failure	A category of condition detected during SST or EST that causes the ventilator to enter the safety valve open state. A ventilator experiencing a failure requires removal from clinical use and immediate service.
flow pattern	A setting that determines the gas flow pattern of mandatory volume-controlled breaths.
gold standard test circuit	Test circuit designed for use with EST.
GUI	Graphical user interface. The ventilator's touch screen used to enter patient settings, and alarm settings, including off-screen keys, soft keys, and knobs.
hard bound	A ventilator setting that has reached its minimum or maximum limit.
high-priority alarm	As defined by international standards organizations, an alarm that requires immediate attention to ensure patient safety. When a high-priority alarm is active, the red high-priority LED indicator flashes and the high-priority audible alarm sounds (a repeating sequence of five tones that repeats twice, pauses, then repeats again), and the alarm banner on the GUI screen shows an alarm message with the (!!!) symbol.
HME	Heat-moisture exchanger. A humidification device, also called an artificial nose.
hPa	Hectopascal. A unit of pressure, approximately equal to 1 cmH ₂ O.
humidification type	A setting for the type of humidification system (HME, non-heated expiratory tube, or heated expiratory tubing) in use on the ventilator.
I:E ratio	The ratio of inspiratory time to expiratory time. Also, the operator- set timing variable that applies to PC and VC+ mandatory breaths.
inspiratory pause	An operator-initiated maneuver that closes the inspiration (proportional solenoid) and exhalation valves at the end of the inspiratory phase of a mandatory breath. The maneuver can be used to determine static compliance (C_{STAT}) and static resistance (R_{STAT}).
invasive ventilation	Patient ventilation while intubated with an endotracheal (or tracheostomy) tube.
kPa	Kilopascal. A unit of pressure approximately equal to 10 cmH ₂ O.
latched alarm	An alarm whose visual alarm indicator remains illuminated after the alarm has autoreset.
low-priority alarm	As defined by international standards organizations, an alarm that indicates a change in the patient-ventilator system. During a low-priority alarm, the yellow low-priority LED indicator lights, the low-priority audible alarm (one tone) sounds, and the GUI screen shows an alarm banner with the (!) symbol.
lockable alarm	An alarm that does not terminate an active audio paused function.
maintenance	All actions necessary to keep equipment in, or restore it to, serviceable condition. Includes cleaning, servicing, repair, modification, overhaul, inspection, and performance verification.

mandatory breath	A breath whose settings and timing are preset; can be triggered by the ventilator, patient, or operator.
mandatory type	The type of mandatory breath: volume control (VC), VC+, or pressure control (PC).
manual inspiration	An operator-initiated mandatory (OIM) breath.
medium-priority alarm	As defined by international standards organizations, an abnormal condition that requires prompt attention to ensure the safety of the patient. When a medium-priority alarm is active, the yellow medium-priority LED indicator flashes, the medium-priority audible alarm (a repeating sequence of three tones) sounds, and the GUI screen shows an alarm banner with the (!!) symbol.
mode	Ventilatory mode. The algorithm that determines type and sequence of breath delivery.
NIST	Non-interchangeable screw thread. A standard for high pressure gas inlet fittings.
non-invasive ventilation (NIV)	Patient ventilation without the use of an endotracheal tube; instead using interfaces such as masks, nasal prongs, or uncuffed endotracheal tubes.
non-technical alarm	An alarm caused due to a fault in the patient-ventilator interaction or a fault in the electrical or gas supplies that the practitioner may be able to alleviate.
normal ventilation	The state of the ventilator when breathing is in progress and no alarms are active.
O ₂ %	Both a ventilator setting and a monitored variable. The R _{TOT} setting determines the percentage of oxygen in the delivered gas. The O ₂ % monitored data is the percentage of oxygen in the gas delivered to the patient, measured at the ventilator outlet upstream of the inspiratory filter.
OIM	Operator-initiated mandatory breath. A breath delivered when the operator presses the manual inspiration key.
ongoing background checks	Continuously running tests during ventilation that assess the ventilator's electronics and pneumatics hardware.
OSC	Occlusion status cycling. A state invoked during a severe occlusion. In this mode, the ventilator periodically attempts to deliver a pressure-based breath while monitoring the inspiratory and expiratory phases for the continuing existence of the occlusion.
OVERRIDDEN	The final status of an SST or EST run in which the operator used the override feature. (The ventilator must have ended the test with an ALERT condition.) Failures cannot be overridden.
patient circuit	The entire inspiratory-expiratory conduit, including tubing, humidifier, and water traps.
patient data alarm	An alarm condition associated with an abnormal condition of the patient's respiratory status.
patient problems	A definition used by the ventilator's safety net. Patient problems are declared when patient data are measured equal to or outside of alarm thresholds and are usually self-correcting or can be corrected by a practitioner. The alarm monitoring system detects and announces patient problems. Patient problems do not compromise the ventilator's performance.

PBW	Predicted body weight, a ventilator setting that specifies the patient's body weight assuming normal fat and fluid levels. Determines absolute limits on tidal volume and peak flow, and allows appropriate matching of ventilator settings to the patient.
PC	Pressure control. A mandatory breath type in which the ventilator delivers an operator-set inspiratory pressure for an operator-set inspiratory time. Available in A/C and SIMV modes, and for operator-initiated mandatory (OIM) breaths in SPONT mode.
PE	Expiratory pressure transducer.
PEEP	Positive end expiratory pressure. The measured circuit pressure (referenced to the patient wye) at the end of the expiratory phase of a breath. If expiratory pause is active, the displayed value reflects the level of any active lung PEEP.
PEEP _I	Intrinsic PEEP. Indicates a calculated estimate of the pressure above the PEEP level at the end of exhalation. Determined during an expiratory pause maneuver.
P _I	Inspiratory pressure. The operator-set inspiratory pressure at the patient wye (above PEEP) during a pressure control (PC) mandatory breath.
PI	Inspiratory pressure transducer.
P _I END	End inspiratory pressure. The pressure at the end of the inspiratory phase of the current breath. If plateau is active, the displayed value reflects the level of end-plateau pressure.
PIM	Patient-initiated mandatory breath. A mandatory breath triggered by patient inspiratory effort.
P _{MEAN}	Mean circuit pressure, a calculation of the measured average patient circuit pressure over an entire respiratory cycle.
P _{PEAK}	Maximum circuit pressure, the maximum pressure during the inspiratory and expiratory phases of a breath.
primary alarm	An initial alarm.
PS	Pressure support, a spontaneous breath type in which the ventilator delivers an operator-set pressure (in addition to PEEP) during the inspiratory phase. Available in SPONT, SIMV, and BiLevel modes.
P _{SENS}	Pressure sensitivity. The operator-set pressure drop below PEEP (derived from the patient's inspiratory flow) required to begin a patient-initiated breath when pressure triggering is selected.
PSOL	Proportional solenoid valve.
P _{SUPP}	Pressure support. A setting of the level of inspiratory assist pressure (above PEEP) at the patient wye during a spontaneous breath (when spontaneous breath type is PS).
P-Trig	Pressure triggering, a method of recognizing patient inspiratory effort in which the ventilator monitors pressure in the patient circuit. The ventilator triggers a breath when the airway pressure drops by at least the value selected for pressure sensitivity (P _{SENS}).
remedy message	A message displayed on the GUI during an alarm condition suggesting ways to resolve the alarm.

resistance	The flow-dependent pressure drop across a conduit. Measured in cmH ₂ O/L/s or hPa/L/s.
restricted phase of exhalation	The time period during the expiratory phase where an inspiration trigger is not allowed. The restricted phase of exhalation is defined as the first 200 ms of exhalation, or the time it takes for expiratory flow to drop to ≤50% of the peak expiratory flow, or the time it takes for the expiratory flow to drop to ≤0.5 L/min (whichever is longest). The restricted phase of exhalation will end after 5 seconds of exhalation have elapsed regardless of the measured expiratory flow rate.
rise time%	A setting that determines the rise time to achieve the set inspiratory pressure in pressure-controlled (PC), VC+, BiLevel, volume supported (VS) or pressure-supported (PS) breaths. The larger the value, the more rapid the rise of pressure.
safety net	The ventilator's strategy for responding to patient problems and system faults.
safety valve (SV)	A valve residing in the ventilator's inspiratory module designed to limit pressure in the patient circuit. When open, it allows the patient to breathe room air (if able to do so).
safety ventilation	A mode of ventilation active if the patient circuit is connected before ventilator startup is complete, or when power is restored after a loss of 5 minutes or more.
service mode	A ventilator mode providing a set of services tailored to the needs of testing and maintenance personnel. When in the service mode, the ventilator does not provide ventilation.
SIMV	Synchronized intermittent mandatory ventilation. A ventilatory mode in which the ventilator delivers one mandatory breath per breath cycle and as many spontaneous breaths as the patient can trigger during the remainder of the breath cycle.
SIS	Sleeved index system. A standard for high pressure gas inlet fittings.
soft bound	A ventilator setting that has reached its recommended high or low limit, accompanied by an audible tone. Setting the ventilator beyond this limit requires the operator to acknowledge a visual prompt to continue.
SPONT	Spontaneous. A ventilatory mode in which the ventilator delivers only spontaneous breaths. In SPONT mode, the patient triggers all breaths delivered by the ventilator with no set mandatory respiratory rate. The patient controls the breath variables, potentially augmented by support pressure.
spontaneous type	A setting that determines whether spontaneous breaths are pressure-supported (PS), tube-compensated (TC), volume-supported (VS), or proportionally assisted (PAV).
SST	Short self test. A test that checks circuit integrity, calculates circuit compliance and filter resistance, and checks ventilator function. Operator should run SST at specified intervals and with any replacement or alteration of the patient circuit.
STPD	Standard temperature and pressure, dry. Defined as dry gas at a standard atmosphere (760 mmHg, 101.333 kPa, approximately 1.0 bar) and 0°C.

SVO	Safety valve open. An emergency state in which the ventilator opens the safety valve so the patient can breathe room air unassisted by the ventilator (if able to do so). An SVO state does not necessarily indicate a ventilator inoperative condition. The ventilator enters an SVO state if a hardware or software failure occurs that could compromise safe ventilation, with the loss of the air and oxygen supplies, or if the system detects an occlusion.
system fault	A definition used by the ventilator's safety net. System faults include hardware faults (those that originate inside the ventilator and affect its performance), soft faults (faults momentarily introduced into the ventilator that interfere with normal operation), inadequate supply (AC power or external gas pressure), and patient circuit integrity (blocked or disconnected circuit).
T _A	Apnea interval, the operator-set variable that defines the breath-to-breath interval which, if exceeded, causes the ventilator to declare apnea and enter apnea ventilation.
T _b	Breath time cycle during mechanical ventilation.
T _E	Expiratory time. The expiratory interval of a breath. Also the operator-set timing variable that determines the expiratory period for pressure-controlled (PC) or VC+ mandatory breaths.
technical alarm	An alarm occurring due to a violation of any of the ventilator's self monitoring conditions, or detected by background checks.
T _I	Inspiratory time, the inspiratory interval of a breath. Also, the operator-set timing variable that determines the inspiratory interval for pressure-controlled (PC) or VC+ mandatory breaths.
T _m	Mandatory interval portion of SIMV breath cycle; it is reserved for a PIM.
T _{PL}	Plateau time. The amount of time the inspiratory phase of a mandatory breath is extended after inspiratory flow has ceased and exhalation is blocked. Increases the residence time of gas in the patient's lungs.
T _s	Spontaneous interval portion of SIMV breath cycle; it is reserved for spontaneous breathing throughout the remainder of the breath cycle.
$\dot{V}_{E\text{ TOT}}$	Minute volume, the expiratory tidal volume normalized to unit time (L/min). The displayed value is compliance- and BTPS-compensated.
VBS	Ventilator breathing system. Includes the gas delivery components of the ventilator the patient circuit with tubing, filters, humidifier, and other accessories; and the ventilator's expiratory metering and measurement components.
VC	Volume control, a mandatory breath type in which the ventilator delivers an operator-set tidal volume, peak flow, and flow pattern. Available in A/C and SIMV modes, and for operator-initiated mandatory (OIM) breaths in SPONT mode.
Ventilation Assurance	A feature on the 980 Series Ventilator that enables ventilation to continue when a critical system error occurs, by entering the Backup Ventilation (BUV) state.
Ventilator Inoperative (vent inop)	An emergency state the ventilator enters if it detects a hardware failure or a critical software error that could compromise safe ventilation. During a ventilator inoperative condition, the safety valve opens to allow the patient to breathe room air (if able to do so) unassisted by the ventilator. Qualified service personnel must power up the ventilator and run EST before normal ventilation can resume.

VIM	Ventilator-initiated mandatory breath. A breath that is delivered at a time determined by the ventilator.
$\dot{V}_{MAX}$	Peak flow. A setting of the peak (maximum) flow of gas delivered during a VC mandatory breath. (Combined with tidal volume, flow pattern, and plateau, constant peak flow defines the inspiratory time.) To correct for compliance volume, the ventilator automatically increases the peak flow.
$\dot{V}_{SENS}$	Flow sensitivity. A setting that determines the rate of flow inspired by the patient that triggers the ventilator to deliver a mandatory or spontaneous breath (when flow triggering is selected).
V_T	Tidal volume. A setting that determines the volume inspired and expired with each breath. The V_T delivered by some Puritan Bennett ventilators is an operator-set variable that determines the volume delivered to the patient during a mandatory, volume-based breath. V_T is compliance-compensated and corrected to body temperature and pressure, saturated (BTPS).
$\dot{V}_{Trig}$	Flow triggering. A method of recognizing patient inspiratory effort in which the ventilator monitors the difference between inspiratory and expiratory flow measurements. The ventilator triggers a breath when the difference between inspiratory and expiratory flows increases to a value that is at least the value selected for flow sensitivity ($\dot{V}_{SENS}$).

Units of Measure

1/min	Breaths per minute. A unit measuring respiratory rate.
cm	Centimeter. A unit of length.
ft	Feet. A unit of length.
Hz	Hertz. A unit of frequency, indicating cycles per second.
kg	Kilogram. A unit of weight.
L	Liter. A unit of volume.
L/min	Liters per minute. A unit of flow or minute volume (volume delivered in one minute).
lb	Pound. A unit of weight.
m	Meter. A unit of length.
mL	Milliliter. A unit of volume.
ms	Millisecond. A unit of time.
s	Second. A unit of time.
SLPM	Standard liters per minute. Flow rate at 1 atm pressure (101.325 kPa) and 70°F (21.1°C).
V	Volts. A unit of voltage.
VA	Volt-amperes. A unit of power.

Technical Abbreviations

AC, also ac	Alternating current. The movement of electrical charge that periodically reverses direction.
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ASCII	American Standard Code for Information Interchange. A standard character encoding scheme.
CE	A certification mark issued under the authority of the European Common Market that indicates compliance with the Medical Device Directive, 93/42/EEC.
CSA	Canadian Standards Association.
CRC	Cyclic Redundancy Check or Code. An algorithm or a computational result based on the remainder of a division defined over the ring of polynomials in the Galois field GF(2). CRC algorithms are the basis for data integrity checks.
DC, also dc	Direct current. The movement of electrical charge flowing in a single direction.
EMC	Electromagnetic compatibility.
EN	European norm (referring to the European Common Market).
ETO	Ethylene oxide.
IEC	International Electrotechnical Commission. A standards organization.
ISO	International Standards Organization. A standards organization.
LCD	Liquid crystal display. A type of visual equipment-operator Interface.
LED	Light-emitting diode. A means of providing visual indications.
MRI	Magnetic resonance imaging.
NVRAM, also NovRam	Non-volatile random access memory. Memory that is kept active across resets and power cycles and is not normally initialized at startup.
POST	Power-on self test. Software algorithms to verify the integrity of application software and the hardware environment. Power-on self test generally occurs at power on, after power loss, or when the device detects an internal fault.
RAM	Random access memory.

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