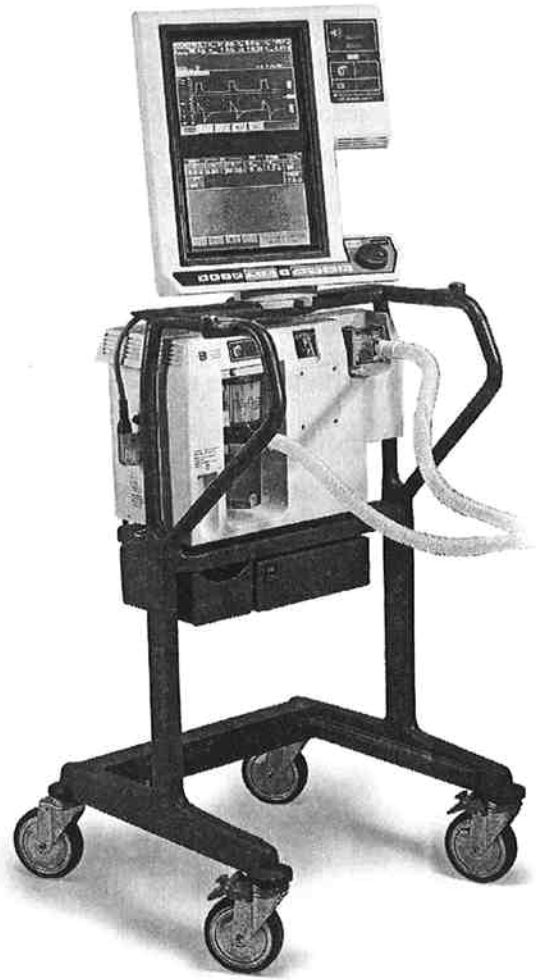
840

Operator's and Technical Reference Manual

Ventilator System

Part No. 4-075609-00
Rev. C
January 1999



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Applicability

The information in this manual applies to *840* Ventilator versions manufactured or updated from January 1999 on. Some of this information may not apply to earlier versions. Contact your Nellcor Puritan Bennett representative if in doubt.

Comments

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Definitions

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

Warning

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

Caution

Indicates a condition that can damage the equipment.

NOTE:

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

Warnings, cautions, and notes

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

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

  The user of this product shall have sole responsibility for any ventilator malfunction due to operation or maintenance performed by anyone not trained by Nellcor Puritan Bennett staff.

- To avoid an electrical shock hazard while servicing the ventilator, be sure to remove all power to the ventilator by disconnecting the power source and turning off all ventilator power switches.

- To avoid a fire hazard, keep matches, lighted cigarettes, and all other sources of ignition (e.g., flammable anesthetics and/or heaters) away from the *840* Ventilator System and oxygen hoses.

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

  In case of fire or a burning smell, immediately disconnect the ventilator from the oxygen supply, facility power, and backup power source.

- When handling any part of the *840* Ventilator System, always follow your hospital infection control guidelines for handling infectious material.

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

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

- Patients on life-support equipment should be appropriately monitored by competent medical personnel and suitable monitoring devices.

  The *840* Ventilator System is not intended to be a comprehensive monitoring device and does not activate alarms for all types of dangerous conditions for patients on life-support equipment.

- For a thorough understanding of ventilator operations, be sure to thoroughly read this manual before attempting to use the system.
- Before activating any part of the ventilator, be sure to check the equipment for proper operation and, if appropriate, run SST as described in Section 3 of the operator's guide.
- Do not use sharp objects to make selections on the graphic user interface (GUI) display or keyboard.
- US federal law restricts this device to sale by or on the order of a physician.
- Check the ventilator periodically as outlined in the *840 Ventilator System Service Manual*; do not use if defective. Immediately replace parts that are broken, missing, obviously worn, distorted, or contaminated.
- An alternative source of ventilation should always be available when using the *840* Ventilator System.
- The *840* Ventilator System is a member of the *800 Series*™ family of products. Any accessory whose model number is 80x (for example, the 802 Backup Power Source or 804 Compressor) operates with all *800 Series* ventilators. An accessory whose model number is 84x operates only with a model *840* Ventilator System.

Year of manufacture

The graphic user interface (GUI), breath delivery unit (BDU), backup power source (BPS), and compressor contain a specific year of manufacture applicable only for that assembly. The year of manufacture is indicated by the fifth and sixth digits of the serial number which is located at the back panel of the GUI, BDU, and BPS, and the side panel of the compressor.

Manufacturer

NELLCOR PURITAN BENNETT™
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Carlsbad, CA
USA

Electromagnetic susceptibility

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

Customer assistance

For further assistance contact your local Nellcor Puritan Bennett representative.

Preface

This manual is divided into two parts: the operator's guide and the technical reference. The operator's guide tells the user how to operate the Nellcor Puritan Bennett *840* Ventilator System. It also provides product specifications and accessory order numbers. The technical reference includes background information about how the ventilator functions, including details on its operating modes, self-tests, and other features. In the table of contents and index, the prefix OP- identifies page numbers in the operator's guide, and the prefix TR- identifies page numbers in the technical reference.While this manual covers the ventilator configurations currently supported by Nellcor Puritan Bennett, it may not be all-inclusive and may not be applicable to your ventilator. Within the USA, contact Nellcor Puritan Bennett at 1-800-635-5267 for questions about the applicability of the information.

Operator's Guide

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Operator's Guide

hnical Reference

Operator's Guide

Technical Reference

SECTION 1

Introduction

The Nellcor Puritan Bennett *840* Ventilator System is a high-capability ventilator intended for acute and subacute care of infant, pediatric, and adult patients. The user interface, breath delivery, and patient monitoring capabilities are designed for easy future enhancement.

The *840* Ventilator System is designed to manage work of breathing, offer different modes of breath delivery, and help a practitioner select the most appropriate ventilator settings. The user interface is intended to be intuitive to anyone who knows how to operate a ventilator, and can be learned with minimal training. The user interface includes the *DualView*™ touch screens that display monitored data separately from ventilator settings for easy assessment of your patient's condition. The *SandBox*™ area allows you to preview settings before applying them to the patient. The *SmartAlert*™ intelligent alarm handling strategy is designed to provide specific information about the cause and suggested resolution of alarms.

The ventilator includes two independent central processing units (CPUs): one for the breath delivery unit (BDU) and one for the graphic user interface (GUI). The BDU CPU delivers breaths according to specified variables and runs extensive background checks. The GUI CPU accepts breath delivery and alarm settings and monitors the ventilator and patient/ventilator interaction. The GUI CPU verifies that the BDU CPU is functioning properly, and prevents a single fault from causing a simultaneous failure of controlling and monitoring functions.

The *840* Ventilator System supplies mandatory or spontaneous breaths with a preset level of positive end expiratory pressure (PEEP), trigger sensitivity, and oxygen concentration. A mandatory breath can be pressure- or volume-controlled, except in the optional *BiLevel*™ mode, when it is always pressure-controlled. A spontaneous breath allows the patient inspiratory flows of up to 200 L/min, with or without pressure support.

The optional 804 Compressor unit provides compressed air to the BDU, and can be used in place of wall or bottled air. The compressor unit is powered through and communicates with the BDU.

The 802 Backup Power Source (BPS) provides dc power to the BDU and GUI in the event that ac power is lost. A new, fully charged BPS lets you run the ventilator (without compressor or humidifier) for at least 30 minutes; thus, the BPS can power the ventilator for transport purposes within the respiratory care facility.

This manual tells you how to operate and perform simple maintenance for the *840* Ventilator System. Nellcor Puritan Bennett recommends that you become familiar with this manual and accompanying labels before attempting to operate or maintain the ventilator. If you need additional copies of this manual, contact your Nellcor Puritan Bennett representative.

To ensure optimum performance of the *840* Ventilator System, Nellcor Puritan Bennett recommends that a qualified service technician perform periodic maintenance on the ventilator. For more information, contact your Nellcor Puritan Bennett representative.

Technical description

By using the touch screen, keys, and knob on the GUI, the practitioner gives instructions and data to the ventilator (see Figure 1-1). The GUI CPU processes this information and stores it in the ventilator's memory. The BDU CPU uses this stored information to control and monitor the flow of gas to and from the patient. Any new settings information is transferred and verified using a four-way transaction between the BDU and GUI CPUs. Each CPU then performs continuous background verification of settings' integrity.

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

offsets, inspiratory time, apnea interval, target pressure for pressure controlled breaths, breath phase start, and time stamp.

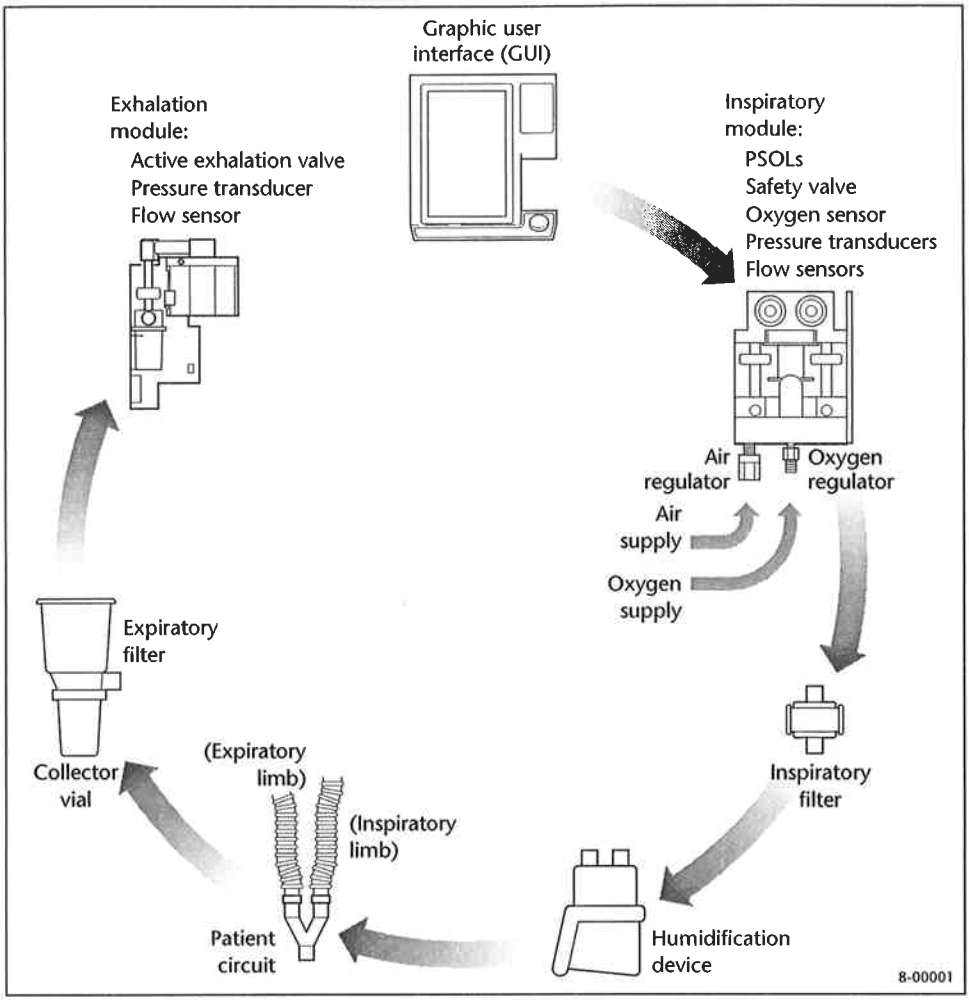

Figure 1-1. *840* Ventilator System block diagram

The GUI logs an event in the diagnostic log and places the ventilator in the ventilator inoperative state if:

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

The ventilator uses flow or pressure triggering to recognize patient effort. When *pressure triggering* is selected, the ventilator monitors pressure in the patient circuit. As the patient draws gas from the circuit and airway pressure drops by at least the value selected for pressure sensitivity, the ventilator triggers a breath.

When *flow triggering* (*Flow-by*®) is selected, the ventilator monitors the difference between the inspiratory and expiratory flow sensor measurements. As the patient inhales, the ventilator measures less exhaled flow while delivered flow remains constant, and the difference between the inspiratory and expiratory flows increases. When the difference is at least the operator-selected value for flow sensitivity, the ventilator triggers. If the patient is not inhaling, any difference between the delivered and exhaled flow is due to sensor inaccuracy or leaks in the patient system. To compensate for leaks in the patient system which can cause autocycling, the operator can increase flow sensitivity setting.

As a backup method of triggering inspiration, a pressure sensitivity of 2 cmH_2O is also in effect. This setting is the most sensitive setting that is still large enough to avoid autocycling, yet will trigger with acceptable patient effort.

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

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

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

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

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

Throughout the respiratory cycle, pressure transducers monitor inspiratory, expiratory, and atmospheric pressures. The temperature of the exhaled gas is heated to a temperature above its dew point to prevent condensation in the exhalation compartment. Appendix C provides a diagram of the ventilator's pneumatic system and patient circuit.

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

The ventilator includes the 802 BPS that supplies dc power to the ventilator if ac power is lost. A fully charged BPS operating under nominal ambient conditions can power the ventilator for at least 30 minutes (the BPS does not power the compressor unit). The BPS recharges during operation from ac power. The GUI indicates when the ventilator is operating on the BPS.

Emergency states include *ventilator inoperative* and *safety valve open (SVO)*. A ventilator inoperative condition always includes the SVO state, but an SVO state does not necessarily indicate a ventilator inoperative condition.

- *Ventilator inoperative*: The ventilator declares a ventilator inoperative condition if a hardware failure, or critical software error that could compromise safe ventilation, occurs. In case of a ventilator inoperative condition, the ventilator inoperative indicator lights and the ventilator enters the SVO state. To correct a ventilator inoperative condition, the ventilator must be turned off, then powered on again; at power on, a qualified service technician must run extended self test (EST). The ventilator must pass EST before normal ventilation can resume.
- *SVO*: The safety valve allows the patient to breathe room air unassisted when the ventilator is in the SVO state. The ventilator remains in the SVO state until the condition that caused the SVO state is corrected or, if the ventilator declared a ventilator inoperative condition, power on self test (POST) verifies that power levels to the ventilator are acceptable and that the major electronics systems are functioning correctly. If the ventilator enters the SVO state, the safety valve open

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

1.2 Graphic user interface

The *840* Ventilator System features a GUI that is designed to be intuitive to respiratory care practitioners. Figure 1-2 shows the ventilator GUI. This subsection defines the keys, indicators, and symbols you see on the GUI.

r screen:
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(alarms,
ent data)

r screen:
entilator
settings

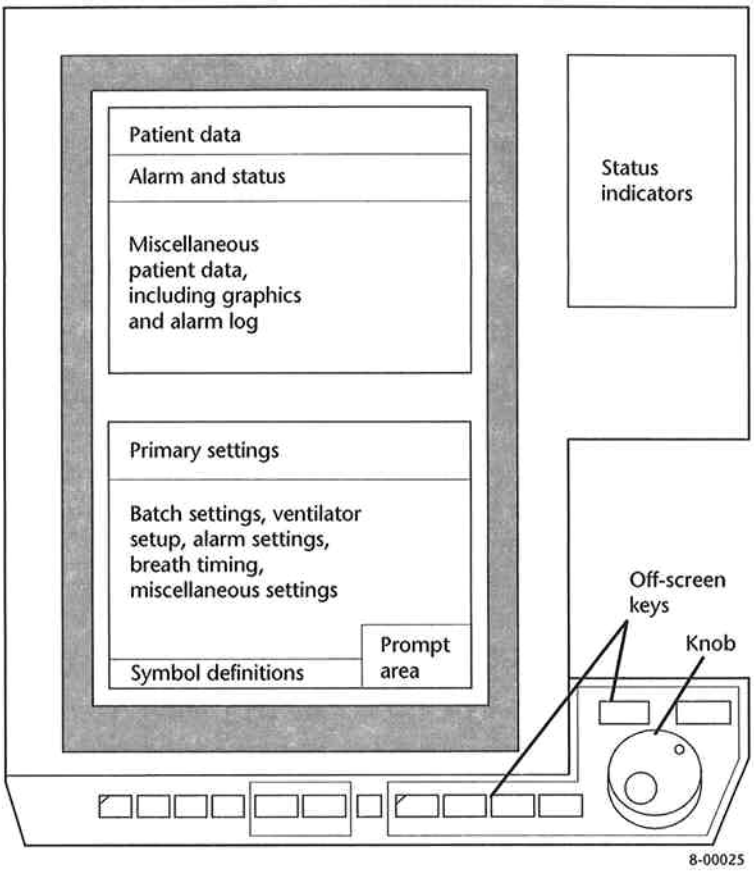


Figure 1-2. *840* Ventilator System graphic user interface (GUI)

1.3 Ventilator controls and indicators

The *840* Ventilator System includes the controls and indicators shown in Table 1-1.

Table 1-1: *840* Ventilator System controls and indicators

Control or indicator	Function
 8-10001	Screen lock key. When the yellow light on the screen lock key is lit, touching the screen or off-screen controls (including the knob and ACCEPT key) has no effect until you press the screen lock key again. New alarms (or when an alarm's urgency level escalates) automatically unlock the screen and controls. The screen lock allows you to clean the touch screen and prevents inadvertent changes to settings and displays.
 8-10002 (Inactive in color GUI)	Display contrast key. Allows you to adjust screen contrast when you hold down this key while turning the knob.
 8-10003 (Inactive in color GUI)	Display brightness key. Allows you to adjust screen brightness when you hold down this key while turning the knob.
 8-10004	Alarm volume key. Allows you to adjust the alarm volume when you hold down this key while turning the knob. You cannot turn off alarm volume.

e 1-1: *840* Ventilator System controls and indicators (continued)

trol or indicator	Function
 8-00402	Alarm silence key. Turns off alarm sound for 2 minutes. The yellow light on the alarm silence key lights during the silence period, and turns off if you press the alarm reset key or the 2-minute interval times out. A new high-urgency alarm cancels the silence. Every time you press the alarm silence key, the silence period resets to 2 minutes. Every time you press the alarm silence key (whether or not there is an active alarm), the keypress is recorded in the alarm log.
 8-00441	Alarm reset key. Clears active alarms or auto-resets high-urgency alarms, cancels an active alarm silence, and is recorded in the alarm log. (Pressing the alarm reset key is not recorded in the alarm log if no alarm is active.) You cannot reset a DEVICE ALERT alarm.
 8-10005	Displays basic operating information about the ventilator.
 8-00401	Delivers 100% oxygen (if available) for 2 minutes and calibrates the oxygen sensor. The green light on this key lights to indicate that 100% O_2 delivery is active. Pressing this key again restarts the 2-minute delivery interval. Oxygen sensor calibration can be tested using the procedure in Section D.2.
 8-00436	Delivers one manual breath to the patient according to the current mandatory settings. To avoid breath stacking, a manual inspiration is not delivered during inspiration or the restricted phase of exhalation. You can use the MANUAL INSP key to supplement minute volume or to help measure a patient data parameter, such as peak inspiratory pressure.

Table 1-1: *840* Ventilator System controls and indicators (continued)

Control or indicator	Function
 8-00419	Causes the ventilator to seal the patient's breathing circuit when the expiratory phase of a designated breath, mandatory or spontaneous, is followed by a mandatory inspiration. The maneuver allows gas pressure in the patient's lungs to equilibrate with that in the ventilator breathing circuit. This results in an elevation in the circuit pressure if $PEEP_I$ is present. An expiratory pause is used to estimate $PEEP_{TOT}$ and $PEEP_I$. The ventilator performs two types of pause maneuver: *automatic*, which is initiated by a momentary pressing of the EXP PAUSE key, and *manual*, which you control by holding the key down. Whatever the pause type, the maneuver begins when the expiratory phase of a breath is ended by the delivery of a subsequent mandatory breath. In the case of an automatic pause, the ventilator continues the maneuver until the pressure stabilizes, then takes its measurements. The pause lasts at least 0.5 second but no longer than 3.0 seconds. The automatic maneuver is best applied to patients whose airways remain open throughout exhalation, a situation that leads to a "crisp and clean" measurement. In the case of a manual pause, the ventilator takes its measurements as soon as the pressure stabilizes or the pause ends. It continues the maneuver until the EXP PAUSE key is released. The pause lasts no longer than 20 seconds. The manual maneuver is best applied to patients whose near end-expiratory flow shows signs of obstruction. The most recently selected graphics are displayed and frozen when the pause maneuver begins, so you can see when the expiratory pressure stabilizes. At the end of the maneuver, the values for $PEEP_I$ and $PEEP_{TOT}$ are displayed.

e 1-1: *840* Ventilator System controls and indicators (continued)

trol or indicator	Function
INSP PAUSE 8-00431	Causes the ventilator to seal the patient's breathing circuit after the end of the gas delivery phase of a designated, volume- or pressure-based mandatory inspiration. This lets the gas pressure in the patient's lungs equilibrate with that in the ventilator breathing circuit, resulting in a pressure "plateau." This maneuver provides a way to measure the patient's static lung-thoracic compliance (C), static resistance (R), and plateau pressure (P_{PLAT}) or to maintain the inflated state of the lungs. The ventilator performs two types of pause maneuver: *automatic*, which is initiated by a momentary pressing of the INSP PAUSE key, and *manual*, which you control by holding the key down. Whatever the pause type, the maneuver begins at the end of gas delivery (VC breath) or when the set inspiratory time (T_I) elapses (PC breath). The maneuver begins at the end of the gas delivery phase of the current or next breath. In the case of an automatic pause, the ventilator continues the maneuver until the pressure stabilizes, then takes its measurements. The pause event lasts at least 0.5 second but no longer than 2.0 seconds. An automatic pause is used to measure C, R (only on square wave, VC breaths), and P_{PLAT}. In the case of a manual pause, the ventilator computes C and R as soon as the pressure stabilizes. It continues the maneuver until the INSP PAUSE key is released, then takes its P_{PLAT} measurement. The pause event lasts no longer than 7 seconds. A manual pause is used to maintain the inflated state of the lungs (for example, to obtain a clearer chest X ray). You may overlay an INSP PAUSE, automatic or manual, on an existing plateau. The rules for activating either pause are the same as those given above. In the case of an automatic pause, because the pause must be at least 2.0 seconds long, a T_{PL} of less than 2.0 seconds is extended up to 2.0 seconds. If T_{PL} exceeds 2.0 seconds and the pause maneuver ends before T_{PL} elapses, the plateau lasts the full T_{PL} interval. In the case of a manual pause, the pause lasts at most the T_{PL} setting or the manual interval but never longer than 7 seconds. Activation of either pause maneuver during an existing plateau causes the ventilator to compute C and R as outlined above.

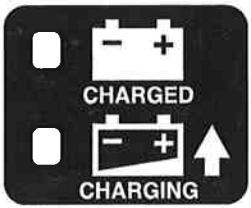
Table 1-1: *840* Ventilator System controls and indicators (continued)

Control or indicator	Function
 8-00431 (cont)	The estimated values for C and R may or may not have been computed from "good" data. For example, a leak may have prevented the establishment of a "flat" plateau, or the lung may not have fully emptied before the next inspiration began. During the pause maneuver, software checks the quality of the data. Compromised estimates for C and R are identified by special formatting and by text messages. The most recently selected graphics are displayed and frozen when the pause maneuver begins, so you can follow and assess the inspiratory pressure. P_{PLAT} is continuously updated and displayed during the inspiratory pause. C and R are displayed at the start of the next inspiratory phase. The R value, however, is computed and displayed only if the mandatory breath type is VC with square flow waveform. See the technical reference portion of this manual for more details.
 8-00433	Adjusts the value of a setting. A button that is highlighted means that the knob is linked to that setting. Where applicable, turning the knob clockwise increases the value, and turning the knob counterclockwise decreases the value.
 8-00415	Cancels a proposed setting.
 8-00406	Applies new settings.

e 1-1: *840* Ventilator System controls and indicators (continued)

rol or indicator	Function
	Red high-urgency alarm indicator (! ! !) blinks rapidly if active; it is steadily lit if autoreset. Yellow medium-urgency alarm indicator (! !) blinks slowly if active; it turns off if autoreset. Yellow low-urgency alarm indicator (!) is steadily lit if active; it turns off if autoreset. Green normal ventilator operation indicator steadily lit. This indicator is off if the ventilator is not in a ventilation mode, for example, during service mode or short self test (SST).
VENT INOP	Red ventilator inoperative indicator. The ventilator cannot support ventilation and requires service. The ventilator enters the safe state and discontinues detection of new patient data or alarm conditions. A qualified service technician must repair the ventilator to correct the problem and must execute EST successfully before normal ventilation is allowed. This indicator is accompanied by an audio signal and cannot be reset.
DISPLAY (GUI) INOP	Red loss of GUI indicator. The ventilator has detected a malfunction that prevents the GUI from reliably displaying or receiving information.
SAFETY VALVE OPEN	Red safety valve open (SVO) indicator. The ventilator has entered its safe state and opened its safety valve to allow the patient to breathe unassisted from room air.
BATTERY READY	Green BPS ready indicator. The ventilator senses that the BPS is installed, operational, and has at least 2 minutes of estimated run time.
BATTERY ON	On BPS power indicator. When yellow bar to the right of a lit BPS ready indicator (battery symbol) is lit, ventilator is operating on BPS, and ac power is insufficient to support ventilator operation. During BPS operation, power to the compressor unit and the humidifier outlet (if available) is off.

Table 1-1: *840* Ventilator System controls and indicators (continued)

Control or indicator	Function
COMPRESSOR READY	Green compressor ready indicator. The compressor logic cable and air supply hose are connected to the ventilator. The compressor is up to operating pressure but not supplying gas to the ventilator. The compressor motor turns on intermittently to keep the compressor chamber pressurized.
COMPRESSOR ON	Green compressor operating indicator. When symbol to the right of a lit compressor unit ready indicator is lit, compressor is supplying air to the ventilator. This indicator does not light unless the compressor is actually supplying air to the ventilator.
 8-00462	BPS charging indicator. When the ventilator is operating on mains power, the top symbol (green indicator next to gray battery icon) indicates that the BPS is charged, and the bottom symbol (yellow indicator next to gray battery icon) indicates that the BPS is charging.

1.3.1 Onscreen symbols and abbreviations

To see the definition of an onscreen symbol, touch it and look at the definition (lower left of lower screen). Table 1-2 summarizes the symbols and abbreviations the ventilator uses.

For example, if you press:

$\dot{V}_{MAX}$
21.8 $\frac{L}{min}$

The symbol definition area shows this message:

$\dot{V}_{MAX}$ **= Peak flow**

Table 1-2: *840* Ventilator System symbols and abbreviations

Symbol or abbreviation	Definition
(blinking) 8-00410	Additional active alarms (monitored information, displayed on upper screen). Symbol blinks if too many alarms are active to fit into alarm area.
↑	Alarm limit (high)
↓	Alarm limit (low)
 8-00409	Alarm log
 8-00409	Alarm log contains events that have not yet been viewed

Table 1-2: *840* Ventilator System symbols and abbreviations (continued)

Symbol or abbreviation	Definition
 8-00421	Flow acceleration
 8-00422	Flow pattern
 OLE2	Minimum or maximum limit reached
 8-00438	More monitored data
 8-00425	Graphics
 8-00449	x-axis adjust
 8-00449	y-axis adjust
 8-00412	Baseline pressure (PEEP) adjust
A/C	Assist control ventilation mode
AV	Apnea ventilation
C	Static compliance
E_{SENS}	Spont expiratory sensitivity %

Table 1-2: *840* Ventilator System symbols and abbreviations (continued)

Symbol or Abbreviation	Definition
EST	Extended self test
f	Respiratory rate (setting)
f_{TOT}	Total respiratory rate (monitored)
$\uparrow f_{TOT}$	High respiratory rate alarm
GUI	Graphic user interface
HME	Heat-moisture exchanger
I:E	Inspiratory to expiratory ratio
O_2	Delivered oxygen percentage (monitored data)
O_2	Oxygen percentage (setting)
$\uparrow O_2\%$	High delivered O_2% alarm
$\downarrow O_2\%$	Low delivered O_2% alarm
PC	Pressure control (mandatory breath type)
$\bar{P}_{CIRC}$	Mean circuit pressure
$\uparrow P_{CIRC}$	High circuit pressure alarm
$\bar{\uparrow} P_{CIRC}$	High circuit pressure alarm limit
$P_{CIRC\ MAX}$	Peak circuit pressure (monitored)
PEEP	Positive end expiratory pressure (setting)
$PEEP_I$	Intrinsic PEEP (monitored)
$PEEP_{TOT}$	Total PEEP (monitored)
$P_{E\ END}$	End expiratory pressure (monitored)
P_I	Inspiratory pressure (setting)

Table 1-2: *840* Ventilator System symbols and abbreviations (continued)

Symbol or abbreviation	Definition
$P_{I\ END}$	End inspiratory pressure (monitored)
P_{PLAT}	Plateau pressure (monitored)
POST	Power on self test
PS	Pressure support (spontaneous breath type)
P_{SENS}	Pressure sensitivity
P_{SUPP}	Pressure support (setting)
P-TRIG	Pressure triggering
$\uparrow P_{VENT}$	High internal ventilator pressure alarm
R	Static resistance
SIMV	Synchronous intermittent mandatory ventilation mode
SPONT	Spontaneous ventilation mode
SST	Short self test
T_A	Apnea interval
T_E	Expiratory time
T_I	Inspiratory time
T_{PL}	Plateau time
$\dot{V}_{E\ SPONT}$	Exhaled spontaneous minute volume
$\uparrow \dot{V}_{E\ TOT}$	High exhaled minute volume alarm
$\downarrow \dot{V}_{E\ TOT}$	Low exhaled minute volume alarm
VC	Volume control (mandatory breath type)
$\dot{V}_{MAX}$	Peak flow (setting)

Table 1-2: *840* Ventilator System symbols and abbreviations (continued)

Symbol or Abbreviation	Definition
$\dot{V}_{SENS}$	Flow sensitivity
V_T	Tidal volume
V_{TE}	Exhaled tidal volume
$\uparrow V_{TE}$	High exhaled tidal volume alarm
$\downarrow V_{TE\ MAND}$	Low exhaled mandatory tidal volume alarm
$\downarrow V_{TE\ SPONT}$	Low exhaled spontaneous tidal volume alarm
$\dot{V}_{TRIG}$	Flow triggering

1.4 Other ventilator labels and symbols

These symbols and labels appear on the *840* Ventilator System.

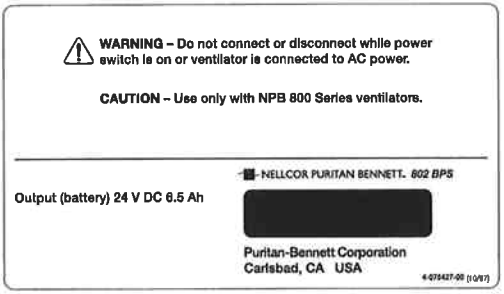
NOTE:
All labels shown are examples, and may not reflect the exact configuration of your ventilator.

ON  8-10006	Power switch positions. **ON** represents the on position; **O** represents the off position for only a part of the equipment. This switch turns off power to the BDU and GUI, but still allows the BPS to be charged if ac power is present.
 8-00400	Refer to manual. When this symbol appears on the product, it means refer to documentation for information.
 8-00445	Type B equipment, per IEC 601-1
 8-00426	Potential equalization point (ground). Provides a means of connection between the equipment and the potential equalization busbar of the electrical connection. A common grounding point for the entire ventilator.
IPX1 8-00432	Indicates the degree of protection provided by enclosure (drip-proof)
CE 0123 8-00414	Signifies compliance with the Medical Device Directive, 93/42/EEC
 8-00417	CSA and National Recognized Test Laboratory approval

1996-05 8-00465	Date of manufacture label
SN	Serial number
Data Key	Data key connection **Caution** Do not remove the data key. The data key cover can only be removed with a special tool designed specifically for that purpose. The data key enables software options and stores ventilator operational hours, compressor unit operational hours, and the serial numbers for the BDU and GUI. The data key is for use by a qualified service technician only, according to Nellcor Puritan Bennett service and installation instructions.
TEST	TEST (service) button. Used during SST and EST.
PTS 2000	Nellcor Puritan Bennett *PTS 2000*™ Performance Test System connection
Display (GUI)	GUI connection
Ventilator circuit breaker	Circuit breaker for ventilator power supply
mpressor & umidifier circuit breaker	Ventilator circuit breaker for compressor and humidifier
8-00405	Alternating current (at ac inlet and ac power indicator)
ompressor utlet: 5.6 A max	Maximum allowed output to auxiliary mains socket (compressor electrical connection)

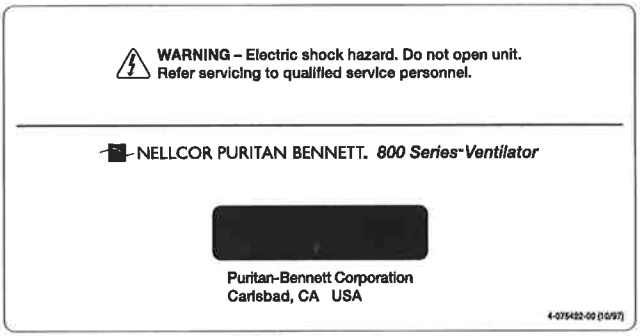
 8-00413	BPS electrical connection
 8-00434	Exhalation filter latch lock/unlock
	Exhalation filter latch open indicator. This red indicator is located on the surface behind the closed latch. It is only visible when the filter latch is open.
 8-00428	GUI mounting latch lock/unlock
RS-232	RS-232 port
 8-00443	Electric shock hazard
 8-00450	Explosion hazard
 8-00417	Fire hazard

BPS product information label



US/75427A

product information label



US/75422A

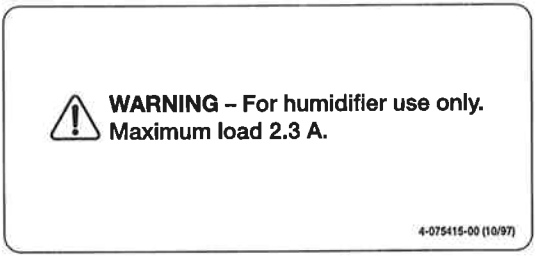
ports label

ote alarm and RS-232 port. Refer to Appendix E for GUI remote alarm and RS-232 specifications.

ENGLISH/75416A

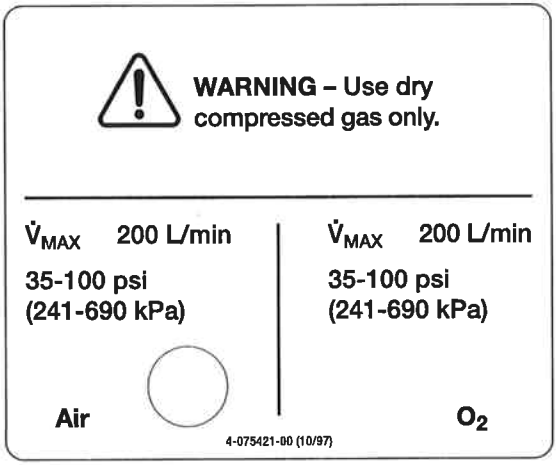
Humidifier electrical label

(This label not visible unless cover plate over humidifier electrical connection is removed.)



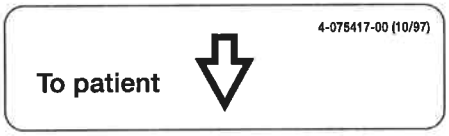
US/75415A

BDU gas inlet label



US/75421A

BDU To patient label

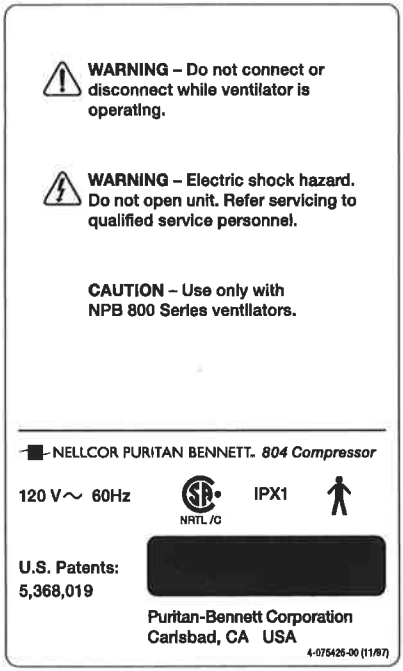


US/75417A

pressor gas connection label

US/75418A

pressor information label



US/75425B

BDU information label

WARNING – This ventilator is not intended to be a comprehensive monitoring device: some types of dangerous conditions will not activate alarms. Patients on life-support equipment should be appropriately monitored by competent medical personnel and suitable monitoring devices.

WARNING – Before use, read Operator's manual thoroughly. Before each use, check equipment for proper operation.

WARNING – Explosion hazard. Do not use near flammable anesthetics.

WARNING – Fire hazard. Keep all sources of ignition away from this device. Combustible materials ignite easily and burn with great intensity in air enriched with oxygen.

WARNING – Electric shock hazard. Do not open unit. Refer servicing to qualified service personnel.

CAUTION – USA federal law restricts this device to sale by or on the order of a physician.

NELLCOR PURITAN BENNETT. *800 Series Ventilator*

Ventilator
120 V~ 4.5 A 60 Hz

Ventilator and compressor
120 V~ 10.1 A 60 Hz

U.S. Patents:
4,954,799 5,161,525 5,271,389
5,301,921 5,319,540 5,339,807
5,390,666

[redacted]

Puritan-Bennett Corporation
Carlsbad, CA USA

LR 58941
NRTL /C

IPX1

4-075423-00 (10/97)

US/75423A

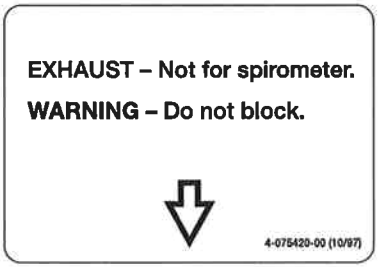
cooling vent label

US/75414A

I/O disconnect label

US/75419A

exhaust information label



US/75420A

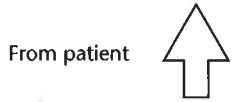
BPS electrical connection label

US/75334Lbl

Compressor lint filter label

US/75426A

Expiratory limb connector on exhalation filter



8-00423

SECTION 2

Getting started

This section tells you how to set up the ventilator, including:

- Connecting the electrical supply
- Connecting the air and oxygen supplies
- Connecting the patient circuit and accessories
- Things to do before beginning patient setup

Warning

- When lifting the ventilator, use assistance and appropriate safety precautions. Figure 2-1 shows the proper lifting technique for ventilator components.
- All components must be securely mounted and connected by a qualified service technician according to the appropriate Nellcor Puritan Bennett installation instructions.
- To avoid the possibility of damage to ventilator components or interrupted ventilator operation, always use the ventilator on a level surface in its proper orientation.
- To avoid the possibility of injury to the patient and ensure proper ventilator operation, *do not* attach any device to the port labeled EXHAUST unless the device is specifically authorized by Nellcor Puritan Bennett.
- To minimize the increased risk of fire due to an oxygen-enriched environment, do not use the ventilator in a hyperbaric chamber.
- To avoid raising the oxygen concentration of room air, use the ventilator in an adequately ventilated room.
- Do not connect or disconnect the ventilator's graphic user interface (GUI), backup power source (BPS), or compressor while the power switch is on or the ventilator is connected to ac power

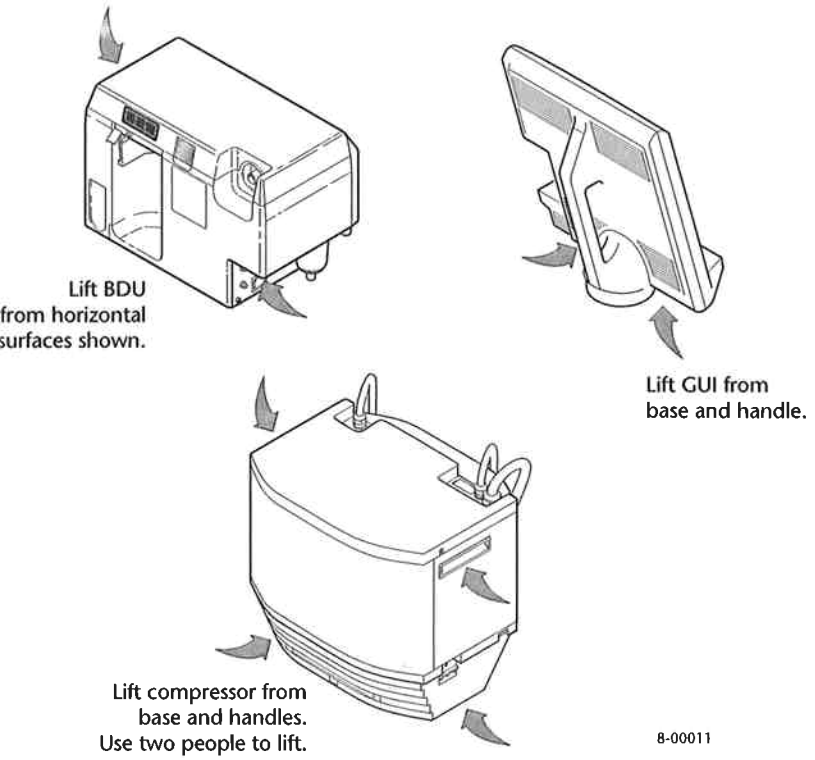


Figure 2-1. Lifting ventilator components

Caution

- Do not obstruct the BDU, GUI, or compressor cooling fan vents.
- To avoid the possibility of damage to ventilator components, do not use the horizontal surfaces of the ventilator to place or stack objects.

NOTE:

- For first-time installation, refer to the separate installation instructions supplied with your ventilator.
- If the compressor module is removed from the ventilator, make sure the compressor port plug is reinstalled.
- Nellcor Puritan Bennett recommends that before using the ventilator for the first time, you wipe the ventilator exterior clean and sterilize its components according to the instructions in Section 7 of this manual. Follow your institution's protocol for cleaning and sterilizing the ventilator and its components.

2.1 Connecting the electrical supply

Warning

- To avoid electrical shock hazard, connect the ventilator power cord into a grounded ac power outlet.
- If used in the US, connect the ventilator to an ac receptacle marked "Hospital Only" or "Hospital Grade" to ensure grounding reliability.
- The BPS must always be installed. Without the BPS, the ventilator is not protected against low or lost ac power. Do not use the ventilator unless a BPS with at least minimal charge is installed.

Normally the *840* Ventilator System is mains-powered. The 802 BPS operates the ventilator when ac power is lost or drops below a minimum level.

A new, fully charged BPS lets you run the ventilator (without compressor or humidifier) for at least 30 minutes; thus, the BPS can power the ventilator for transport purposes within the respiratory care facility.

NOTE:

The BPS is intended for short-term use only, and is not intended as a primary alternative power source. The BPS is intended to power the BDU and GUI only. In case of ac power loss, no power is available for the compressor and humidifier.

If you turn on the ventilator after it has been unplugged for an extended period, the LOW BATTERY alarm may become active. If so, recharge the BPS by leaving it connected to a powered-on ventilator for up to 8 hours. If the LOW BATTERY alarm is still active or if the INOPERATIVE BATTERY alarm is active, the BPS battery must be replaced (contact a qualified service technician).

Figure 2-2 shows how to connect the power cord to ac power. A power cord retainer protects against accidental disconnection, and must always be in place during operation.

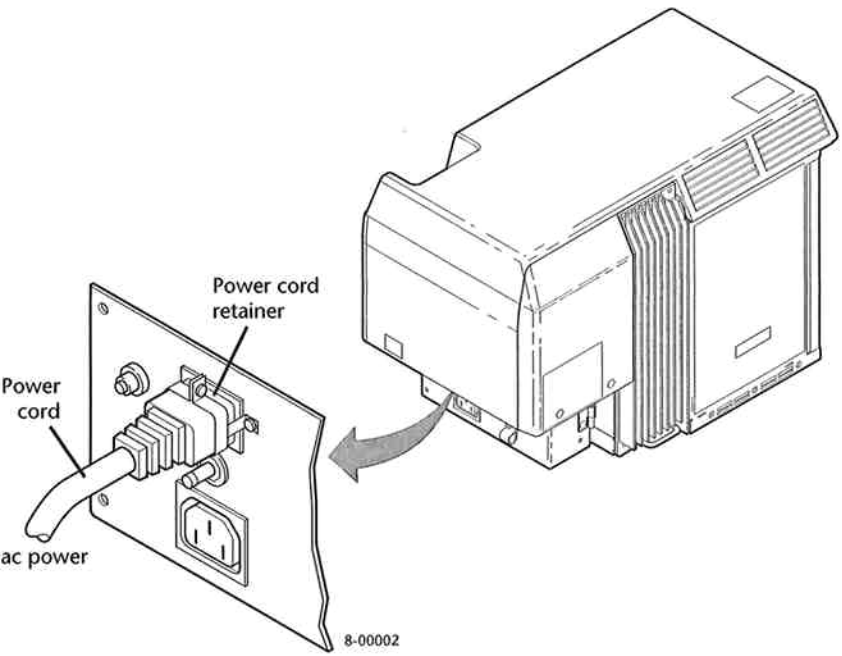


Figure 2-2. Connecting the ventilator power cord

Figure 2-3 shows the power switch and ac indicator. The ac indicator indicates that the ventilator is receiving ac power and that the BPS will be recharged as needed. The ac indicator is independent of the power switch, and the power switch does not turn off ac power to the ventilator power supply. When the power switch and ac indicator are on, power is available to the humidifier and compressor.

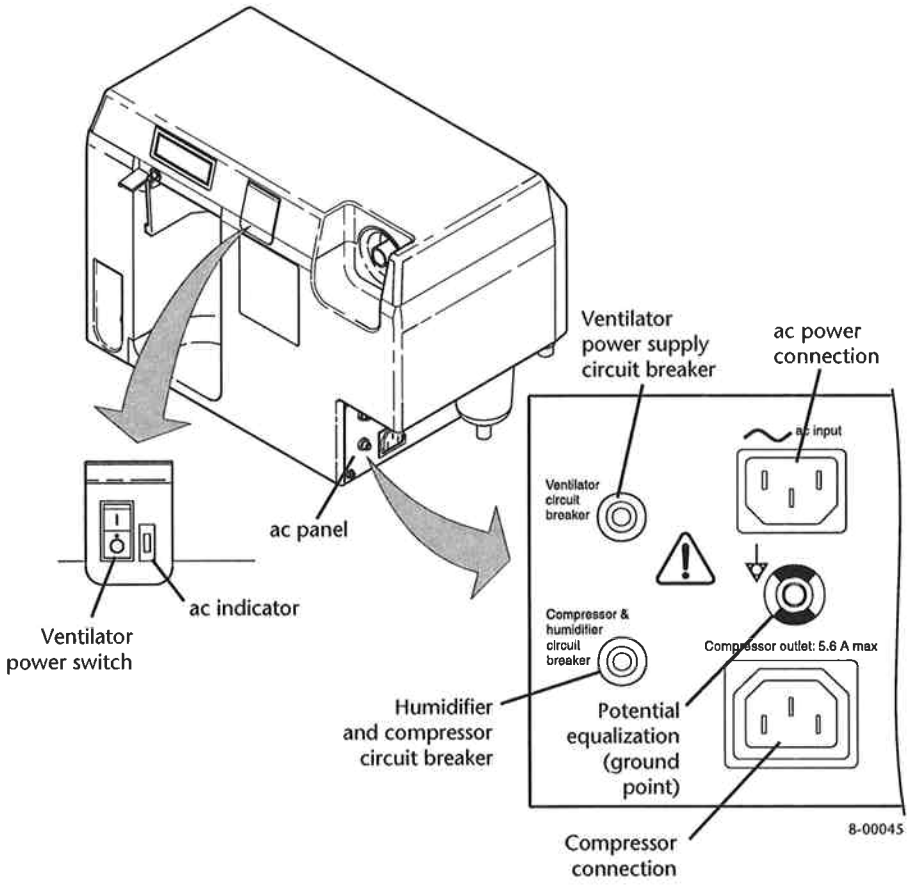


Figure 2-3. Ventilator power switch, ac indicator, and ac panel

If the ventilator power supply circuit breaker (located on the ventilator's ac panel, Figure 2-3) opens but ac power is still present and the ventilator is operating on BPS, power is still available to the humidifier and compressor connectors (although ventilator software disables compressor operation).

When the power cord is not in use, you can wrap the power cord around the hook on the back of the cart for convenient storage (see Figure 2-4).

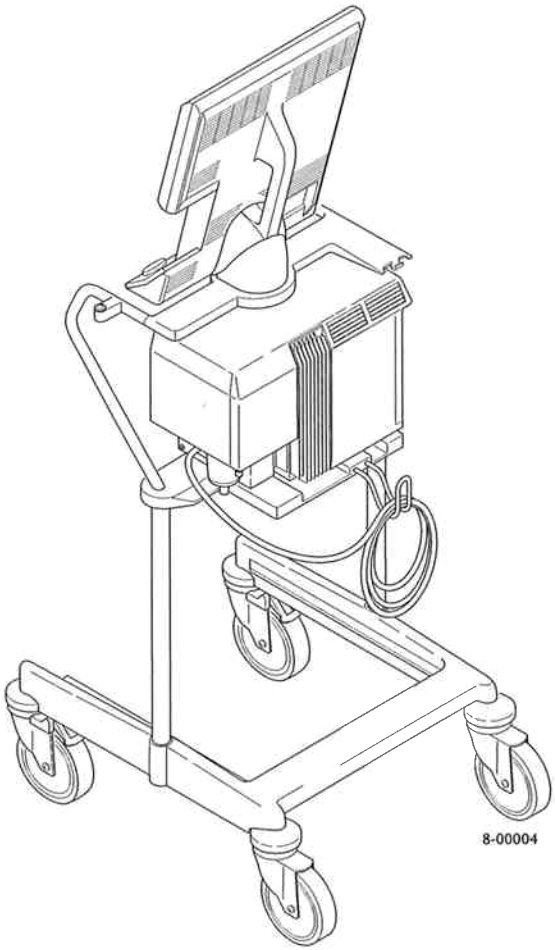


Figure 2-4. Storing the power cord on the cart

2.2 Connecting the air and oxygen supplies

The *840* Ventilator System can use air and oxygen from cylinder or wall supplies. Follow these steps to connect the air and oxygen supplies:

1. Ensure that the supply pressures are 35 to 100 psi (241 to 690 kPa).
2. Connect the supply hoses to the inlet connectors at the rear of the ventilator (see Figure 2-5).

Warning

- Connect only air to the air inlet, and only oxygen to the oxygen inlet. Do not attempt to switch air and oxygen or connect any other gas.
- To ensure that a constant gas supply is available to the patient, always connect at least two gas sources to the ventilator. There are three gas source connections: the compressor, air inlet, and oxygen inlet.

Caution

To prevent damage to the ventilator, ensure that the connections to the air and oxygen supplies are clean and unlubricated, and that there is no water in the air or oxygen supply gas. If you suspect water in the air supply gas, use an external wall air water trap to prevent water damage to the ventilator or its components.

NOTE:

Whenever a pressurized air or oxygen source is connected to the ventilator, the air and oxygen regulators have a maximum bleed rate of 3 L/min, even when the ventilator is not in use. Always factor in this bleed rate when calculating air and oxygen usage.

When the air and oxygen hoses are not in use, you can wrap them around the hook on the back of the cart for convenient storage (Figure 2-5).

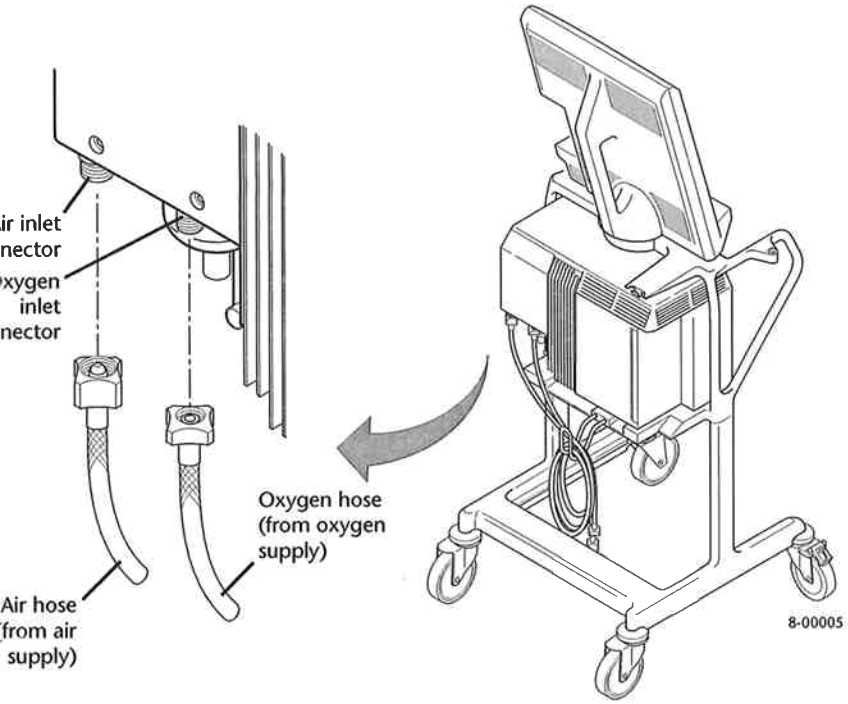


Figure 2-5. Connecting the air and oxygen supplies

2.3 Connecting the patient circuit

Warning

- To minimize the risk of bacterial contamination or component damage, inspiratory and expiratory filters must always be handled with care and connected to the ventilator during use.
- To minimize the risk of patient injury, use only patient circuits qualified for use in oxygen-enriched environments with the *840* Ventilator System. Do not use antistatic or electrically conductive tubing. To ensure a leak-tight connection, only use connectors and tubes with ISO-standard cone and socket fittings (or use adapters to connect barbed cuff fittings to ISO-standard fittings).
- Using an external, pneumatically-powered nebulizer with the *840* Ventilator adds flow to the patient circuit and can adversely affect spirometry, delivered O_2%, delivered tidal volumes, and breath triggering.
- Nellcor Puritan Bennett recommends that you use one of the patient circuits identified by Nellcor Puritan Bennett, or their equivalents to ensure that the maximum pressure/flow values specified by EN794-1 are not exceeded (see Appendix A of this manual for patient circuit testing specifications). Using a circuit with a higher resistance does not prevent ventilation, but can cause a short self test (SST) fault or compromise the patient's ability to breathe through the circuit.

NOTE:

- Nellcor Puritan Bennett recommends that you run SST every 15 days, between patients, and when you change the patient circuit (particularly when you change circuit type, for example, from adult to pediatric). Nellcor Puritan Bennett recognizes that the protocol for running SST varies widely among health care institutions. It is not possible for Nellcor Puritan Bennett to specify or require specific practices that will meet all needs, or to be responsible for the effectiveness of those practices.
- Use low-compliance patient circuits to ensure optimum compliance compensation, and use only pediatric patient circuits when the patient ideal body weight (IBW) is less than or equal to 24 kg (53 lb). For patients whose IBW is less than or equal to 24 kg the compliance compensation volume limit is four times the set tidal volume, in addition to the set tidal volume. To avoid triggering a SEVERE OCCLUSION alarm, do not use neonatal patient circuits.
- The ventilator uses an oxygen sensor to trigger an alarm if the delivered O_2% is seven percentage points above or below the O_2% setting, or below 18%.

Figure 2-6 shows how to connect the patient circuit, including the inspiratory filter, humidifier (if used), inspiratory limb, patient wye, expiratory limb, collector vial, and expiratory filter.

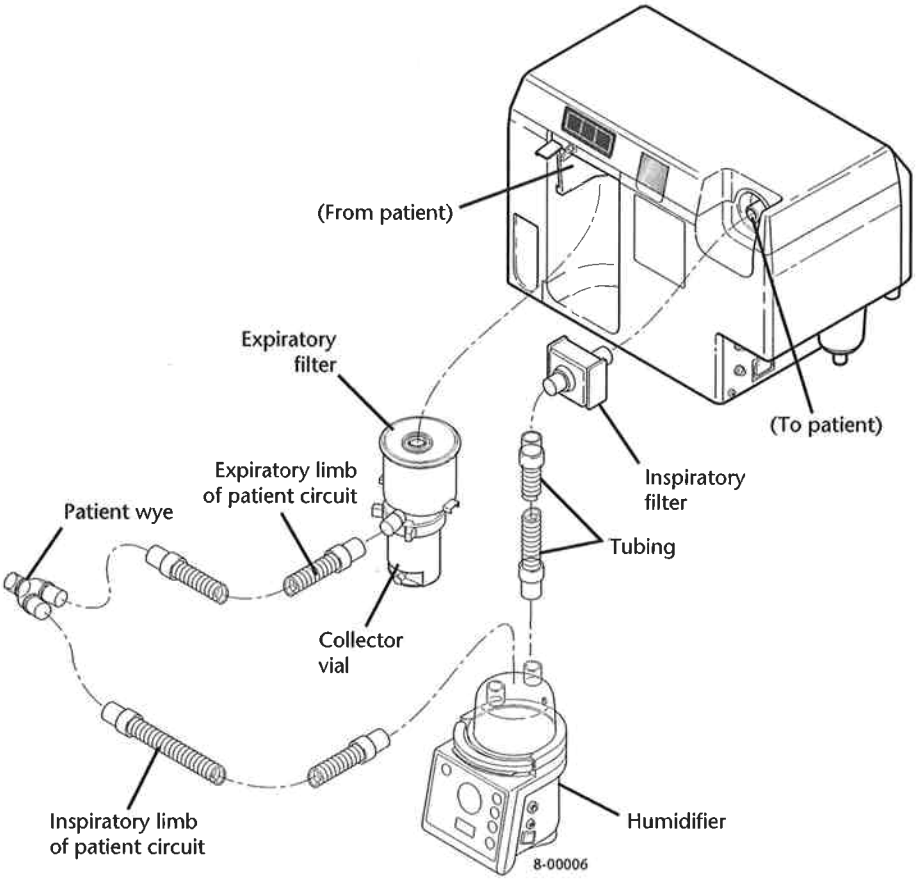


Figure 2-6. Connecting the patient circuit

2.3.1 Installing the expiratory filter and collector vial

Install the expiratory filter and collector vial as follows:

1. With the exhalation filter latch in up position (see Figure 2-7), slide filter into housing area with expiratory limb connection facing toward you.
2. Push latch down; it will position the filter properly.
3. Attach the expiratory limb of the patient circuit to the filter's expiratory limb connection.

If you are not using the drain bag, cap the collector vial drain port.

If you are using the drain bag:

1. Install clamp on tubing.
2. Uncap collector vial drain port and install tubing to collector vial drain port.
3. Connect other end of tubing to drain bag.

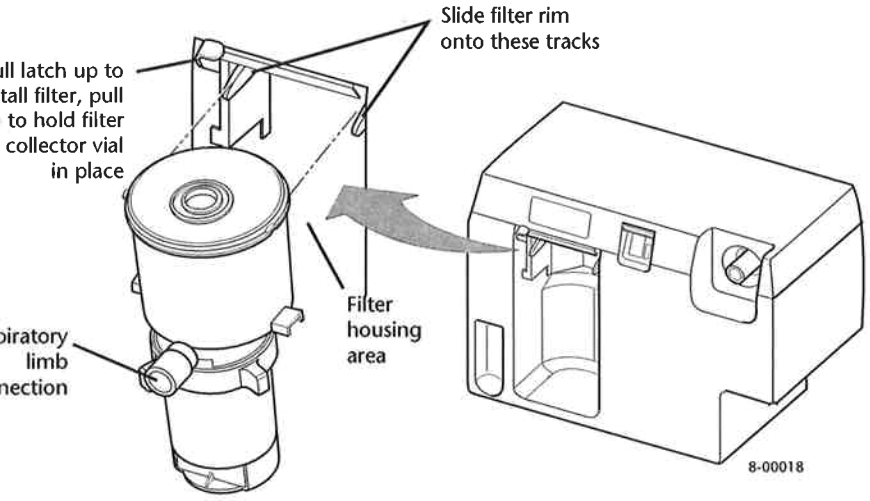


Figure 2-7. Installing the expiratory filter and collector vial

4. If the ventilator is mounted on the cart, place the drain bag in the cart drawer (Figure 2-8).

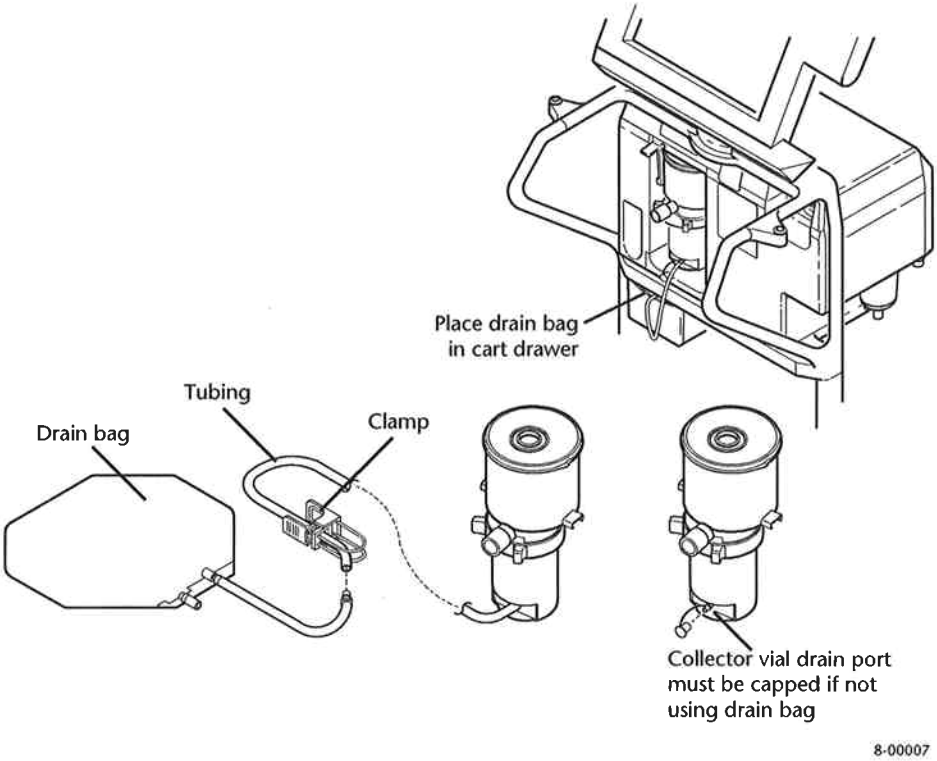


Figure 2-8. Using the collector vial with or without drain bag

Warning

To ensure that all patient circuit connections are leak-tight, perform a circuit leak test by running SST every time you install the filter on a ventilator.

Caution

Adding accessories to the ventilator can increase system resistance. Ensure that any changes to the recommended ventilator circuit configurations do not exceed the values for inspiratory and expiratory resistance provided in Appendix A. Do not add accessories to the patient circuit after running SST (which measures circuit compliance).

NOTE:

- The drain bag is designed to lie flat, and should not be suspended.
- Check the inspiratory and expiratory limbs of patient circuit and the collector vial and in-line water traps regularly for water buildup. Under certain conditions, they can fill quickly. Empty and clean the collector vial and in-line water traps as necessary.

2.3.2 Installing the flex arm

Figure 2-9 shows you how to install the flex arm onto one of the threaded sockets on the cart.

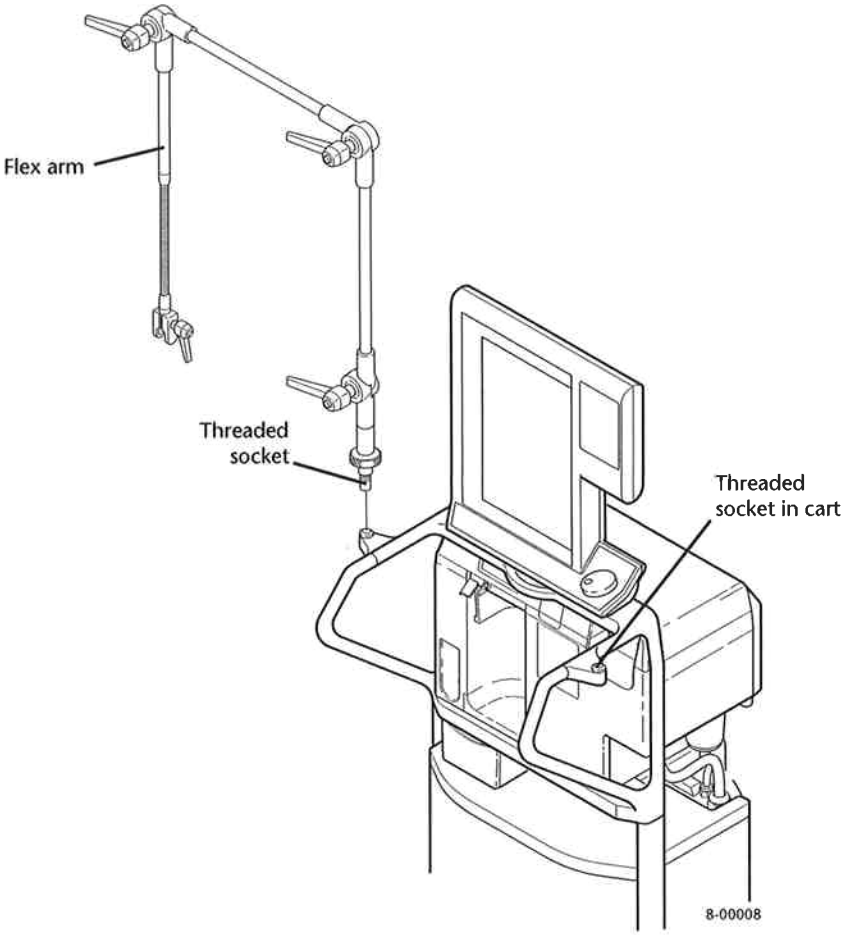


Figure 2-9. Installing the flex arm

2.3.3 Installing the humidifier

The ventilator has an electrical outlet for a humidifier. Figure 2-10 shows you how to install the humidifier onto the ventilator; a Fisher & Paykel humidifier is shown.

Warning

When using a Fisher & Paykel humidifier with the *840* Ventilator, use the Fisher & Paykel model 210 or 250 humidifier chamber for adult patients and the model 220 or 290 humidifier chamber for pediatric patients. The use of other Fisher & Paykel humidifier chambers may result in water being splashed into the patient circuit during circuit disconnects and high peak flow rate conditions.

Caution

- A qualified service technician must install the humidifier mounting hardware.
- To avoid equipment damage due to liquid ingress, do the following:
  - When the humidifier is not plugged into the ventilator, make sure the flat cover plate is installed over the humidifier outlet.
  - When the humidifier is plugged into the ventilator, make sure the plug cover is installed.

NOTE:

- To ensure uninterrupted ventilator operation, do not install a humidifier whose maximum current capabilities exceed 2.3 A (maximum power consumption 270 VA).
- When installing a Fisher & Paykel humidifier, make sure the humidifier has a right-angle electrical plug. A short power cord is preferable.
- To ensure that ventilator occlusion detection operates properly, do not use Puritan-Bennett Cascade humidifiers with the *840* Ventilator System. If you have further questions regarding humidifiers qualified for use with the *840* Ventilator System, contact your Nellcor Puritan Bennett representative.

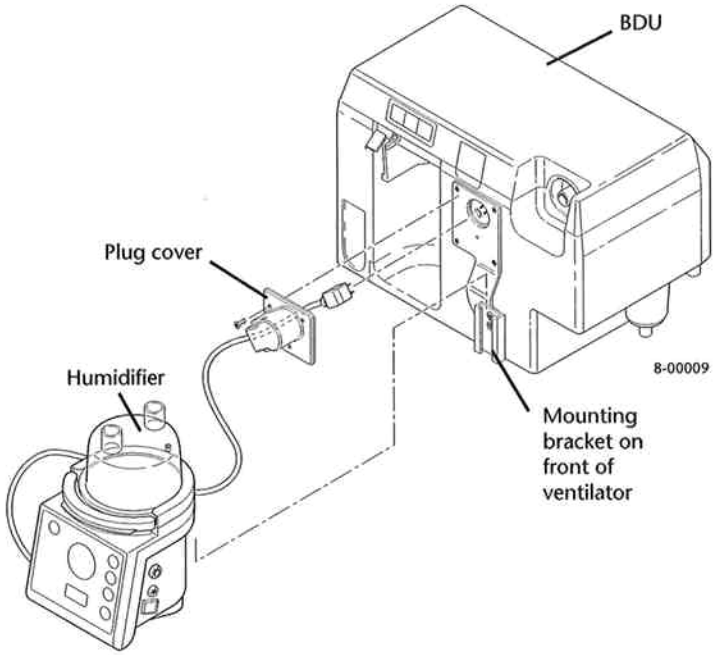


Figure 2-10. Installing the humidifier (Fisher & Paykel version shown)

2.3.4 Using the ventilator cart

Figure 2-11 shows you how to lock and unlock the cart's front wheels.

Warning

To avoid the possibility of interrupted ventilator operation or damage to ventilator components, use the cart to move the ventilator. Do not use cables or circuit components to push or pull the ventilator.

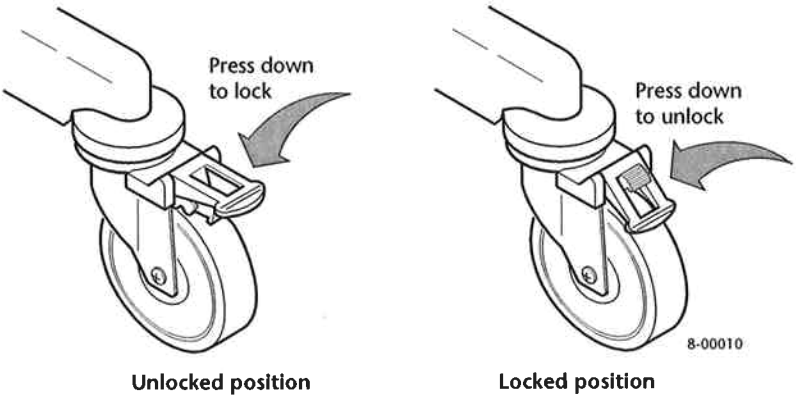


Figure 2-11. Locking and unlocking the cart's front wheels

2.4 Before you begin patient setup

NOTE:

For optimal ventilator performance, let the unit run for at least 10 minutes before using on a patient or running SST to allow heaters to warm up.

Follow these steps before you begin patient setup (described in Section 4):

1. Run SST to verify correct ventilator operation, check the patient circuit for leaks, and calculate patient circuit compliance. Section 3 tells you how to run SST.
2. Press the 100% O_2/CAL 2 min key to calibrate the oxygen sensor. Pressing this key also delivers 100% O_2, if available, for 2 minutes.
3. A qualified service technician must run extended self test (EST), including exhalation valve, flow sensor, and atmospheric pressure transducer calibration, before using the ventilator for the first time. The *840 Ventilator System Service Manual* tells you how to run EST.

NOTE:

Alarm functionality is tested and verified as part of POST, SST, and EST. You may also want to run an alarm check, found in Appendix D, which demonstrates the alarms' operation.

SECTION 3

Running short self test

Short self test (SST) is a short (about 3 minutes) and simple sequence of tests that verify proper ventilator operation, check the patient circuit (including tubing, humidification device, and filters) for leaks, and measure the circuit compliance. SST also checks exhalation filter resistance.

Warning

- Disconnect the ventilator from the patient before running SST. Running SST while the ventilator is connected to the patient can injure the patient.
- An ALERT identified in SST indicates that the ventilator or an associated component is defective. A defective ventilator or associated component should be repaired before the ventilator is returned to service, unless it can be determined with certainty that the defect cannot create a hazard for the patient, or add to the risks which may arise from other hazards.
- When running SST, make sure the patient circuit is configured exactly as it will be used on the patient (for example, with same accessories). Do not add accessories to the patient circuit after running SST.

NOTE:

- Nellcor Puritan Bennett recommends that you run SST every 15 days, between patients, and when you change the patient circuit. Nellcor Puritan Bennett recognizes that the protocol for running SST varies widely among health care institutions. It is not possible for Nellcor Puritan Bennett to specify or require specific practices that will meet all needs, or to be responsible for the effectiveness of those practices.
- Use SST to check the patient circuit for leaks and to calculate circuit compliance and resistance. Always rerun SST whenever you change the circuit type or the humidification type, or when you install a new or sterilized exhalation filter. Table 3-1 summarizes the functions of SST.
- If the ventilator has not reached operating temperature from recent usage, allow it to warm up for at least 10 minutes before running SST to ensure accurate testing.

Table 3-1: SST sequence of tests

Test step	Function	Comments
SST Setup	Asks you to specify the patient circuit type and humidification type.	Once you've specified these components, press ACCEPT. Incorrectly specifying the circuit or humidification types can cause faulty occlusion detection and expiratory spirometry.
SST Flow Sensor Test *Connect circuit with insp filter and without humidifier*	Asks you to connect the patient circuit with inspiratory filter (but without humidifier).	Once you've connected the patient circuit with inspiratory filter (but without humidifier), press ACCEPT.
	NOTE: Even if you are using a patient circuit with humidifier, you must remove it during this step.	
SST Flow Sensor Test *Block wye*	Asks you to block the patient wye.	Once you've blocked the wye, press ACCEPT.
SST Flow Sensor Test *Connect humidifier if applicable*	Asks you to now connect the humidifier. Checks the accuracy of the exhalation flow sensors.	To ensure proper compliance compensation when using a humidifier, make sure the jar is full of water. FAILURE if not passed (cannot be overridden).
Circuit Pressure Test	Verifies proper function of pressure sensors.	FAILURE if not passed (cannot be overridden).
Circuit leak	Displays the drop in circuit pressure in 10 seconds. (Determines the ability of the circuit to hold pressure.)	Overriding an ALERT could cause improper compliance compensation, inaccurate tidal volume delivery, or autocycling. FAILURE if test detects excessive leak.

Table 3-1: SST sequence of tests (continued)

Test step	Function	Comments
Expiratory filter *Disconnect at FROM PATIENT port*	Asks you to detach circuit tubing from the expiratory filter.	Once you've detached the tubing, press ACCEPT.
Expiratory filter *Connect to FROM PATIENT port*	Displays the pressure drop across the expiratory filter. Asks you to reattach tubing.	Once you've reattached the tubing, press ACCEPT. Overriding an ALERT could cause inaccurate patient pressure estimation. FAILURE if test detects exhalation compartment occlusion, expiratory filter occlusion, or if you do not follow prompts to detach and reattach tubing correctly.
Circuit Resistance *Unblock wye*	Asks you to unblock the patient wye.	Once you've unblocked the wye, press ACCEPT.
Circuit Resistance	Displays the pressure drop across the inspiratory and expiratory limbs, including the effect of all devices on each limb (filters, humidifier, water traps).	Overriding an ALERT could cause inaccurate patient pressure estimation. FAILURE if test detects excessive or low limb resistance, or if you do not follow the prompt to unblock the wye.
Compliance calibration *Block wye*	Asks you to block the patient wye.	Once you've blocked the wye, press ACCEPT.
Compliance calibration	Displays the compliance of the patient circuit.	Overriding an ALERT could cause improper compliance compensation or inaccurate tidal volume delivery. FAILURE if test detects out-of-range compliance.
Compliance calibration *Unblock wye*	Asks you to unblock the patient wye.	Once you've unblocked the wye, press ACCEPT.

1. If attached, remove the gold standard circuit (the test circuit designed for use with extended self test (EST)) from the ventilator, and install the circuit to be used on the patient. Do not attach a test lung to the circuit.

Caution

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

2. Ensure that the patient is not connected to the circuit and that the patient wye is unblocked.
3. Turn the power switch (at the front of the ventilator) on and enter normal ventilation.
4. At the *Ventilator Startup* screen (lower GUI screen), touch SST, then press the TEST button (on the side of the ventilator) within 5 seconds. Waiting longer than 5 seconds cancels the SST prompt.
5. At the *SST Setup* screen (lower GUI screen), select the patient circuit and humidification type, then press ACCEPT.

Warning

Incorrectly specifying the patient circuit type or humidification type (or changing either type after you've run SST) can affect the accuracy of compliance calculation and delivered and measured exhaled tidal volume. You must rerun SST to change the circuit type. You can change the humidification type during ventilation by touching the OTHER SCREENS, then the More Settings buttons.

6. The ventilator automatically starts the test sequence. The SST Flow Sensor, Expiratory Filter, Circuit Resistance, and Compliance Calibration tests require your intervention, and will wait indefinitely for your response. Otherwise you don't need to do anything until a test result is ALERT or FAILURE, or SST is complete.

7. As each test is performed, the *SST Status* screen shows test results (see Table 3-2).

Warning

To ensure reliable SST results, *do not* repeat an individual test with a different patient circuit if the test result is FAILURE or ALERT. If you suspect a defective patient circuit, restart SST from the beginning with a different patient circuit.

Table 3-2: SST individual test results

test is:	It means:	Do this:
ED	No faults found.	Nothing, unless prompted by the ventilator.
T	Test results not ideal, but not critical. SST halts.	Touch one of these buttons, then press ACCEPT: RESTART SST — Repeat SST from the beginning REPEAT — Repeat the test NEXT — Skip to the next test
URE	A critical problem has been detected, and SST cannot complete until the ventilator passes the failed test.	Touch one of these buttons: RESTART SST — Repeat SST from the beginning REPEAT — Repeat the test

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

Warning

To ensure ventilation that correctly compensates for circuit resistance and compliance, do not exit SST and begin normal ventilation until the entire SST has been successfully completed with the circuit to be used attached.

9. When all of the tests in SST are complete, the *SST Status* screen displays all individual test results and SST outcome. Table 3-3 summarizes overall SST outcomes and how to proceed in each case.
10. To begin normal ventilation (if SST has not detected an ALERT or FAILURE), touch EXIT SST, then press ACCEPT. The ventilator reruns POST.
11. The ventilator displays the *Ventilator Startup* screen. Confirm or change the last valid settings.

Table 3-3: Overall SST outcomes

ome	It means:	Do this:
d	All tests passed.	Touch one of these buttons: EXIT SST — Exit SSt and begin normal ventilation. Press ACCEPT. RESTART SST — Then press ACCEPT to repeat SST from the beginning.
T	One or more faults were detected. If it can be determined with certainty that this cannot create a hazard for the patient, or add to the risks which may arise from other hazards, the user can choose to override the ALERT status and authorize ventilation.	Touch one of these buttons: RESTART SST — Then press ACCEPT to repeat SST from the beginning. OVERRIDE — Then press ACCEPT to override the alert, as allowed by your institution's protocol. Touch EXIT SST, then press ACCEPT to begin normal ventilation.
IRE	One or more critical faults were detected. The ventilator enters a ventilator inoperative state and cannot be used for normal ventilation until it passes SST. Service required.	Restart SST with a different patient circuit. Touch: RESTART SST — Then press ACCEPT to repeat SST from the beginning. If the FAILURE persists, contact a qualified service technician.

SECTION 4

Ventilator settings

This section tells you:

- How to start up the ventilator for a new or previous patient
- When to attach a patient
- How to change settings one at a time
- How to change several settings at once (batch setting changes)
- How to set the humidification type, expiratory sensitivity, O_2 sensor enable/disable, and disconnect sensitivity
- How to set the variable that remains constant during rate change
- How to set alarms
- The ranges and accuracies for settings, alarms, and monitored data

NOTE:

- Early ventilator versions have a PROCEED button, which has been removed in later versions. If your ventilator has the button, follow onscreen prompts for its use. (In some procedures you touch the PROCEED button before pressing the ACCEPT key.)
- The graphic user interface (GUI) *DualView* touchscreens use light beams to detect where you have touched the screen. To avoid triggering a DEVICE ALERT alarm, do not place any foreign substances or objects on the screen.

Patient setup

Warning

Do not attach a patient before completing patient setup. Attaching a patient before the setup procedure is complete causes a PROCEDURE ERROR alarm and begins safety ventilation.

Once you turn on the ventilator, the ventilator runs POST, then displays the *Ventilator Startup* screen (see Figure 4-1) on the lower screen. Watch the prompt area (lower righthand corner of lower screen) for directions throughout the setup process.

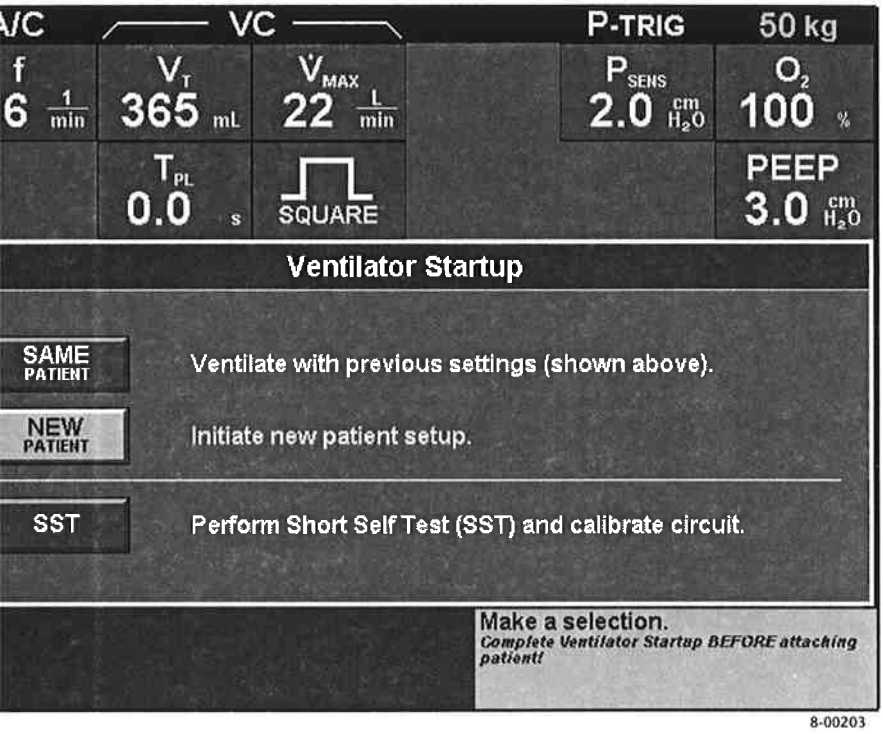


Figure 4-1. *Ventilator Startup* screen

If you touch SAME PATIENT: Press ACCEPT to continue ventilating with the most recent settings. Ventilation does not begin until a patient is connected.

If you touch NEW PATIENT:

1. Touch the ideal body weight (IBW) button, then turn the knob to adjust the IBW. Many initial settings and setting limits are automatically determined based on the IBW. The proposed value is highlighted (shown in *italics* and with a different color).

Warning

For proper operation of the *840* Ventilator, a setting of the patient's ideal body weight (IBW) must be entered. Several initial settings, boundary limits, and parameter values are set based on the value for IBW. The relationship between a patient's height and IBW can be determined from Table 4-5.

2. Touch CONTINUE (this button does not appear until you touch IBW), or touch RESTART to return to the *Ventilator Startup* screen.
3. At the next new patient settings screen, these settings appear:

   Mode: assist/control (A/C), SIMV, SPONT, or BILEVEL.

   Mandatory Type: pressure control (PC) or volume control (VC). The mandatory type is always PC if you chose the BILEVEL mode. In the SPONT mode, the mandatory type setting applies to manual inspirations only.

   Spontaneous Type: pressure support (PS) or NONE. The spontaneous type button doesn't appear if the selected mode is A/C.

   Trigger Type: P-TRIG (pressure) or V̇-TRIG (flow).

   For any setting you want to change, touch its button and turn the knob to select the value. When you are finished changing settings, touch CONTINUE.

4. At the final new patient settings screen, more settings appear. Touch each setting you want to change, then turn the knob to select its value. To cancel a selected change press CLEAR immediately after you've made a change.
5. Press ACCEPT to put all settings into effect. Normal ventilation begins once a patient is connected.
6. The *APNEA SETUP* screen appears. Apnea settings are automatically determined based on IBW and mandatory breath type, but can be changed. Although you aren't required to change or confirm apnea settings, you should verify that they are appropriate for the patient. If you change any apnea settings, press ACCEPT to apply.

NOTE:

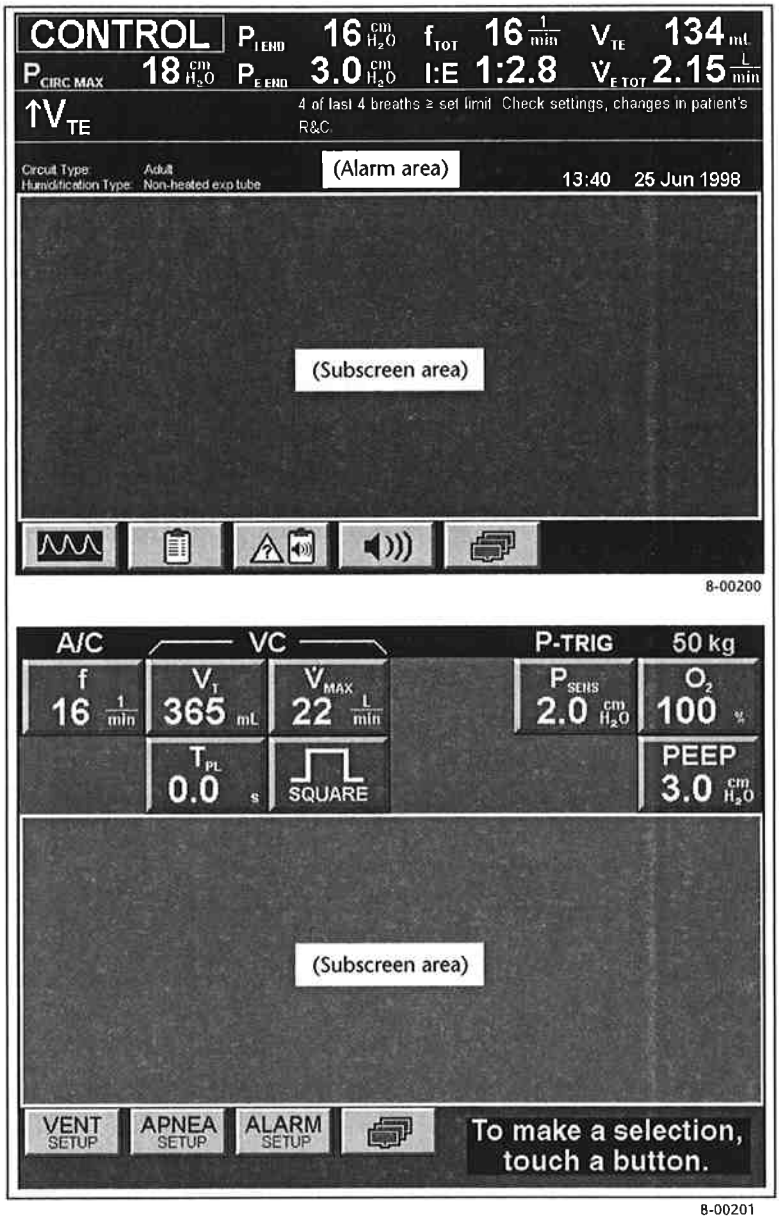
To calibrate the ventilator's oxygen sensor, press the 100% O_2/CAL 2 MIN key. This causes the ventilator to deliver 100% oxygen (if available) for 2 minutes and calibrates the oxygen sensor. The ventilator's oxygen monitoring feature is always active unless you disable the oxygen sensor (see the *More Settings* screen).

When patient setup is complete

Once the settings are accepted, you can attach a patient to the ventilator. Ventilation only begins when the ventilator senses that a patient is attached. If you attach a patient before completing setup, the ventilator begins safety ventilation and declares a PROCEDURE ERROR alarm that resets once patient setup is complete.

The top of the upper screen shows monitored data (out-of-range data flashes). Once ACCEPT has been pressed to put all settings into effect, ventilator settings are displayed across the top of the lower screen. See Figure 4-2.

After ventilation starts, you can change ventilator settings by using the procedures that follow.



Monitored data (upper GUI screen)

Ventilator settings (lower GUI screen)

Figure 4-2. Screen displays after normal ventilation begins

Main settings (individual) changes

Main settings are the buttons displayed at the top of the lower screen, and you can only change them individually. Follow these steps to change main settings:

1. *Touch* the setting you want to change.
2. *Turn* the knob to the set the desired value.
3. Press *ACCEPT* to apply the new setting.

Mode, breath type, and batch (multiple) changes

1. Touch the VENT SETUP button on the lower screen. The *Current Vent Setup* screen appears.
2. To change ventilation setup (mode, mandatory breath type, spontaneous type, or trigger type), *touch* its button then *turn* the knob to set the value. Proposed changes are highlighted. Press CLEAR to cancel a change you've just made.
3. Once you've made all the changes you want (you don't have to make any changes at all), touch CONTINUE. Appropriate settings for the ventilation setup you've selected appear on the lower screen.
4. For each of the ventilator settings you want to change, *touch* its button, then *turn* the knob to set its value. Press CLEAR to cancel a change you've just made.
5. Once you've made any changes you want, review the settings, then press ACCEPT to apply all the new settings at the same time. Touch PROPOSED SETUP to cancel all changes.

NOTE:

Once the changes are in effect, the PREVIOUS SETUP button appears at the bottom of the lower screen when you press VENT SETUP. This allows you to restore the entire previous setup (including alarm and apnea settings) that was in effect immediately before you made settings changes using the *Ventilator Setup* screen. To restore the previous setup, touch PREVIOUS SETUP, then press ACCEPT.

4.5 Constant during rate change

If you selected pressure control (PC) as the mandatory breath type during ventilator setup, you can select one of three timing variables to be held constant when the respiratory rate setting changes. Follow these steps to view or change the setting that is held constant during rate changes:

1. Touch VENT SETUP.
2. Touch CONTINUE. The breath timing bar (shown in Figure 4-3) appears in the lower screen.

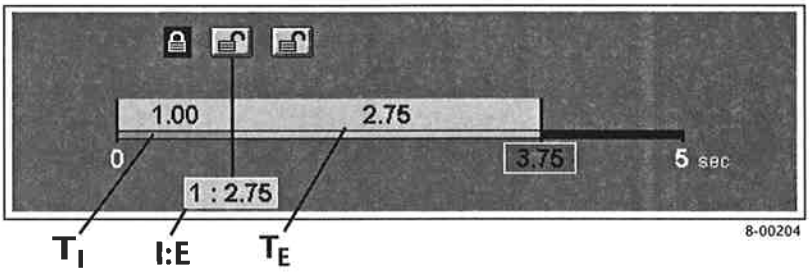


Figure 4-3. Constant during rate change (I:E ratio selected)

3. Touch one of the lock icons to select T_I, I:E, or T_E as the setting that remains constant when the rate setting changes.

   T_I = inspiratory time
   I:E = inspiratory to expiratory ratio
   T_E = expiratory time

4. Review settings and change if necessary, then press ACCEPT. The displayed timing variable is the one held constant during rate changes, and becomes the only one of the three settings you can adjust directly.

NOTE:

You can change the value of the constant setting at any time, but the value does not change as a result of changing the respiratory rate setting. For example, if you select T_I to remain constant during rate change, you can still change the value of T_I. Otherwise, the value of T_I does not change (and the values of I:E and T_E *do* change) when you change the respiratory rate setting.

Apnea ventilation settings changes

1. Touch the APNEA SETUP button on the lower screen. The current *APNEA SETUP* screen appears (Figure 4-4).
2. You are given the option of changing the apnea mandatory type setting with the CHANGE VC/PC button. If desired, change the setting, then press CONTINUE to review the settings applicable to the chosen apnea mandatory type.
3. For each setting you want to change, *touch* its button, then *turn* the knob to set its value. Proposed changes are highlighted. Press CLEAR to cancel a change you've just made.
4. Once you've made any changes you want, review the settings, then press ACCEPT to apply all the new settings at the same time. Touch PROPOSED SETUP to cancel all changes.

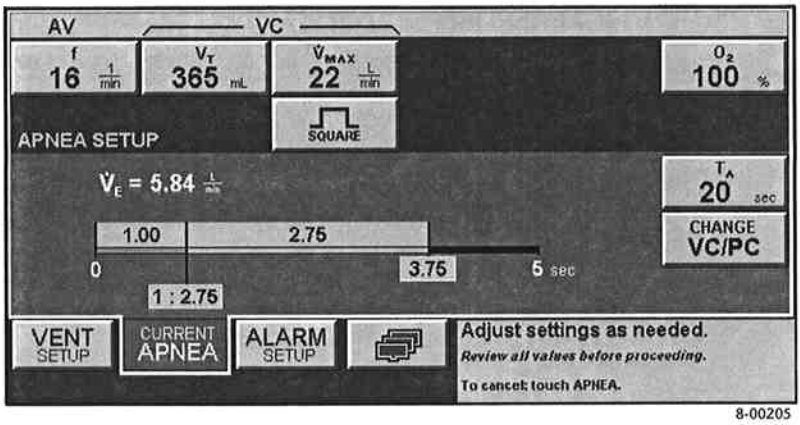


Figure 4-4. *APNEA SETUP* screen

4.7 Setting alarms

Remember: touch, turn...touch, turn...ACCEPT!

Most alarm settings are initially set based on the patient's IBW. You should review all alarm settings, but you don't have to confirm or change them at startup.

1. Touch the ALARM SETUP button (lower screen) to view the current alarm setup (see Figure 4-5). The pointer to the left of each bar shows the current patient data value for each parameter. The buttons to the right of each bar show the alarm limit(s) for each parameter.
2. Touch the button for each alarm limit you want to change.
3. Turn the knob to set the value you want (the button moves up or down with the selected value). Proposed values are highlighted. You can change more than one alarm setting before applying the changes. To cancel a highlighted change press CLEAR.

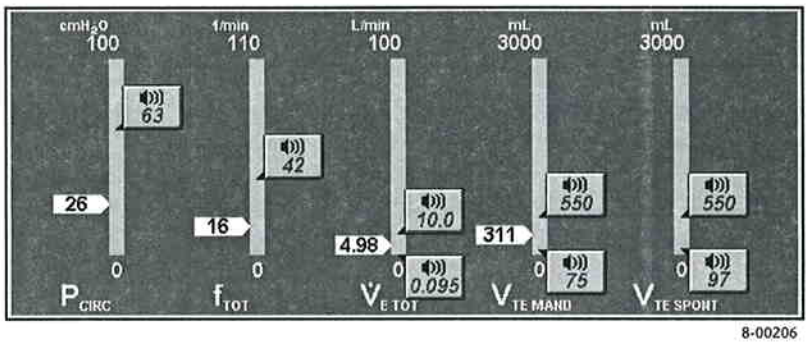


Figure 4-5. Alarm setup

NOTE:

- You cannot set the upper limit of an alarm below the lower limit, nor can you set the lower limit of an alarm above its upper limit.
- 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. Once you've made all the changes you want, review all settings. Press ACCEPT to apply the new alarm settings. Or touch the PROPOSED ALARM button before you press ACCEPT to cancel all alarm changes.
5. Press ACCEPT to apply the new alarm settings. Or touch the ALARM SETUP button before you press ACCEPT to cancel all alarm changes.
6. You can touch the ALARM SETUP button at any time during ventilation to show the current limits and monitored value for each alarm limit.

Humidification type, O_2 sensor enable/disable, E_{SENS}, and D_{SENS}

The *More Settings* screen includes settings that usually change infrequently. To change humidification type, expiratory sensitivity (E_{SENS}), or disconnect sensitivity (D_{SENS}), or to enable or disable the O_2 sensor, follow these steps:

1. Touch the OTHER SCREENS button, then touch the MORE SCREENS button.
2. Touch each setting you want to change (you can change multiple settings), then turn the knob to set its value. To leave settings unchanged, touch the OTHER SCREENS button again.
3. Review the proposed settings, then press ACCEPT to apply the new settings.

4.9 Descriptions and ranges: settings, alarms, and monitored data

Warning

Displayed pressure values are estimates and not directly measured pressures. Displayed pressures are often the actual pressure at the wye, but under some conditions such as partial occlusions of the inspiratory limb, the displayed pressures will be closer to the pressure at the inspiratory port. If the clinical circumstances suggest that the validity of the displayed pressure estimates is questionable, examine the breathing circuit and correct any occlusion and rerun SST, or use a separate portable manometer to measure the pressure.

Table 4-1 gives the description and range for ventilator settings. Table 4-2 gives the description and range for alarm settings. Table 4-3 gives the description and range for monitored data. Table 4-4 gives the description of other displayed data including diagnostic codes, operational time, software revision level, and date/time setting.

Table 4-1: Ventilator settings

Setting	Function	Range
Apnea ventilation	A safety mode that starts if the patient does not receive a breath for a time that exceeds the apnea interval.	See apnea settings.
Apnea mandatory type	Same as for non-apnea.	See mandatory type.
Apnea flow pattern	Same as for non-apnea.	See flow pattern.
Apnea peak flow ($\dot{V}_{MAX}$)	Same as for non-apnea.	See peak flow.

Table 4-1: Ventilator settings (continued)

Setting	Function	Range
a atory ure (P_I)	Same as for non-apnea.	See inspiratory pressure.
a atory time	Same as for non-apnea.	See inspiratory time.
a interval	Defines the interval after which the ventilator declares apnea.	10 to 60 seconds.
a atory rate	Same as for non-apnea.	2.0 to 40/min.
a tidal ne (V_T)	Same as for non-apnea.	See tidal volume.
a O_2%	Same as for non-apnea.	21 to 100%, and not below non-apnea O_2%.
a I:E ratio	Same as for non-apnea.	≤ 1.00:1.
a atory time	Same as for non-apnea.	$T_E \geq 0.2$ second.
tant during change	Specifies which of the three breath timing variables is directly operator-adjustable and remains constant when the set respiratory rate changes. Applicable in pressure control ventilation only.	Inspiratory time, I:E ratio, or expiratory time. New patient value: Inspiratory time.
	NOTE: You can change the value of the selected variable at any time, but the value does not change as a result of changing the respiratory rate setting.	

Table 4-1: Ventilator settings (continued)

Setting	Function	Range
Disconnect sensitivity (D_{SENS})	Sets the allowable loss (in %) of delivered volume which, if exceeded, causes the ventilator to detect a CIRCUIT DISCONNECT alarm. The greater the setting, the more returned volume must be lost before CIRCUIT DISCONNECT is detected. For example, a setting of 95% means that more than 95% the delivered volume must be lost before the ventilator detects a CIRCUIT DISCONNECT alarm.	Range: 20 to 95%. New patient value: 75%.
Expiratory sensitivity (E_{SENS})	The percent of peak inspiratory flow at which the ventilator cycles from inspiration to exhalation for spontaneous breaths.	1 to 45%. New patient value: 10%.
Expiratory time (T_E)	Sets the expiratory period for pressure control (PC) mandatory breaths.	$T_E \geq 0.2$ second. New patient value: (3.75 - new patient T_I) seconds.
Flow acceleration %	Sets how quickly inspiratory pressure rises to achieve the set (target) inspiratory pressure in pressure control (PC) or pressure support (PS) breaths. A higher value means that the target pressure is reached more quickly. **Warning** Under certain clinical circumstances (e.g., stiff lungs or high airway resistance), a flow acceleration % > 50% could cause a transient pressure overshoot and premature transition to exhalation. Carefully evaluate the patient's condition before setting the flow acceleration % above the default setting of 50%.	1 to 100%. New patient value: 50%.

Table 4-1: Ventilator settings (continued)

Setting	Function	Range
pattern	The gas flow pattern of mandatory volume-controlled breaths.	Square or descending ramp. New patient value: Square.
sensitivity s)	The flow inspired by the patient that triggers the ventilator to deliver a mandatory or spontaneous breath (when flow triggering is selected).	0.5 to 20 L/min. New patient value: 3 L/min (> 24 kg IBW); 2 L/min (≤ 24 kg IBW).
dification	Indicates the type of humidification device used on the ventilator. Can be changed during SST and normal ventilation (see the *More Settings* screen).	HME, NON-HEATED EXPIRATORY TUBE, or HEATED EXPIRATORY TUBE. New patient value: Previous setting.
body ht (IBW)	Indicates an approximate value for patient's body weight assuming normal fat and fluid levels. Determines absolute limits on tidal volume and peak flow. Determines new patient settings for tidal volume, peak flow, and volume related alarms. Changes to IBW are only allowed during ventilator startup. See Table 4-5 to determine IBW from patient height.	3.5 to 150 kg (7.7 to 330 lb). New patient value: 3.5 kg (7.7 lb).
tio	Sets the ratio of inspiratory time to expiratory time. Applicable to pressure control (PC) mandatory breaths in SIMV or A/C only.	1:299 ≤ I:E ≤ 4.00:1; 1:299 < I:E ratio < 149:1 (BILEVEL mode only). New patient value: 1:2.00.
atory ure (P_I)	Sets the inspiratory pressure at the patient wye (above PEEP) during a pressure control (PC) mandatory breath.	5 to 90 cmH_2O. New patient value: 15 cmH_2O.

Table 4-1: Ventilator settings (continued)

Setting	Function	Range
Inspiratory time (T_I)	Sets the duration of inspiration during pressure control (PC) mandatory breaths.	0.20 to 8.00 seconds; 0.20 to 30.00 seconds (BILEVEL mode only). New patient value: 1 second.
Mandatory type	Sets the type of mandatory breath: volume control (VC) or pressure control (PC).	VC or PC. New patient value: VC.
Mode	Defines ventilatory mode, which defines the allowable breath types: *A/C* allows VC or PC mandatory breaths. *SPONT* allows only spontaneous breaths (with or without pressure support, PS), except for mandatory inspirations. *SIMV* allows mandatory breaths (VC or PC) and spontaneous breaths (with or without PS). *BILEVEL* (optional) allows PC mandatory breaths and spontaneous breaths (with or without pressure support). BILEVEL establishes two levels of positive airway pressure.	A/C, SIMV, SPONT, or BILEVEL. New patient value: A/C.
	NOTE: Ventilator settings unique to the BILEVEL mode are described in the *BiLevel* option addendum to this manual.	

Table 4-1: Ventilator settings (continued)

Setting	Function	Range
	Sets the percentage of oxygen in the delivered gas.	21 to 100%. New patient value: 100%.
	NOTE: A significant change to the O_2% setting can cause the V_{TE} (exhaled tidal volume) to be transiently displayed as lower or higher than the actual exhaled volume. This is a result of initial spirometry calculations and does not reflect actual volume exhaled by the patient.	
nt circuit	Indicates the type of circuit used on the ventilator. Setting can be changed only during SST.	PEDIATRIC or ADULT. New patient value: Previous setting.
	NOTE: To ensure optimum compliance compensation, specify PEDIATRIC patient circuit when patient IBW ≤ 24 kg.	
flow)	Sets the peak (maximum) inspiratory flow during VC mandatory breaths.	3.0 to 150 L/min for IBW > 24 kg; 3.0 to 60 L/min for IBW ≤ 24 kg. New patient value: 3 L/min or 0.435 (IBW) L/min, whichever is greater.
	Sets the positive end expiratory pressure, the positive pressure targeted in the patient circuit during exhalation (also called *baseline*).	0 to 45 cmH_2O. New patient value: 3 cmH_2O.
au time	Sets the extension of a VC mandatory breath during which gas delivery stops and exhalation is blocked. Increases the residence time of gas in the patient's lungs.	0.0 to 2.0 seconds. New patient value: 0.0 seconds.

Table 4-1: Ventilator settings (continued)

Setting	Function	Range
Pressure sensitivity (P_{SENS})	Sets the pressure drop below PEEP required to begin a patient-initiated breath (when pressure triggering is selected).	0.1 to 20 cmH_2O below PEEP. New patient value: 2 cmH_2O.
Pressure support (P_{SUPP})	Sets the inspiratory assist pressure (above PEEP) at the patient wye during a spontaneous breath (when spontaneous breath type is PS).	0 to 70 cmH_2O. New patient value: 0 cmH_2O.
Respiratory rate (f)	Sets the minimum number of mandatory breaths the patient receives per minute. Active in A/C and SIMV.	1.0 to 100/min. New patient value: 16/min.
Safety ventilation	A mode of ventilation that becomes active if the patient circuit is connected before ventilator startup is complete. These settings are not adjustable. Safety ventilation annunciates a high-urgency PROCEDURE ERROR alarm and sets these alarm limits: high circuit pressure = 20 cmH_2O, low exhaled minute volume = 0.01 L. All other alarms are inactive.	Safety ventilation settings include: mode = A/C mandatory type = PC respiratory rate = 16/min inspiratory time = 1 second inspiratory pressure = 10 cmH_2O PEEP = 3 cmH_2O trigger type = pressure pressure sensitivity = 2 cmH_2O flow acceleration = 50% O_2% = 100% (21% if O_2 not available)
Spontaneous type	Determines whether spontaneous breaths are pressure-supported.	PS or NONE. New patient value: PS.

Table 4-1: Ventilator settings (continued)

Setting	Function	Range
volume	Sets the volume of gas delivered to the patient's lungs during a mandatory volume-based breath. Tidal volume is compensated for body temperature and pressure, saturated (BTPS) and the compliance of the patient circuit.	25 to 2500 mL absolute range. (IBW-based range is 1.16 x IBW minimum; 45.7 x IBW maximum.) New patient value: 7.25 (IBW) mL.
er type	Determines whether breaths are triggered based on flow or pressure. See flow sensitivity and pressure sensitivity.	Pressure (P-TRIG) or flow ($\dot{V}$-TRIG). New patient value: P-TRIG.

Table 4-2: Alarm settings

Alarm	Meaning	Range
a interval	Sets the maximum time from the beginning of one inspiration to the beginning of the next inspiration, after which the ventilator enters apnea ventilation. T_A setting is made using the APNEA button.	10 to 60 seconds. New patient value: 20 seconds.
circuit ure $_{IRC}$)	Sets the maximum circuit pressure (relative to ambient) allowed during inspiration. Stops inspiration and begins exhalation.	7 to 100 cmH_2O. New patient value: 40 cmH_2O.
exhaled te volume $_{TOT}$)	Sets the maximum exhaled minute volume limit (including mandatory and spontaneous breaths).	0.050 L to 99.5 L or OFF. New patient value: 0.1392 x IBW.

Table 4-2: Alarm settings (continued)

Alarm	Meaning	Range
High exhaled tidal volume ($\uparrow V_{TE}$)	Sets the maximum exhaled tidal volume limit for spontaneous or mandatory breaths.	50 to 3000 mL or OFF. New patient value: 8.7 x IBW.
High respiratory rate ($\uparrow f_{TOT}$)	Sets the maximum breath rate limit.	10 to 110/min or OFF. New patient value: OFF.
Low exhaled mandatory tidal volume ($\downarrow V_{TE\ MAND}$)	Sets the minimum exhaled mandatory tidal volume limit.	5 to 2500 mL or OFF. New patient value: 5.8 x IBW.
Low exhaled minute volume ($\downarrow V_{E\ TOT}$)	Sets the minimum exhaled minute volume limit for all breaths.	0.010 to 60.0 L. New patient value: 0.0928 x IBW.
Low exhaled spontaneous tidal volume ($\downarrow V_{TE\ SPONT}$)	Sets the minimum exhaled spontaneous tidal volume limit.	5 to 2500 mL or OFF. New patient value: 5.8 x IBW.

Table 4-3: Monitored data

Data	Function	Range
Breath type	Indicates the type and phase of the breath being delivered. Background is light during inspiration, dark during exhalation. This display stays on throughout the entire breath cycle, and is updated at the beginning of each inspiration and exhalation. The breath indicator display is not synchronized with the exhaled tidal volume (V_{TE}) display, which applies to the previous breath cycle.	Type: Control, assist, or spontaneous. Phase: Inspiration or exhalation.
Delivered O_2% (O_2%)	Indicates the percentage of oxygen in the gas delivered to the patient, measured at the ventilator outlet upstream of the inspiratory filter. The high and low O_2% alarms are set internally and are based on the set O_2% value.	0 to 103%.
End expiratory pressure ($P_{E\ END}$)	Indicates the pressure at the end of the expiratory phase of the previous breath. Updated at the beginning of the next inspiration. If expiratory pause is active, the displayed value reflects the level of any active lung PEEP.	-20.0 to 100 cmH_2O.
End inspiratory pressure ($P_{I\ END}$)	Indicates the pressure at the end of the inspiratory phase of the current breath. Updated at the beginning of the exhalation phase. If plateau is active, the displayed value reflects the level of end-plateau pressure.	-20.0 to 130 cmH_2O.
Exhaled minute volume ($\dot{V}_{E\ TOT}$)	Displays a calculated total of the volumes exhaled by the patient for mandatory and spontaneous breaths for the previous 1-minute interval. The displayed value is compliance- and BTPS-compensated. Updated at the beginning of the next inspiration.	0.00 to 99.9 L.

Table 4-3: Monitored data (continued)

Data	Function	Range
Exhaled tidal volume (V_{TE})	Indicates the volume exhaled by the patient for the previous mandatory or spontaneous breath. The displayed value is compliance- and BTPS-compensated. Updated at the beginning of the next inspiration.	0 to 6000 mL.
	NOTE: A significant change to the O_2% setting can cause the V_{TE} (exhaled tidal volume) to be transiently displayed as lower or higher than the actual exhaled volume. This is a result of initial spirometry calculations and does not reflect actual volume exhaled by the patient.	
I:E ratio	Indicates the ratio of inspiratory time to expiratory time for the previous breath, regardless of type. Updated at the beginning of the next inspiration. Due to limitations in setting the I:E ratio in pressure control ventilation, the monitored data display and the setting may not match precisely.	1:599 to 9.99:1; 1:599 to 149:1 (BILEVEL mode only).
Intrinsic PEEP ($PEEP_I$)	Indicates a calculated estimate of the pressure above the PEEP level at the end of exhalation. It is determined during an expiratory pause maneuver.	-20.0 to 130 cmH_2O.
Maximum circuit pressure ($P_{CIRC\ MAX}$)	Indicates the maximum pressure during the previous breath, relative to the patient wye, including the inspiratory and expiratory phases. Updated at the beginning of the next inspiration.	-20.0 to 130 cmH_2O.
Mean circuit pressure ($\bar{P}_{CIRC}$)	Indicates the average circuit pressure over the entire breath cycle of the previous breath, regardless of type. Updated at the beginning of the next inspiration.	-20.0 to 130 cmH_2O.

Table 4-3: Monitored data (continued)

Data	Function	Range
ıu pressure -)	Displays the pressure in the ventilator breathing circuit at the end of an inspiratory pause maneuver. It is the best estimate of the pressure in the patient's lungs. Updated continuously.	-20.0 to 130 cmH_2O.
taneous te volume $_{ONT}$)	Displays a calculated total of the volumes exhaled by the patient for spontaneous breaths for the previous 1-minute interval. Values for mandatory breaths during this period are not included. The displayed value is compliance- and BTPS-compensated. Updated at the beginning of the next inspiration.	0.00 to 99.9 L.
liance (C)	Displays an estimate of the elasticity of the patient's lungs.	0 to 500 ml/cmH_2O.
resistance	Displays an estimate of how restricitve the patient's airway is.	0 to 500 $cmH_2O/L/s$.
PEEP $_{TOT}$)	Displays the pressure during an expiratory pause maneuver. It is an estimate of the total pressure at the end of exhalation, referenced to atmosphere.	-20.0 to 130 cmH_2O.
respiratory f_{TOT})	Displays a calculated value of the number of mandatory and spontaneous breaths delivered to the patient for the previous 1-minute interval. Updated at the beginning of the next inspiration.	0 to 200/min.

Table 4-4: Other displayed data

Data	Meaning:	Range
Diagnostic codes	Allow qualified service technicians to troubleshoot the ventilator. Accessible during normal ventilation (by pressing the OTHER SCREENS button on the upper GUI screen) and in service mode.	Not applicable.
Operational time	Allows you to view operational times for the ventilator and compressor during normal operation and in service mode. This information is not continuously displayed, and is useful for maintenance procedures and records.	Operational times have an accuracy of ± 2% over 10,000 hours.
Software revision level	Allows you to view the software revision level in service mode and during normal operation. Upgrades or modifications change the revision level information.	Not applicable.
Time/date	Allows you to view the operator-set time-of-day and calendar date. The date is displayed in a day-month-year format, with the month shown in non-numeric form.	Time is based on a 24-hour clock, and date includes a check for correct number of days in a month (for example, you cannot enter February 30).

Table 4-5: Determining IBW based on patient height

Patient height		IBW (lb)
ft	in.	
1	9	8
1	10	9
1	11	10
2	0	11
2	1	13
2	2	14
2	3	15
2	4	17
2	5	18
2	6	19
2	7	21
2	8	22
2	9	24
2	10	26
2	11	29
3	0	31
3	1	33
3	2	35
3	3	37
3	4	40
3	5	42

Patient height		IBW (lb)
ft	in.	
3	6	44
3	7	46
3	8	49
3	9	51
3	10	53
3	11	57
4	0	60
4	1	62
4	2	66
4	3	68
4	4	71
4	5	75
4	6	79
4	7	82
4	8	86
4	9	90
4	10	93
4	11	97
5	0	101
5	1	104
5	2	108

Table 4-5: Determining IBW based on patient height (continued)

Patient height		IBW (lb)
ft	in.	
5	3	112
5	4	117
5	5	121
5	6	126
5	7	130
5	8	134
5	9	141
5	10	146
5	11	150
6	0	154
6	1	161
6	2	165
6	3	172
6	4	176
6	5	183
6	6	187
6	7	194
6	8	201
6	9	207
6	10	212
6	11	218
7	0	225

Patient height		IBW (lb)
ft	in.	
7	1	231
7	2	238
7	3	245
7	4	251
7	5	258
7	7	269
7	8	278
7	9	287
7	10	293
7	11	300
8	0	309
8	1	317
8	2	324
8	3	331

SECTION 5

Alarm handling

This section describes ventilator alarms and what to do if they occur. Figure 5-1 shows the alarm indicators. Alarms on the *840* Ventilator System are classified as high- medium-, or low-urgency:

- *High-urgency alarms* require immediate attention to ensure patient safety. During a high-urgency alarm, the red high-urgency ! ! ! indicator flashes rapidly, the high-urgency audible alarm (a sequence of five tones that repeats twice, pauses, then repeats again) sounds, and the top of the upper screen flashes an alarm message. If a high-urgency alarm goes away spontaneously (autoresets), its indicator remains lit (not flashing) until you press the alarm reset key.
- *Medium-urgency alarms* require prompt attention. During a medium-urgency alarm, the yellow medium-urgency ! ! indicator flashes slowly, the medium-urgency audible alarm (a repeating sequence of three tones) sounds, and the upper screen flashes an alarm message.
- *Low-urgency alarms* tell you that there has been a change in the patient-ventilator system. During a low-urgency alarm, the yellow low-urgency ! indicator lights, the low-urgency audible alarm (two tone, non-repeating) sounds, and the upper screen displays an alarm message.

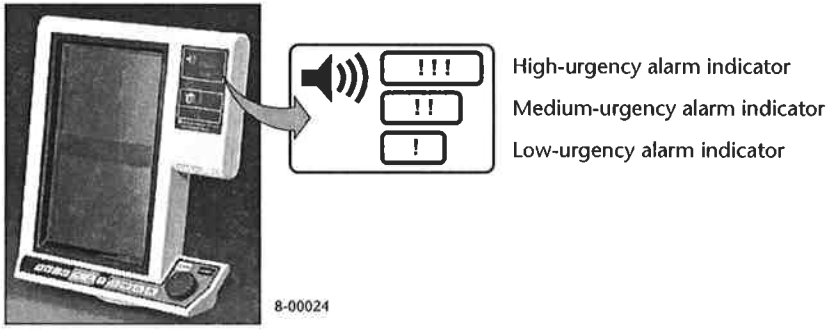


Figure 5-1. Alarm indicators

NOTE:

You can always change an alarm setting even when alarms are active. You do not need to press the alarm reset key or wait for the alarm to autoreset. After you change the alarm setting, the appropriate alarm indicator remains lit and the appropriate alarm setting icon blinks until the alarm is reset.

Alarm silence

Warning

Never leave patient unattended when alarm silence is activated.

Pressing the alarm silence key mutes the alarm sound for 2 minutes. The key lights during the silence period, and turns off if the alarm is reset. Every time you press the alarm silence key, the silence period resets for 2 minutes.

If a new high-urgency alarm occurs during the alarm silence period, the alarm silence is canceled and alarm sound turns on.

Every time you press the alarm silence key (whether or not there is an active alarm), the key press is recorded in the alarm log. The ventilator makes another entry into the alarm log when the alarm silence ends (whether due to an elapsed alarm silence interval, the detection of a high-urgency alarm, or an alarm reset).

5.2 Alarm reset

Pressing the off-screen alarm reset key resets the detection algorithms of all active alarms, except for these:

- AC POWER LOSS
- COMPRESSOR INOPERATIVE
- DEVICE ALERT
- INOPERATIVE BATTERY
- LOW AC POWER
- LOW BATTERY
- NO AIR SUPPLY
- NO O_2 SUPPLY
- PROCEDURE ERROR

Pressing the alarm reset key has no effect on patient data. Pressing the alarm reset key does not affect the 100% O_2/CAL 2 min function. The ventilator makes an entry into the alarm log when an active alarm is reset, and when an alarm silence terminated due to pressing the alarm reset key. No key press is recorded unless there is an active alarm.

If an alarm condition persists, the alarm becomes active again, according to the detection algorithm for that alarm. For example, if the APNEA alarm is active, the alarm reset key resets the apnea detection algorithm to its initial state and returns the ventilator to normal ventilation.

Pressing the alarm reset key cancels alarm silence, if active (this avoids silencing an alarm condition that arises shortly after pressing the alarm reset key). Pressing the alarm reset key clears any high-urgency alarm that has autoreset (and the steadily lit high-urgency alarm indicator turns off).

The alarm reset key gives you a way to return the ventilator to normal operation if an alarm condition has been resolved, without waiting for alarm detection algorithms to reset the alarm. The ventilator reannunciates any alarm condition that persists after pressing the alarm reset key.

Alarm log

To view the alarm log, touch the alarm log button on the upper screen. The alarm log shows alarm events (including time-stamped alarms, silences, and resets) in order of occurrence, with the most recent event at the top of the list. Figure 5-2 is an illustration of this screen.

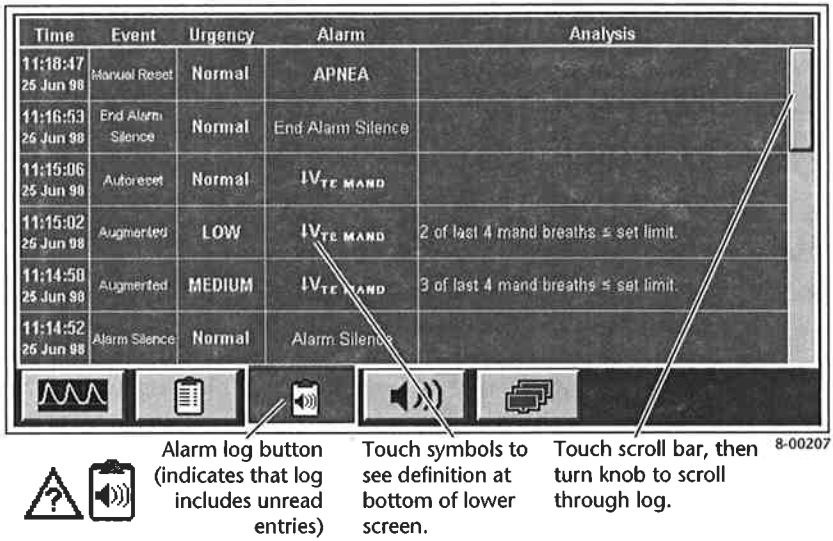


Figure 5-2. Alarm log

A question mark in a triangle appears on the ALARM LOG button if the log includes an event that hasn't been viewed yet. The question mark in a triangle disappears after you've viewed the event.

To scroll through the alarm log, touch the scroll bar, then turn the knob. An icon shows your relative position in the log.

The ventilator makes a time-stamped entry into the alarm log whenever:

- an alarm is detected
- an alarm changes urgency level
- an alarm autoresets

- you press the alarm reset key when there is an active alarm
- you press the alarm silence key
- alarm silence times out
- alarm silence is terminated by an alarm reset
- alarm silence is terminated by a new high-urgency alarm

The alarm log can store up to 50 of the most recent entries. Completing a new patient setup clears the alarm log from memory.

5.4 Alarm volume

The off-screen alarm volume key allows you to adjust the volume of all audible alarms, regardless of urgency level. Pressing the alarm volume key produces an alarm volume sound that:

- is equivalent in volume to the sound of an audible alarm
- is distinct from the sounds of low-, medium-, and high-urgency audible alarms
- continues as long as you hold down the key
- has priority over active audible alarms

If ventilator power is cycled, alarm volume remains unchanged. Because an alarm can require immediate clinical attention, you cannot turn alarm volume off. The selectable range is designed to ensure that you can discern a ventilator alarm above background noise levels.

5.5 Alarm messages

The upper screen displays the two highest-urgency active alarms. An alarm icon flashes on the MORE ALARMS button if there are other active alarms. Pressing the MORE ALARMS button displays a full screen of up to eight active alarms.

Each alarm message consists of a *base message*, an *analysis message* (supplementary information that includes any associated alarm conditions), and a *remedy message* that suggests corrective actions.

Figure 5-3 shows how an alarm message is displayed on the upper screen. Table 5-1 lists possible alarm messages.

NOTE:

When more than one alarm is active and their alarm messages vary in their degree of seriousness, you should assume that the most serious message is applicable.

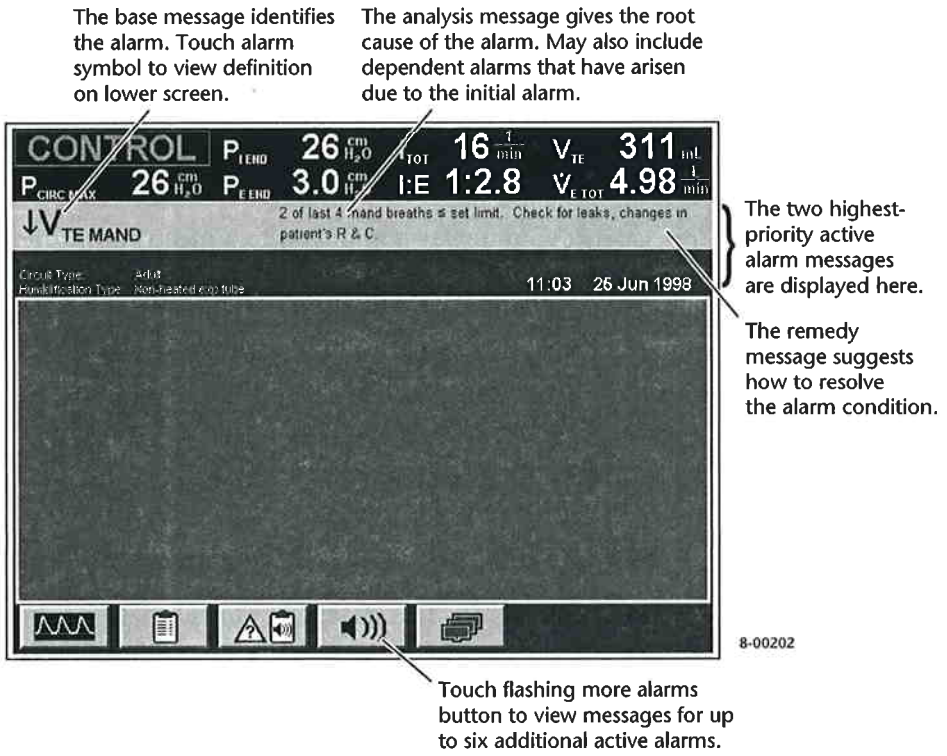


Figure 5-3. Alarm message format

Table 5-1: Alarm messages

When you see this message...	It means...	Do this...
AC POWER LOSS	The power switch is ON, ac power is not available, and the ventilator is being powered by the BPS.	Prepare for power loss. Obtain alternate ventilation. Check integrity of ac power source. Contact service if necessary.
APNEA	The set apnea interval has elapsed without the ventilator, patient, or operator triggering a breath. The ventilator has entered apnea ventilation.	Check patient and settings.
CIRCUIT DISCONNECT	There is a disconnection in the patient circuit.	Check patient. Reconnect patient circuit. Press the alarm reset key.
COMPRESSOR INOPERATIVE	Compressor cannot maintain sufficient supply pressure.	Check patient. Obtain alternative ventilation. Remove ventilator from use and contact service.
DEVICE ALERT	A background test or POST has detected a problem.	Check patient. If prompted to do so; obtain alternate ventilation and contact service.
$\uparrow P_{CIRC}$ (High circuit pressure)	The measured airway pressure is equal to or greater than the set limit. Reduced tidal volume likely.	Check patient, patient circuit, and endotracheal tube.
$\uparrow O_2\%$ (High delivered $O_2\%$)	The $O_2\%$ measured during any phase of a breath cycle is 7% (12% during the first hour of operation) or more above the $O_2\%$ setting for at least 30 seconds. These percentages increase by 5% for 4 minutes following a decrease in the $O_2\%$ setting.	Check patient, air and oxygen supplies, oxygen analyzer, and ventilator.

Table 5-1: Alarm messages (continued)

n you see message...	It means...	Do this...
exhaled volume)	The patient's exhaled tidal volume for any breath is equal to or greater than the set limit.	Check patient and settings. Consider whether the patient's compliance or resistance has changed.
OT exhaled minute ne)	The patient's expiratory minute volume is equal to or greater than the set limit.	Check patient and settings.
atory rate)	The breath rate from all breaths is greater than or equal to the set limit.	Check patient and settings.
NT internal ator ure)	The inspiratory pressure transducer has measured a pressure of at least 100 cmH_2O. Active only during volume-controlled breaths. Ventilator transitions to exhalation. Reduced tidal volume likely.	Check patient. Obtain alternate ventilation. Remove ventilator from use and contact service.
ERATIVE ERY	The BPS is installed but not functioning.	Contact service.
RATION LONG	IBW-based inspiratory time for a spontaneous breath exceeds ventilator-set limit.	Check patient. Check for leaks.
OF ER	The ventilator power switch is on and there is insufficient power from ac and the BPS. There may not be a visual indicator for this alarm, but an independent audio alarm sounds for at least 120 seconds.	Check integrity of ac power and BPS connections. Obtain alternative ventilation if necessary.

Table 5-1: Alarm messages (continued)

When you see this message...	It means...	Do this...
LOW AC POWER	Mains ac power has dropped below 80% of nominal voltage for at least 1 second. Warns that ac power has dropped significantly, and that a more severe power drop may be imminent. The ventilator turns off the compressor (if installed), and otherwise operates normally.	Check integrity of connection to ac power. Check ac power supply.
LOW BATTERY	The BPS is installed and has less than 2 minutes of operational time remaining.	Replace BPS or allow it to recharge during normal ventilator operation.
↓O_2% (Low delivered O_2%)	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. These percentages increase by 5% for 4 minutes following an increase in the O_2% setting.	Check patient, air and oxygen supplies, oxygen analyzer, and ventilator. Calibrate oxygen sensor (press 100% O_2/CAL 2 min key).
↓$V_{TE\ MAND}$ (Low exhaled mandatory tidal volume)	The patient's exhaled mandatory tidal volume is less than or equal to the set limit.	Check patient. Check for leaks or changes in the patient's resistance or compliance.
↓$V_{TE\ SPONT}$ (Low exhaled spontaneous tidal volume)	The patient's exhaled spontaneous tidal volume is less than or equal to the set limit.	Check patient and settings.
↓$\dot{V}_{E\ TOT}$ (Low exhaled total minute volume)	The minute volume for all breaths is less than or equal to the set limit.	Check patient and settings.

Table 5-1: Alarm messages (continued)

When you see this message...	It means...	Do this...
NO AIR SUPPLY	Air supply pressure is less than the minimum required pressure for correct ventilator operation. O_2% delivery may be compromised. This alarm cannot be set or disabled.	Check patient and air source. Obtain alternative ventilation if necessary.
NO O_2 SUPPLY	Oxygen supply pressure is less than the minimum required pressure for correct ventilator operation. Accuracy of O_2% delivery may be compromised. This alarm cannot be set or disabled.	Check patient and oxygen source. Obtain alternative ventilation if necessary.
PROCEDURE ERROR	Patient attached before ventilator startup is complete. Safety ventilation is active.	Provide alternate ventilation. Complete ventilator startup procedure.
SCREEN BLOCK	Possible blocked beam or touch screen fault.	Remove obstruction or contact service.
SEVERE OCCLUSION	Patient circuit is severely occluded.	Check patient. Obtain alternative ventilation if necessary. Check patient circuit for bulk liquid, crimps, blocked filter. If problem persists, remove ventilator from use and contact service.

Graphics

The graphics function displays real-time patient data, including:

- Pressure-time curve
- Flow-time curve
- Volume-time curve
- Pressure-volume loop

Figure 6-1 shows an example of a pressure-volume loop.

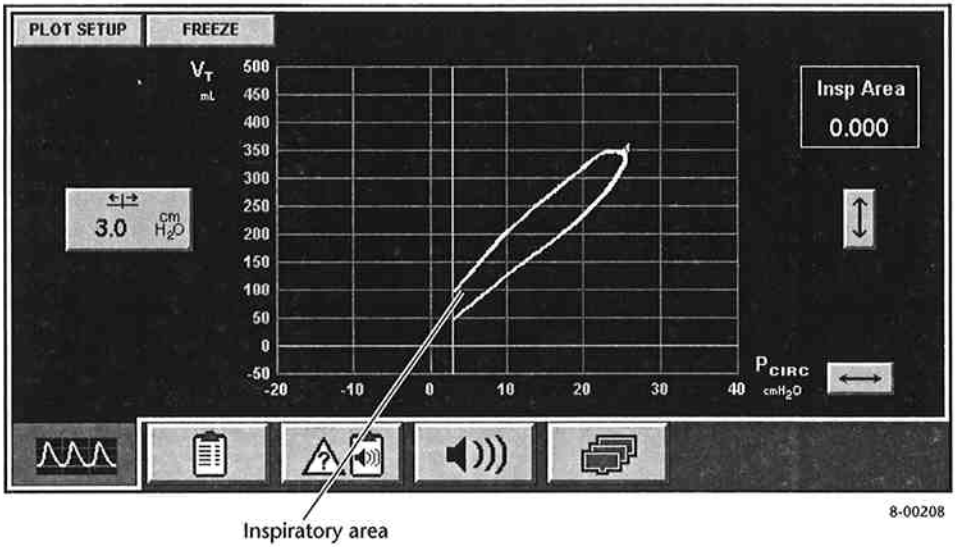
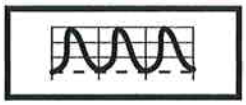


Figure 6-1. Pressure-volume loop

6.1 Setting up graphics

You can choose to display one or two time curves at a time. The pressure-volume loop uses the entire screen, so no other waveform can be displayed at the same time.



1. Touch the graphics button at the lower left of the upper screen. Graphics appear.

PLOT SETUP

2. Touch PLOT SETUP at the upper left of the screen.

Plot 1
Pressure-Time

3. Touch Plot 1, then turn the knob to select any one of the waveforms. If you select pressure-volume, which uses the entire screen, Plot 2 disappears.

Plot 2
Flow-Time

4. Touch Plot 2, if applicable. Turn the knob to select either of the two remaining waveforms, or none. If you select none, only one enlarged plot (with higher resolution) appears.

CONTINUE

5. Touch CONTINUE to display the graphics you've selected. You don't have to press ACCEPT.

6.2 Once graphics are displayed

- If you selected the pressure-volume loop, the loop for the next full breath is displayed, then updated every other breath.
- The inspiratory area is calculated based on the area inside the loop to the left of the baseline.

- To move the baseline on a pressure-volume loop, touch the baseline pressure button, then use the knob to position the baseline. The default position of the baseline is the positive end expiratory pressure (PEEP) setting. If the PEEP setting changes, the baseline resets to PEEP.
- Curves (pressure-time, flow-time, and volume-time) are drawn on the screen at the start of a breath, beginning with the last ½ second of the previous breath.

- To adjust vertical and horizontal scales, touch the arrow buttons, then turn the knob to select. You don't have to press ACCEPT.

6.3 The FREEZE function

Follow these steps to freeze graphics on the screen so that you can view them for an extended period of time.

1. Touch FREEZE. The screen flashes the message FREEZING, the UNFREEZE button appears, and the scaling buttons disappear. Plotting continues until the screen is full.
2. Once the screen is filled and frozen, the other on-screen scaling buttons reappear. You can now redo the plot setup and adjust the scales for the last 48 seconds of frozen data. The pressure-volume display shows only the most recent full breath within the 48-second freeze period.

   Graphics remain frozen even if you switch to another screen (for example, MORE ALARMS) and then return to the graphics screen.

3. Press UNFREEZE at any time to view current graphics.

6.4 Graphics are automatically displayed when...

You press EXP PAUSE. The measured values for intrinsic and total PEEP are displayed at the end of the expiratory pause, and the most recently selected graphics are displayed and frozen.

6.5 Graphics *won't* be displayed when...

- The ventilator goes into apnea ventilation or safety ventilation. However, you can choose to redisplay graphics, by pressing the graphics button.
- You touch the MORE PATIENT DATA, ALARM LOG, MORE ALARMS, or OTHER SCREENS button.
- You touch the graphics button, if graphics were already displayed.

SECTION 7

Maintenance and service

To ensure proper ventilator operation, perform the following maintenance procedures at the recommended intervals. All procedures should be adapted to your institution's policies and protocol.

This section describes:

- Cleaning, disinfecting, and sterilizing
- Preventive maintenance
- Storage
- Repacking and shipping

For instructions for qualified service technicians on performing more detailed testing, troubleshooting, or other service procedures, see the *840 Ventilator System Service Manual* for more information, including theory of operation, calibration instructions, parts list, and circuit diagrams. Ventilator electronic components are not field-repairable.

Warning

Unqualified personnel must not attempt to service the ventilator. Improper repair or unauthorized modification can compromise safety and result in patient injury.

NOTE:

Dispose of all parts removed from the ventilator during maintenance procedures according to your institution's protocol. Sterilize before nondestructive disposal. Follow local governing ordinances and recycling plans regarding disposal or recycling of device components.

Cleaning, disinfection, and sterilization

Table 7-1 tells you how to clean, disinfect, and sterilize ventilator components.

Warning

- Do not attempt to remove, clean, or flush the flow sensor with liquids or pressurized air.
- To avoid patient exposure to sterilizing agents, be sure to sterilize parts according to the techniques described in Table 7-1. Exposure to sterilizing agents may reduce the useful life of some parts.
- Handle filters with care, to minimize the risk of bacterial contamination or physical damage.
- Always follow your institution's infection control guidelines.

NOTE:

Nellcor Puritan Bennett recognizes that sanitation practices vary widely among health care institutions. It is not possible for Nellcor Puritan Bennett to specify or require specific practices that will meet all needs, or to be responsible for the effectiveness of cleaning, disinfecting, sterilizing, and other practices carried out in the patient care setting. This manual can only give general guidelines for cleaning, disinfecting, and sterilizing. It is the user's responsibility to ensure the validity and effectiveness of the methods used.

Table 7-1: Cleaning, disinfecting, sterilizing

Part	Procedure	Comments
Ventilator exterior (including touch screen and flex arm)	Wipe clean with a damp cloth and mild soap solution or with one of these chemicals or their equivalents. Use water to rinse off chemical residue as necessary. • Mild dishwashing detergent • Isopropyl alcohol (70% solution) • Bleach (10% solution) • Window cleaning solution (with isopropyl alcohol and ammonia) • Ammonia (15% solution) • Hydrogen peroxide (3% solution) • Formula 409® cleaner (Clorox Company) • Amphyl disinfectant (National Laboratories, Reckitt & Colman Inc.) • Cavicide® surface disinfectant (Metrex Research Corporation) • Control III germicide (Meril Products Inc.) • Glutaraldehyde (3.4% solution) Vacuum vents at the back of the graphic user interface (GUI) to remove dust.	Do not allow liquid or sprays to penetrate the ventilator or cable connections. Do not attempt to sterilize the ventilator by exposing to ethylene oxide (ETO) gas. Do not use pressurized air to clean or dry the ventilator, including the GUI vents.
	Caution • To avoid damaging filter materials used on the back of the GUI, do not use hydrogen peroxide to clean the GUI. • To prevent damage to ventilator labeling and ventilator surfaces in general, use only the listed chemicals to clean the ventilator exterior.	

Table 7-1: Cleaning, disinfecting, sterilizing (continued)

Part	Procedure	Comments
nt circuit g	Disassemble and clean, then autoclave, pasteurize, or chemically disinfect. Single-patient use: Discard.	If submerged in liquid, use pressurized air to blow moisture from inside the tubing before use. Inspect for nicks and cuts, and replace if damaged. Run SST to check for leaks when a new circuit is installed.
	Caution Steam sterilization is a viable sterilizing method for *840* Ventilator patient circuits supplied by Nellcor Puritan Bennett, but it may shorten the tubing's life span. Discoloration (yellowing) and decreased tubing flexibility are expected side effects of steam sterilizing this tubing. These effects are cumulative and irreversible.	
e water	Disassemble and clean, then autoclave, pasteurize, or chemically disinfect.	Inspect for cracks and replace if damaged.
lings and ectors	Autoclave, pasteurize, or chemically disinfect.	If submerged in liquid, use pressurized air to blow moisture from inside the part before use. Inspect for nicks and cuts, and replace if damaged.
ctor vial	Reusable: Clean, then autoclave or chemically disinfect. Single-patient use: Discard.	Inspect for cracks and replace if damaged.

Table 7-1: Cleaning, disinfecting, sterilizing (continued)

Part	Procedure	Comments
Expiratory and inspiratory bacteria filters	Reusable. Autoclave. Before discarding, disinfect or sterilize according to your institution's protocol. Single-patient use: Discard.	Effective sterilization of Nellcor Puritan Bennett inspiratory and expiratory filters occurs by steam autoclaving at 132 °C (270 °F) for 20 minutes for gravity displacement cycles. Do not chemically disinfect or expose to ETO gas. Check filter resistance before reuse. Follow manufacturer's recommendations for reusability.
Compressor inlet filter	Every 250 hours or as necessary: wash in mild soap solution, rinse, and air-dry.	Replace filter element if torn or damaged.
Drain bag, tubing, and clamp	Discard bag when filled to capacity or at circuit change. Clean and autoclave reusable tubing. Wipe clamp clean with alcohol or pasteurize.	Do not autoclave clamp. Replace clamp if visibly damaged.
Air inlet filter bowl	Wash exterior with mild soap solution if needed.	Avoid exposure to aromatic solvents, especially ketones. Replace if cracks or crazing are visible.
Other accessories	Follow manufacturer's instructions.	

7.1.1 Cleaning: general guidelines

Do not clean or reuse single-patient use or disposable products. When cleaning parts, do not use hard brushes or other instruments that could damage surfaces.

1. Wash parts in warm water and mild soap solution.
2. Rinse parts thoroughly in clean, warm water (tap water is fine) and wipe dry.
3. Nellcor Puritan Bennett recommends that you inspect all parts at every cleaning. Replace any damaged parts.
4. Whenever you replace parts on the ventilator, run short self test (SST) and any other tests recommended in the *840 Ventilator System Service Manual*.

Caution

Follow the soap manufacturer's instructions. Exposure to soap solution that is more highly concentrated than necessary can shorten the useful life of the products. Soap residue can cause blemishes or fine cracks, especially on parts exposed to elevated temperatures during sterilization.

7.1.2 Disinfection and sterilization

Do not disinfect, sterilize, or reuse single-patient use or disposable products. When sterilizing tubing, coil it in a large loop, avoiding kinks or crossing tubing. The tubing lumen should be free of any visible droplets prior to wrapping.

7.1.2.1 Autoclave sterilization

Separate components and wrap each in muslin or equivalent paper before autoclaving. Effective sterilization occurs by steam autoclaving at 132 °C (270 °F) for 20 minutes for gravity displacement cycles. Follow the steam sterilizer manufacturer's instructions. Follow these steps:

1. Disassemble
2. Clean
3. Inspect
4. Reassemble
5. Sterilize
6. Run SST

7.1.2.2 Pasteurization

Place parts in heat pasteurizer at 76 to 79 °C (169 to 174 °F) for 30 minutes. Follow these steps:

1. Disassemble
2. Clean
3. Inspect
4. Disinfect
5. Reassemble
6. Run SST

7.1.2.3 Chemical disinfection

Caution

Formaldehyde and phenol-based disinfectants are not recommended because they can cause plastic parts to crack and craze. Exposing parts to disinfectant concentrations stronger than required for excessive times may shorten product life. To prevent spotting and blemishing when exposed to elevated temperatures, thoroughly rinse and dry parts.

Immerse parts in disinfectant according to manufacturer's instructions. Acceptable disinfectants include the following or their equivalents: ammonia (15% solution), Amphyl, bleach (10% solution), Cavicide, Cidex, Control III, and isopropyl alcohol (70% solution). Follow these steps:

1. Disassemble
2. Clean
3. Inspect
4. Disinfect
5. Reassemble
6. Run SST

Preventive maintenance

Table 7-2 summarizes preventive maintenance intervals and procedures. See the *Ventilator Information* screen for total hours of operation for the ventilator and compressor.

Table 7-2: Preventive maintenance intervals

requency	Part	Maintenance
al times a r as required our ution's y	Patient circuit: inspiratory and expiratory limbs	Check for water build-up, empty and clean as necessary.
	Inspiratory and expiratory bacteria filters	Inspect and check the resistance across inspiratory and expiratory filters before every use, after 15 days of continuous use in the exhalation limb, or if you suspect excess resistance. SST checks the resistance of the expiratory filter.
	Collector vial, water traps, and drain bag	Check and empty as needed.

Table 7-2: Preventive maintenance intervals (continued)

Frequency	Part	Maintenance
Daily or as necessary	Oxygen sensor	Calibrate oxygen sensor by pressing the 100% O_2/ CAL 2 min key. Oxygen sensor calibration can be tested using the procedure in Section D.2.
	Air inlet filter bowl	If cracked, replace bowl. If any sign of moisture is visible, remove ventilator from use and contact service or maintenance.
Every 250 hours (or more often, if required)	Compressor inlet filter	Clean.
Every 6 months	Entire ventilator	Run EST. Must be done by a qualified service technician according to instructions in the *840 Ventilator System Service Manual.*
Every year	Atmospheric pressure transducer, expiratory valve, flow sensors, and vent inop test	Perform calibration/test. Must be done by a qualified service technician according to instructions in the *840 Ventilator System Service Manual.*
	Entire ventilator	Run performance verification. This includes running an electrical safety test and inspecting ventilator for mechanical damage and for label illegibility.
Every year or after 100 autoclave cycles	Reusable inspiratory and expiratory bacteria filters	Replace. Sterilize between patients and circuit changes, or according to your institution's policy. Sterilize before nondestructive disposal.

Table 7-2: Preventive maintenance intervals (continued)

equency	Part	Maintenance
ventilator on changes 00 feet of de	Atmospheric pressure transducer	Perform calibration. Must be done by a qualified service technician according to instructions in the *840 Ventilator System Service Manual.*
2 years or cessary	Oxygen sensor and BPS internal battery pack	Replace. Must be replaced by a qualified service technician according to instructions in the *840 Ventilator System Service Manual.* Actual sensor life depends on operating environment; operation at higher temperature or O_2% levels will result in shorter sensor life. Actual BPS life depends on the history of use and ambient conditions.
10,000	Various parts	Use appropriate preventive maintenance kit. Preventive maintenance must be performed by a qualified service technician according to instructions in the *840 Ventilator System Service Manual.*

Caution

To avoid component damage due to excessive wear, perform preventive maintenance and replace components at recommended intervals. You may find it convenient to note anticipated replacement dates for all components based on typical use rates or recommended intervals.

7.2.1 Several times a day or as required: inspiratory and expiratory bacteria filters

Warning

The use of nebulized medication can cause a build-up of exhalation flow resistance and may even block the expiratory filter. Inspect and test expiratory filters at patient setup and frequently during use.

Inspect and check the resistance across inspiratory and expiratory filters before every use, and after 15 days of continuous use in the exhalation limb. SST checks the resistance of the expiratory filter. At every circuit change, autoclave reusable filters or discard single-patient use filters. Effective sterilization of the filter occurs by steam autoclaving at 132 °C (270 °F) for 20 minutes for gravity displacement cycles. Follow the steam sterilizer manufacturer's instructions.

For inspiratory filters:

- Filter resistance of 1 cmH_2O (1 hPa) or less at 60 L/min flow or 0.5 cmH_2O (0.5 hPa) or less at 30 L/min flow can indicate a ruptured filter. Discard the filter.
- Filter resistance greater than 4 cmH_2O (4 hPa) at 60 L/min flow or 2 cmH_2O (2 hPa) at 30 L/min flow can indicate an occluded filter. For reusable filters, autoclave and check the resistance again. For single-patient use filters, discard and replace with a new filter.

For expiratory filters:

- Filter resistance of 0.6 cmH_2O (0.6 hPa) or less at 60 L/min flow or 0.3 cmH_2O (0.3 hPa) or less at 30 L/min flow can indicate a ruptured filter. Discard the filter.
- Filter resistance greater than 2.4 cmH_2O (2.4 hPa) at 60 L/min flow or 1.2 cmH_2O (1.2 hPa) at 30 L/min flow can indicate an occluded filter. For reusable filters, autoclave and check the resistance again. For single-patient use filters, discard and replace with a new filter.

Replace reusable filters after a maximum of one year of service or 100 autoclave cycles, whichever comes first. When you put a filter into service, write the anticipated replacement date on the filter and keep of record of the number of autoclave cycles to which the filter has been subjected.

7.2.2 Daily or as required: collector vial and drain bag

Warning

- Empty the collector vial before fluid reaches the maximum fill line. Collector vial overflow can allow fluid to enter the filter or patient circuit, and can cause increased flow resistance.
- Removing the collector vial while the patient is connected to the ventilator can cause loss of circuit pressure, ventilator autocycling, or direct contact with liquid.

NOTE:

For best fit between the exhalation filter and collector vial, do not mix single-patient use and reusable components (both should be reusable or both should be single-patient use).

At every patient circuit change, autoclave or disinfect reusable collector vials and discard single-patient use collector vials.

To avoid increased expiratory resistance, empty the collector vial before liquid reaches the maximum fill line (see Figure 7-1). Under certain conditions, the collector vial can fill in as little as 2 hours. To remove the vial, turn the ring at the bottom of the exhalation filter to release the vial. Replace the empty vial and turn the ring to lock the vial into place. If you remove the collector vial during normal ventilation, the ventilator will annunciate a CIRCUIT DISCONNECT alarm.

If you are using a drain bag, squeeze the clamp to drain liquid from the collector vial to the drain bag. When the drain bag fills, disconnect the bag from the tubing, then install bag fitting into tab to seal the bag. Discard bag. See Figure 7-1.

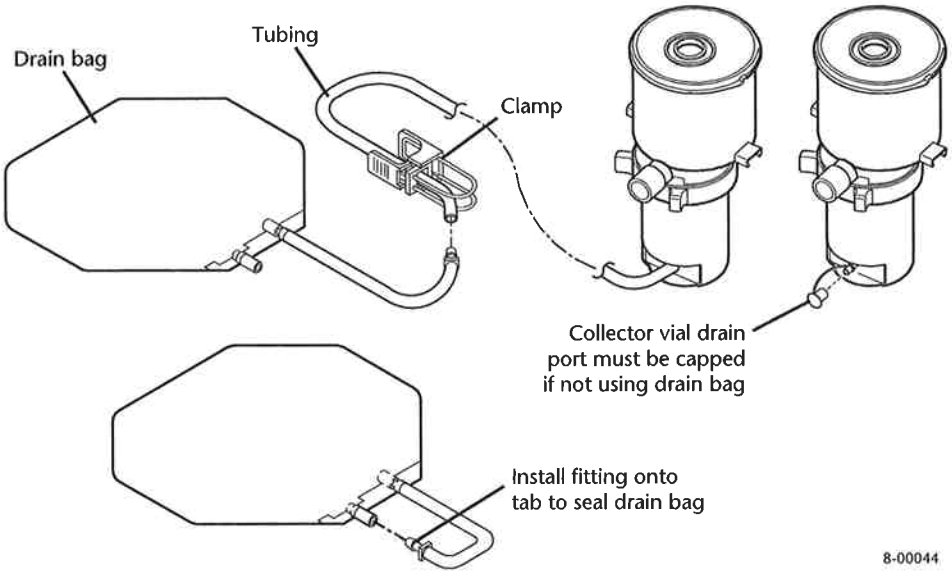


Figure 7-1. Emptying the collector vial, sealing the drain bag

Discard the drain bag and tubing every 24 hours (or as needed), and at every circuit change. The clamp is reusable: remove it before discarding the bag. To seal the bag before disposal, connect the tubing to the tab on the bag.

7.2.3 Daily or as required: in-line water traps

Drain as required.

7.2.4 Every 250 hours: compressor inlet filter

Raise the compressor inlet cover and remove filter (see Figure 7-2). Wash the compressor inlet filter in a mild soap solution, rinse well, then dry thoroughly to ensure an unrestricted flow of air through the compressor compartment.

NOTE:

Clean the filter more often than every 250 hours if necessary (some environments cause lint and dust to collect more quickly).

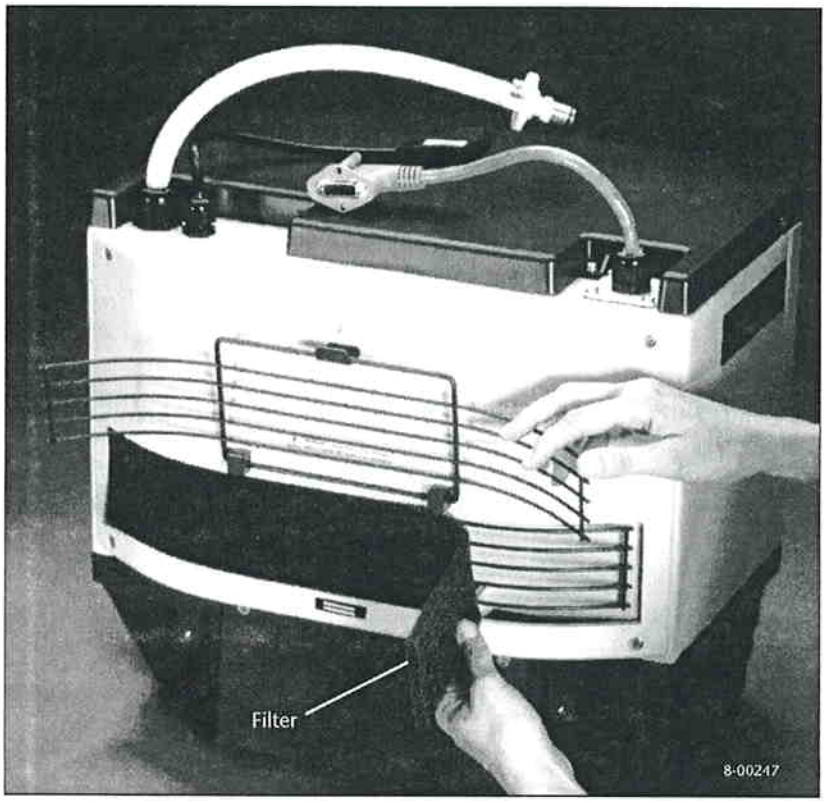


Figure 7-2. Removing the compressor inlet filter

7.2.5 Every year: ventilator inspection

Inspect the ventilator exterior for evidence of mechanical damage and for label illegibility. If damage or label illegibility is noted, have a qualified service person service the ventilator.

7.2.6 Every 2 years or as necessary: oxygen sensor

The ventilator's oxygen sensor has a nominal life of 2 years. Its actual life depends on the operating environment. Operation at higher temperatures or FIO_2 levels will result in shorter sensor life.

A qualified service technician must replace the oxygen sensor according to the instructions in the *840 Ventilator System Service Manual*.

7.2.7 Every 2 years or as necessary: BPS internal battery pack

The ventilator's BPS internal battery pack has a nominal life of 2 years. Its actual life depends on the operating environment. Operation at higher temperatures will result in shorter battery pack life.

A qualified service technician must replace the BPS internal battery pack according to the instructions in the *840 Ventilator System Service Manual.*

7.2.8 Every 10,000 hours: preventive maintenance kits

Nellcor Puritan Bennett recommends that a qualified service technician perform maintenance after every 10,000 hours of ventilator use.

NOTE:

Because the ventilator and compressor can accrue hours separately, be sure to confirm the elapsed time for each (to view operational hours, press the MORE SCREENS button on the upper screen, then select the *Operational Time* subscreen).

Nellcor Puritan Bennett offers preventive maintenance kits that include the parts necessary for each maintenance interval. (See Appendix B for part numbers.)

Storage

If you are storing the ventilator for 6 months or longer, Nellcor Puritan Bennett recommends that you disconnect the BPS or recharge it every 3 to 6 months, depending on storage temperatures (see Specifications, Appendix A).

Caution

- Disconnect the oxygen supply if you do not intend to use the ventilator immediately.
- To avoid damaging the ventilator, do not place the cart on its back or side with the breath delivery unit (BDU) or GUI attached. To store or move the cart on its back or side, disassemble the GUI and BDU from the cart first.

NOTE:

An audible alarm will sound for at least 2 minutes after power is lost if no batteries are connected.

Repacking and shipping

If it is necessary to ship the ventilator for any reason, use the original packing materials. If those materials are not available, order a repacking kit. See the *840 Ventilator System Service Manual* for repacking instructions.

APPENDIX A

Specifications

This appendix provides specifications for the *840* Series Ventilator System, including:

- Physical
- Environmental
- Power
- Compliance and approvals
- Technical
- Ranges, resolutions, and accuracies for ventilator settings, alarm settings, and monitored data.

A.1 Physical

Weight	Breath delivery unit (BDU): 18.2 kg (40.1 lb) Graphic user interface (GUI): 5.7 kg (12.6 lb) Backup power source (BPS): 6.6 kg (14.6 lb) Cart: 15.5 kg (34.2 lb) Compressor unit: 31.6 kg (69.7 lb)
Dimensions	BDU: 330 mm high x 457 mm wide x 254 mm deep (13 in. high x 18 in. wide x 10 in. deep) GUI: 460 mm high x 394 mm wide x 170 mm deep (18.1 in. high x 15.5 in. wide x 6.7 in. deep) BPS: 83 mm high x 244 mm wide x 254 mm deep (3.25 in. high x 9.6 in. wide x 10 in. deep) Cart: 998 mm high x 582 mm wide x 602 mm deep (39.3 in. high x 22.9 in. wide x 23.7 in. deep) Compressor: 417 mm high x 458 mm wide x 362 mm deep (16.4 in. high x 18 in. wide x 14.25 in. deep)

ectors	Inspiratory limb connector: ISO 22-mm conical male Expiratory limb connector (on expiratory filter): ISO 22-mm conical male Air and oxygen inlets: DISS male, DISS female, NIST, Air Liquide, or SIS fitting (depending on country and configuration)
atory/ atory	See filter instruction sheets for complete specifications.
gen r life	2 years or 10,000 hours of use, nominal. Actual sensor life depends on operating environment; operation at higher temperature or O_2% levels will result in shorter sensor life.
mixing m	Range of flow from the mixing system: Can be set to 150 L/min standard temperature and pressure, dry (STPD). Additional flow is available (up to 80 L/min for pediatric patients whose IBW ≤ 24 kg, and up to 200 L/min for adults whose IBW > 24 kg) for compliance compensation. Leakage from one gas system to another: Meets standard Operating pressure range: 35 to 100 psi (241 to 690 kPa) Air/oxygen regulator bleed: Up to 3 L/min
n volume	45 dB(A) to 85 dB(A)

Environmental

perature	Operating: 10 to 40 °C (50 to 104 °F) at 10 to 95% relative humidity, noncondensing Storage: -20 to 50 °C (-4 to 122 °F) at 10 to 95% relative humidity, noncondensing
spheric pressure	Operating: 700 to 1060 hPa (10.2 to 15.4 psi) Storage: 500 to 1060 hPa (7.3 to 15.4 psi)
ude	Operating: -443 to 3,280 m (-1350 to 10,000 ft) Storage: up to 6,560 m (20,000 ft)
gen and air inlet lies	Pressure: 241 to 690 kPa (35 to 100 psi) Flow: Maximum of 200 L/min

A.3 Power

Input power	Ventilator operation without compressor: 120 V~, 60 Hz; 4.5 A Ventilator operation with compressor: 120 V~, 60 Hz; 10.1 A Mains overcurrent release: Ventilator: 5 A Auxiliary mains: 10 A

NOTE:
Above values obtained using the following ventilator settings at 22 °C ambient temperature: mode, A/C; mandatory type, PC; IBW, 85 kg; f_{TOT}, 20/min; P_{SUPP}, 30 cmH_2O; T_I, 1 second; flow acceleration %, 50%; O_2%, 50%; $P_{CIRC\ MAX}$, 50 cmH_2O; P_{SENS}, 3 cmH_2O. Input power specifications are for ventilators with Fisher & Paykel MR730 humidifiers.

Leakage current	Earth leakage current: 300 µA Enclosure/patient leakage current: 100 µA maximum Humidifier leakage current: 50 µA maximum Patient auxiliary leakage current: Not applicable.

Warning

In the event of a defective earth conductor, connecting equipment to the auxiliary mains socket outlet(s) (that is, the humidifier or compressor connections) may increase patient leakage current to values that exceed the allowable limits.

Backup r e (BPS)	24 V dc, 6.5 Ah Operating time (for a new, fully charged battery): at least 30 minutes. Actual duration depends on ventilator settings, battery age, and level of battery charge. Recharge time: Automatically recharges within 8 hours maximum while ventilator is connected to ac power. Shelf life: 24 months from date of manufacture. Storage conditions: Store at -20 to 50 °C (-4 to 122 °F), 25 to 85% relative humidity; avoid direct sunlight. Recharge requirements: Recharge every 6 months when storage temperature is -20 to 29 °C (-5 to 84 °F); every 3 months when storage temperature is 30 to 40 °C (86 to 104 °F); every 2 months when storage temperature is 41 to 50 °C (105 to 122 °F). **NOTE:** BPS battery life specifications are approximate. To ensure maximum battery life, maintain full charge and minimize the number of complete discharges.

Compliance and approvals

The *840* Ventilator System was developed in accordance with pertinent FDA guidances, and North American and international standards (Table A-1).

The ventilator's IEC 601-1/EN 60601-1 classification is Protection class I, Type B, internally powered, drip-proof equipment, continuous operation.

General	The *840* Ventilator System was developed in accordance with pertinent FDA guidances, and North American and international standards.
Configuration	120 V ac, 60 Hz
IEC 601-1 classification	Shock protection Class I, Type B patient-applied parts, drip-proof equipment, continuous operation.
Certification agency	Canadian Standards Association (CSA)
Certification to these standards and requirements	UL and CSA, North American standards: CSA C22.2 No. 601-1 CSA C22.2 No. 601-1 Supplement 1 CSA C22.2 No. 601-2-12 UL No. 2601-1 Authorized to bear the CSA certification mark with NRTL/C indicator, signifying the product has been evaluated to the applicable ANSI/UL and CSA standards, for use in the US and Canada. CB Scheme, international standards: IEC 601-1 + Amendments 1 and 2 IEC 601-2-12

Technical

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

mum ed ure	127.5 cmH_2O (130 hPa)
mum ing ure	100 cmH_2O (102 hPa), ensured by high pressure limit 90 cmH_2O (pressure-based ventilation)
uring display es	Pressure measurements: Type: Silicon solid-state differential pressure transducer Sensing position: Inspiratory and expiratory limbs (used to algorithmically approximate circuit wye pressure) Measurements: Mean circuit pressure (range: -20 to 120 cmH_2O, -20.4 to 122 hPa); peak circuit pressure (range: -20 to 130 cmH_2O, -20.4 to 133 hPa)
	Volume measurements: Type: Hot film anemometer Sensing position: Exhalation compartment Measurements: Exhaled tidal volume (range: 0 to 6,000 mL); total minute volume (range: 0 to 99.9 L)
	Oxygen measurement: Type: Galvanic cell Sensing position: Inspiratory manifold Measurement: Delivered % O_2 (range: 0 to 103%)
	Display of settings, alarms, and monitored data: Type: Two liquid crystal display (LCD) touch screens
te ne $_{DT}$) bility	25 to 75 L/min

Results of ventilator patient circuit testing (using circuits identified for use with *840* Ventilator (Figure A-1))	Inspiratory pressure drop from inlet of open safety valve to output port without inspiratory filter: At 30 standard liters per minute (SL/min): 0.28 cmH_2O At 60 SL/min: 0.95 cmH_2O Inspiratory pressure drop across inspiratory filter: At 30 SL/min: 0.56 cmH_2O At 60 SL/min: 1.37 cmH_2O
	Inspiratory pressure drop from inlet of open safety valve with inspiratory filter: At 30 SL/min: 0.84 cmH_2O At 60 SL/min: 2.32 cmH_2O
	Pressure drop across 1.68 m (5.5 ft) inspiratory or expiratory limb with water trap, to patient wye: Pediatric patient circuit at 30 SL/min: 0.73 cmH_2O Adult patient circuit at 60 SL/min: 1.05 cmH_2O
	Pressure drop across 1.22 m (4 ft) inspiratory or expiratory limb without water trap, to patient wye: Pediatric patient circuit at 30 SL/min: 0.56 cmH_2O Adult patient circuit at 60 SL/min: 0.70 cmH_2O
	Pressure drop across Fisher & Paykel humidifier and lead-in tube: Pediatric patient circuit at 30 SL/min: 0.28 cmH_2O Adult patient circuit at 60 SL/min: 0.93 cmH_2O
	Expiratory pressure drop across exhalation compartment: At 30 SL/min: 1.5 cmH_2O At 60 SL/min: 3.40 cmH_2O Total inspiratory pressure drop: Pediatric patient circuit with water traps at 30 SL/min: 1.85 cmH_2O Pediatric patient circuit without water traps at 30 SL/min: 1.68 cmH_2O Adult patient circuit with water traps at 60 SL/min: 4.30 cmH_2O Adult patient circuit without water traps at 60 SL/min: 3.95 cmH_2O

ts of lator nt circuit g (using ts ified for vith *840* lator))	Total expiratory pressure drop: Pediatric patient circuit with water traps at 30 SL/min: 2.23 cmH_2O Pediatric patient circuit without water traps at 30 SL/min: 2.06 cmH_2O Adult patient circuit with water traps at 60 SL/min: 4.45 cmH_2O Adult patient circuit without water traps at 60 SL/min: 4.10 cmH_2O
	Internal volume: Inspiratory pneumatics: 50 mL ±5 mL Expiratory pneumatics: 1000 mL ±25 mL (including expiratory filter and collector vial) The *840* Ventilator automatically adjusts for volume losses due to gas compressibility (that is, automatic compliance compensation), subject to a maximum delivered volume of 2500 mL.

TE:

Patient circuit testing specifications are with the ventilator powered off, and are based on the recommended configurations shown in Figure A-1 (heated wire humidifier without water traps and non-heated wire humidifier with water traps). Patient circuit part numbers are listed in Appendix B.

To ensure that compliance compensation functions correctly, the user must run SST with the circuit configured as intended for use on the patient.

ria filter ency	99.97% for nominal particle size of 0.3 µm (micron) at 100 L/min

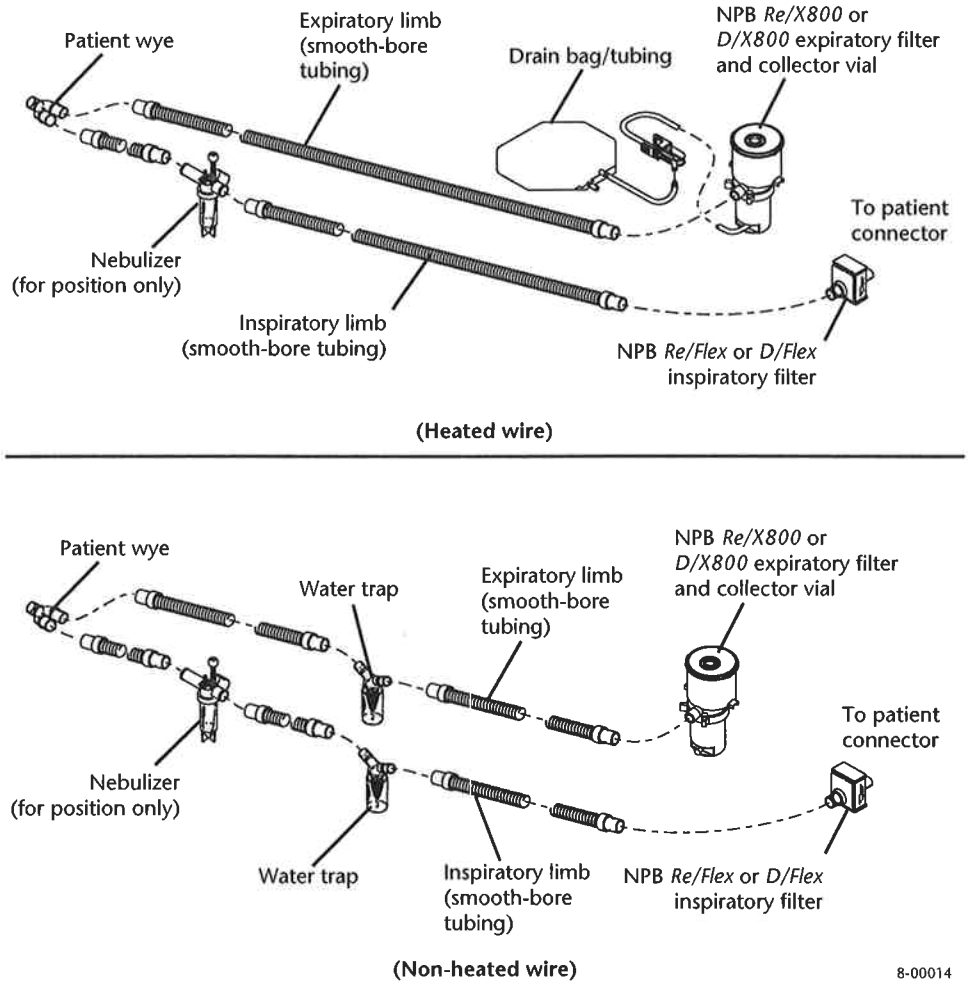


Figure A-1. Recommended patient circuit configurations

Ranges, resolutions, and accuracies

Table A-1 lists ranges, resolutions, and accuracies for ventilator settings, Table A-2 for alarm settings, and Table A-3 for monitored data.

Table A-1: Ventilator settings range, resolution, accuracy

Setting	Range, resolution, accuracy
a ventilation	See apnea settings
a expiratory (T_E)	Range: $T_E \geq 0.2$ second Resolution: Same as for non-apnea Accuracy: Same as for non-apnea
a flow pattern	See flow pattern (same as for non-apnea)
a I:E ratio	Range: ≤1.00:1 Resolution: Same as for non-apnea Accuracy: Same as for non-apnea
a inspiratory ure (P_I)	See inspiratory pressure (same as for non-apnea)
a inspiratory (T_I)	See inspiratory time (same as for non-apnea)
a interval (T_A)	Range: 10 to 60 seconds Resolution: 1 second Accuracy: ±0.01 second
a mandatory	See mandatory type (same as for non-apnea)
a O_2%	Range: 21 to 100% Resolution: 1% Accuracy: Same as for non-apnea
a peak ratory flow)	See peak inspiratory flow (same as for non-apnea)

Table A-1: Ventilator settings range, resolution, accuracy (continued)

Setting	Range, resolution, accuracy
Apnea respiratory rate (f)	Range: 2.0 to 40/min Resolution: 0.1/min for 2.0 to 9.9/min 1/min for 10 to 40/min Accuracy: ±0.1/min (+0.6% of setting)
Apnea tidal volume rate (V_T)	See tidal volume (same as for non-apnea)
Constant during rate change	Range: Inspiratory time, I:E ratio, or expiratory time Resolution: Not applicable Accuracy: Not applicable
Disconnect sensitivity (D_{SENS})	Range: 20 to 95% Resolution: 1% Accuracy: Not applicable
Expiratory sensitivity (E_{SENS})	Range: 1 to 45% Resolution: 1% Accuracy: Not applicable
Expiratory time (T_E)	Range: $T_E \geq 0.2$ second Resolution: 0.01 second Accuracy: ±0.01 second
Flow acceleration %	Range: 1 to 100% Resolution: 1% Accuracy: Not applicable
Flow pattern	Range: Square or descending ramp Resolution: Not applicable Accuracy: Not applicable
Flow sensitivity ($\dot{V}_{SENS}$)	Range: 0.5 to 20 L/min Resolution: 0.1 L/min Accuracy: Not applicable

A-1: Ventilator settings range, resolution, accuracy (continued)

Setting	Range, resolution, accuracy	
dification type	Range:	HME, non-heated expiratory tube, or heated expiratory tube
	Resolution:	Not applicable
	Accuracy:	Not applicable
body weight	Range:	3.5 to 150 kg (7.7 to 330 lb)
	Resolution:	0.5 kg for 3.5 to 9.9 kg; 1 kg for 10 to 150 kg
	Accuracy:	Not applicable
io	Range:	1:299 ≤ I:E ≤ 4.00:1 1:299 < I:E ratio < 149:1 (BILEVEL mode only)
	Resolution:	1 for 1:299 to 1:100 0.1 for 1:99.9 to 1:10.0 0.01 for 1:9.99 to 4.00:1
	Accuracy:	±0.01 second of the inspiratory time determined by the I:E ratio and respiratory rate settings
atory pressure	Range:	5 to 90 cmH_2O
	Resolution:	1.0 cmH_2O
	Accuracy:	±3.0 (+4% of setting) cmH_2O, measured at patient wye (end inspiratory pressure after 1 second)
atory time (T_I)	Range:	0.20 to 8.00 seconds 0.20 to 30.00 seconds (BILEVEL mode only)
	Resolution:	0.01 second
	Accuracy:	±0.01 second
datory type	Range:	VC or PC
	Resolution:	Not applicable
	Accuracy:	Not applicable
e	Range:	A/C, SIMV, SPONT, or BILEVEL
	Resolution:	Not applicable
	Accuracy:	Not applicable

Table A-1: Ventilator settings range, resolution, accuracy (continued)

Setting	Range, resolution, accuracy	
O_2%	Range:	21 to 100%
	Resolution:	1% O_2
	Accuracy:	±3% by volume over the entire breath
Patient circuit type	Range:	Pediatric or adult
	Resolution:	Not applicable
	Accuracy:	Not applicable
Peak inspiratory flow ($\dot{V}_{MAX}$)	Range:	3.0 to 150 L/min for IBW >24 kg 3.0 to 60 L/min for IBW ≤24 kg
	Resolution:	0.1 L/min for flows of 3 to 20 L/min 1 L/min for flows above 20 L/min
	Accuracy:	±0.5 (+10% of setting) L/min (BTPS) after the first 100 ms of inspiration and without compliance compensation.
PEEP	Range:	0 to 45 cmH_2O
	Resolution:	0.5 cmH_2O for 0 to 19.5 cmH_2O 1 cmH_2O for 20 to 45 cmH_2O
	Accuracy:	±2.0 (+4% of setting) cmH_2O measured at patient wye. PEEP measured with returned flow <5 L/min.
Plateau time (T_{PL})	Range:	0.0 to 2.0 seconds
	Resolution:	0.1 second
	Accuracy:	±0.01 second
Pressure sensitivity (P_{SENS})	Range:	0.1 to 20 cmH_2O below PEEP
	Resolution:	0.1 cmH_2O
	Accuracy:	Not applicable
Pressure support (P_{SUPP})	Range:	0 to 70 cmH_2O
	Resolution:	1 cmH_2O
	Accuracy:	±3.0 (+2.5% of setting) cmH_2O measured at patient wye (end inspiratory pressure after 1 second).

e A-1: Ventilator settings range, resolution, accuracy (continued)

Setting	Range, resolution, accuracy	
ratory rate (f)	Range:	1.0 to 100/min
	Resolution:	0.1/min for 1.0 to 9.9/min 1/min for 10 to 100/min
	Accuracy:	±0.1 (+0.6% of setting)/min
/ ventilation	Settings are identical to the new patient values, except: mode = A/C, mandatory type = PC, respiratory rate = 16/min, inspiratory time = 1 second, inspiratory pressure = 10 cmH_2O, PEEP = 3 cmH_2O, trigger type = pressure, pressure sensitivity = 2 cmH_2O, flow acceleration = 50%, O_2% = 100% (21% if O_2 not available) Alarm settings in safety ventilation: high circuit pressure = 20 cmH_2O, high exhaled minute volume = OFF, high exhaled tidal volume = OFF, high respiratory rate = OFF, low exhaled mandatory tidal volume = OFF, low exhaled minute volume = 0.05 L, low exhaled spontaneous tidal volume = OFF	
ort type	Range:	PS or NONE
	Resolution:	Not applicable
	Accuracy:	Not applicable
volume (V_T)	Range:	25 to 2500 mL absolute range. IBW-based range is 1.16 x IBW minimum; 45.7 x IBW maximum.
	Resolution:	1 mL for 25 to 99 mL 5 mL for 100 to 395 mL 10 mL for 400 to 2500 mL
	Accuracy:	Compliance- and BTPS-compensated: For T_I <600 ms, ±10 (+10% x (600 ms/T_I) of setting) mL For T_I >600 ms, ±10 (+10% of setting) mL
er type	Range:	Pressure or flow
	Resolution:	Not applicable
	Accuracy:	Not applicable

Table A-1: Ventilator settings range, resolution, accuracy (continued)

Setting	Range, resolution, accuracy
Setting limits for volume control (VC) mandatory breaths	Tidal volume: 25 mL ≤ V_T ≤ 2500 mL; 1.16 mL/kg ≤ V_T ≤ 45.7 mL/kg (default 7.25 mL/kg) Inspiratory time: 0.2 second ≤ T_I ≤ 8 seconds; 0.2 second ≤ T_I ≤ 30.00 seconds (BILEVEL mode only) Expiratory time: 0.2 second ≤ T_E ≤ 59.8 seconds I:E ratio: 1:299 ≤ I:E ≤ 4.00:1; 1:299 ≤ I:E ≤ 149:1 (BILEVEL mode only) Flow (at 1/min ≤ f ≤ 100/min): 3 L/min ≤ $\dot{V}$ ≤ 60 L/min for IBW ≤ 24 kg 150 L/min ≤ $\dot{V}$ for IBW > 24 kg Minute volume (using square flow pattern, I:E = 1:1, and f ≥ 30/min): 30 L/min ≤ $\dot{V}_E$ for IBW < 24 kg 30 L/min < $\dot{V}_E$ < 75 L/min for IBW 24 to 54 kg Maximum $\dot{V}_E$ = 75 L/min for IBW 55 to 150 kg T_I is a function of V_T, flow pattern, T_{PL}, and $\dot{V}_{MAX}$ T_E is a function of V_T, flow pattern, T_{PL}, and f I:E is the result of T_I and T_E Any combination of settings for V_T, $\dot{V}_{MAX}$, T_{PL}, f, and flow pattern that violates these boundaries will be rejected. Please refer to the technical reference part of this manual for more details.

e A-1: Ventilator settings range, resolution, accuracy (continued)

Setting	Range, resolution, accuracy
ng limits for ure control mandatory hs	Inspiratory pressure: P_I = 5 to 90 cmH_2O; P_I + PEEP ≤ 90 cmH_2O; P_I + PEEP + 2 cmH_2O ≤ $\uparrow P_{CIRC}$ Inspiratory time: 0.2 second ≤ T_I ≤ 8 seconds; 0.2 second ≤ T_I ≤ 30.00 seconds (BILEVEL mode only) Expiratory time: 0.2 second ≤ T_E ≤ 59.8 seconds I:E ratio: 1:299 ≤ I:E ≤ 4.00:1; 1:299 ≤ I:E ≤ 149:1 (BILEVEL mode only) Respiratory rate: 1/min ≤ f ≤ 100/min High circuit pressure limit: 7 cmH_2O ≤ $\uparrow P_{CIRC}$ ≤ 100 cmH_2O T_I is a function of f (for I:E or T_E constant during rate change) and T_E. T_E is a function of f (for I:E or T_I constant during rate change) and T_I. I:E is a function of f (for T_I or T_E constant during rate change), T_I, and T_E. Any combination of settings for P_I, PEEP, $\uparrow P_{CIRC}$, f, T_I, I:E, or T_E that violates these boundaries will be rejected. Please refer to the technical reference part of this manual for more details.
ng limits when ted support is pressure ort (PS)	Support pressure: P_{SUPP} = 0 to 70 cmH_2O; P_{SUPP} + PEEP ≤ 90 cmH_2O PEEP: PEEP = 0 to 45 cmH_2O; PEEP + 7 cmH_2O ≤ $\uparrow P_{CIRC}$ High circuit pressure limit: P_{SUPP} + PEEP + 2 cmH_2O ≤ $\uparrow P_{CIRC}$ Any combination of settings for P_{SUPP}, PEEP, or $\uparrow P_{CIRC}$ that violates the above boundaries will be rejected. Please refer to the technical reference part of this manual for more details.

Table A-2: Alarm settings range, resolution, accuracy

Setting	Range, resolution, accuracy
Apnea interval (T_A)	Range: 10 to 60 seconds Resolution: 1 second
High circuit pressure limit ($\uparrow P_{CIRC}$)	Range: 7 to 100 cmH_2O Resolution: 1 cmH_2O
High exhaled minute volume limit ($\uparrow \dot{V}_{E\ TOT}$)	Range: 0.050 to 99.5 L or OFF Resolution: 0.005 L for 0.050 to 0.495 L 0.05 L for 0.50 to 4.95 L 0.5 L for 5.0 to 99.5 L
High exhaled tidal volume limit ($\uparrow V_{TE}$)	Range: 50 to 3000 mL or OFF Resolution: 1 mL for 50 to 99 mL 5 mL for 100 to 399 mL 10 mL for 400 to 3000 mL
High respiratory rate limit ($\uparrow f_{TOT}$)	Range: 10 to 110/min or OFF Resolution: 1/min
Low exhaled mandatory tidal volume limit ($\downarrow V_{TE\ MAND}$)	Range: 5 to 2500 mL or OFF Resolution: 1mL for 5 to 99 mL 5 mL for 100 to 395 mL 10 mL for 400 to 2500 mL
Low exhaled minute volume limit ($\downarrow \dot{V}_{E\ TOT}$)	Range: 0.010 to 60.0 L Resolution: 0.005 L for 0.010 to 0.495 L 0.05 L for 0.50 to 4.95 L 0.5 L for 5.0 L to 60.0 L
Low exhaled spontaneous tidal volume limit ($\downarrow V_{TE\ SPONT}$)	Range: 5 to 2500 mL or OFF Resolution: 1 mL for 5 to 99 mL 5 mL for 100 to 395 mL 10 mL for 400 to 2500 mL

Table A-3: Monitored data range, resolution, accuracy

Parameter	Range, resolution, accuracy	
h type	Range:	Type: Control, assist, or spontaneous Phase: Inspiration or exhalation
	Resolution:	Not applicable
	Accuracy:	Not applicable
ered O_2%)	Range:	0 to 103%
	Resolution:	1% O_2
	Accuracy:	±3% O_2 of full scale
xpiratory ure ($P_{E\ END}$)	Range:	-20.0 to 130 cmH_2O
	Resolution:	0.1 cmH_2O for -20.0 to 9.9 cmH_2O 1 cmH_2O for 10 to 130 cmH_2O
	Accuracy:	±3 (+4% of reading) cmH_2O (relative to pressure measured at the exhalation side of the patient wye)
nspiratory ure ($P_{I\ END}$)	Range:	-20.0 to 130 cmH_2O
	Resolution:	0.1 cmH_2O for -20.0 to 9.9 cmH_2O 1 cmH_2O for 10 to 130 cmH_2O
	Accuracy:	± 3 (+4% of reading) cmH_2O (relative to the patient wye for pressure control breaths with inspiratory times of 1 second or longer)
ed minute ne ($\dot{V}_{E\ TOT}$)	Range:	0.00 to 99.9 L
	Resolution:	0.01 L for 0.00 to 9.99 L 0.1 L for 10.0 to 99.9 L
	Accuracy:	For T_E < 600 ms: ±10 x respiratory rate (+10% x (600 ms/T_E) of reading) mL For T_E > 600 ms: ±10 x respiratory rate (+10% of reading) mL
ed tidal ne (V_{TE})	Range:	0 to 6000 mL
	Resolution:	1 mL
	Accuracy:	For T_I < 600 ms: ±10 (+10% (600 ms/T_E) of setting) mL For T_I > 600 ms: ±10 (+10% of setting) mL Compliance- and BTPS-compensated T_E = time to exhale 90% of exhaled volume

Table A-3: Monitored data range, resolution, accuracy (continued)

Parameter	Range, resolution, accuracy	
I:E ratio	Range:	1:599 to 9.99:1 1:599 to 149:1 (BILEVEL mode only)
	Resolution:	1 for 1:599 to 1:10 0.1 for 1:9.9 to 9.9:1 1 for 10:1 to 149:1
	Accuracy:	±0.1
Intrinsic PEEP ($PEEP_I$)	Range:	-20.0 to 130 cmH_2O
	Resolution:	0.1 cmH_2O for -20.0 to 9.9 cmH_2O 1 cmH_2O for 10 to 130 cmH_2O
	Accuracy:	±3 (+4% of reading) cmH_2O
Maximum circuit pressure ($P_{CIRC\ MAX}$)	Range:	-20.0 to 130 cmH_2O
	Resolution:	0.1 cmH_2O for -20.0 to 9.9 cmH_2O 1 cmH_2O for 10 to 130 cmH_2O
	Accuracy:	±3 (+4% of reading) cmH_2O
Mean circuit pressure ($\bar{P}_{CIRC}$)	Range:	-20.0 to 130 cmH_2O
	Resolution:	0.1 cmH_2O for -20.0 to 9.9 cmH_2O 1 cmH_2O for 10 to 130 cmH_2O
	Accuracy:	±3 (+4% of reading) cmH_2O
Plateau pressure (P_{PLAT})	Range:	-20.0 to 130 cmH_2O
	Resolution:	0.1 cmH_2O for -20.0 to 9.9 cmH_2O 1 cmH_2O for 10 to 130 cmH_2O
	Accuracy:	±3 (+4% of reading) cmH_2O
Spontaneous minute volume ($\dot{V}_{E\ SPONT}$)	Range:	0.00 to 99.9 L
	Resolution:	0.01 L for 0.00 to 9.99 L 0.1 L for 10.0 to 99.9 L
	Accuracy:	For T_E < 600 ms: ± (10 x respiratory rate +10% (600 ms/T_E) of reading) mL For T_E > 600 ms: ± (10 x respiratory rate +10% of reading) mL

le A-3: Monitored data range, resolution, accuracy (continued)

Parameter	Range, resolution, accuracy	
compliance	Range:	0 to 500 ml/cmH_2O
	Resolution:	0.1 ml/cmH_2O for 0 to 9.9 ml/cmH_2O 1 ml/cmH_2O for 10 to 500 ml/cmH_2O
	Accuracy:	± (1 + 20% of actual value) ml/cmH_2O for 1 to 100 ml/cmH_2O
resistance (R)	Range:	0 to 500 cmH_2O/L/s
	Resolution:	0.1 cmH_2O/L/s for 0 to 9.9 cmH_2O/L/s 1 cmH_2O/L/s for 10 to 500 cmH_2O/L/s
	Accuracy:	± (3 + 20% of actual value) cmH_2O/L/s (Does not apply if C < 5 ml/cmH_2O or $\dot{V}_{MAX}$< 20 L/min)
PEEP P_{TOT})	Range:	-20.0 to 130 cmH_2O
	Resolution:	0.1 cmH_2O for -20.0 to 9.9 cmH_2O 1 cmH_2O for 10 to 130 cmH_2O
	Accuracy:	±3 (+4% of reading) cmH_2O
respiratory f_{TOT})	Range:	0 to 200/min
	Resolution:	0.1/min for 0.0 to 9.9/min 1/min for 10 to 200/min
	Accuracy:	±0.8/min

APPENDIX

B

Part numbers

This appendix lists user-replaceable *840* Ventilator parts and accessories. Figure B-1 shows ventilator parts corresponding to the part numbers listed in Table B-1.

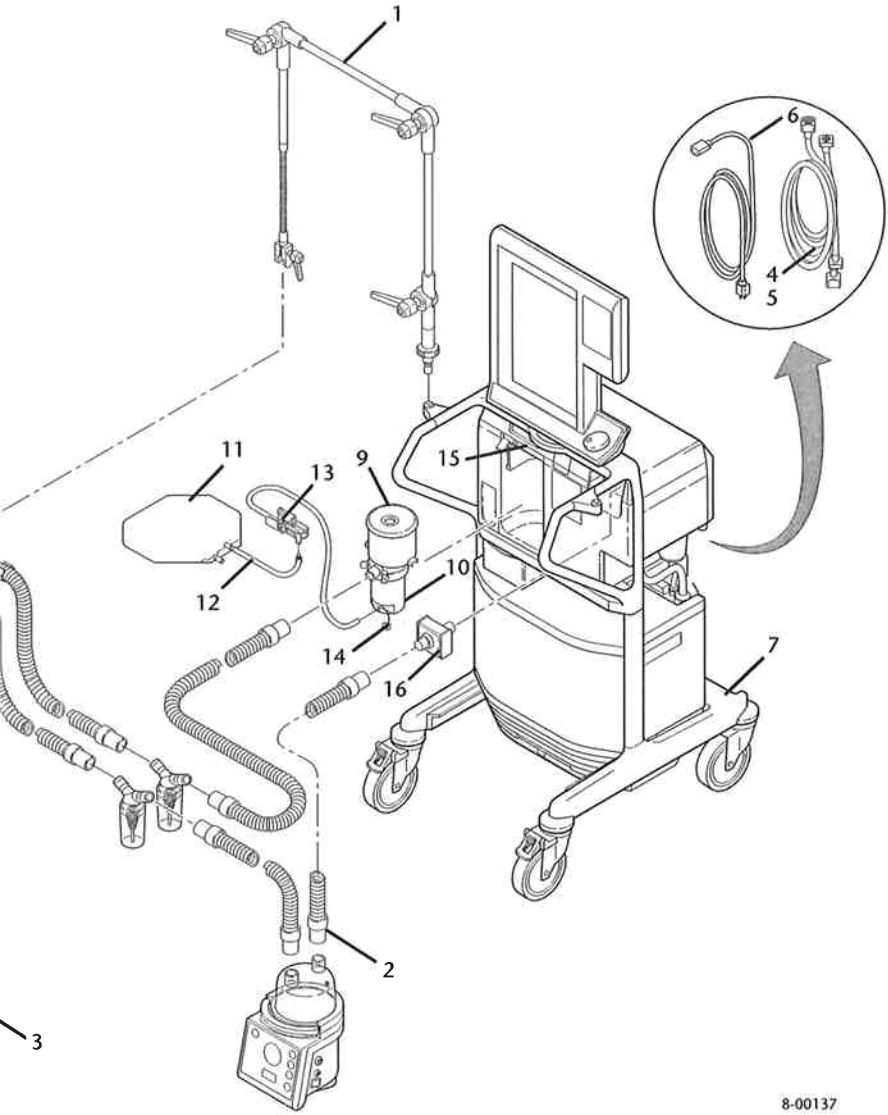


Figure B-1. Ventilator accessories

Table B-1: Ventilator parts and accessories

Item number	Description	Part number
1	Flex arm assembly	4-032006-00
2	Ventilator breathing circuit, adult, reusable. Includes:	G-061208-00
	Tube, adult, 120-cm (2 included)	G-061439-00
	Tube, adult, 40-cm (2 included)	G-061440-00
	Tube, adult, 15-cm (2 included)	G-061441-00
	Wye, adult, with temperature port	4-900MR1-27
	Water trap, in-circuit (2 included)	4-900MR1-39
	Adapter, 22-mm male x 22-mm male	4-900MR5-34
	Tube hanger	G-061214-00
	Ventilator breathing circuit, adult, reusable, with heated wire, for Fisher & Paykel humidifiers.* Includes:	G-061235-00
	Tube, adult, 15-cm (2 included)	G-061441-00
	Tube, adult, 150-cm (2 included)	G-061438-00
	Wye, adult, with temperature port	4-900MR1-27
	Adapter, 22-mm male x 22-mm male	4-900MR5-34
	Tube hanger	G-061214-00
	Adapter, hose heater	4-900MR5-56
	Temperature probe, dual-airway	4-900MR5-69
	Heater wire, inspiratory limb	4-900MR5-21
	Heater wire, expiratory limb	4-900MR5-22
	Draw wire, 1.5-m	4-900MR0-70

*Not shown

Table B-1: Ventilator parts and accessories (continued)

m ber	Description	Part number
nt)	Ventilator breathing circuit, pediatric, reusable.* Includes:	G-061223-00
	Tube, pediatric, 120-cm (2 included)	G-061452-00
	Tube, pediatric, 40-cm (2 included)	G-061453-00
	Tube, pediatric, 15-cm (2 included)	G-061454-00
	Wye, pediatric, straight	G-061480-00
	Water trap, in-circuit (2 included)	4-900MR1-39
	Adapter, 22-mm male/15-mm female, with temperature port	G-061482-00
	Adapter, 22-mm male/15-mm female (2 included)	G-061481-00
	Tube hanger	G-061214-00
	Adapter, 22-mm male x 22-mm male	4-900MR5-34
	Ventilator breathing circuit, pediatric, reusable, with heated wire, for Fisher & Paykel humidifiers.* Includes:	G-061237-00
	Tube, pediatric, 15-cm (2 included)	G-061454-00
	Tube, pediatric, 150-cm (2 included)	G-061451-00
	Wye, pediatric, straight	G-061480-00
	Adapter, 22-mm male x 22-mm male	4-900MR5-34
	Tube hanger	G-061214-00
	Adapter, hose heater	4-900MR5-56
	Temperature probe, dual-airway	4-900MR5-69
	Heater wire, inspiratory limb	4-900MR5-21
	Heater wire, expiratory limb	4-900MR5-22
	Draw wire, 1.5-m	4-900MR0-70
	Adapter, 22-mm male/15-mm female, with temperature port	G-061482-00
	Adapter, 22-mm male/15-mm female (2 included)	G-061481-00
	Test lung	4-000612-00

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Table B-1: Ventilator parts and accessories (continued)

Item number	Description	Part number
4	Hose assembly, oxygen, DISS, for USA	4-001474-00
5	Hose assembly, air, for USA (DISS)	4-006541-00
6	Power cord, for North America	4-071420-00
7	Cart, ventilator	4-076102-00
9	Expiratory bacteria filter, 22-mm ISO connectors, with collector vial, single-patient use (*D/X800*, carton of 12)	4-070315-00
	Expiratory bacteria filter, 22-mm ISO connectors, reusable (*Re/X800*, each)*	4-070305-00
10	Collector vial, reusable (*Re/X800*, each)	4-074647-00
11	Drain bag, single-patient use (package of 25)	4-048491-00
12	Tubing, drain bag, single-patient use (package of 10)	4-048493-00
13	Clamp, reusable (carton of 5)	4-048492-00
14	Drain cap	4-074613-00
15	Seal, expiratory filter	4-070311-00
16	Inspiratory bacteria filter, 22-mm ISO connectors, disposable (*D/Flex*, carton of 12)	4-074601-00
	Inspiratory bacteria filter, 22-mm ISO connectors, reusable (*Re/Flex*, each)	4-074600-00
17	Wall Air Water Trap kit, cart-mount, DISS male (Includes water trap, bracket with mounting hardware, and interconnect hose)*	4-075315-00
18	Mounting kit, Fisher & Paykel 480/730 humidifier*	4-075313-00
19	Operator's and technical reference manual, US English*	4-075609-00

*Not shown

Table B-1: Ventilator parts and accessories (continued)

m ber	Description	Part number
)	Service manual, English*	4-070089-00
	Oxygen sensor (To be replaced every 2 years or as necessary by a qualified service technician.)*	4-072214-00
2	802 Backup Power Source (BPS) battery pack (To be replaced every 2 years or as necessary by a qualified service technician.)*	4-070523-SP
3	10,000-hour preventive maintenance kit, BDU/GUI (Preventive maintenance kits must be installed by a qualified service technician.)*	4-079046-00
4	10,000-hour preventive maintenance kit, compressor (Preventive maintenance kits must be installed by a qualified service technician.)*	4-079040-00
5	Filter, compressor inlet*	4-074374-00
6	Test (gold standard) hose, 21 inches (53 cm) (for use with EST)*	4-018506-00
7	Cable assembly, GUI-to-BDU extension, 10 ft (for shelf mount)*	4-071441-00

hown

Pneumatic schematic

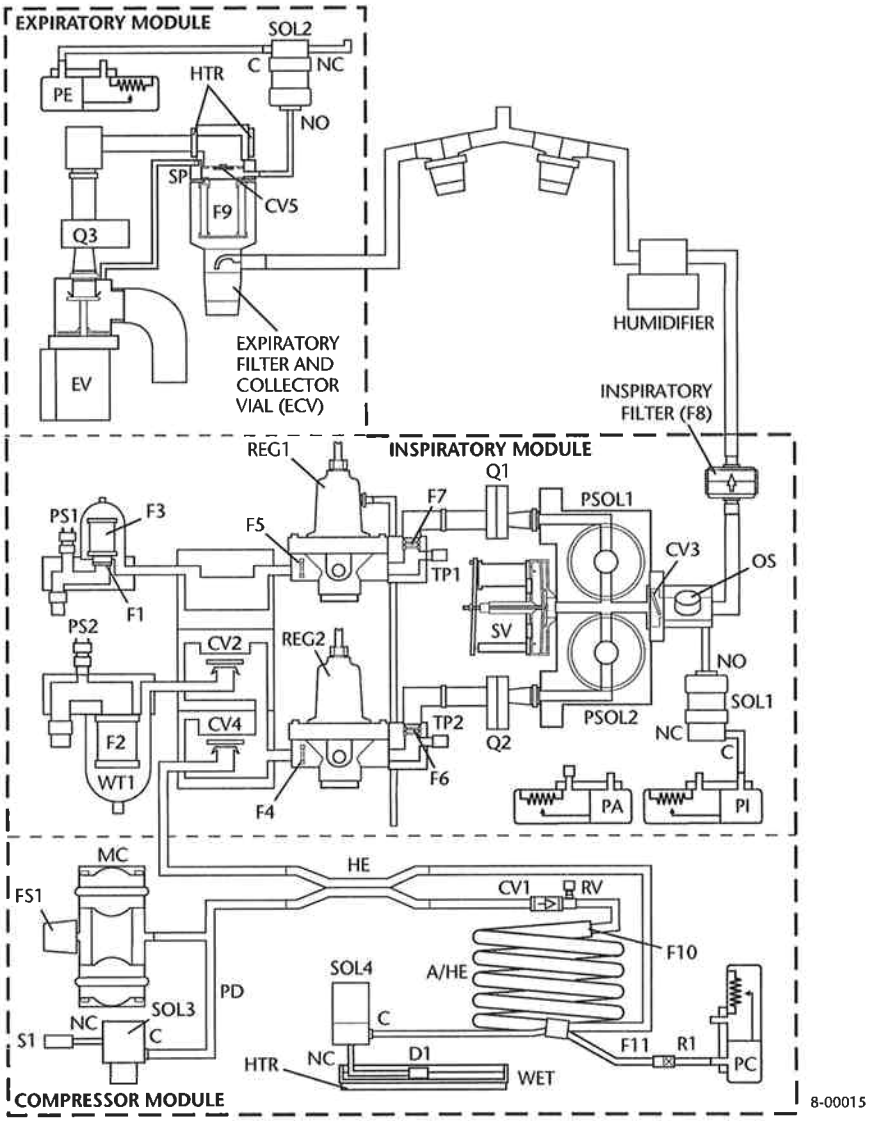


Figure C-1. Pneumatic schematic

APPENDIX D

Alarm and oxygen sensor calibration testing

Test the alarms and the oxygen sensor calibration as required, using the procedures below.

D.1 Alarm test

Alarm tests require an oxygen and air source and stable ac facility power. High and low delivered O_2 alarm testing requires a length of adult disposable flex tubing and a length of low-pressure oxygen supply tubing with an oxygen connector on one end. If any alarm does not annunciate as indicated, verify ventilator setup, ventilator settings, and repeat the alarm test. Alarm testing checks the operation of the following alarms:

- CIRCUIT DISCONNECT
- LOW EXHALED MANDATORY TIDAL VOLUME ($\downarrow V_{TE\ MAND}$)
- HIGH VENTILATOR PRESSURE ($\uparrow P_{VENT}$)
- HIGH CIRCUIT PRESSURE ($\uparrow P_{CIRC}$)
- SEVERE OCCLUSION
- AC POWER LOSS
- APNEA
- NO O_2 SUPPLY
- LOW DELIVERED O_2% ($\downarrow O_2$%)
- HIGH DELIVERED O_2% ($\uparrow O_2$%)

1. Disconnect patient circuit from ventilator and turn off ventilator for at least 5 minutes.
2. Turn the ventilator on. Ventilator automatically runs power on self test (POST).
3. In the GUI lower subscreen, select NEW PATIENT.

4. Set up new patient as follows:

   IBW: 70 kg

   Mode: A/C

   Mandatory Type: VC

   Trigger Type: $\dot{V}$-TRIG

5. Set new patient settings as follows:

   f: 6/min

   V_T: 500 mL

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

   T_{PL}: 0 seconds

   Flow pattern: SQUARE

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

   O_2: 21%

   PEEP: 5 cmH_2O

6. Set apnea settings as follows:

   T_A: 10 seconds

   f: 6.0/min

   O_2: 21%

7. Set alarm settings as follows:

   P_{CIRC}: 70 cmH_2O

   f_{TOT}: OFF

   $\dot{V}_{E\ TOT}$: low limit 1 L/min, high limit 3.5 L/min

   $V_{TE\ MAND}$: low limit 300 mL, high limit OFF

   $V_{TE\ SPONT}$: low limit OFF, high limit OFF

8. Connect an adult patient circuit to the ventilator and attach a test lung (P/N 4-000612-00) to the patient wye.

NOTE:

To ensure proper test results, do not touch the test lung or patient circuit during the next two steps.

9. **CIRCUIT DISCONNECT alarm test:** 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 DISONNNECT alarm after the inspiratory filter is disconnected.

   Connect the inspiratory filter to the *To patient* port.

10. **LOW EXHALED MANDATORY TIDAL VOLUME alarm test:** Set V_T to 200 mL.

    The ventilator annunciates a LOW EXHALED MANDATORY TIDAL VOLUME ($\downarrow V_{TE\ MAND}$) alarm on the third consecutive breaths after ACCEPT is pressed.

11. **HIGH VENTILATOR PRESSURE alarm test:**

    Set patient and alarm settings as follows:

    V_T: 1000 mL

    $\dot{V}_{MAX}$: 100 L/min

    P_{CIRC}: 100 cmH_2O

    Allow the ventilator to deliver at least 4 breaths, then press the alarm reset key to reset alarms.

    Remove the test lung and block the wye.

    The GUI annunciates a HIGH VENTILATOR PRESSURE alarm ($\uparrow P_{VENT}$) during the first breath after blocking the wye.

    Unblock the wye and attach the test lung to the patient wye.

    Press the alarm reset key to reset alarm.

12. **HIGH CIRCUIT PRESSURE alarm test:**

Set patient and alarm settings as follows:

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

P_{CIRC}: 20 cmH_2O

Allow the ventilator to deliver at least 4 breaths, press the alarm reset key to reset all alarms, then press MANUAL INSP.

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

13. **SEVERE OCCLUSION alarm test:**

Set alarm setting as follows:

P_{CIRC}: 50 cmH_2O

Press the alarm reset key to reset all alarms.

Slowly pinch the patient circuit expiratory limb at any point until the GUI annunciates a SEVERE OCCLUSION alarm. While you maintain the occlusion, observe that the safety valve open indicator lights, the upper screen shows the elapsed time without normal ventilation support, and the test lung inflates periodically as the ventilator delivers pressure-based breaths.

Release the expiratory limb. The ventilator should return to normal ventilation within three breaths. Press the alarm reset key to reset all alarms.

14. **AC POWER LOSS alarm test:** Allow the ventilator to deliver at least four breaths, press the alarm reset key to reset all alarms, then disconnect the power cord from ac facility power.

If the BPS is charged, the GUI annunciates an AC POWER LOSS alarm. If less than 2 minutes of battery backup are available, the GUI annunciates a LOW BATTERY alarm. If a BPS is not installed, the GUI annunciates a LOSS OF POWER alarm.

Connect the power cord to ac facility power. The AC POWER LOSS, LOW BATTERY, or LOSS OF POWER alarm autoresets.

15. **APNEA alarm test:**

Set up patient as follows:

Mode: SPONT

Spontaneous Type: PS

NOTE:

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

The GUI annunciates an APNEA alarm 10 seconds after pressing CONTINUE.

Squeeze the test lung twice to simulate two subsequent patient-initiated breaths. The APNEA alarm autoresets.

Set up patient as follows:

Mode: A/C

16. **NO O_2 SUPPLY alarm test:** Disconnect the oxygen inlet supply.

The ventilator annunciates a NO O_2 SUPPLY alarm within one breath.

Connect the oxygen inlet supply.

The NO O_2 SUPPLY alarm autoresets within 2 breaths after oxygen is reconnected.

17. **LOW DELIVERED O_2% and HIGH DELIVERED O_2% alarm test:**

Set patient and alarm settings as follows:

Trigger sensitivity: P-TRIG

P_{SENS}: 2 cmH_2O

O_2: 100%

Set apnea settings as follows:

T_A: 60 seconds

Replace the inspiratory filter with a 6-inch piece of adult disposable flex tubing with a ¼-inch slit in its side, about 3 inches from the end. Insert a length of low-pressure oxygen supply tubing into the slit and about 1½ inches into the *To patient* port. Attach the other end of the oxygen supply tubing to a known air supply (for example, a medical-grade air cylinder).

Set the flow from the air supply to 1 L/min, and watch the upper GUI screen. The value for O_2 (delivered O_2%) should decrease, and the ventilator should annunciate a $\downarrow O_2$% alarm within 30 seconds.

Remove the oxygen supply tubing from the air supply and attach it to a known 100% O_2 source (for example, a medical-grade oxygen cylinder). Set O_2% to 21%. Set the flow from the oxygen source to 1 L/min, and watch the upper GUI screen. The value for O_2 (delivered O_2%) should increase, and the ventilator should annunciate a $\uparrow O_2$% alarm within 30 seconds.

Remove the disposable flex tubing and oxygen supply tubing, replace inspiratory filter and standard patient circuit, then press the alarm reset key to clear all alarms.

D.2 Oxygen sensor calibration test

Test the oxygen sensor calibration as follows:

1. Connect the ventilator's oxygen hose to a known 100% O_2 source (for example, a medical-grade oxygen cylinder). Press the 100% O_2/CAL 2 min key to calibrate the oxygen sensor. Proceed to the next step once the key light turns off.
2. Connect the ventilator oxygen hose to another known 100% O_2 source (for example, a second medical-grade oxygen cylinder).
3. Set O_2% to each of the following values, and allow 1 minute after each for the monitored value to stabilize:

   21%

   40%

   90%
4. Watch the upper screen to see that the value for O_2 (delivered O_2%) is within 3% of each setting within 1 minute of selecting each setting.

APPENDIX

E

Remote alarm and RS-232 ports

This appendix tells you how to use the *840* Ventilator's remote alarm (nurse's call) and RS-232 ports (see Figure E-1).

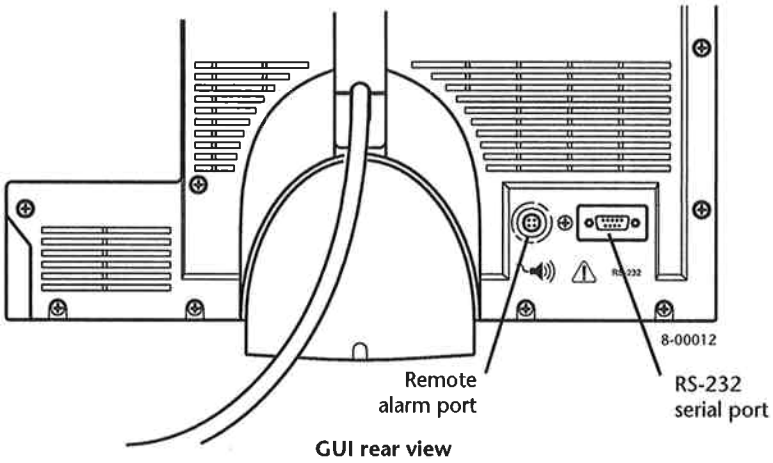


Figure E-1. Remote alarm and RS-232 ports

Warning

To ensure that the ventilator is properly grounded and to protect against electrical hazard, always connect the ventilator ac power cord to a grounded wall power outlet (even if the ventilator is operating from the 802 Backup Power Source) when the ventilator is connected to an external device via the RS-232 or remote alarm port.

NOTE:

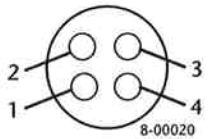
To prevent the risk of excessive enclosure leakage current from external equipment connected to the RS-232 and remote alarm ports, a means for external separation of the conductive earth paths must be provided. Refer to the *840 Ventilator System Service Manual* for information and instructions for construction of cable assemblies providing electrical separation, or contact Nellcor Puritan Bennett for assistance.

Remote alarm port

The ventilator's remote alarm (nurses's call) capability allows medium- and high-urgency alarm conditions to be annunciated at locations away from the ventilator (for example, when the ventilator is in an isolation room). The ventilator signals an alarm using a normally open or a normally closed signal. The ventilator asserts a remote alarm when there is an active medium- or high-urgency alarm condition, unless the alarm silence function is active. The remote alarm port is a 4-pin female connector. Figure E.2 shows the remote alarm port pinout.

NOTE:

Allowable current is 100 mA at 12 V dc (minimum) and 500 mA at 30 V dc (maximum).



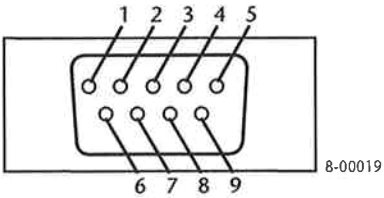
Pin	Signal
1	Normally open (NO)
2	Relay common
3	Normally closed (NC)
4	Not connected

Figure E-2. *840* Ventilator System remote alarm port pinout

E.2 RS-232 port

The RS-232 serial port is a 9-pin male connector configured as data terminal equipment (DTE). Figure E-3 shows the serial port pinout.

NOTE:
Allowable current is 0.2 A at 10 V dc (maximum).



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

Figure E-3. *840* Ventilator System RS-232 serial port pinout

RS-232 port commands

Consult the technical reference part of this manual for information on RS-232 port protocol.

SECTION 1

Introduction to breath delivery

The ventilator delivers and measures exhaled volumes to the specified accuracies when using conventional humidification, heated-wire systems, or heat-moisture exchangers (HMEs). In volume control (VC) ventilation, the ventilator compliance-compensates tidal volumes to ensure that the clinician-set tidal volume is delivered to the lung. Regardless of mode and breath type, all expiratory volumes are compliance-compensated. Both inspiratory and expiratory volumes are reported in body temperature and pressure, saturated (BTPS) units.

Oxygen and air connect directly to the breath delivery unit (BDU), supplying gas to each of two proportional solenoid (PSOL) valves. Software controls each valve independently and, according to the operator-set O_2%, mixes the breathing gas as it is delivered. Mixed breathing gas passes by a safety valve, then through a one-way valve, bacteria filter, and humidification device on the way to the patient. Exhaled gas is directed to the exhalation compartment, which includes a collector vial, bacteria filter, a one-way valve, a flow sensor, and an active exhalation valve ("active" means that the exhalation valve can open and close in precise increments throughout inspiration and exhalation, allowing the ventilator to deliver breaths aggressively while minimizing pressure overshoots, controlling PEEP, and relieving excess pressures). The ventilator does not normally use the safety valve to regulate pressure.

Rather than measure flow and pressure in the harsh environment of the patient wye, the ventilator uses two flow sensors at the delivery ("To patient") side of the BDU to deliver and measure inspired flow, and a flow sensor in the exhalation compartment ("From patient") to measure exhaled flow. Circuit pressure referenced to the wye fitting is measured by two pressure transducers: one in the exhalation compartment, and one in the inspiratory pneumatic system, just downstream of the PSOLs.

For the purposes of calculating patient data (including waveforms), the ventilator uses the inspiratory and expiratory pressure transducers to calculate "wye" pressure. All sensors (including flow, pressure, and temperature sensors) are monitored continuously by background tests to ensure that gas delivery and exhalation occur according to ventilator settings.

SECTION 2

Detecting and initiating inspiration

To deliver a mandatory or spontaneous breath, the breath delivery unit (BDU) uses the operator settings in conjunction with one of the following triggering strategies to initiate a mandatory or spontaneous breath:

- *Internal triggering:* Patient effort or a clock signal. A clock signal can be based on a ventilator setting (for example, respiratory rate or apnea interval) or breath timing within a mode (for example, in SIMV the ventilator delivers a mandatory breath if the patient doesn't initiate a breath in the early part of a breath interval). A clock signal can also occur during alternate ventilation modes such as apnea ventilation, ventilation during occlusion, and safety ventilation.
- *Operator triggering:* The operator presses MANUAL INSP.

The BDU does not allow a second mandatory inspiration during a mandatory or spontaneous inspiration. To prevent autocycling and allow a minimum expiratory time, a mandatory breath cannot be delivered during the restricted phase of exhalation. The restricted phase of exhalation is complete when:

- The first 200 ms of exhalation (regardless of breath type) have elapsed.
- Measured expiratory flow falls to less than 50% of the peak expiratory flow or less than 0.5 L/min, or 5 seconds of exhalation have elapsed and expiratory flow is still greater than 50% of peak expiatory flow.

A mandatory breath can be delivered if a mandatory inspiration is internally time-cycled, regardless of the exhaled flow rate.

Internally triggered inspiration

The ventilator triggers inspiration internally based on:

- Pressure sensitivity
- Flow sensitivity
- Time-cycling
- Other software-generated signals

Mandatory breaths triggered using pressure or flow sensitivity are called *patient-initiated mandatory* (*PIM*) breaths. The ventilator is designed to minimize autocycling when pressure sensitivity is greater than 1 cmH_2O, or when flow sensitivity is greater than 1 L/min for pediatric patients or 1.5 L/min for adult patients.

2.1.1 Pressure sensitivity

When pressure triggering (P-TRIG) is selected, the ventilator initiates breaths based on the monitored pressure at two locations in the patient circuit: inspiratory pressure (P_I) is monitored inside the inspiratory manifold downstream of the proportional solenoid (PSOL) valves, and expiratory pressure (P_E) is monitored just after the expiratory check valve.

Figure 2-1 shows that as the patient draws gas from the circuit (event A), airway pressure drops below baseline. When airway pressure drops below baseline by the value selected for pressure sensitivity (event B), the ventilator initiates a patient-triggered inspiration. The A-B interval depends on two factors:

- How quickly circuit pressure declines (that is, the aggressiveness of the inspiratory effort). The more aggressive the inspiratory effort, the shorter the A-B interval.
- The pressure sensitivity (P_{SENS}) setting. The smaller the setting, the shorter the A-B interval. (The minimum P_{SENS} setting is limited by autocycling, and the triggering criteria include filtering algorithms that minimize the probability of autocycling.)

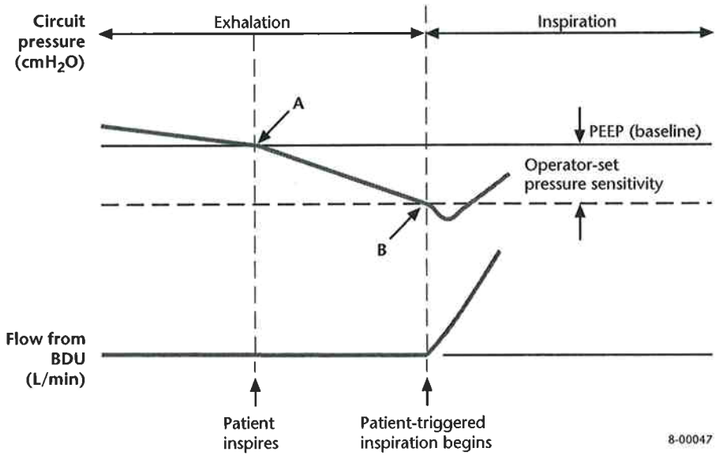


Figure 2-1. Declaring inspiration using pressure sensitivity

2.1.2 Flow sensitivity

When flow triggering (V̇-TRIG) is selected, the BDU maintains constant flow of gas through the patient circuit (called *base flow*) during the latter part of exhalation. The value of this base flow is 1.5 L/min greater than the operator-selected value for flow sensitivity (state A), shown in Figure 2-2.

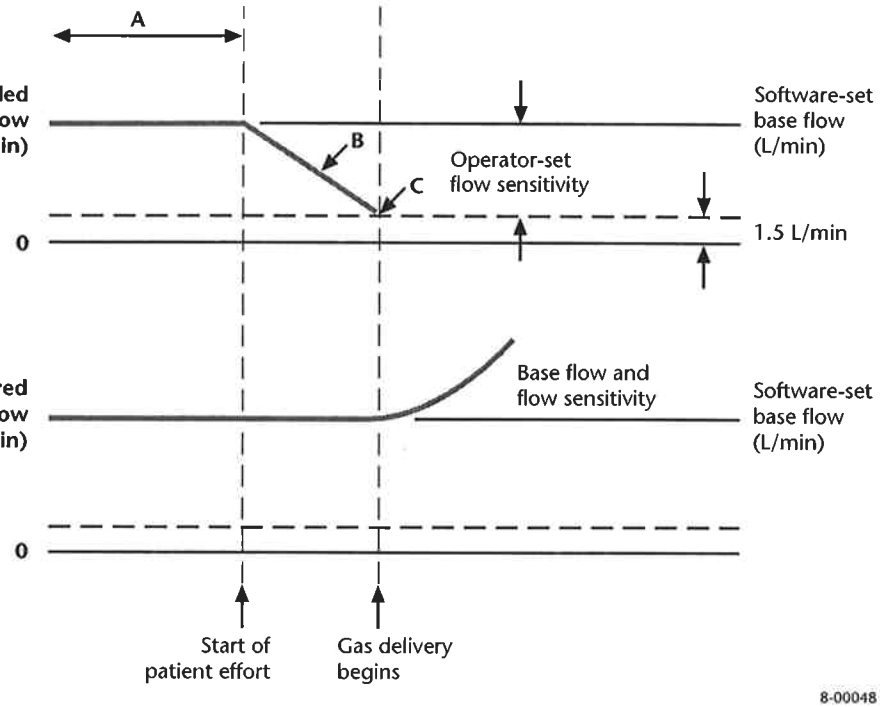


Figure 2-2. Declaring inspiration using flow sensitivity

The ventilator's inspiratory flow sensors measure the delivered flow, and the expiratory flow sensor measures the exhaled flow. The ventilator indirectly measures patient flow (assuming minimal leaks) by monitoring the difference between the two flow measurements. If the patient is not inspiring, any difference between the delivered and exhaled flow is due to sensor inaccuracy or leaks in the patient system. To compensate for leaks in the patient system, the operator can increase the flow sensitivity, which ideally equals desired flow sensitivity + leak flow.

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

The ventilator declares an inspiration when the flow inspired by the patient (that is, the difference between the measured flows) is equal to or greater than the operator-selected value for flow sensitivity (event C). As with pressure triggering, the delay between the start of patient effort and gas delivery depends on two factors:

- How quickly circuit pressure declines (that is, the aggressiveness of the inspiratory effort). The more aggressive the inspiratory effort, the shorter the interval.
- The flow sensitivity ($\dot{V}_{SENS}$) setting. The smaller the setting, the shorter the interval.

The primary difference between pressure triggering and flow triggering is that when flow triggering is selected, the patient experiences flow during the interval between the start of patient effort and the beginning of gas delivery. When pressure triggering is selected, the patient experiences an isometric effort during this interval.

As a backup method of triggering inspiration, a pressure sensitivity of 2 cmH_2O is also in effect. This setting is the most sensitive setting that is still large enough to avoid autocycling, yet triggers with acceptable patient effort.

2.1.3 Time-cycled inspiration

The ventilator monitors time intervals from a specific event (for example, triggering a PIM or the transition from inspiration to exhalation). During A/C in the absence of patient effort, the ventilator delivers one inspiration at the beginning of every breath period, as shown in Figure 2-3. Such a breath is called a *ventilator-initiated mandatory* (*VIM*) breath. If the patient's inspiratory efforts generate a pressure or flow trigger before the breath cycle has elapsed, the ventilator delivers a PIM.

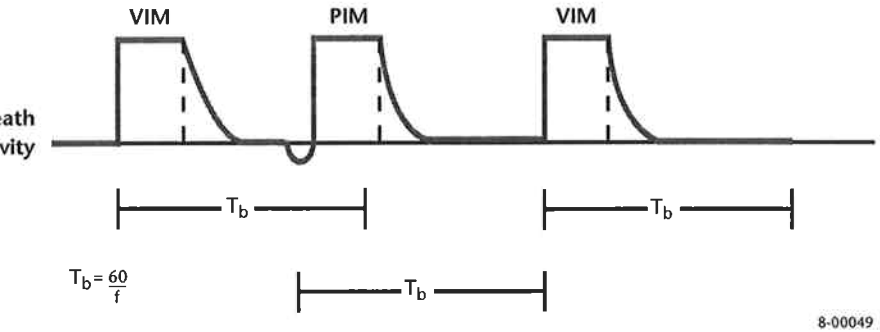


Figure 2-3. Time-cycled inspiration

Operator-triggered inspiration

Mandatory breaths triggered when the operator presses the MANUAL INSP key are called *operator-initiated mandatory* (*OIM*) breaths. The ventilator does *not* deliver an OIM during:

- An ongoing inspiration
- The restricted phase of exhalation
- Occlusion and disconnect alarm conditions

SECTION 3

Detecting and initiating exhalation

The ventilator can declare exhalation based on internal triggers or backup limits.

3.1 Internally triggered exhalation

Internal exhalation triggers include:

- The *time-cycling method*
- The *end-inspiratory flow method*
- The *airway pressure method*

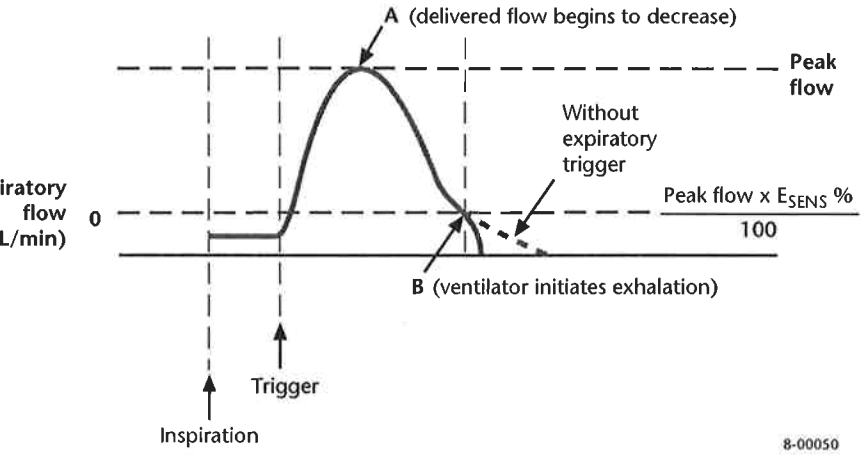
3.1.1 Time-cycled exhalation

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

For pressure-based mandatory breaths, the inspiratory time (T_I) defines the length of the inspiratory phase. For volume-based mandatory breaths, the settings for tidal volume, peak flow, flow pattern, and plateau time define the inspiratory time. Compliance compensation increases peak flow as necessary to ensure that the set tidal volume is delivered to the patient, in the inspiratory time prescribed.

3.1.2 End-inspiratory flow method

During spontaneous breaths (with or without pressure support), the ventilator preferentially uses measurements of end-inspiratory flow to initiate exhalation. The ventilator monitors delivered flow throughout the inspiratory phase. Regardless of whether the patient begins to exhale, delivered flow decreases due to the decreasing pressure gradient from the patient wye to the alveoli (event A in Figure 3-1). When end-inspiratory flow is equal to or less than (peak flow x E_{SENS} %)/100, the ventilator initiates exhalation (event B).



ure 3-1. Initiating exhalation using the end-inspiratory flow method

3.1.3 Airway pressure method

If expiratory sensitivity (E_{SENS}) is set to a value that is too low for the patient-ventilator combination, a vigorous expiratory effort could cause circuit pressure (P_{CIRC}) to rise to the pressure triggering threshold. The ventilator monitors circuit pressure throughout the inspiratory phase, and initiates an exhalation when the pressure equals the inspiratory pressure target value + an incremental value. Figure 3-2 shows an example of an exhalation initiated using the airway pressure method.

NOTE:

The allowable incremental value above the target pressure is 1.5 cmH_2O 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 to a maximum of 8 cmH_2O. From 200 ms to T_n, the incremental pressure decreases in a linear fashion from the initial value to 1.5 cmH_2O.

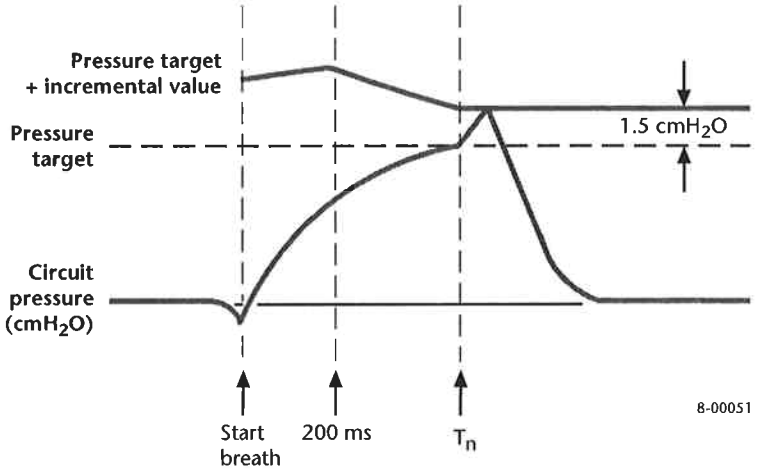


Figure 3-2. Initiating exhalation using the airway pressure method

Backup limits

In addition to the internal triggering methods of triggering exhalation, backup limits are intended to prevent inspirations of excessive duration or pressure. If a particular breath is subject to more than one backup limit, exhalation is triggered by whichever limit is violated first.

3.2.1 Time limit

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

3.2.2 High circuit pressure limit

The high circuit pressure limit applies to all breaths. If the airway pressure equals or exceeds the high circuit pressure limit during any inspiration (except during occlusion status cycling, OSC), the ventilator terminates the inspiration and initiates exhalation.

3.2.3 High ventilator pressure limit

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

SECTION 4

Mandatory breath delivery

This section describes the following aspects of mandatory breath delivery:

- Pressure- and volume-based mandatory breaths
- Compliance and body temperature and pressure, saturated (BTPS) compensation for volume-based mandatory breaths
- Manual inspirations

4.1 Comparison of pressure- and volume-based mandatory breaths

Table 4-1 compares pressure- and volume-based breath delivery.

NOTE:

As a general rule, when there are multiple methods of detection, inspiration or exhalation is triggered by the strategy that declares it first.

Table 4-1: Comparison of pressure- and volume-based mandatory breaths

acteristic	Pressure-based	Volume-based
atory tion	Pressure sensitivity, flow sensitivity (including the pressure trigger backup), or time-cycling. Inspiration can also be operator-triggered using MANUAL INSP.	See pressure-based.
ure or during ation	Pressure is targeted to the sum of the operator-selected PEEP + inspiratory pressure. The maximum flow is 200 L/min for patients whose IBW > 24 kg, and 80 L/min for patients whose IBW ≤ 24 kg. The wye pressure trajectory depends upon the settings for inspiratory pressure, inspiratory time, and flow acceleration %. The flow-delivery profile is a function of the flow acceleration % setting, the patient's compliance and resistance, and the patient's inspiratory effort (if any). As the flow acceleration % setting is increased from minimum to maximum, the time to achieve the pressure target decreases.	Inspiratory flow trajectories are defined by the settings for tidal volume, peak inspiratory flow, and flow pattern (including compliance compensation). The maximum setting for peak flow is 150 L/min for adults and 60 L/min for pediatric patients. Additional flow is available (up to 200 L/min) for compliance compensation.
ation during ation	Adjusts to minimize pressure overshoot and maintain target pressure.	Closed.
atory s during ation	Adjust flow to maintain target pressure.	Adjusts to achieve target flow trajectory.

Table 4-1: Comparison of pressure- and volume-based mandatory breaths (continued)

Characteristic	Pressure-based	Volume-based
Expiratory detection	Exhalation is initiated by the time-cycling method. When the time elapsed since the beginning of inspiration equals the inspiratory time (an operator-selected value), the ventilator initiates exhalation. The high pressure limit can also trigger exhalation as a backup strategy.	The operator specifies tidal volume, peak flow, flow pattern, and plateau time, and the ventilator computes an inspiratory time. Exhalation is initiated when the computed inspiratory time has elapsed. The $\uparrow P_{CIRC}$ and $\uparrow P_{VENT}$ alarms can also trigger exhalation as a backup strategy.
Pressure or flow during exhalation	Pressure is controlled to PEEP. If flow-triggering is selected, base flow is re-established near the end of expiratory flow. Various strategies operate to minimize autocycling.	See pressure-based.
Inspiratory valve during exhalation	For pressure triggering: near the end of expiratory flow, opens to establish 1 L/min bias flow. For flow triggering: set to deliver base flow.	See pressure-based.
Exhalation valve during exhalation	Adjusts to maintain the operator-selected value for PEEP.	See pressure-based.

Compliance compensation for volume-based mandatory breaths

When the ventilator delivers a volume of gas into the patient circuit, not all of the gas actually enters the patient's respiratory system. Part of the delivered volume, called the *compliance volume* (V_C), remains in the patient circuit.

$$V_C = C_{pt\ ckt} (P_{end\ insp} - P_{end\ exh})$$

where:

$C_{pt\ ckt}$	is the compliance of the patient circuit
$P_{end\ insp}$	is the pressure at the patient wye at the end of the current inspiration
$P_{end\ exh}$	is the pressure at the patient wye at the end of the current exhalation

For volume ventilation, practitioners often 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 on the part of the practitioner. In addition, $P_{end\ insp}$ and $P_{end\ exh}$ can change with time.

In the *840* Ventilator, an iterative algorithm automatically computes the compliance volume. For all flow patterns, compliance compensation does not change inspiratory time (T_I). Compliance compensation is achieved by increasing flow (increasing the amplitude of the flow patterns). 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 ideal body weight (IBW), and is summarized by this equation:

$V_{comp,max}$ = Factor x Tidal volume

where:

$V_{comp,max}$ is the maximum compliance volume

Factor is the linear interpolation of the values in Table 4-2.

Table 4-2: Compliance volume factors

Adult patient circuit type		Pediatric patient circuit type	
IBW (kg)	Factor	IBW (kg)	Factor
≤ 10	5	≤ 10	5
15	4.6	11	3.5
30	3.4	12.5	2.9
60	2.75	15	2.7
≥ 150	2.5	≥ 30	2.5

4.3 BTPS compensation for volume-based mandatory breaths

The goal of volume ventilation is to deliver a specified volume of gas of known oxygen concentration to the patient's lungs. Since gas volume depends on gas temperature, pressure, and composition, clinicians report and specify tidal volume under the conditions of body temperature (37 °C), existing barometric pressure, and fully saturated with water vapor (100% humidity). This is called *body temperature and pressure, saturated* (*BTPS*). All volumes (flows) set or reported by the ventilator are at existing barometric pressure, 37 °C, and fully saturated with water vapor (BTPS). Graphics data is not BTPS-compensated.

4.4 Manual inspiration

A manual inspiration is an operator-initiated mandatory (OIM) inspiration. When the operator presses MANUAL INSP, the ventilator delivers the currently specified mandatory breath (if permitted), either volume- or pressure-based. A volume-based manual inspiration is compliance-compensated.

SECTION 5

Spontaneous breath delivery

This section describes spontaneous breaths (available in SIMV and SPONT modes), with or without pressure support. Table 5-1 compares spontaneous breaths with and without pressure support.

NOTE:

As a general rule, when there are multiple methods of detection, inspiration or exhalation is triggered by the strategy that declares it first.

Table 5-1: Comparison of spontaneous breaths with and without pressure support

Characteristic	Spontaneous breaths with pressure support	Spontaneous breaths without pressure support
Inspiratory detection	Either pressure or flow sensitivity, whichever is selected.	See spontaneous breaths *with* pressure support.
Pressure or flow during inspiration	Pressure rises according to the selected flow acceleration % and IBW setting, and is targeted to the sum of the operator-selected level of P_{SUPP} + PEEP. The inspiratory flow profile is determined by patient demand and the flow acceleration % setting. As the flow acceleration % setting is increased from minimum to maximum, the time to achieve the pressure target decreases. The maximum available flow is up to 80 L/min for pediatric patients (IBW ≤ 24 kg), and up to 200 L/min for adults (IBW > 24 kg).	Identical to spontaneous breaths *with* pressure support, except that target pressure is slightly (1.5 cmH_2O) above PEEP to improve work of breathing.
Exhalation valve during inspiration	Adjusts to minimize pressure overshoot and maintain the target pressure.	See spontaneous breaths *with* pressure support.

ble 5-1: Comparison of spontaneous breaths with and without pressure support (continued)

acteristic	Spontaneous breaths with pressure support	Spontaneous breaths without pressure support
atory during ation	Adjust to maintain target pressure. Because the exhalation valve acts as a relief valve that vents any excess flow, inspiratory flow can be delivered aggressively and allows improved work of breathing.	See spontaneous breaths *with* pressure support.
tory tion	The end-inspiratory flow or airway pressure method, whichever detects exhalation first. Time backup and the $\uparrow P_{CIRC}$ alarm are also available as backup strategies.	See spontaneous breaths *with* pressure support.
re or luring ation	Pressure is controlled to PEEP. For pressure triggering: set to deliver a bias flow of 1 L/min near the end of expiratory flow. For flow triggering: set to deliver base flow.	See spontaneous breaths *with* pressure support.
atory during ation	For pressure triggering: set to deliver a bias flow of 1 L/min near the end of expiratory flow. For flow triggering: set to deliver base flow near the end of expiratory flow.	See spontaneous breaths *with* pressure support.
ation during ation	Adjusts to maintain the operator-selected value for PEEP.	See spontaneous breaths *with* pressure support.

SECTION 6

Assist/control (A/C) mode

In A/C mode the ventilator delivers only mandatory breaths. When the ventilator detects patient inspiratory effort, it delivers a patient-initiated mandatory (PIM) breath (also called an *assisted* breath). If the ventilator does not detect inspiratory effort, it delivers a ventilator-initiated mandatory (VIM) breath (also called a *control* breath) at an interval based on the set respiratory rate. Breaths can be pressure- or flow-triggered in A/C mode.

6.1 Breath delivery in A/C

In A/C mode, the ventilator calculates the breath period (T_b) as:

$$T_b = 60/f$$

where:

T_b	is the breath period in seconds
f	is the set respiratory rate in breaths per minute

The length of the inspiratory phase depends on the current breath delivery settings. The ventilator transitions to the expiratory phase at the end of the inspiratory phase. The ventilator calculates the length of the expiratory phase as:

$$T_E = T_b - T_I$$

where:

T_E	is the length of the expiratory phase in seconds
T_b	is the breath period in seconds
T_I	is the length of the inspiratory phase in seconds

Figure 6-1 shows A/C breath delivery when no patient inspiratory effort is detected and all inspirations are VIMs.

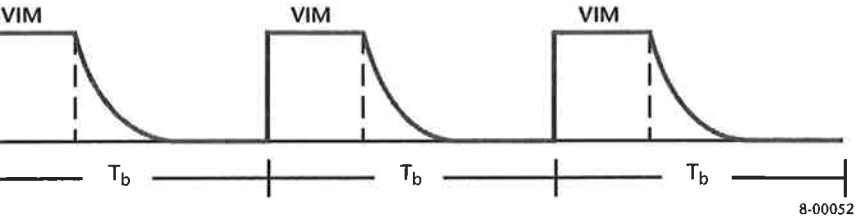


Figure 6-1. A/C mode, no patient effort detected

Figure 6-2 shows A/C breath delivery when patient inspiratory effort is detected. The ventilator delivers PIM breaths at a rate ≥ the set respiratory rate.

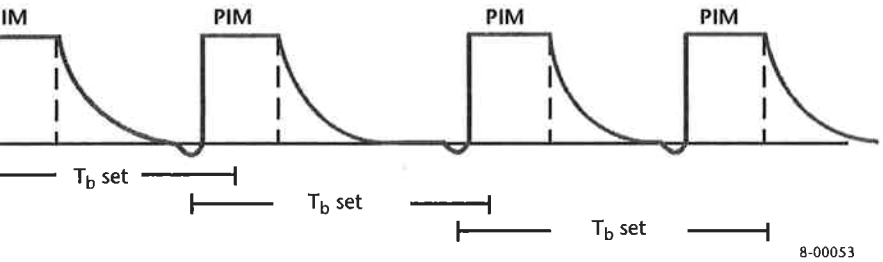


Figure 6-2. A/C mode, patient effort detected

Figure 6-3 shows A/C breath delivery when there is a combination of VIM and PIM breaths.

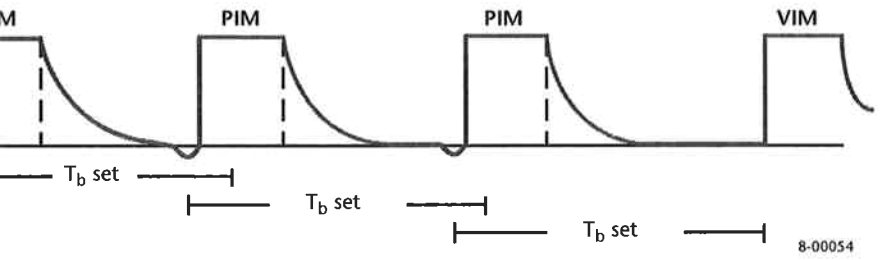


Figure 6-3. A/C mode, VIM and PIM breaths

6.2 Rate change during A/C

Changes to the respiratory rate setting are phased in during exhalation only. The new breath period, based on the new respiratory rate, is based on the start of the current breath, and follows these rules:

- The inspiratory time of current breath 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 will be delivered is 3.5 times the current inspiratory time *or* the length of the new breath cycle (whichever is greater), 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.

6.3 Changing to A/C mode

Switching the ventilator to A/C 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 cycle. Following this VIM, and before the next A/C cycle begins, the ventilator responds to the patient's inspiratory efforts by delivering mandatory breaths.

The first A/C breath (the VIM breath) is phased in according to these rules:

- The breath is not delivered during an inspiration.
- The breath is not delivered during the restricted phase of exhalation.
- The ventilator ensures that the apnea interval elapses at least 5 seconds after the beginning of exhalation.
- Any other specially scheduled event (such as 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 that are active when the mode change is requested.

- If the current mode is SIMV or SPONT and the current or last breath type is spontaneous or an OIM, the time *t* until the first VIM of the new A/C mode is whichever is less:
  - 3.5 x current inspiratory time, or
  - the length of the apnea interval.
- If the mode is SIMV and the current or last breath is or was mandatory (but not an OIM), the time *t* until the first VIM of the new A/C mode is whichever is less:
  - 3.5 x current inspiratory time, or
  - the length of the apnea interval, or
  - the length of the current breath cycle.

SECTION 7

Synchronous intermittent mandatory ventilation (SIMV)

SIMV is a mixed ventilatory mode that allows both mandatory and spontaneous breaths. The mandatory breaths can be volume- or pressure-based, and the spontaneous breaths can be pressure-assisted (for example, when pressure support is in effect). You can select pressure- or flow-triggering in SIMV.

The SIMV algorithm is designed to guarantee one mandatory breath each SIMV breath cycle. This mandatory breath is either a patient-initiated mandatory (PIM) breath (also called an *assisted* breath) or a ventilator-initiated mandatory (VIM) breath (in case the patient's inspiratory effort is not sensed within the breath cycle).

As Figure 7-1 shows, each SIMV breath cycle (T_b) has two parts: the first part of the cycle is the mandatory interval (T_m) and is reserved for a PIM. If a PIM is delivered, the T_m interval ends and the ventilator switches to the second part of the cycle, the spontaneous interval (T_s), which is reserved for spontaneous breathing throughout the remainder of the breath cycle. At the end of an SIMV breath cycle, the cycle repeats. If a PIM is not delivered, the ventilator delivers a VIM at the end of the mandatory interval, then switches to the spontaneous interval.

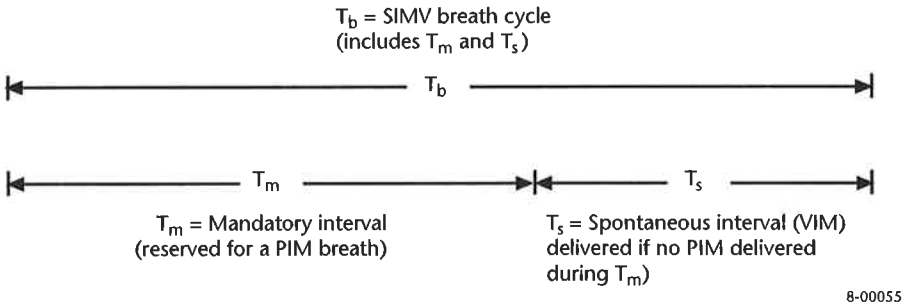
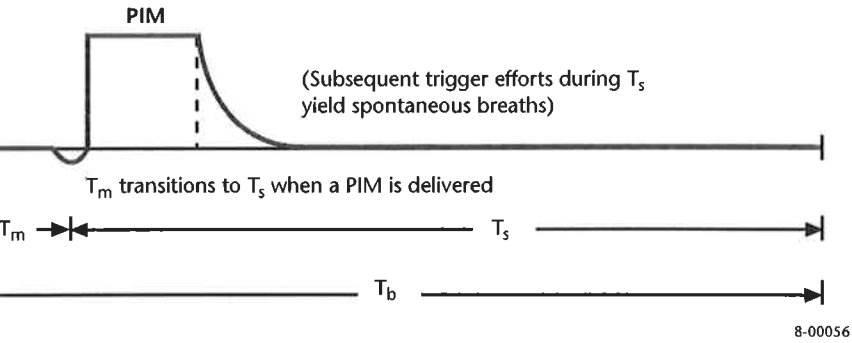


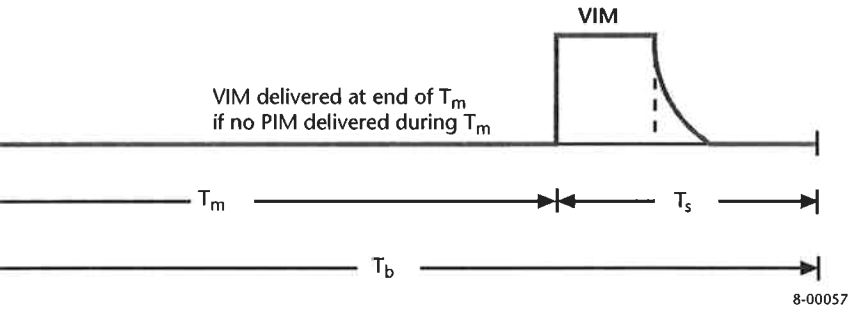
Figure 7-1. SIMV breath cycle (mandatory and spontaneous intervals)

Figure 7-2 shows an SIMV breath cycle where a PIM is delivered within the mandatory interval.



ure 7-2. SIMV breath cycle, PIM delivered within mandatory interval

Figure 7-3 shows an SIMV breath cycle where a PIM is *not* delivered within the mandatory interval.



e 7-3. SIMV breath cycle, PIM *not* delivered within mandatory interval

Breath delivery in SIMV

Mandatory breaths in SIMV are identical to mandatory breaths in A/C mode, and spontaneous breaths in SIMV are identical to spontaneous breaths in SPONT mode. Patient triggering must meet the requirements for flow and pressure sensitivity.

The procedure for setting the SIMV respiratory rate is the same as in A/C. Once the respiratory rate (f) is set, the SIMV interval cycle (T_b) in seconds is:

$$T_b = 60/f$$

The SIMV breathing algorithm delivers one mandatory breath each cycle interval, regardless of the patient's ability to breath 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 T_m to transition to T_s.)

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, T_m ends, T_s begins, and any further trigger efforts yield spontaneous breaths. During the spontaneous interval, the patient can take an unlimited number of spontaneous breaths. 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 maximum mandatory interval for any valid respiratory rate setting in SIMV is defined as whichever is less:

- 0.6 x the SIMV interval cycle (T_b), or
- 10 seconds

In SIMV, the interval from mandatory breath to mandatory breath can be as long as 1.6 x the SIMV cycle interval (but no longer than the cycle interval + 10 seconds). At high respiratory rates and too-large tidal volumes, *breath stacking* (the delivery of a second inspiration before the first exhalation is complete) is inevitable. 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.

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.

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 ≥ the f setting). If the patient triggers a breath at the beginning of a breath cycle, 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.

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 begin apnea ventilation.
- If T_A elapses during the spontaneous interval, apnea ventilation begins.

Figure 7-4 shows how SIMV is designed to deliver a VIM rather than trigger apnea ventilation when possible.

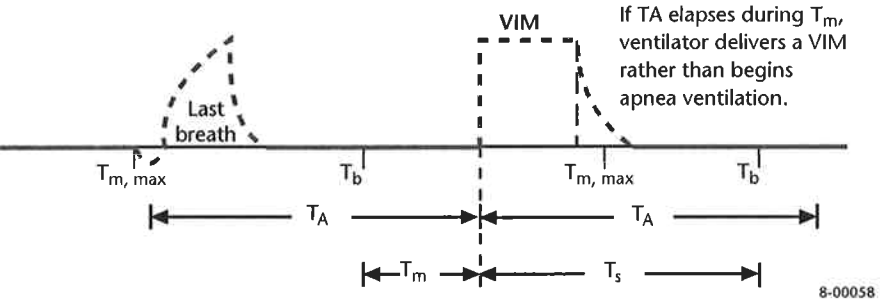


Figure 7-4. Apnea ventilation in SIMV

7.3 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 cycle. Following this VIM, and before the next SIMV cycle begins, the ventilator responds to successful inspiratory efforts by delivering spontaneous breaths. The first SIMV VIM breath is phased in according to these 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 x T_I, current T_A, or the length of the current breath cycle.
- 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 x T_I, or current T_A.

If the command to change to SIMV occurs more than 5 seconds after the beginning of exhalation but before exhaled flow ≤ 50% peak exhaled flow, and before a next breath or the apnea interval has elapsed, the ventilator delivers the first SIMV VIM the moment that the command is recognized.

7.4 Rate change during SIMV

A change to the respiratory rate is 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 cycle interval, following these rules:

- Inspiratory time 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 cycle interval *or* 3.5 x the last or current T_I,
- but not greater than the current SIMV cycle interval.

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 giving a spontaneous breath.

SECTION 8

Spontaneous (SPONT) mode

In spontaneous (SPONT) mode, inspiration is usually initiated by patient effort. Breaths are initiated via pressure or flow triggering, whichever is currently active. An operator can also initiate a manual inspiration during SPONT. VIM breaths are not possible in SPONT mode.

8.1 Breath delivery in SPONT

The inspiratory phase begins when the ventilator detects patient effort. Unless the breath is an OIM breath, breath delivery during the inspiratory phase is determined by the settings for pressure support, PEEP, flow acceleration %, and expiratory sensitivity.

8.2 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 exhalation phase and waits for the detection of patient inspiratory effort, a manual inspiration, or apnea detection.

SECTION 9

Apnea ventilation

The ventilator's apnea detection strategy follows these rules:

- 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 that 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 (for example, expiratory pause), but still detect a true apnea event.

9.1 Apnea detection

The ventilator declares apnea when no breath has been delivered by the time that 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-, ventilator-, 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.

Figure 9-1 shows an apnea interval equal to the breath period.

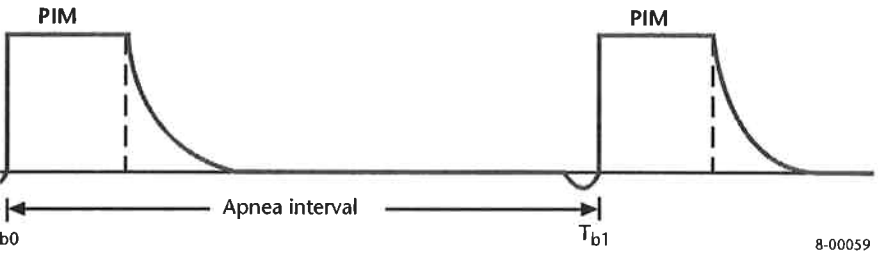


Figure 9-1. Apnea interval equals breath period

Figure 9-2 shows an apnea interval greater than the breath period.

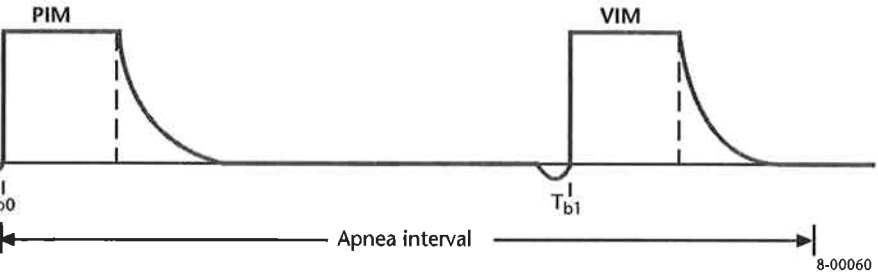


Figure 9-2. Apnea interval greater than breath period

Figure 9-3 shows an apnea interval less than the breath period.

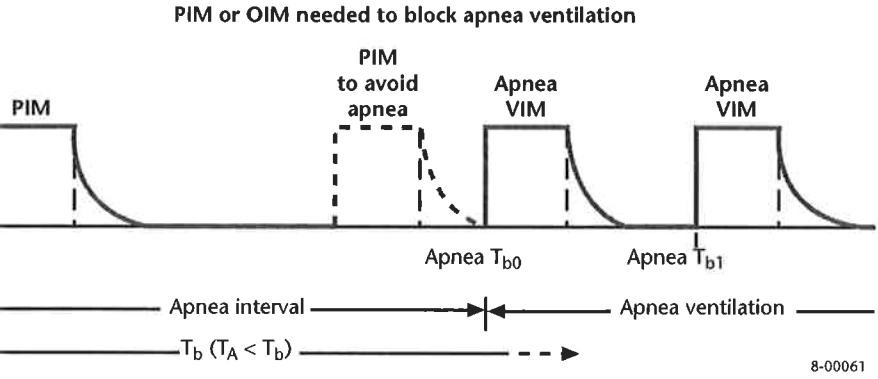


Figure 9-3. Apnea interval less than breath period

9.2 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 upper screen of the graphic user interface (GUI). Regardless of the apnea interval setting, apnea ventilation cannot begin until inspiration is complete and the restricted phase of exhalation has elapsed.

9.3 Key entries 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 (see Section 11 for information on phasing in settings). If apnea ventilation is active, new settings are accepted but not implemented until non-apnea ventilation begins. Allowing key entries after apnea detection allows you to adjust the apnea interval at setup, regardless of whether apnea has been detected. During apnea ventilation, the MANUAL INSP key is active, and the EXP PAUSE key is not active. The 100% O_2/CAL 2 min key is active during apnea ventilation, because apnea detection is likely during suctioning.

9.4 Resetting apnea ventilation

Apnea ventilation is intended as a backup mode of ventilation when there is no patient inspiratory effort. Apnea ventilation can be reset to normal ventilation by the operator (manual reset) 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 autocycling caused by large leaks in the patient circuit.

9.4.1 Resetting to A/C

Switching to A/C from apnea ventilation causes the ventilator to deliver a VIM and set the start time for the beginning of the first A/C cycle. The second VIM breath is phased in according to these rules:

- The VIM is not delivered during an inspiration.
- The VIM is not delivered until the first 200 ms of exhalation have elapsed and the expiratory flow is ≤ 50% of peak expiratory flow.
- The time until the first VIM is delivered is 3.5 times the apnea inspiratory time, or the apnea breath period, whichever occurs first.

9.4.2 Resetting to SIMV

Switching to SIMV from apnea ventilation causes the ventilator to deliver a VIM and set the start time for the beginning of the first SIMV cycle. Unless the patient triggers a synchronized PIM first, the VIM breath is phased in according to these rules:

- The VIM is not delivered during an inspiration.
- The VIM is not delivered during the restricted phase of exhalation.
- The time until the first VIM is delivered is 3.5 times the apnea inspiratory time, or the apnea breath period, whichever occurs first.

9.4.3 Resetting to SPONT

Once the ventilator switches to SPONT from apnea ventilation, the apnea interval begins at the start of the last or current apnea breath. The ventilator waits for detection of inspiratory effort, a manual inspiration, or apnea detection. If a valid breath is not delivered before the apnea interval elapses, the ventilator re-enters apnea ventilation.

9.5 Phasing in new apnea intervals

These rules apply to apnea settings:

- The apnea respiratory rate must be greater than or equal to $60/T_A$.
- Apnea settings cannot result in an I:E ratio greater than 1.00:1.

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 but does not implement the new setting until non-apnea ventilation begins. 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.

Detecting occlusion and disconnect

SECTION 10

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

10.1 Occlusion

The ventilator detects a severe occlusion if:

- The inspiratory or expiratory tube is completely occluded.
- The ventilator EXHAUST port or device attached to it is fully blocked.
- The exhalation valve fails in the closed position (occlusion detection at the "From patient" port begins after 200 ms of exhalation has passed).
- Water in a lazy loop of the patient tubing (inspiratory or expiratory) completely occludes the lumen.

The ventilator does *not* declare a severe occlusion if:

- The pressure difference between the inspiratory and the expiratory transducers is less than or equal to 5 cmH_2O.
- The exhalation valve fails in the closed position and the pressure in the exhalation limb is less than 2 cmH_2O.
- A Wright spirometer or 6 feet of silicone tubing is attached to the EXHAUST port of the ventilator.

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

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 that the patient has been without ventilatory support. Severe occlusion is detected regardless of what mode or triggering strategy in effect. When a severe occlusion is detected, the ventilator terminates normal ventilation, annunciates an occlusion alarm, and enters the safe state (exhalation and inspiratory valve de-energized and safety valve open) for 15 seconds or until inspiratory pressure drops to 5 cmH_2O or less, whichever comes first.

During a severe occlusion, the ventilator enters *occlusion status cycling* (OSC), in which it periodically attempts to deliver a pressure-based breath while monitoring the inspiration and expiration phases for the existence of a severe occlusion. If the severe occlusion is corrected, the ventilator detects the corrected condition after two complete OSC breath cycles 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, then delivers breath with a target pressure of 15 cmH_2O for 2000 ms, then cycles to exhalation. During OSC (and only during OSC), the $\uparrow P_{CIRC}$ (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 and reinstates breath delivery according to current settings.

Apnea detection, expiratory pause, and manual inspirations are suspended during a severe occlusion. Maneuvers are withheld during a severe occlusion, and resume during their next scheduled occurrence. During a severe occlusion, you can change ventilator settings.

10.2 Disconnect

The ventilator bases its disconnect detection strategy on variables that are specific to each breath type. The ventilator's disconnect detection strategy is designed to detect actual disconnects (at the inspiratory limb, expiratory limb, or patient wye) while rejecting false detections.

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.
- If the inspiratory limb is disconnected, 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 that must be lost during the exhalation phase of the same breath to declare a disconnect) setting to detect a disconnect.
- If the disconnect occurs during a spontaneous breath, the ventilator detects that inspiratory flow rises to the maximum allowable, in an unsuccessful effort to achieve the set level of pressure support or CPAP within the maximum inspiratory time.
- If the disconnect occurs at the patient side of 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 3 consecutive breaths. The D_{SENS} setting helps avoid false detections due to leaks in the circuit or the patient's lungs, and the 3 consecutive breaths requirement helps avoid false detections due to a patient out-drawing the ventilator during volume control (VC) breaths.

Once the ventilator detects a patient circuit disconnect, the ventilator declares a high-urgency alarm and enters *idle mode*, regardless of what mode (including apnea) was active when the disconnect was detected. The ventilator displays the length of time that the patient has been without ventilatory support. During idle mode, the exhalation valve opens, *idle flow* (10 L/min flow at 100% O_2, if available) begins, and breath triggering is disabled.

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 100 to 1000 ms.

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 that were in effect before the disconnect was detected. Maneuvers are withheld during a disconnect, and resume during their next scheduled occurrence.

Flow triggering (if active), apnea detection, expiratory pause, 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, you can change ventilator settings.

10.3 Occlusions and disconnect annunciation

Occlusion and disconnection cannot be declared at the same time. Therefore, the ventilator annunciates only the first event to be declared.

SECTION 11

Phasing in setting changes

These rules govern how the ventilator phases in setting changes:

- Individual settings are handled separately and phased in according to the rule for each setting.
- Batch settings and individual settings not yet phased in are merged together. If there are conflicting settings, the most recently entered value is used.
- Breath delivery batch settings are phased in according to the phase-in requirements of the individual settings. Settings are phased in in the most economical manner, applying the most restrictive rules.
- Apnea interval, flow sensitivity, pressure sensitivity, exhalation sensitivity, and disconnect sensitivity are considered batch-independent and are phased in according to their individual rules.
- During non-apnea ventilation, apnea-specific settings are ready when apnea ventilation begins.
- During apnea ventilation, non-apnea settings are ready when normal ventilation begins. Apnea settings and shared settings (for example, PEEP) are phased in according to batch setting rules.

SECTION 12

Ventilator settings

This section provides supplementary information about selected ventilator settings for the *840* Ventilator. For settings ranges, resolutions, new patient values, and accuracy of all ventilator settings, see the operator's guide part of this manual.

Current settings are saved in non-volatile memory. Some ventilator settings have absolute limits, which are intended to prevent settings that are outside the permissible operational range of the ventilator. Other settings limits are determined by ideal body weight (IBW) or the interrelationship with other settings.

12.1 Apnea ventilation

Apnea ventilation is a backup mode. Apnea ventilation starts if the patient fails to breathe for a time that exceeds the apnea interval (T_A) currently in effect. T_A is an operator setting that defines the maximum allowable time between the start of inspiration and the start of the next inspiration. Apnea ventilation settings include respiratory rate (f), O_2%, mandatory type (volume control, VC, or pressure control, PC), tidal volume (V_T), flow pattern, peak inspiratory flow $\dot{V}_{MAX}$, inspiratory pressure (P_I), and inspiratory time (T_I). If the apnea mandatory breath type is VC, plateau time (T_{PL}) is 0.0 seconds. If the apnea mandatory breath type is PC, flow acceleration % is 50%, and T_I is constant during rate change.

Because the minimum value for T_A is 10 seconds, apnea ventilation cannot be invoked when non-apnea f is 6/min or greater. The ventilator does not enter apnea ventilation if T_A is equal to the breath cycle interval. You can set T_A to a value less than the expected or current breath cycle interval as a way of allowing the patient to initiate breaths while protecting the patient from the consequences of apnea.

Apnea settings are subject to these rules:

- Apnea ventilation O_2% must be set equal to or greater than non-apnea ventilation O_2%.
- Minimum apnea f is ($60/T_A$).
- Apnea ventilation settings cannot result in an I:E ratio greater than 1.00:1.

If apnea is possible (that is, if ($60/f$) > T_A) and you increase the non-apnea O_2% setting, apnea ventilation O_2% automatically changes to match. However, apnea ventilation O_2% does not automatically change if you decrease the non-apnea O_2%. Whenever there is an automatic change to an apnea setting, a message is displayed on the graphic user interface (GUI), and the subscreen for apnea settings appears.

When apnea is not possible (that is, if ($60/f$) < T_A), you can still change apnea settings, but O_2% does not automatically change to match the non-apnea value.

During apnea ventilation you can change T_A and all non-apnea settings, 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 reentering apnea ventilation once normal ventilation resumes.

12.2 Expiratory sensitivity (E_{SENS})

The E_{SENS} setting defines the percentage of the projected peak inspiratory flow at which the ventilator cycles from inspiration to exhalation. When inspiratory flow falls to the level defined by E_{SENS}, exhalation begins. E_{SENS} is active during every spontaneous breath. E_{SENS} is not a primary setting and is not continuously visible (although it is accessible whenever the ventilator is on). Changes to the E_{SENS} setting are phased in any time during inspiration or exhalation.

E_{SENS} complements flow acceleration %. Flow acceleration % should be adjusted to match the patient's inspiratory drive, and the E_{SENS} setting should cause ventilator exhalation at a point that is 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.

12.3 Expiratory time (T_E)

The T_E setting defines the duration of exhalation for PC mandatory breaths only. Changes to the T_E setting are phased in at the start of inspiration. Setting f and T_E automatically determines the value for I:E ratio and T_I.

12.4 Flow acceleration %

The flow acceleration % setting allows you to adjust how quickly the ventilator generates inspiratory pressure for pressure-based breaths (that is, spontaneous breaths with PS (including a setting of 0 cmH_2O)) or PC mandatory breaths. The higher the value of flow acceleration %, 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 flow acceleration % setting only appears when pressure-based breaths are available (when PC is selected or spontaneous breaths are available).

- For PC breaths, the lowest flow acceleration setting produces a pressure trajectory that reaches 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, the lowest flow acceleration setting produces a pressure trajectory that reaches 95% of the inspiratory target (PEEP + P_{SUPP}) in an interval that is a function of IBW.
- When both PC and spontaneous breaths are active, the inspiratory pressure targets as well as the pressure trajectories can be different. Changes to T_I and P_I cause PC pressure trajectories to change. Changes in flow acceleration % are phased in during exhalation or at start of inspiration.
- When P_{SUPP} = NONE, the flow acceleration % setting determines how quickly the ventilator drives circuit pressure to PEEP + 1.5 cmH_2O.

You can adjust flow acceleration % for optimum flow delivery into lungs with high impedance (that is, low compliance and high resistance) or low impedance (that is, high compliance and low resistance). To match the flow demand of an actively breathing patient, observe simultaneous pressure-time and flow-time curves, and adjust the flow acceleration % to maintain a smooth rise of pressure to the target value. A flow acceleration % setting that reaches 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 flow acceleration for gently breathing patients is less than or equal to the default (50%), while optimum flow acceleration % 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 flow acceleration % setting above 50% could cause a transient pressure overshoot and premature transition to exhalation, or oscillatory pressures during inspiration. Carefully evaluate the patient's condition (watch the patient's pressure-time and flow-time curves) before setting the flow acceleration % above the default setting of 50%.

Flow pattern

The flow pattern setting defines the gas flow pattern of volume-controlled (VC) mandatory breaths. The selected values for V_T and $\dot{V}_{MAX}$ apply to either the square or descending ramp flow pattern. 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 during exhalation or at the start of inspiration.

The settings for flow pattern, V_T, f, and $\dot{V}_{MAX}$ are interrelated, and changing any of these settings causes the ventilator to generate new values for the other settings. If any setting change would cause any of the following, the ventilator does not allow you to select that setting and displays a limit-violation message:

- I:E ratio > 4:1
- T_I > 8.0 seconds or T_I < 0.2 second
- T_E < 0.2 second

12.6 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 $\dot{V}_{SENS}$ is on, a base flow of gas travels through the patient circuit. The patient inhales from the base flow. When the patient's inspiratory flow equals the $\dot{V}_{SENS}$ setting, the ventilator delivers a breath. 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). Changes in $\dot{V}_{SENS}$ are phased in at the start of exhalation or during inspiration.

For example, if you select a $\dot{V}_{SENS}$ of 4 L/min, the ventilator establishes a base flow of 5.5 L/min through the patient circuit. When the patient inspires at a rate of 4 L/min, the corresponding 4 L/min decrease in the base flow triggers the ventilator to deliver a breath.

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 cmH_2O 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 0.5 L/min can result in autocycling (that is, when the ventilator delivers a breath based on fluctuating flows not caused by patient demand), it can be appropriate for pediatric or very weak patients. The maximum setting of 20 L/min is intended to avoid autocycling when there are significant leaks in the patient circuit. The selected $\dot{V}_{SENS}$ is

phased in during inspiration or at the start of exhalation in case the patient cannot trigger a breath using the previous sensitivity setting.

12.7 Humidification type

The humidification type setting allows you to select the type of humidification system (heated expiratory tube, non-heated expiratory tube, or heat-moisture exchanger -- HME) being used on the ventilator and can be changed during normal ventilation or short self test (SST). Changes in humidification type are phased in at the start of inspiration.

SST calibrates spirometry partly based on the humidification type. If you change the humidification type without rerunning SST and the ventilator displays a message (when there are fewer than two active alarms), then the accuracy of spirometry and delivery may be affected.

The output 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 expiratory filter differ based on the humidification type, spirometry calculations also differ according to humidification type. For optimum accuracy, rerun SST to change the humidification type.

12.8 I:E ratio

The I:E setting defines 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. You cannot directly set the I:E ratio in VC mandatory breaths. Changes in the I:E ratio are phased in at start of inspiration.

Setting f and I:E automatically determines the value 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.

12.9 Ideal body weight (IBW)

The IBW setting determines the new patient values and absolute limits on the apnea and non-apnea settings for V_T and $\dot{V}_{MAX}$. You can only change the IBW during Ventilator Startup for a new patient. While IBW is being set or viewed, its value is displayed in kilograms (kg) and pounds (lb).

Based on the IBW, the ventilator calculates V_T settings as follows:

- Default V_T = 7.25 mL/kg
- Minimum V_T = 1.16 mL/kg
- Maximum V_T = 45.7 mL/kg

Based on the IBW, the ventilator calculates $\dot{V}_{MAX}$ settings as follows:

- Maximum $\dot{V}_{MAX}$ = 80 L/min for IBW ≤ 24 kg
- Maximum $\dot{V}_{MAX}$ = 200 L/min for IBW > 24 kg

The IBW setting also determines the constants used in breath delivery algorithms and the INSPIRATION TOO LONG alarm.

12.10 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 cmH_2O, and P_I is 20 cmH_2O, the ventilator delivers gas to the patient at 25 cmH_2O.) Changes to the P_I setting are phased in during exhalation or at the start of inspiration.

The sum of PEEP + P_I + 2 cmH_2O cannot exceed the high circuit pressure ($\uparrow P_{CIRC}$) limit. To increase this sum of pressures, you must first raise the $\uparrow P_{CIRC}$ limit before increasing the settings for PEEP or P_I. The minimum setting is intended for pediatric patients. The maximum setting is intended for patients with low compliance (stiff lungs).

12.11 Inspiratory time (T_I)

The T_I setting defines the time during which an inspiration is delivered to the patient for PC mandatory breaths. You cannot set T_I in VC mandatory breaths. The ventilator accepts a T_I setting as long as the resulting I:E ratio and T_E settings are valid. Changes in the T_I are phased in at the start of inspiration.

The minimum setting is intended for infants, and the maximum is the longest reasonable inspiratory time required for adult ventilation. The ventilator rejects T_I settings that result in an I:E ratio greater than 4.00:1, a T_I greater than 8 seconds, or a T_E less than 0.2 second to ensure that the patient has adequate time for exhalation. (For example, if the f setting is 30/min, a T_I setting of 1.8 seconds would result in an I:E ratio of 9:1 -- which is out of range for I:E ratio settings.)

Inspiratory time is offered in addition to I:E ratio because the T_I setting is commonly used for pediatric ventilation and may be a more useful setting at lower respiratory rates. 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 relation between T_I, I:E, T_E, and cycle time (60/f):

$$T_I = (60/f)\ [(I:E)/(1 + I:E)]$$

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 you choose to set, a breath timing bar always shows the interrelationship between T_I, I:E, T_E, and f.

12.12 Mode and mandatory breath type

Specifying the mode defines the types and sequences of breaths allowed, as summarized in Table 12-1.

Table 12-1: *840* Ventilator modes and breath types

Mode	Mandatory breath type	Spontaneous breath type	Sequence
A/C	VC or PC	Not allowed	All mandatory (ventilator- or patient-triggered)
SPONT	Not allowed (except for manual inspiration)	Pressure-supported (PS) or none (that is, CPAP breath)	All spontaneous (except for manual inspirations)
SIMV	VC or PC	Pressure-supported (PS) or none (that is, CPAP breath)	Each new breath begins with a mandatory interval, during which a patient effort yields a synchronized mandatory breath. If no patient effort is seen during the mandatory interval, the ventilator delivers a mandatory breath. Subsequent patient efforts before the end of the breath yield spontaneous breaths.

Breath types must be defined before settings can be specified. There are only two kinds of breath type: mandatory and spontaneous. Mandatory breaths are volume controlled (VC) or pressure controlled (PC). The *840* Ventilator currently offers spontaneous breaths that are pressure supported (PS) or not pressure supported (that is, the "classic" CPAP breath with no pressure support). Figure 12-1 shows the modes and breath types available on the *840* Ventilator.

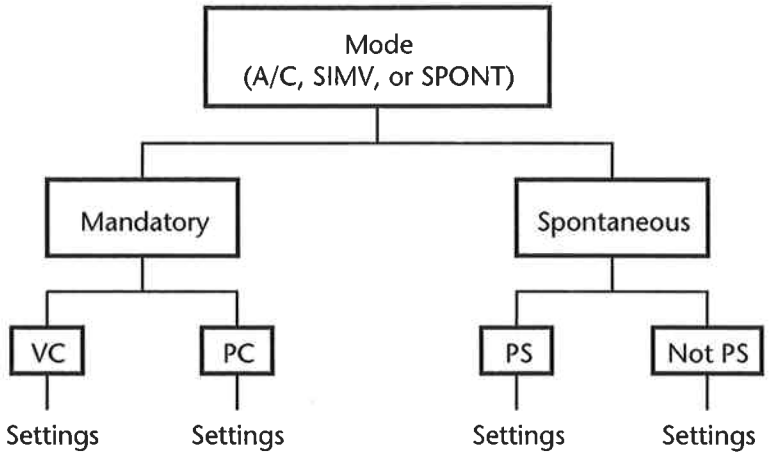


Figure 12-1. *840* Ventilator modes and breath types

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 VC or PC.
- *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.

- *Synchronous 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.

Changes to the mode are phased in at 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 during exhalation or at start of inspiration.

12.13 O_2%

The *840* Ventilator's oxygen sensor uses a galvanic cell to monitor O_2%. This cell is mounted on the inspiratory manifold of the BDU and monitors the percentage of oxygen in the mixed gas (not the actual oxygen concentration in the gas the patient inspires). Changes to the O_2% setting are phased in at the start of inspiration or the start of exhalation.

The O_2% setting can range from room air (21%) up to a maximum of 100% oxygen. The galvanic cell reacts with oxygen to produce a voltage proportional to the partial pressure of the mixed gas. Since ambient atmosphere contains approximately 21% oxygen, the galvanic cell constantly reacts with oxygen and always produces a voltage. The useful life of the *840* Ventilator galvanic sensor is approximately 750,000 O_2% hours. Constant exposure to 100% O_2 would drain the cell in approximately 7,500 hours (44.5 weeks of constant use). Constant exposure to room air (21% O_2) would drain the cell in approximately 35,000 hours (4 years and 4 weeks of constant use). The useful life of the cell can also be shortened by exposure to elevated temperatures. During normal use in the ICU, cell life easily exceeds 10,000 hours -- the interval for routine preventive maintenance.

Because the galvanic cell constantly reacts with oxygen, it requires periodic calibration to prevent inaccurate O_2% alarm

annunciation. The *840* Ventilator calibrates its oxygen sensor every time you press the 100% O_2/CAL 2 min key. Once a calibrated oxygen sensor and the *840* Ventilator reach a steady-state operating temperature, the monitored O_2% will be within 3 percentage points of the actual value for at least 24 hours. To ensure that the oxygen sensor remains calibrated, press the 100% O_2/CAL 2 min key at least once every 24 hours.

4 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. Changes in $\dot{V}_{MAX}$ are phased in during exhalation or at the stratify inspiration. The $\dot{V}_{MAX}$ setting only affects the delivery of mandatorybreaths. Mandatory breaths are compliance-compensated even at the maximum $\dot{V}_{MAX}$ setting.

When you propose 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}. If the new $\dot{V}_{MAX}$ is within the acceptable range but would result in an I:E ratio that exceeds 4.00:1, or a T_I greater than 8.0 seconds or less than 0.2 second, or a T_E less than 0.2 second, the ventilator does not allow the change to the $\dot{V}_{MAX}$ setting.

5 PEEP

The PEEP setting defines the positive end expiratory pressure (PEEP), also called baseline pressure. PEEP is the positive pressure maintained in the patient circuit during exhalation. Changes to the PEEP setting are phased in at start of exhalation (if PEEP is increased or decreased) or at start of inspiration (only if PEEP is decreased).

The sum of:

- PEEP + 7 cmH_2O, or
- PEEP + P_I + 2 cmH_2O (if PC is active), or
- PEEP + P_{SUPP} + 2 cmH_2O (if PS is on)

cannot exceed the $\uparrow P_{CIRC}$ limit. To increase the sum of pressures, you must first raise the $\uparrow P_{CIRC}$ limit before increasing the settings for PEEP, P_I, or P_{SUPP}.

12.16 Plateau time (T_{PL})

The T_{PL} setting defines 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 or during exhalation.

When you propose 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. If the new T_{PL} is within the acceptable range but would result in an I:E ratio that exceeds 4:1, or a T_I greater than 8 seconds or less than 0.2 second, or a T_E less than 0.2 second, the ventilator does not allow the change. For I:E ratio calculation, T_{PL} is considered part of the inspiration phase.

12.17 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 in P_{SENS} are phased in any time during exhalation or inspiration. 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 autocycling at very low P_{SENS} settings. The maximum P_{SENS} setting avoids autocycling under worst-case conditions if patient circuit leakage is within specified limits.

The ventilator phases in a new P_{SENS} setting immediately (rather than at the next inspiration) in case the patient cannot trigger a breath using the previous sensitivity setting.

8 Pressure support (P_{SUPP})

The P_{SUPP} setting determines the level of positive pressure supplied to the patient's airway during a spontaneous breath. P_{SUPP} is only available in SIMV and SPONT, in which spontaneous breaths are allowed. The level of P_{SUPP} is in addition to PEEP. 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 during exhalation or at the start of inspiration. Pressure support affects only spontaneous breaths.

The sum of PEEP + P_{SUPP} + 2 cmH_2O cannot exceed the $\uparrow P_{CIRC}$ limit. To increase the sum of pressures, you must first raise the $\uparrow P_{CIRC}$ limit before increasing the settings for PEEP or P_{SUPP}. Since the $\uparrow P_{CIRC}$ limit is the highest pressure considered safe for the patient, a P_{SUPP} setting that would cause a $\uparrow P_{CIRC}$ alarm requires you to first reevaluate the maximum safe circuit pressure.

9 Respiratory rate (f)

The f setting determines the minimum number of mandatory breaths per minute for ventilator-initiated mandatory breaths (both PC and VC). For PC mandatory breaths, setting f and any one of the following parameters automatically determines the value of the others: I:E, T_I, and T_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 less than 0.2 second, the T_I to be greater than 8 seconds, or I:E ratio greater than 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.)

12.20 Safety ventilation

Safety ventilation is intended as a mode of ventilation that is safe, regardless of the type of patient (adult or pediatric) attached. It is invoked during the power-on initialization process, or if power has been removed from the ventilator for 5 minutes or more and circuit connection is sensed before Ventilator Startup is complete.

Safety ventilation settings are the new patient settings, with these exceptions:

Ventilator settings	Alarm limits
Mode: A/C	P_{CIRC}: 20 cmH_2O
Mandatory type: PC	$\overline{\uparrow}\dot{V}_{E\ TOT}$: High alarm limit OFF, low alarm limit: 0.01 L
f: 16 /min	$\overline{\uparrow}V_{TE}$: OFF
T_I: 1 s	$\overline{\uparrow}f_{TOT}$: OFF
P_I: 10 cmH_2O	$\downarrow V_{TE\ MAND}$: OFF
PEEP: 3 cmH_2O	$\downarrow V_{TE\ SPONT}$: OFF
Trigger type: P-TRIG	
Flow acceleration %: 50%	
P_{SUPP}: 2 cmH_2O	
O_2%: 100% (21% if oxygen not available)	

1 Spontaneous breath type

The spontaneous breath type setting determines whether spontaneous breaths are pressure-assisted using pressure support (PS). A setting of NONE for spontaneous breath type is equivalent to a pressure support setting of 0 cmH_2O.

Once you have selected the spontaneous breath type, you can choose the level of pressure support (P_{SUPP}) and specify the flow acceleration % and E_{SENS}. Changes to the spontaneous breath type setting are phased in during exhalation or the start of inspiration.

During spontaneous breathing, the patient's respiratory control center rhythmically activates the inspiratory muscles. The support type setting allows you to select pressure support, to supplement the patient's pressure-generating capability.

2 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 during exhalation or at the start of inspiration. The V_T setting only affects the delivery of mandatory breaths.

When you propose 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 V_T setting is within the acceptable range but would result in an I:E ratio that exceeds 4.00:1 or a T_I greater than 8.0 seconds or less than 0.2 second, or a T_E less than 0.2 second, the ventilator disallows the change.

SECTION 13

Alarms

This section discusses the ventilator's alarm handling strategy and provides supplementary information about selected ventilator alarms for the *840* Ventilator. For settings ranges, resolutions, and new patient values of all alarms, see the operator's guide section of this manual.

Current alarm settings are saved in nonvolatile memory. All ventilator settings have absolute limits, which are intended to prevent settings that are outside the safe or permissible operational range of the ventilator. These limits may be fixed or depend on other settings, such as ideal body weight (IBW).

13.1 Alarm handling

The *840* Ventilator's alarm handling strategy is to:

- Detect and call attention to legitimate causes for caregiver concern as quickly as possible, while minimizing nuisance alarms.
- Identify the cause and suggest corrective action for an alarm where possible.
- Make it easy to discern an alarm's urgency level.
- Allow quick and easy alarm setup.

Alarm annunciations include a level of urgency, which is an estimate of how quickly a caregiver must respond to ensure patient protection. Table 13-1 summarizes alarm urgency levels.

Table 13-1: Alarm urgency levels

gency level	Visual indication	Audible indication	Autoreset handling
rdous ion that res immediate nse	Red flashing	High-priority tone (repeating sequence of five tones; sequence repeats twice, pauses, then repeats again)	If all high-urgency alarm conditions return to normal, the audible indicator turns off, the red high-urgency indicator switches from flashing to steadily lit, and autoreset is entered in the alarm history log. Press the alarm reset key to turn off the visual indicator.
um: rmal situation equires pt response	Yellow flashing	Medium-priority tone (repeating sequence of three tones)	If all medium-urgency alarm conditions return to normal, the audible and visual indicators turn off and autoreset is entered into the alarm history log.
ge in status, ming clinician	Yellow, steadily lit	Low-priority tone (two tone, non-repeating)	If all low-urgency alarm conditions return to normal, the audible and visual indicators turn off and autoreset is entered in the alarm history log.
al: arm itions active include eset alarms)	Green, steadily lit	None	Not applicable.

13.1.1 Alarm messages

In addition to displaying the urgency level of an alarm, the ventilator displays alarm messages for the two highest-priority active alarms near the top of the graphic user interface (GUI) upper screen. Figure 13-1 shows the format for alarm messages.

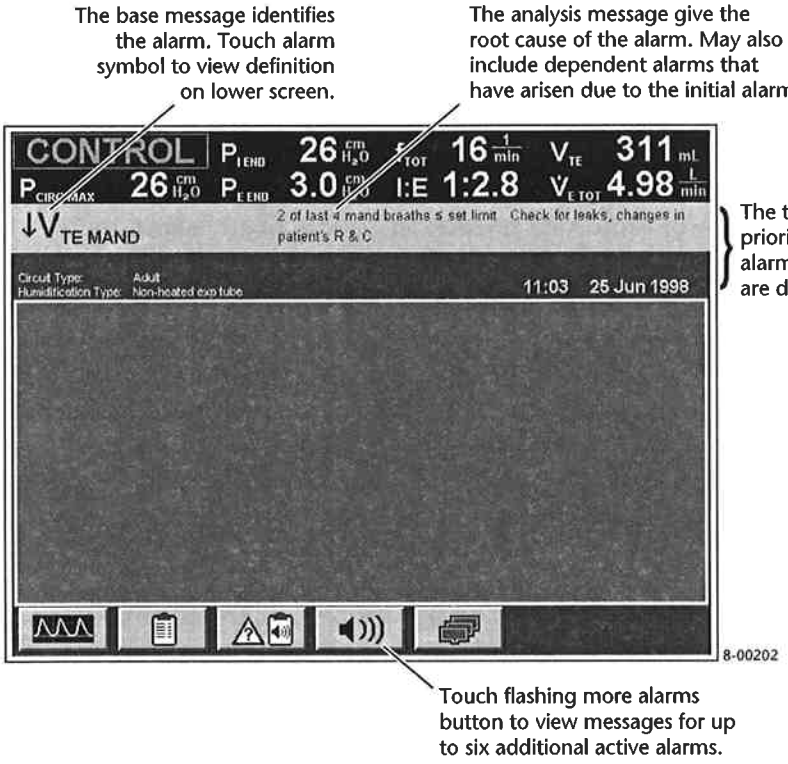


Figure 13-1. Alarm message format (upper GUI screen)

These rules define how alarm messages are displayed:

- If the ventilator is interfaced to an external device to collect data for trending and other monitoring purposes, that external data is not considered in alarm handling.
- An alarm that arises as a result of another alarm is called a *dependent alarm*. The initial alarm is called the *primary alarm*.
- Dependent alarms are added to the analysis messages of each active primary alarm with which they are associated. If a dependent alarm resets, it is removed from the analysis message of the primary alarm.
- The urgency level of a primary alarm is equal to or greater than the urgency 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 dependent alarms that remain active become primary unless they are also dependent alarms of another active primary alarm.
- If you change an alarm limit, the new alarm limit is applied to alarm calculations from that point forward.
- The urgency level of a dependent alarm is based solely on its detection conditions (not the urgency of any associated alarms).
- When an alarm causes the ventilator to go to idle mode, occlusion status cycling (OSC), or safety valve open (SVO), the patient data display (including waveforms) is blanked. The elapsed time without ventilatory support (that is, since idle mode, OSC, or SVO began) is displayed on the upper GUI screen. If the alarm causing idle mode, OSC, or SVO is autoreset, the ventilator resets *all* patient data alarm detection algorithms.

13.1.2 Alarm summary

Table 13-2 summarizes ventilator alarms, including urgency, messages, and other information.

Table 13-2: Alarm summary

Base message	Urgency	Analysis message	Remedy message	Comments
AC POWER LOSS	Low	Operating on battery.	Prepare for power loss.	Power switch on, ac power not available, ventilator operating on BPS. BPS operating indicator turns on. Resets when ac power is restored.
	Medium	Operational time < 2 minutes.	Prepare for power loss.	
APNEA	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 when patient initiates 2 consecutive breaths. Possible dependent alarm: $\downarrow \dot{V}_{E\,TOT}$.
	High	Apnea ventilation. ≥ 2 events in 10 apnea intervals.	Check patient & settings.	
	High	Apnea ventilation lasting > 2 apnea intervals.	Check patient & settings.	
	High	Apnea ventilation with ≥ 2 events and duration > 2 intervals.	Check patient & settings.	

Table 13-2: Alarm summary (continued)

Base essage	Urgency	Analysis message	Remedy message	Comments
UIT ONNECT	High	No ventilation.	Check patient/ ventilator status.	Ventilator has recovered from unintended power loss, detects circuit disconnect, and switches to idle mode; upper screen displays elapsed time without ventilator support. Resets when ventilator senses reconnection.
	High	No ventilation.	Check patient. Reconnect circuit.	Ventilator detects circuit disconnect and switches to idle mode; upper screen displays elapsed time without ventilator support. Resets when ventilator senses reconnection.
PLIANCE ED V_T.	Low	Compliance compensation limit reached.	Inspired volume may be < set. Check patient & circuit type.	Compliance volume required to compensate delivery of a volume controlled breath exceeds the maximum allowed for 3 of the last 4 breaths.

Table 13-2: Alarm summary (continued)

Base message	Urgency	Analysis message	Remedy message	Comments
COMPRESSOR INOPERATIVE	Low	No compressor air. No operation during low A/C power.	Replace compressor.	Compressor ready indicator turns off. Resets when full ac power is restored.
	Low	No compressor air. No operation during A/C power loss.	Replace compressor.	Ventilator turns off compressor. Resets when full ac power is restored.
	Low	No compressor air.	Replace compressor.	Compressor ready indicator turns off.
DEVICE ALERT	Low	Breath delivery not affected.	Service required.	Background checks have detected a problem. Resets when ventilator passes EST.
	Low	Ventilation continues as set.	Replace & service ventilator.	Background checks have detected a problem. Resets when ventilator passes EST.
	Low	Breath delivery not affected. Compromised spirometry.	Replace & service ventilator.	Background checks have detected a problem. Resets when ventilator passes EST.
	Low	Breath delivery not affected. Possible compromise of other functions.	Service required.	POST has detected a problem. Resets when ventilator passes POST.

Table 13-2: Alarm summary (continued)

Base essage	Urgency	Analysis message	Remedy message	Comments
CE ALERT)	Medium	Ventilation continues as set.	Replace & service ventilator.	Background checks have detected a problem. Accuracy of exhalation flow sensor temperature may be affected. Resets when ventilator passes EST.
	Medium	Ventilation continues as set.	Replace & service ventilator.	Background checks have detected a problem. Accuracy of oxygen flow sensor temperature may be affected, ventilator using nominal value. Resets when ventilator passes EST.
	Medium	Breath delivery not affected. Compromised spirometry.	Replace & service ventilator.	Background checks have detected a problem that has persisted for over 10 minutes. Resets when ventilator passes EST.
	Medium	Ventilation continues as set. Only O_2 available.	Replace & service ventilator.	Background checks have detected a problem. Ventilator delivers 100% O_2. Resets when ventilator passes EST.

Table 13-2: Alarm summary (continued)

Base message	Urgency	Analysis message	Remedy message	Comments
DEVICE ALERT (cont)	Medium	Breath delivery not affected. Compromised spirometry.	Check patient. Replace & service ventilator.	Background checks have detected a problem. Accuracy of exhalation flow sensor temperature may be affected. Resets when ventilator passes EST.
	Medium	Ventilation continues as set. Only air available.	Replace & service ventilator.	Background checks have detected a problem. Ventilator delivers 21% O_2. Resets when ventilator passes EST.
	High	Breath delivery not affected.	Replace & service ventilator.	Background checks have detected a problem. Loss of GUI indicator lights. Setting changes disabled. Resets when ventilator passes EST.
	High	Ventilation unaffected.	O_2 sensor out of calibration/ failure. Press 100% O_2 CAL, replace or disable.	Background checks have detected a problem. Resets when operator successfully calibrates oxygen sensor, or disables oxygen sensor.

Table 13-2: Alarm summary (continued)

Base essage	Urgency	Analysis message	Remedy message	Comments
CE ALERT	High	Unable to determine status of breath delivery.	Check patient. Replace & service ventilator.	Background checks have detected a problem. Loss of GUI indicator lights. Resets when communication between GUI and BDU is re-established.
	High	Ventilation continues as set.	Replace & service ventilator.	Background checks have detected a problem. Loss of GUI indicator lights. Alarms, setting changes, and monitored data disabled. Resets when ventilator passes EST.
	High	Ventilation continues as set.	Replace & service ventilator.	Background checks have detected a problem. Setting changes, monitored data, and alarms disabled. Resets when ventilator passes EST.

Table 13-2: Alarm summary (continued)

Base message	Urgency	Analysis message	Remedy message	Comments
DEVICE ALERT (cont)	High	Ventilation continues as set. Delivery/spiro may be compromised.	Replace & service ventilator.	Background checks have detected a problem. Setting changes not allowed. Resets when ventilator passes EST.
	High	Breath delivery not affected. Compromised spiro. Trig = pres.	Check patient. Replace & service ventilator.	Background checks have detected a problem and flow triggering was selected. Accuracy of exhalation flow sensor temperature may be affected. Resets when ventilator passes EST.
	High	Ventilation continues as set, except O_2% = 100.	Check patient. Replace & service ventilator.	Background checks have detected a problem. Ventilator delivers 100% O_2 instead of set O_2%. Resets when ventilator passes EST.

Table 13-2: Alarm summary (continued)

Base essage	Urgency	Analysis message	Remedy message	Comments
CE ALERT)	High	Ventilation continues as set. Compromised air delivery.	Replace & service ventilator. Check patient.	Background checks have detected a problem. Accuracy of air flow sensor temperature may be affected, ventilator using nominal value. Resets when ventilator passes EST.
	High	Ventilation continues as set. Compromised O_2 delivery.	Replace & service ventilator. Check patient.	Background checks have detected a problem. Accuracy of oxygen flow sensor temperature may be affected, ventilator using nominal value. Resets when ventilator passes EST.
	High	Power loss & recovery occurred with a pre-existing Device Alert.	Check Alarm log. EST required.	Background checks have detected a problem. Loss of GUI indicator lights. Resets when ventilator passes EST.

Table 13-2: Alarm summary (continued)

Base message	Urgency	Analysis message	Remedy message	Comments
DEVICE ALERT (cont)	High	Ventilation continues as set, except O_2% = 21.	Check patient. Replace & service ventilator.	Background checks have detected a problem. Ventilator delivers 21% O_2 instead of set O_2%. Resets when ventilator passes EST.
	High	No ventilation. Safety Valve Open.	Provide alternate ventilation. Replace & service ventilator.	Background checks have detected a problem. Safety valve open indicator lights. Upper screen displays elapsed time without ventilator support. Resets when ventilator passes EST.
	High	No ventilation. Safety Valve Open.	Check patient. Replace & service ventilator.	
	High	No ventilation. Safety Valve Open.	Provide alternate ventilation. Replace & service ventilator.	Background checks have detected a problem. Ventilator inoperative and safety valve open indicators light. Message may not be visible. If possible, upper screen displays elapsed time without ventilator support. Resets when ventilator passes EST.

Table 13-2: Alarm summary (continued)

Base essage	Urgency	Analysis message	Remedy message	Comments
C	Low	1 breath ≥ set limit.	Check patient circuit & ET tube.	Measured airway pressure ≥ set limit. Ventilator truncates current breath unless already in exhalation. Possible dependent alarms: $\downarrow V_{TE\ MAND}$, $\downarrow \dot{V}_{E\ TOT}$, $\uparrow f_{TOT}$.
	Medium	2 breaths ≥ set limit.	Check patient circuit & ET tube.	
	High	3 or more breaths ≥ set limit.	Check patient circuit & ET tube.	
%	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.) Alarm updated at 1-second intervals.
	High	Measured O_2% > set for ≥ 2 min.	Check patient, gas sources, O_2 analyzer, & ventilator.	

Table 13-2: Alarm summary (continued)

Base message	Urgency	Analysis message	Remedy message	Comments
$\uparrow V_{TE}$	Low	2 of last 4 breaths ≥ set limit.	Check settings, changes in patient's R & C.	Exhaled tidal volume ≥ set limit. Alarm updated whenever exhaled tidal volume is recalculated. Possible dependent alarm: $\uparrow \dot{V}_{E\,TOT}$.
	Medium	3 of last 4 breaths ≥ set limit.	Check settings, changes in patient's R & C.	
	High	4 of last 4 breaths ≥ set limit.	Check settings, changes in patient's R & C.	
$\uparrow \dot{V}_{E\,TOT}$	Low	$\dot{V}_{E\,TOT}$ ≥ set limit for ≤ 20s.	Check patient & settings.	Expiratory minute volume ≥ set limit. Alarm updated whenever an exhaled minute volume is recalculated. Possible dependent alarm: $\uparrow V_{TE}$.
	Medium	$\dot{V}_{E\,TOT}$ ≥ set limit for > 20s.	Check patient & settings.	
	High	$\dot{V}_{E\,TOT}$ ≥ set limit for > 40s.	Check patient & settings.	

Table 13-2: Alarm summary (continued)

Base essage	Urgency	Analysis message	Remedy message	Comments
T	Low	f_{TOT} ≥ set limit for ≤ 20s.	Check patient & settings.	Total respiratory rate ≥ set limit. Alarm updated at the beginning of each inspiration. Reset when measured respiratory rate falls below the alarm limit. Possible dependent alarms: $\downarrow V_{TE\ MAND}$, $\downarrow V_{TE\ SPONT}$, $\dot{V}_{E\ TOT}$.
	Medium	f_{TOT} ≥ set limit for > 20s.	Check patient & settings.	
	High	f_{TOT} ≥ set limit for > 40s.	Check patient & settings.	
NT	Low	1 breath ≥ limit.	Check patient circuit & ET tube.	Inspiratory pressure > 100 cmH_2O and mandatory type = VC. Ventilator truncates current breath unless already in exhalation. Possible dependent alarms: $\downarrow V_{TE\ MAND}$, $\downarrow \dot{V}_{E\ TOT}$, $\uparrow f_{TOT}$.
	Medium	2 breaths ≥ limit.	Check patient circuit & ET tube.	
	High	3 or more breaths ≥ limit.	Check patient circuit & ET tube.	
ERATIVE ERY	Low	Inadequate charge or non-functional battery system.	Service/ replace battery.	BPS installed but not functioning. Resets when BPS is functional.

Table 13-2: Alarm summary (continued)

Base message	Urgency	Analysis message	Remedy message	Comments
INSPIRATION TOO LONG	Low	1 or 2 of last 4 spont breaths = IBW based T_I limit.	Check patient. Check for leaks.	Inspiratory time for spontaneous breath ≥ IBW-based limit. Ventilator transitions to exhalation. Resets when T_I falls below IBW-based limit.
	Medium	3 of last 4 spont breaths = IBW based T_I limit.	Check patient. Check for leaks.	
	High	4 of last 4 spont breaths = IBW based T_I limit.	Check patient. Check for leaks.	
LOSS OF POWER	Not applicable			The ventilator power switch is on and there is insufficient power from ac and the BPS (if installed). 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.

Table 13-2: Alarm summary (continued)

Base essage	Urgency	Analysis message	Remedy message	Comments
AC ER	Low	Ventilator currently not affected.	Power interrupt possible.	Mains (ac) power has dropped below 80% of nominal for 1 second. Ventilator continues operation as close to settings as possible. Resets when there is no low ac power signal for 1 second.
BATTERY	Low	Operational time < 2 minutes.	Replace or allow recharge.	Resets when BPS has more than approximately 2 minutes of operational time remaining.
%	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.) Alarm updated at 1-second intervals.

Table 13-2: Alarm summary (continued)

Base message	Urgency	Analysis message	Remedy message	Comments
$\downarrow V_{TE\ MAND}$	Low	2 of last 4 mand. breaths ≤ set limit.	Check for leaks, changes in patients R & C.	Exhaled mandatory tidal volume ≤ set limit. Alarm updated whenever exhaled mandatory tidal volume is recalculated. Possible dependent alarms: $\uparrow \dot{V}_{E\ TOT}$, $\uparrow f_{TOT}$.
	Medium	3 of last 4 mand. breaths ≤ set limit.	Check for leaks, changes in patients R & C.	
	High	4 of last 4 mand. breaths ≤ set limit.	Check for leaks, changes in patients R & C.	
$\downarrow V_{TE\ SPONT}$	Low	2 of 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: $\downarrow \dot{V}_{E\ TOT}$, $\uparrow f_{TOT}$.
	Medium	3 of last 4 spont breaths ≤ set limit.	Check patient & settings.	
	High	4 of last 4 spont breaths ≤ set limit.	Check patient & settings.	
$\downarrow \dot{V}_{E\ TOT}$	Low	$\dot{V}_{E\ TOT}$ ≤ set limit for ≤ 20s.	Check patient & settings.	Total minute volume ≤ set limit. Alarm updated whenever exhaled minute volume is recalculated. Possible dependent alarms: $\downarrow V_{TE\ MAND}$, $\downarrow V_{TE\ SPONT}$, $\uparrow f_{TOT}$.

Table 13-2: Alarm summary (continued)

Base essage	Urgency	Analysis message	Remedy message	Comments
OT (cont)	Medium	$\dot{V}_{E\,TOT} \leq$ set limit for > 20s.	Check patient & settings.	Total minute volume ≤ set limit. Alarm updated whenever exhaled minute volume is recalculated. Possible dependent alarms: $\downarrow V_{TE\,MAND}$, $\downarrow V_{TE\,SPONT}$, $\uparrow f_{TOT}$.
	High	$\dot{V}_{E\,TOT} \leq$ set limit for > 40s.	Check patient & settings.	
AIR LY	Low	Ventilation continues as set. Only O_2 available.	Check air source.	Ventilator delivers 100% O_2. Resets if air supply connected.
	Low	Compressor inoperative. Ventilation continues as set. Only O_2 available.	Check air source.	
	High	Ventilation continues as set except $O_2\% = 100$.	Check patient & air source.	Ventilator delivers 100% O_2 instead of set $O_2\%$. Resets if air supply connected.
	High	Compressor inoperative. Ventilation continues as set, except $O_2\% = 100$.	Check patient & air source.	

Table 13-2: Alarm summary (continued)

Base message	Urgency	Analysis message	Remedy message	Comments
NO AIR SUPPLY (cont)	High	No ventilation. Safety Valve Open.	Provide alternate ventilation. Check both gas sources.	Safety valve open indicator lights. Upper screen displays elapsed time without ventilator support. Resets if air and O_2 supplies are connected.
NO O_2 SUPPLY	Low	Ventilation continues as set. Only air available.	Check O_2 source.	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.
	High	No ventilation. Safety Valve Open.	Provide alternate ventilation. Check both gas sources.	Safety valve open indicator lights. Upper screen displays elapsed time without ventilator support. Resets if air and oxygen supplies are connected.
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.

Table 13-2: Alarm summary (continued)

Base essage	Urgency	Analysis message	Remedy message	Comments
EN CK	Medium	Possible blocked beam or touch screen fault.	Remove obstruction or service ventilator.	Background checks have detected a problem. Resets when ventilator passes EST.
RE LUSION	High	Little/no ventilation.	Check patient. Provide alternate ventilation. Clear occlusions; drain circuit.	Ventilator enters occlusion status cycling (OSC) and upper screen displays elapsed time without ventilator support.

13.2 AC POWER LOSS alarm

The AC POWER LOSS alarm indicates that the ventilator power switch is on and the ventilator is being powered by the backup power source (BPS). The ventilator annunciates a low-urgency alarm when the ventilator has been operated by the BPS for at least 3 seconds and at least 2 minutes of BPS power are available. The ventilator annunciates a medium-urgency alarm when less than 2 minutes of BPS power are estimated available.

The AC POWER LOSS alarm tells you that the ventilator is being powered by the BPS and that an alternate power source may soon be required to sustain normal ventilator operation.

13.3 APNEA alarm

The APNEA alarm indicates that 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 selected via the apnea ventilation settings.

The APNEA alarm autoresets when the patient initiates two successive breaths, and is intended to establish that the patient's inspiratory drive is reliable enough to resume normal ventilation. To ensure that the breaths are patient-initiated (and not due to autocycling), exhaled volumes must be at least half the V_T (this avoids returning to normal ventilation if there is a disconnect, or entering apnea ventilation during a routine suctioning procedure).

The ventilator monitors breathing from the start of inspiration to the start of inspiration and allows the ventilator to declare apnea when the patient fails to take a breath, rather than when he/she fails to exhale on schedule.

CIRCUIT DISCONNECT alarm

The CIRCUIT DISCONNECT alarm indicates that the patient circuit is disconnected at the ventilator or the patient side of the patient wye. You can set the sensitivity of the CIRCUIT DISCONNECT alarm by adjusting the D_{SENS} setting. There is no ventilation during a CIRCUIT DISCONNECT alarm.

When the ventilator determines that the patient circuit is reconnected, the CIRCUIT DISCONNECT alarm autoresets and normal ventilation resumes. Because the CIRCUIT DISCONNECT alarm can autoreset, apnea ventilation can begin when the circuit is reconnected 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.

DEVICE ALERT alarm

A DEVICE ALERT alarm indicates that a background test or power on self test (POST) has failed. Depending on which test failed, the ventilator either declares an alarm and 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 you of an abnormal condition that requires service.

13.6 High circuit pressure ($\uparrow P_{CIRC}$) alarm

The $\uparrow P_{CIRC}$ alarm indicates that the currently measured airway pressure is equal to or greater than the set $\uparrow P_{CIRC}$ limit. The $\uparrow P_{CIRC}$ limit is active during mandatory and spontaneous breaths, and during inspiration and exhalation. The $\uparrow P_{CIRC}$ limit is active in all normal ventilation modes. The $\uparrow P_{CIRC}$ limit is not active during a SEVERE OCCLUSION alarm.

The $\uparrow P_{CIRC}$ limit cannot be set less than:

PEEP + 7 cmH_2O, or

PEEP + P_I + 2 cmH_2O, or

PEEP + P_{SUPP} + 2 cmH_2O

You cannot disable the $\uparrow P_{CIRC}$ limit. The ventilator phases in changes to the $\uparrow P_{CIRC}$ limit immediately to allow prompt notification of a high circuit pressure condition.

The minimum $\uparrow P_{CIRC}$ limit (7 cmH_2O) corresponds to the lowest peak pressures not due to autocycling anticipated during a mandatory breath. The maximum $\uparrow P_{CIRC}$ limit (100 cmH_2O) was selected because it is the maximum pressure that may be required to inflate the lungs of a patient with 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 $\uparrow P_{CIRC}$ alarm. This triggering profile helps avoid nuisance alarms due to possible transient pressure overshoot in the airway when aggressive values of flow acceleration are selected. A pressure overshoot measured in the patient circuit is unlikely to be present at the carina.

The $\uparrow P_{CIRC}$ alarm is active throughout inspiration and exhalation to provide redundant patient protection (for example, to detect occlusions downstream of the pressure-sensing device) or that could be required for future ventilatory modes.

High delivered O_2% ($\uparrow O_2$%) alarm

The $\uparrow O_2$% alarm indicates that the measured O_2% during any phase of a breath is at or above the error percentage above the O_2% setting for at least 30 seconds. Although the ventilator automatically sets the $\uparrow O_2$% alarm limits, you can disable the oxygen sensor. (The error percentage is 12% above setting for the first hour of ventilator operation, 7% above setting after the first hour of operation, and an additional 5% above setting for the first 4 minutes following a decrease in the setting.)

The ventilator automatically adjusts the $\uparrow O_2$% alarm limit when O_2% changes due to 100% O_2, apnea ventilation, circuit disconnect, or a NO AIR SUPPLY alarm. The ventilator checks the $\uparrow O_2$% alarm limit against the measured oxygen percentage at 1-second intervals.

The $\uparrow O_2$% alarm detects malfunctions in ventilator gas delivery or oxygen monitor. The $\uparrow O_2$% alarm limit is automatically adjusted during 100% O_2 suction, apnea ventilation, patient circuit disconnect, or low air inlet pressure because O_2% changes are expected under those circumstances. The ventilator declares a $\uparrow O_2$% alarm after 30 seconds to eliminate nuisance alarms due to transient O_2% delivery variations.

High exhaled tidal volume ($\uparrow V_{TE}$) alarm

The $\uparrow V_{TE}$ alarm indicates that the measured exhaled tidal volume for spontaneous and mandatory breaths is equal to or greater than the set $\uparrow V_{TE}$ limit. The $\uparrow V_{TE}$ alarm is updated whenever a new measured value is available.

The $\uparrow V_{TE}$ alarm can detect increased exhaled tidal volume (due to greater compliance and lower resistance) and prevent hyperventilation during pressure control ventilation or pressure support. You can turn the $\uparrow V_{TE}$ 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.)

13.9 High respiratory rate ($\uparrow f_{TOT}$) alarm

The $\uparrow f_{TOT}$ alarm indicates that the measured breath rate is greater than or equal to the set $\uparrow f_{TOT}$ limit. 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 that the tidal volume is too low or that 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.

13.10 INSPIRATION TOO LONG alarm

The INSPIRATION TOO LONG alarm indicates that the inspiratory time of a spontaneous breath exceeds this time limit:

(1.99 + 0.02 x IBW) seconds

where *IBW* is the current setting for ideal 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. You cannot set or disable the INSPIRATION TOO LONG alarm.

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.

1 Low delivered O_2% ($\downarrow O_2$%) alarm

The $\downarrow O_2$% alarm indicates that the measured O_2% during any phase of a breath is at or below the error percentage below the O_2% setting, or equal to less than 18%, for at least 30 seconds. Although the ventilator automatically sets the $\downarrow O_2$% alarm, you can disable the oxygen sensor. (The error percentage is 12% below setting for the first hour of ventilator operation, 7% below setting after the first hour of operation, and an additional 5% below setting for the first 4 minutes following a increase in the setting.)

The ventilator automatically adjusts the $\downarrow O_2$% alarm limit when O_2% changes due to apnea ventilation, circuit disconnect, or a NO O_2 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 that the patient is adequately oxygenated. The $\downarrow O_2$% alarm limit is automatically adjusted during apnea ventilation, patient circuit disconnect, or low air inlet pressure because O_2% changes are expected under those circumstances. The ventilator declares a $\downarrow O_2$% alarm after 30 seconds to eliminate nuisance alarms due to transient O_2% delivery variations.

13.12 Low exhaled mandatory tidal volume ($\downarrow V_{TE\ MAND}$) alarm

The $\downarrow V_{TE\ MAND}$ alarm indicates that the measured exhaled mandatory tidal volume is less than or equal to the $\downarrow V_{TE\ MAND}$ limit. The $\downarrow V_{TE\ MAND}$ alarm is updated whenever 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. 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.

13.13 Low exhaled spontaneous tidal volume ($\downarrow V_{TE\ SPONT}$) alarm

The $\downarrow V_{TE\ SPONT}$ alarm indicates that the measured exhaled spontaneous tidal volume is less than or equal to the $\downarrow V_{TE\ SPONT}$ limit. The $\downarrow V_{TE\ SPONT}$ alarm is updated whenever 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. 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.

4 Low exhaled total minute volume ($\downarrow\dot{V}_{E\,TOT}$) alarm

The $\downarrow\dot{V}_{E\,TOT}$ alarm indicates that the measured minute volume (for mandatory and spontaneous breaths) is less than or equal to the set $\downarrow\dot{V}_{E\,TOT}$ limit. The $\downarrow\dot{V}_{E\,TOT}$ alarm is updated whenever a new value for exhaled minute volume is calculated. You cannot turn off the $\downarrow\dot{V}_{E\,TOT}$ alarm.

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.

5 PROCEDURE ERROR alarm

The ventilator declares a PROCEDURE ERROR alarm if ventilator is powered up (either by turning on the power switch or following a power loss of at least 5 minutes) and detects a patient attached before Ventilator Startup has been completed. Until ventilator settings are confirmed, the ventilator annunciates a high-urgency alarm and enters safety ventilation.

The PROCEDURE ERROR alarm is intended to require you to confirm ventilator settings whenever ventilator power is restored, in case a new patient is attached to the ventilator. Safety ventilation is an emergency mode of ventilation that provides ventilation according to displayed settings until you have confirmed ventilator settings.

SECTION 14

Monitored data

This section provides supplementary information about selected monitored data displayed on the *840* Ventilator's graphic user interface (GUI). For ranges, resolutions, and accuracies of all monitored data displays, see the operator's guide part of this manual.

The ventilator displays monitored data on the upper GUI screen. Monitored data that is under-range or over-range flashes the minimum or maximum value. Alarm reset has no effect on monitored data collection. Monitored data based on 1-minute averaging is reset if you change a ventilator setting that directly affects that information.

14.1 Delivered O_2%

The ventilator measures the percentage of oxygen in the gas at the ventilator outlet, upstream of the inspiratory filter. Delivered O_2% is displayed on the GUI in the *More Patient Data* screen. Delivered O_2% is used to detect $\uparrow O_2$% and $\downarrow O_2$% alarms.

The delivered O_2% parameter independently checks the O_2% setting. The delivered O_2% measurement monitors the O_2% at the ventilator (*not* the O_2% delivered to the patient). If the oxygen mix is affected downstream of the inspiratory filter (for example, by nebulization), delivered O_2% does *not* reflect that change. Delivered O_2% is measured upstream of the inspiratory filter to avoid having to sterilize the oxygen sensor.

The measurement range is the full range of possible percentages, including cases where the oxygen percentage is actually lower than the 21% found in room air (as could be the case if gas supplies function improperly).

End expiratory pressure ($P_{E\ END}$)

$P_{E\ END}$ is the pressure measured at the end of the exhalation phase of the just completed breath, whether mandatory or spontaneous. $P_{E\ END}$ is updated at the beginning of the inspiratory phase. If expiratory pause is active, $P_{E\ END}$ may reflect the lung PEEP level.

$P_{E\ END}$ is the last value of the low-pass filtered airway pressure during exhalation when the expiratory pause maneuver is active. Otherwise, $P_{E\ END}$ is the last low-pass filtered value when flow has reached 0.5 L/min, or when a mandatory breath has interrupted exhalation, whichever occurs first. The accuracy of the $P_{E\ END}$ measurement is relative to pressure measured at the exhalation side of the patient wye.

$P_{E\ END}$ can be useful for making lung PEEP assessments using the EXP PAUSE key. The ventilator measures $P_{E\ END}$ when expiratory flow has reached 0.5 L/min, or when exhalation has been interrupted by a mandatory breath, to avoid measuring a patient trigger.

End inspiratory pressure ($P_{I\ END}$)

$P_{I\ END}$ is the pressure measured at the end of the inspiratory phase of the current breath, whether mandatory or spontaneous. $P_{I\ END}$ is updated at the beginning of the exhalation phase. The ventilator displays negative $P_{I\ END}$ values. If plateau is active, the $P_{I\ END}$ display indicates the pressure at the end of the plateau.

$P_{I\ END}$ is the last value in inspiration of the low-pass filtered airway pressure. The accuracy of the $P_{I\ END}$ measurement is relative to the patient wye for pressure control (PC) breaths with inspiratory times of 1 second or longer.

For volume-based breaths, $P_{I\ END}$ is usually the same as peak circuit pressure ($P_{CIRC\ MAX}$). For pressure-based breaths, $P_{I\ END}$ is more indicative of the pressures actually exerted on the lungs ($P_{CIRC\ MAX}$, on the other hand, only shows a pressure spike and is not as meaningful for pressure ventilation). The $P_{I\ END}$ is the plateau pressure when a plateau follows mandatory breath delivery. Plateau pressure can be used to compute lung compliance (stiffness) and resistance to flow. Plateaus are also delivered to overcome blockages, to ventilate under-inflated

lungs, and to improve gas distribution. Plateau pressure is measured after pressure equilibrates. With a small airway in place, the pressure difference due to equilibration can be as much as 20 cmH_2O.

The displayed range includes low pressures that can occur when the patient "out-draws" the ventilator and the high pressures in low-compliance patients. The 130 cmH_2O maximum allows the ventilator to measure pressure overshoots of breaths that are truncated at the maximum high pressure limit (100 cmH_2O).

14.4 Exhaled minute volume ($\dot{V}_{E\ TOT}$)

$\dot{V}_{E\ TOT}$ is an estimate of the sum of volumes exhaled for mandatory and spontaneous breaths over the previous 1-minute interval. $\dot{V}_{E\ TOT}$ is BTPS- and compliance-compensated.

During the first minute of operation following power-up or a change to respiratory rate (f) or tidal volume (V_T) settings, $\dot{V}_{E\ TOT}$ is updated at the beginning of each new inspiration or at 10-second intervals, whichever comes first. The ventilator uses this formula to compute $\dot{V}_{E\ TOT}$ based on up to 8 breaths:

$$\dot{V}_{E\ TOT} = 60 \times (\text{total } V_T \text{ in t seconds})/t$$

where *t* is the time in seconds since the computation started.

After the first minute, the ventilator computes $\dot{V}_E$ based on up to 8 mandatory and spontaneous exhaled tidal volumes occurring in the past 60 seconds, and updates the computation at the beginning of the next inspiration or the next 10-second interval, whichever comes first. However, if the next inspiration occurs within 0.5 second of the last update, the computation is not updated at that time.

The $\dot{V}_{E\ TOT}$ computation is based on full and partial breaths that occurred during the preceding 1-minute period. If the 1-minute period includes a partial breath, then the interval is extended to include the entire breath, and the sum of all tidal volumes over this extended interval is normalized to 1 minute.

For example, if 8 full breaths and part of a ninth breath occur in the last minute, $\dot{V}_{E\,TOT}$ would be the sum of the 9 full breaths normalized by this ratio:

60 : (the number of seconds in the extended interval)

If the patient stops breathing, $\dot{V}_{E\,TOT}$ continues to be updated every 10 seconds, and automatically decrements.

Exhaled tidal volume (V_{TE})

V_{TE} is the volume exhaled from the patient's lungs for a mandatory or spontaneous breath. It is computed by integrating the net flow over the expiratory period, then compliance- and BTPS-compensating that value. The V_{TE} is computed from the just-completed breath only; it is not a running average. It is updated at the beginning of the next inspiratory phase.

V_{TE} is a basic indicator of the patient's ventilatory capacity and can be an indicator of the accuracy of the tidal volume setting for mandatory breaths.

I:E ratio (I:E)

I:E is the ratio of inspiratory time to expiratory time of any breath (mandatory and spontaneous), whether volume- or pressure-based. I:E is updated at the beginning of every inspiratory phase and is computed breath-to-breath (the value is not filtered).

The I:E ratio is a fundamental parameter that indicates whether a patient's breathing pattern is normal and is displayed according to respiratory care convention.

14.7 Intrinsic (auto) PEEP ($PEEP_I$) and total PEEP ($PEEP_{TOT}$)

$PEEP_{TOT}$ and $PEEP_I$ are determined during an operator-initiated expiratory pause, in which the PSOL valves and exhalation valves are closed. $PEEP_{TOT}$ is the pressure measured during the pause maneuver. It is an estimate of the total pressure at the end of exhalation, referenced to atmosphere. $PEEP_I$ is an estimate of the pressure above the PEEP level at the end of exhalation.

During the pause, the most recently selected graphics are displayed and frozen, so you can follow and assess when expiratory pressure stabilizes.

14.8 Mean circuit pressure ($\overline{P}_{CIRC}$)

$\overline{P}_{CIRC}$ is the average circuit pressure, for an entire breath cycle, including both inspiratory and expiratory phases (whether the breath is mandatory or spontaneous). The ventilator displays negative $\overline{P}_{CIRC}$ values. The $\overline{P}_{CIRC}$ display is updated at the beginning of each inspiration.

The ventilator computes $\overline{P}_{CIRC}$ by averaging all pressure measurements made through an entire breath cycle. Accuracy is relative to pressure measured at the exhalation side of the patient wye and is based on the accuracy of the circuit pressure measurement.

14.9 Peak circuit pressure ($P_{CIRC\ MAX}$)

$P_{CIRC\ MAX}$ is the maximum pressure measured during the inspiratory or expiratory phase of the current mandatory or spontaneous breath and is updated at the beginning of the next inspiratory phase. The ventilator displays negative $P_{CIRC\ MAX}$ values. The ventilator displays the most positive value of the low-pass filtered airway pressure measured during the entire breath.

$P_{CIRC\ MAX}$ can be used to evaluate trends in lung compliance and resistance. For volume-based breaths, $P_{CIRC\ MAX}$ is usually the same as end inspiratory pressure ($P_{I\ END}$). For pressure-based breaths, $P_{I\ END}$ is more indicative of the pressures actually exerted on the lungs ($P_{CIRC\ MAX}$, on the other hand, may only show a pressure spike and may not be meaningful for pressure ventilation).

The minimum displayed range includes low pressures found when the patient "out-draws" the ventilator. The maximum displayed value allows the ventilator to display the high pressures in low-compliance patients and pressure overshoots of breaths that are truncated at the maximum high pressure limit (100 cmH_2O).

0 Plateau pressure (P_{PLAT})

P_{PLAT} is the pressure measured in the ventilator breathing circuit at the end of an inspiratory pause maneuver. Because the pause maneuver is conducted with the ventilator breathing circuit sealed (PSOL valves and exhalation valve closed and assuming a leak-tight system), P_{PLAT} is the best estimate of the pressure in the patient's lungs.

Beginning with the start of the pause maneuver, P_{PLAT} is displayed and updated continuously. At the end of the maneuver P_{PLAT}, along with the other pause data, is "frozen," enabling you to view all of the data together. Pressing "UNFREEZE" causes the data to be discarded.

1 Spontaneous minute volume ($\dot{V}_{E\ SPONT}$)

$\dot{V}_{E\ SPONT}$ is the sum of spontaneous exhaled volumes, normalized to 1 minute. The displayed $\dot{V}_{E\ SPONT}$ is compliance- and BTPS-compensated. As more mandatory breaths are delivered, the displayed $\dot{V}_{E\ SPONT}$ is computed and updated whenever $\dot{V}_{E\ TOT}$ is computed and updated. The computation for $\dot{V}_{E\ SPONT}$ is the same as for $\dot{V}_{E\ TOT}$, except that only spontaneous breaths are included, and the 1-minute interval is not extended unless the partial breath is a spontaneous breath. (See exhaled minute volume for details.)

$\dot{V}_{E\ SPONT}$ can help determine how much ventilation takes place solely due to spontaneous breathing, and does not include patient-initiated mandatory breaths. Minute volume establishes a patient's ventilatory adequacy, and $\dot{V}_{E\ SPONT}$ indicates how much of total ventilation is due to the patient's efforts. $\dot{V}_{E\ SPONT}$ can be used to assess whether a patient being ventilated in SIMV is ready to be weaned.

14.12 Static compliance and resistance (C and R)

C (or C_{STAT}, static compliance) is an estimate of the elasticity of the patient's lungs; it is expressed in mL/cmH_2O. R (or $R_{AW\ STAT}$, static resistance) is the total inspiratory resistance across the artificial airway and respiratory system. It is an estimate of how restrictive the patient's airway is, based on the pressure drop at a given flow; it is expressed in cmH_2O/L/second. These values are computed during an operator-initiated inspiratory pause, in which the PSOL valves and exhalation valve are closed. C is computed during a mandatory breath. R is computed during a VC mandatory breath with a square waveform.

C is computed from this equation:

$$C_{STAT} = \frac{V_{EXH}}{P_{PL\ END} - P_{PE\ END}} - C_C$$

where:

V_{EXH}	is the total expiratory volume (patient and breathing circuit)
$P_{PL\ END}$	is the pressure in the patient circuit measured at the end of the 100-ms interval that defines the pause-mechanics plateau
$P_{E\ END}$	is the pressure in the patient circuit measured at the end of exhalation
C_C	is the compliance of the VBS during the pause maneuver (derived from SST)

R is computed from this equation once C_{STAT} is computed (assuming the breath type was VC with square flow waveform):

$$R = \frac{\left[1 + \frac{C_C}{C_{STAT}}\right](P_{CIR\ MAX} - P_{PL\ MID})}{\dot{V}_{PAT}}$$

where:

C_C	is as given above
C_{STAT}	is as given above
$P_{PL\ MID}$	is the mean pressure in the patient circuit over the 100-ms interval that defines the pause-mechanics plateau
$P_{CIRC\ MAX}$	is the pressure in the patient circuit at the end of the square flow waveform
$\dot{V}_{PAT}$	is the flow into the patient during the last 100 ms of the waveform

During the pause, the most recently selected graphics are displayed and frozen, so you can see when inspiratory pressure stabilizes. C and R are displayed at the start of the next inspiration following the inspiratory pause. They take this format:

C xxx

or

R yyy

If the software determines that variables in the equations or the resulting C or R values are out of bounds, it identifies the questionable C and R values with special formatting and text messages:

- Parentheses ( ) signify questionable C or R values, derived from questionable variables.
- Flashing C or R values are out of bounds.
- Asterisks (******) mean that variables fall below noise-level bounds.

- R------ means that resistance could not be computed, because the breath was not of a mandatory, VC type with square flow waveform.

Refer to Table 14-1 for further troubleshooting.

Table 14-1: Inspiratory pause maneuver displays

Compliance (C)	Resistance (R) (if displayed)	Meaning	Corrective action
C (******)	R (******)	C < 0.1 mL/cmH_2O or patient flow < 0.1 L/min. This points to questionable inputs to the C equation, which would in turn render R questionable. The low patient flow is below the threshold of reliable measurement.	Check the breathing waveforms and monitored patient data for clues about these questionable inputs.
C (******)	R (******)	The difference in pressure between end plateau and end exhalation < 0.1 cmH_2O. This is below the limits of reliable resolution. The R and C values are therefore questionable.	Check the breathing waveforms and monitored patient data for clues about these questionable inputs.
C (0) *or* C (500)	R ( ) *Message as dictated by other tests*	C ≤ 0 mL/cmH_2O or C < 500 mL/cmH_2O. These measurements are outside of physiological limits.	Check the patient-ventilator interaction, the breathing waveforms, and the patient circuit for underlying causes.
C ( ) *Message as dictated by other tests*	R (0) *or* R (500)	R ≤ 0 cmH_2O/L/s or R < 500 cmH_2O/L/s. These measurements are outside of physiological limits.	Check the patient-ventilator interaction, the breathing waveforms, and the patient circuit for underlying causes.

Table 14-1: Inspiratory pause maneuver displays (continued)

npliance (C)	Resistance (R) (if displayed)	Meaning	Corrective action
x)	R (yyy) Sub-threshold input value(s)	C < 1/3 of ventilator breathing system compliance (derived from SST). Both C and R are questionable.	If the patient's IBW ≤ 24 kg, consider installing a pediatric patient circuit.
x) nplete ation	R (yyy) Incomplete exhalation	Exhalation was not complete. This renders end-expiratory pressure and total exhaled flow values questionable.	Check for an insufficient expiratory interval. If possible, shorten inspiration time and reduce respiratory rate.
x) lateau	R (yyy) No plateau	Plateau is not "flat" (lung and circuit pressures did not equilibrate) or pause pressure was excessively noisy. These problems render R and C questionable.	If plateau continues to decline, check for a leak in the breathing circuit, possibly around the cuff. If plateau is unstable, check for moisture condensing in a "lazy" loop or a breathing circuit being jiggled.
x) of range	R (yyy) Questionable measurement	C < 1.0 mL/cmH_2O. This results from questionable input data. This out-of-range value also renders R questionable.	Check the breathing waveforms and monitored patient data for clues about these questionable inputs.
		C > 100 mL/cmH_2O. This results from questionable input data. This out-of-range value also renders R questionable.	Check the breathing waveforms and monitored patient data for clues about these questionable inputs.

Table 14-1: Inspiratory pause maneuver displays (continued)

Compliance (C)	Resistance (R) (if displayed)	Meaning	Corrective action
C (xxx) Questionable measurement	R (yyy) Out of range	R > 150 $cmH_2O/L/s$. This results from questionable input data, possibly C.	Check the breathing waveforms and monitored patient data for clues about these questionable inputs.
C (xxx) Questionable measurement	R (yyy) Questionable measurement	The pressure rose slowly at the end of the square flow waveform. This suggests that the pressures, volumes, and flows involved are minimal and questionable. This is not expected during normal ventilation.	Check the pressure-time waveform to see whether the patient delayed inspiration until the end of gas delivery.
C (xxx) Sub-threshold input value(s)	R (yyy) Questionable measurement	The difference between the circuit pressure at the end of the plateau and the pressure at the end of exhalation < 0.5 cmH_2O. This results in a questionable R value.	Check for a highly compliant lung inflated slightly. If the tidal volume can be safely increased, try that.

Table 14-1: Inspiratory pause maneuver displays (continued)

npliance (C)	Resistance (R) (if displayed)	Meaning	Corrective action
	R (yyy) Out of range	R < 0.5 $cmH_2O/L/s$. This results because the patient flow or the pressure difference from peak to plateau is questionable.	Check the breathing waveforms and monitored patient data for clues about these questionable inputs.
	R (yyy) Questionable measurement	The pressure rose too quickly at the end of the square flow waveform. This points to poor patient-ventilator synchrony and suggests that the lung was very stiff or the flow very high. This renders R questionable.	If the patient's condition permits, consider reducing the set tidal volume and/or increasing the inspiratory time (equivalent to reducing the peak flow). Check the pressure-time waveform to see whether the patient may have triggered the mandatory breath, then relaxed toward the end of inspiration.
	R (yyy) Subthreshold input value(s)	The difference between the circuit pressure at the end of the square flow waveform and at the end of the plateau < 0.5 cmH_2O. This results in a questionable R value.	Check for: low patient flow through a relatively large-diameter artificial airway, low absolute flow and a relatively long inspiratory time, or a small patient connected to a breathing circuit with a relatively large compliance.

Table 14-1: Inspiratory pause maneuver displays (continued)

Compliance (C)	Resistance (R) (if displayed)	Meaning	Corrective action
NA		Patient flow < 20 L/min and C < 4 mL/cmH_2O. This results in a questionable R value.	Check for: low patient flow through a relatively large-diameter artificial airway, low absolute flow and a relatively long inspiratory time, or a small patient connected to a breathing circuit with a relatively large compliance.

14.13 Total respiratory rate (f_{TOT})

f_{TOT} is the number of breaths delivered to a patient normalized to 1 minute, whether mandatory or spontaneous, and is updated at the beginning of each inspiratory phase.

During the first minute of operation following power-up or a change to any setting that affects the rate of mandatory breath delivery, f_{TOT} is updated at the beginning of each inspiration. The ventilator uses this formula to compute f_{TOT} based on up to 8 breaths:

$$\text{Startup } f_{TOT} = \frac{60 \times (\text{total number of inspirations in } t)}{t}$$

where *t* is the time in seconds since the computation started.

After the first minute, the ventilator computes f_{TOT} based on up to 8 breaths initiated during the last minute and updates the computation at the beginning of the next inspiration or the next 10-second interval, whichever comes first. However, if the next inspiration occurs within 0.5 second of the last update, the computation is not updated at that time.

Except for the start-up calculation and the 10-second interval, f_{TOT} is calculated based on a whole number of breaths. Therefore, the 60-second interval is extended to include the next breath initiation. The ventilator uses this formula to calculate the f_{TOT}:

$$\text{Post-startup } f_{TOT} = \frac{\text{total whole number of breaths in 60 s + x}}{\text{60 s + x}}$$

where *x* is the number of seconds the 60-second interval was extended to include the next inspiration.

f_{TOT} is one of the most sensitive parameters of respiratory function and is an important indicator of ventilatory adequacy. The displayed range can apply where no breaths are delivered to the patient within the last minute, or when the patient is receiving the maximum respiratory rate that can be delivered.

Safety net

The ventilator's *safety net strategy* refers to how the ventilator responds to patient problems and system faults.

- *Patient problems* are declared when patient data is 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.
- *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). System faults are not usually self-correcting and are handled under the assumption that they can affect the ventilator's performance. "System" refers to the ventilator, external gas and power supplies, and the machine-patient interconnections.

The ventilator is designed to alarm and 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 (this emergency state is called *safety valve open*, SVO). Safety mechanisms are designed to be verified periodically or have redundancy. The ventilator is designed to ensure that a single-point failure does not cause a safety hazard or affect the ventilator's ability to annunciate a high-urgency audible alarm.

15.1 Patient problems

In case of patient problems, the ventilator remains fully operative and annunciates the appropriate alarm. The patient problem determines the detection, response, and urgency of each alarm.

System faults

The ventilator is designed to prevent system faults. The ventilator is modular, and it allows the breath delivery unit (BDU) to operate independently of the graphic user interface (GUI) or other subsystems not related to breath delivery. If the ventilator detects a system fault and ventilation can continue, it alarms and provides ventilatory support as close to the current settings as possible, depending on the specific system fault. Most system faults are DEVICE ALERT alarms, and can be high-, medium-, or low-urgency alarms.

The ventilator uses these strategies to detect system faults:

- *Ongoing background checks* and *hardware monitoring circuitry* function during normal operation.
- *Power on self test (POST)* checks the system at power-up.
- *Short self test (SST)* and *extended self test (EST)* check the ventilator when a patient is not attached to the ventilator.

If the ventilator cannot provide reliable ventilatory support and fault monitoring, then the ventilator alarms and enters the SVO emergency state. During SVO, the ventilator deenergizes the safety, exhalation, and inspiratory valves, annunciates a high-urgency alarm, and turns on the SVO indicator.

During SVO, a patient can spontaneously inspire room air and exhale. Check valves on the inspiratory and expiratory sides minimize rebreathing 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.

15.3 Ongoing background checks

Ongoing background checks assess the ventilator's electronics and pneumatics hardware continuously during ventilation, and include:

- *Periodically initiated tests:* Tests initiated at intervals of a specified number of machine cycles. These tests check the hardware components that directly affect the breath delivery system, safety mechanisms, and user interface. These tests detect and correct data corruption of control variables.
- *Boundary checks:* Checks that are performed at every analog measurement. Boundary checks verify measuring circuitry, including sensors.
- *CPU cross-checks:* The ventilator's GUI central processing unit (CPU) monitors the BDU CPU's activity. Cross-checks provide independent verification that each processor is functional. They focus on circuit pressure, breath periodicity, length of inspiration, alarm annunciation, oxygen percentage, and ventilator settings. Communications errors between CPUs are detected and corrected.

Specific background checks include:

- *Memory tests:* RAM (parity-check only), ROM, and nonvolatile memory (NVRAM) are tested (without corrupting data stored in memory) on an ongoing basis.
- *Analog-to-digital converter (ADC) reasonability checks:* Flow sensors, thermistors, and pressure sensors are checked against predetermined ranges to ensure proper functioning of the system's analog measuring capability and transducers.
- *Voltage calibration check:* The ventilator reads the system reference voltage through the ADCs, then uses this reference voltage to scale all analog measurements.
- *Digital-to-analog converter (DAC) and ADC circuitry checks*: Signals from both the expiratory and inspiratory DAC are fed back to the microprocessor through the ADC, and the original DAC input value is compared to the converted ADC signal.
- *Power supply voltage checks:* The ventilator periodically checks system voltages (+12, +15, -15, and +5 V dc), battery voltage, and the cable and voltage of the speaker.

- *Pressure transducers:* The ventilator periodically checks to ensure that transducer drift doesn't cause system accuracy limits to be exceeded.
- *Touchscreen checks:* The ventilator checks for failures in the touchscreen system, including optical obstruction of one or more LED/photodiode pair.
- *Offscreen keys:* The ventilator checks for key stuck.
- *SmartAlert audio annunciation system (SAAS):* The ventilator verifies that the SAAS can annunciate alarms properly.
- *Options:* The ventilator periodically checks for the existence of any options, its pass/fail status, and whether or not the option is active. The results of whatever checks an option performs on itself are reported to the BDU and GUI CPUs.

If any of these background tests detects a fault, the ventilator alarms and provides the most appropriate level of ventilatory support consistent with the detected system fault.

Hardware monitoring circuitry

The ventilator has hardware circuitry dedicated to monitoring software activity and power failure problems. The ventilator also has monitoring circuitry built into the CPU.

- *Watchdog (WD) time-out circuitry:* WD time-out circuitry monitors software activity and indicates if software is executed irregularly. WD circuitry is independent of the CPUs and software. In case of irregular software execution, WD circuitry invokes POST. If POST does not confirm an error, the ventilator returns to normal operation to minimize the interruption to normal breath delivery. If three WD time-outs occur within 24 hours, the ventilator alarms and declares a ventilator inoperative state.
- *Bus time-out monitoring circuitry:* Bus time-out circuitry is independent of the CPU and monitors whether any bus activity has taken place for a predetermined time. If no bus activity is detected, bus time-out circuitry invokes POST. If POST does not confirm an error, the ventilator returns to normal operation to minimize the interruption to normal breath delivery. If three bus time-outs occur within 24 hours,

the ventilator alarms and declares a ventilator inoperative state.

- *Built-in CPU monitoring circuitry:* Mechanisms are built into the CPU to detect out-of-boundary operation and detect system faults. If the CPU circuitry detects a problem, the ventilator alarms, the CPU resets, and the ventilator provides the highest level of ventilatory assistance possible.
- *Power fail monitoring:* The power fail module monitors the dc power supply. When the power switch is ON and +5 V is out of range ±0.25 V, the ventilator locks access to RAM, enters SVO, closes the proportional solenoid valves (PSOLs), and turns on the ventilator inoperative indicator and audio alarm. Ventilator alarms monitor ac power.

15.5 Power on self test (POST)

POST checks the integrity of the ventilator's electronic hardware whenever it is powered up. POST detects system faults without operator intervention.

15.6 Short self test (SST)

SST is designed to be performed when the patient circuit or humidification system is changed. SST primarily tests the patient circuit for leaks, calibrates the patient circuit, and measures the resistance of the expiratory filter. SST requires minimal operator participation and no external test equipment.

15.7 Extended self test (EST)

EST performs a more thorough system test than POST or SST, and is also intended to detect system faults. EST requires operator participation, but no external test equipment other than the "gold standard" circuit (the test circuit designed for use with EST). EST can also serve as a confidence check following repair or a temporary problem.

Oxygen sensor calibration

The ventilator performs a single-point oxygen sensor calibration during the 100% suctioning procedure (that is, when you press the 100% O_2/CAL 2 MIN key), allowing you to calibrate the oxygen sensor frequently without having to disconnect the patient. If the oxygen sensor calibration fails, the ventilator declares a DEVICE ALERT alarm that resets when the ventilator successfully calibrates the oxygen sensor. The ventilator's oxygen sensor is always active unless you disable it.

Exhalation valve calibration

The exhalation valve calibration, available in service mode, builds a table that lists digital-to-analog (DAC) commands that correspond to expiratory pressure levels.

0 Ventilator inoperative test

The ventilator inoperative test, available in service mode, verifies that the ventilator is capable of establishing the ventilator inoperative state. This test verifies the two redundant ventilator inoperative commands separately and checks that each command establishes a ventilator inoperative state.

1 Flow sensor offset calibration

This function, available in service mode, calibrates the offsets out of the exhalation flow sensor (relative to the air and oxygen flow sensors).

2 Atmospheric pressure transducer calibration

This function, available in service mode, calibrates the atmospheric pressure transducer using an external barometer.

SECTION 16

Power on self test (POST)

POST tests the integrity of the ventilator's electronic subsystem without operator intervention. It is executed when the ventilator is powered up, before it enters service mode, or if the ventilator detects selected fault conditions. A full-length POST takes under 10 seconds (from power on until Ventilator Startup begins).

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

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

16.1 Safety

The ventilator does not provide ventilatory support to the patient during POST. The ventilator alarms if POST lasts longer than 10 seconds or if an unexpected fault is detected. POST is designed to minimize the delay until normal ventilation begins and to provide immediate notification in case a fault is detected. The ventilator runs a short version of POST after recovering from a brief power loss.

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

POST characteristics

Each processor in the ventilator runs its own POST. Upon completion, each processor reports its test results to the GUI processor. POST starts with the software kernel, then tests the hardware that directly interfaces to the kernel. POST then tests the rest of the hardware. Hardware that is linked to each processor through a communication channel is checked once the communication link is verified.

The main characteristics of POST are:

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

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

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

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

Once POST is complete, ventilator startup (following power-up or a power interruption of longer than 5 minutes) or normal ventilation begins, unless service mode is requested or the ventilator detects any of the following:

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

16.3 POST following power interruptions

The ventilator executes a normal POST following a long power interruption (5 minutes or more) while the power switch is on. The ventilator runs a full POST after a long power interruption under the assumption that the patient would have been disconnected and ventilated by other means, and because circumstances that cause a lengthy power loss warrant a full POST.

The ventilator runs a short POST (which tests the BDU only) if power is interrupted for less than 5 minutes. After a short power interruption (during which the status of the patient cannot be assumed), the ventilator resumes normal ventilation as soon as possible, in case the patient remains connected. Running a short POST (3 seconds or less from return of ac power to beginning breath delivery) allows for short power interruptions due to common events (for example, switching to generator power) that do not require a normal POST, and assumes that a patient may still be connected to the ventilator. Short POST checks the

software kernel, verifies checksums for code, and determines what event invoked POST.

POST fault handling

How the ventilator handles a POST failure depends on which test has failed and whether the failure occurred during the kernel test. Fault information is logged in nonvolatile random access memory (NOVRAM) and is time-stamped. POST failures are classified as *minor* or *major faults*:

Minor POST fault: A fault that does not affect ventilation or patient safety checks. Normal ventilation is allowed to begin if POST detects a minor fault. A minor fault does not interrupt the regular POST sequence. The ventilator displays POST fault information and logs it into NOVRAM.

Major POST fault: A fault that affects ventilation or patient safety checks. A major fault interrupts the regular sequence of POST. Fault information is sent to the GUI (if possible) and to a set of discrete visual indicators on the GUI and BDU. The ventilator logs major fault information into NOVRAM, if possible, and sends a command to turn on audio, visual, and remote alarms. The safety valve and exhalation valve remain open to allow the patient to breathe room air. The ventilator cannot execute GUI and BDU software until it passes POST.

POST system interface

POST is the first process to run when the ventilator turns on. Breath delivery cannot start until the ventilator completes POST with no major POST faults, and until no major system, SST, or EST faults exist. Once POST starts, the ventilator opens the safety valve and exhalation valve to the atmosphere (the default state of the ventilator at power-up or reset), and both remain open until ventilation begins. Minor faults are recorded in NOVRAM without interrupting POST.

Unless prevented by a POST, the transition to service mode can occur upon operator request. During service mode, the operator can select EST or system level tests. POST software can be updated without affecting the operational software (GUI and BDU).

16.6 POST user interface

POST includes these visual indicators:

- An indicator that the ventilator is not delivering breaths.
- The message "System Initializing..."
- Discrete visual indicators on the BD CPU PCB that indicate the current test and step number.
- The normal ventilator operation indicator on the BDU signals that the user can press TEST to trigger service mode.
- If possible, a display of fault information in case POST detects a failure.

If POST detects a major fault, a qualified service technician must run EST and correct the problem.

SECTION 17

Short self test (SST)

SST is a short (about 2 to 3 minutes) and simple sequence of tests that verifies proper operation of breath delivery hardware (including pressure and flow sensors), check the patient circuit (including tubing, humidification device, and filters) for leaks, and measure the circuit compliance and resistance. SST also checks the resistance of the exhalation filter. Nellcor Puritan Bennett recommends that you run SST every 15 days, between patients, and when you change the patient circuit or its configuration (including changing the humidifier type, adding or removing an in-line water trap, or using a different type or style of patient circuit). The operator's guide part of this manual tells you how to run SST. The ventilator does not begin SST if it senses that a patient is connected.

SST prompts you to verify that no patient is attached and asks you to select the patient circuit and humidifier types. SST prompts you to block the wye, then verifies that it is blocked. SST then tests the accuracy of the expiratory flow sensors, verifies proper function of pressure sensors, tests the patient circuit for leaks, calculates the compliance compensation for the patient circuit, measures the pressure drop across the expiratory filter, measures the resistance of the inspiratory and expiratory limbs of the patient circuit, then checks the pressure drop across the inspiratory limb.

Possible SST outcomes are:

- *Passed:* All tests passed (no faults detected).
- *ALERT:* A fault was detected. If it can be determined with certainty that this cannot create a hazard for the patient, or add to the risk which may arise from other hazards, the user can choose to override the ALERT status and authorize ventilation.
- *OVERRIDDEN:* An ALERT status was overridden, and ventilation is authorized.
- *FAILURE:* One or more critical problems were detected. You cannot skip a test whose result is FAILURE. The ventilator does not allow ventilation until SST runs without failing any tests.

If SST is interrupted and ventilation was allowed before you started SST, normal ventilation is allowed if:

- SST did not detect any failures or alerts before the interruption, and
- no other errors that would prevent ventilation occurred, and
- you did not change the circuit type at the start of the interrupted SST. (If you *did* change the patient circuit type, you must successfully complete SST before normal ventilation can begin.)

During SST, the ventilator displays the current SST status, including the test currently in progress, results of completed tests, and measured data (where applicable). The ventilator logs SST results, and that information is available following a power failure. These keys are disabled during SST: alarm silence, alarm reset, MANUAL INSP, 100% O_2/CAL 2 min, and EXP PAUSE. The INFO key is functional during SST.

SECTION 18

Extended self test (EST)

EST verifies the integrity of the ventilator's subsystems using operator participation. EST requires a "gold standard" test circuit. All test resources, including the software code to run EST, are in the ventilator. EST testing, excluding tests of optional equipment (such as the compressor), takes about 15 minutes.

EST checks the pneumatics system (including the compressor), memory, safety system, front panel controls and indicators, digital and analog electronics, power supplies, analog out system, transducers, and options.

EST can run only when the ventilator is in service mode. Air and oxygen supplies are required (the compressor can supply the air source). EST is a comprehensive ventilator test that is designed to be run by a qualified service technician for periodic and corrective maintenance.

The main characteristics of EST include:

- EST fully tests the ventilator's electrical system, including non-major electronic functions (for example, battery power) and electronics subsystems that require operator intervention (for example, display/keyboard verification, and calibration).
- EST checks the pneumatics subsystem, including gas supplies, proportional solenoid (PSOL) valve, flow sensors, circuit pressure accuracy, safety valve, and exhalation valve.
- EST tests available options, including the compressor.
- Ventilator safe state tests (both GUI and BDU can force the ventilator into a ventilator inoperative state).

EST results

The ventilator displays the current test name, automatically runs tests that do not require operator action, prompts the operator to run tests that do require operator action, and displays test results. Once a test begins, it runs to completion. If an EST failure or alert occurs, the test name and results are displayed, and you can choose to rerun the test (for a FAILURE or an ALERT), skip to the next test (for an ALERT only), or quit EST.

At the end of EST, one of these overall results is displayed:

- *Passed*: All tests passed; normal ventilation can begin.
- *ALERT*: A fault was detected. If it can be determined with certainty that this cannot create a hazard for the patient, or add to the risk which may arise from other hazards, the technician can choose to override the ALERT status and authorize ventilation.
- *OVERRIDDEN*: An ALERT status was overridden, and ventilation is authorized.
- *FAILURE*: One or more critical problems were detected. The ventilator does not allow normal ventilation until EST runs without failing any tests.

The technician must switch the ventilator to service mode, then choose to invoke EST. If the ventilator is powered down in EST after detecting one or more EST failures or alerts, the technician must run EST without a failure or non-overridden alert before the ventilator can begin normal ventilation.

If EST is interrupted and ventilation was allowed before you started EST, normal ventilation is allowed if EST did not detect any failures or alerts before the interruption, and no other errors occurred that would prevent ventilation.

EST is required if there is a major POST failure, a major system failure, or an EST failure or non-overridden alert. (Any minor or major POST fault that occurs outside of the kernel test is logged and time-stamped in nonvolatile memory.) When EST is required, normal ventilation is not allowed. EST is required until EST is completed without failures or non-overridden alerts.

18.2 EST failure handling

Ventilator response to EST failures or alerts depends on the type of test. If a failed test (failure or alert) is immediately repeated, the new results replace the previous results in memory. An EST failure or alert interrupts the regular sequence of EST tests.

18.3 EST safety considerations

To run EST, the technician must switch the ventilator to service mode, then request EST. (The technician can also use service mode to run field tests or upgrade software in the field.) The ventilator cannot provide ventilatory support during service mode, and is designed to prevent a software fault from causing an unrequested transition to service mode. You can enter service mode only upon power up, and a hardware interlock is required before the ventilator can switch to service mode.

SECTION 19

RS-232 commands

The *840* Ventilator System offers two commands that allow communication to and from the ventilator using the RS-232 port:

- RSET
- SNDA

NOTE:
The ventilator responds only if it receives a carriage return <CR>.

19.1 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:

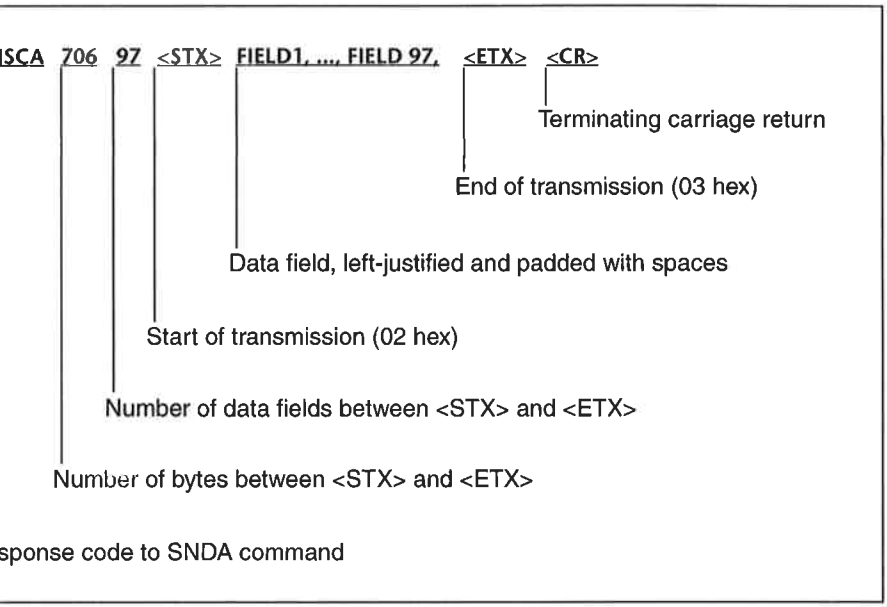
RSET<CR>

SNDA command

The SNDA command instructs the ventilator to send information on ventilator settings and monitored 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 MISCA, followed by ventilator settings and monitored data information. The MISCA response follows this format:



The MISCA response (including data fields) is as given in Table 19-1.

Table 19-1: MISCA response

Component	Description
MISCA	Response to SNDA command (5 characters)
706	The number of bytes between <STX> and <ETX> (3 characters)
97	The number of fields between <STX> and <ETX> (2 characters)
<STX>	Start of transmission character (02 hex)
Field 1	Ventilator time (HH:MM_) (6 characters)
Field 2	Not used (18 characters)
Field 3	Not used (6 characters)
Field 4	Date (MMMDDYYYY___) (12 characters)
Field 5	Mode (CMV___, SIMV__, or CPAP__) (CMV = A/C, CPAP = SPONT) setting (6 characters)
Field 6	Respiratory rate setting in breaths per minute (6 characters)
Field 7	Tidal volume setting in liters (6 characters)
Field 8	Peak flow setting in liters per minute (6 characters)
Field 9	O_2% setting (6 characters)
Field 10	Pressure sensitivity setting in cmH_2O (6 characters)
Field 11	PEEP setting in cmH_2O (6 characters)
Field 12	Plateau time in seconds (6 characters)
Field 13	Not used (6 characters)
Field 14	Not used (6 characters)
Field 15	Not used (6 characters)
Field 16	Not used (6 characters)
Field 17	Apnea interval in seconds (6 characters)

Table 19-1: MISCA response (continued)

ponent	Description
18	Apnea tidal volume setting in liters (6 characters)
19	Apnea respiratory rate setting in breaths per minute (6 characters)
20	Apnea peak flow setting in liters per minute (6 characters)
21	Apnea O_2% setting (6 characters)
22	Pressure support setting in cmH_2O (6 characters)
23	Flow pattern setting (SQUARE or RAMP__) (6 characters)
24	Not used (6 characters)
25	Not used (6 characters)
26	100% O_2 state (ON____ or OFF___) (6 characters)
27	Not used (6 characters)
28	Not used (6 characters)
29	Not used (6 characters)
30	Total respiratory rate in breaths per minute (6 characters)
31	Exhaled tidal volume in liters (6 characters)
32	Exhaled minute volume in liters (6 characters)
33	Spontaneous minute volume in liters (6 characters)
34	Maximum circuit pressure in cmH_2O (6 characters)
35	Mean airway pressure in cmH_2O (6 characters)
36	End inspiratory pressure in cmH_2O (6 characters)
37	Expiratory component of monitored value of I:E ratio, assuming inspiratory component of 1 (6 characters)
38	High circuit pressure limit in cmH_2O (6 characters)
39	Not used (6 characters)
40	Not used (6 characters)

Table 19-1: MISCA response (continued)

Component	Description
Field 41	Low exhaled tidal volume limit in liters (6 characters)
Field 42	Low exhaled minute volume limit in liters (6 characters)
Field 43	High respiratory rate limit in breaths per minute (6 characters)
Field 44	High circuit pressure alarm status (NORMAL, ALARM_, or RESET_) (6 characters)
Field 45	Not used (6 characters)
Field 46	Not used (6 characters)
Field 47	Low exhaled tidal volume (mandatory or spontaneous) alarm status (NORMAL, ALARM_, or RESET_) (6 characters)
Field 48	Low exhaled minute volume alarm status (NORMAL, ALARM_, or RESET_) (6 characters)
Field 49	High respiratory rate alarm status (NORMAL, ALARM_, or RESET_) (6 characters)
Field 50	No O_2 supply alarm status (NORMAL, ALARM_, or RESET_) (6 characters)
Field 51	No air supply alarm status (NORMAL, ALARM_, or RESET_) (6 characters)
Field 52	Not used (6 characters)
Field 53	Apnea alarm status (NORMAL, ALARM_, or RESET_) (6 characters)
Field 54	Not used (6 characters)
Field 55	Not used (6 characters)
Field 56	Ventilator time (HH:MM_) (6 characters)
Field 57	Not used (6 characters)
Field 58	Date (MMMDDYYYY___) (12 characters)
Field 59	Not used (6 characters)
Field 60	Not used (6 characters)

Table 19-1: MISCA response (continued)

ponent	Description
61	Not used (6 characters)
62	Not used (6 characters)
63	Not used (6 characters)
64	Not used (6 characters)
65	Not used (6 characters)
66	Ventilator-set base flow in liters per minute (6 characters)
67	Flow sensitivity setting in liters per minute (6 characters)
68	Not used (6 characters)
69	Not used (6 characters)
70	Not used (6 characters)
71	Not used (6 characters)
72	Not used (6 characters)
73	Not used (6 characters)
74	Not used (6 characters)
75	Not used (6 characters)
76	Not used (6 characters)
77	Not used (6 characters)
78	Not used (6 characters)
79	Not used (6 characters)
80	End inspiratory pressure in cmH_2O (6 characters)
81	Inspiratory pressure setting in cmH_2O (6 characters)
82	Inspiratory time setting in seconds (6 characters)
83	Apnea interval setting in seconds (6 characters)

Table 19-1: MISCA response (continued)

Component	Description
Field 84	Apnea inspiratory pressure setting in cmH_2O (6 characters)
Field 85	Apnea respiratory rate setting in breaths per minute (6 characters)
Field 86	Apnea inspiratory time setting in seconds (6 characters)
Field 87	Apnea O_2% setting (6 characters)
Field 88	High circuit pressure limit in cmH_2O (6 characters)
Field 89	Alarm silence state (ON____ or OFF___) (6 characters)
Field 90	Apnea alarm status (NORMAL or ALARM_) (6 characters)
Field 91	Disconnect alarm status (NORMAL or ALARM_) (6 characters)
Field 92	Inspiratory component of I:E ratio setting (6 characters)
Field 93	Expiratory component of I:E ratio setting (6 characters)
Field 94	Inspiratory component of apnea I:E ratio setting (6 characters)
Field 95	Expiratory component of apnea I:E ratio setting (6 characters)
Field 96	Constant during rate setting change for pressure control mandatory breaths (I-TIME or I/E___) (6 characters)
Field 97	Monitored value of I:E ratio (6 characters)
<EXT>	End of transmission character (03 hex)
<CR>	Terminating carriage return

NOTE:

To interpret onscreen abbreviations, consult Section 1 of the operator's guide part of this manual.

A	Amperes (unit of current)
A/C	Assist/control mode. A ventilatory mode in which the ventilator delivers only mandatory breaths (patient-, ventilator-, or operator-initiated) according to the current settings.
ac	Alternating current.
alarm log	A record of alarm events (including time-stamped alarms, silences, and resets) in order of occurrence, with the most recent event at the top of the list.
alarm message	A message that accompanies alarm annunciation that consists of a *base message* (which identifies the alarm), an *analysis message* (which lists the root cause and any associated alarms that may have arisen due to the initial alarm), and a *remedy message* (which suggests corrective actions).
alarm reset key	Key that clears all alarm indicators and cancels the alarm silence period.
alarm silence key	Key that silences alarm sound for two minutes from the most recent key press, but does not change visual indicators.
ALERT	A category of condition detected during SST or EST. An ALERT may be overridden provided that it can be determined with certainty that the defect in the ventilator or associated component cannot create a hazard for the patient, or add to the risks that may arise from other hazards.
apnea	Cessation of breathing. The *840* Ventilator System declares apnea and begins apnea ventilation when the breath-to-breath interval exceeds the set apnea interval (T_A).
autoreset	When an alarm becomes inactive (that is, alarm conditions no longer exist) without pressing the alarm reset key.
background checks	Continuously running tests during ventilation that assess the ventilator's electronics and pneumatics hardware.

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.
n changes	Changes to multiple settings that go into effect at the same time. On the *840* Ventilator System, no setting changes go into effect until you press the ACCEPT key.
DU	Breath delivery or breath delivery unit. The ventilator component that includes inspiratory and expiratory pneumatics and electronics. The *840* Ventilator System BDU includes its own independent CPU that controls ventilation.
	British Oxygen Company, a standard for high pressure gas inlet fittings.
	Backup Power Source. The 802 BPS provides dc power to the BDU power supply in the event that ac power is lost. Depending on ventilator settings, the BPS can supply backup power for at least 30 minutes under nominal conditions.
h stacking	The delivery of a second inspiration before the first exhalation is complete.
hs per minute	Unit of respiratory rate (/min).
	Body temperature and pressure, saturated, 37 °C, at ambient barometric pressure, at 100% relative humidity.
	A certification mark issued under the authority of the European Common Market that indicates compliance with the Medical Device Directive, 93/42/EEC.
al alarm	An alarm that can indicate an abnormal physiologic condition.
	Centimeter (unit of length).
O	Centimeters of water (unit of pressure approximately equal to 1 hPa).
liance volume	The volume of gas that remains in the patient circuit and does not enter the patient's respiratory system.

compressor	On the *840* Ventilator System, the optional 804 Compressor, which provides compressed air to the BDU, and can be used in place of wall or bottled air. The 804 Compressor is powered through and communicates with the BDU.
constant during rate change	One of three breath timing variables (inspiratory time, I:E ratio, or expiratory time) that the operator can set to be held constant when the respiratory rate setting changes. Applies only to the pressure control (PC) mandatory breath type. You can change the value of the constant parameter at any time, but the value does not change as a result of changing the respiratory rate setting.
CPU	Central processing unit.
CSA	Canadian Standards Association.
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.
dc	Direct current.
dependent alarm	An alarm that arises as a result of another *primary* alarm.
DISS	Diameter index safety standard, a standard for high pressure gas inlet fittings.
DualView	The *840* Ventilator System's two touch screens, which display monitored data separately from ventilator settings.
E_{SENS}	Expiratory sensitivity, the percent of peak inspiratory flow at which the ventilator cycles from inspiration to exhalation for spontaneous breaths.
EMC	Electromagnetic compatibility.
EN	European norm (referring to the European Common Market).
EST	Extended self test, a comprehensive test of ventilator function, intended to be run by a qualified service technician.
ETO	Ethylene oxide.

PAUSE	Expiratory pause, an operator-initiated maneuver that closes the inspiration (proportional solenoid) and exhalation valves during the exhalation phase of a VIM breath. The maneuver can be used to determine intrinsic (auto) PEEP ($PEEP_I$).
T	Respiratory rate, as a setting (f) in A/C and SIMV, 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.
URE	A category of condition detected during SST or EST that causes the ventilator to enter the safety valve open state. A ventilator that has experienced a FAILURE requires removal from clinical use and immediate service.
acceleration %	A setting that determines the rise time to achieve the set inspiratory pressure in pressure-controlled (PC) or pressure-supported (PS) breaths. The larger the value, the more aggressive the rise of pressure.
pattern	The gas flow pattern of mandatory volume-controlled breaths (the *840* Ventilator System offers the choice of square or descending ramp flow patterns).
by flow ering	The patented flow-triggering strategy used on *800 Series* Ventilators.
	Feet (unit of length).
standard t	Test circuit designed for use with EST.
nics	A standard function on the *840* Ventilator System that displays real-time patient data, including: pressure-time curve, flow-time curve, volume-time curve, pressure-volume loop.
	Graphic user interface, the ventilator component that includes the touch screens, keys, and knob. The GUI includes its own independent CPU that monitors ventilator and patient data. The upper screen displays monitored information, including alarms, monitored data, and graphics. The lower screen shows ventilator settings, symbol definitions, and prompts.

high-urgency alarm	As defined by international standards organizations, an alarm that requires immediate attention to ensure patient safety. When a high-urgency alarm is active, the red high-urgency indicator (! ! !) flashes and the high-urgency audible alarm sounds (a repeating sequence of five tones that repeats twice, pauses, then repeats again), and the top of the upper screen shows an alarm message.
HME	Heat-moisture exchanger, a humidification device, also called an artificial nose.
hPa	Hectopascal (unit of pressure, approximately equal to 1 cmH_2O).
humidification type	A setting for the type of humidification system (HME, non-heated expiratory tube, or heated expiratory tubing) in use on the ventilator.
Hz	Hertz (unit of frequency, indicating cycles per second).
I:E ratio	The ratio of inspiratory time to expiratory time. Also, the operator-set timing variable that applies to PC mandatory breaths.
IBW	Ideal body weight, a ventilator setting selected only during ventilator startup, 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 patient.
idle mode	A ventilation mode in effect during a patient circuit disconnect. When the ventilator is in this mode, the exhalation valve opens, *idle flow* (10 L/min flow at 100% O_2, if available) begins, and breath triggering is disabled.
IEC	International Electrotechnical Commission, a standards organization.
INSP PAUSE	Inspiratory pause, an operator-initiated maneuver that closes the inspiration (proportional solenoid) and exhalation valves during the inspiratory phase of a mandatory breath. The maneuver can be used to determine static compliance (C) and resistance (R).
ISO	International Standards Organization, a standards organization.
kg	Kilogram (unit of weight).

	Liter (unit of volume).
	Liters per minute (unit of flow).
	Pound (unit of weight).
rgency alarms	As defined by international standards organizations, an alarm that indicates a change in the patient-ventilator system. During a low-urgency alarm, the yellow low-urgency indicator (!) lights, the low-urgency audible alarm (one tone) sounds, and the upper screen shows an alarm message.
	Meter (unit of length).
tenance	All actions necessary to keep equipment in, or restore it to, serviceable condition. Includes cleaning, servicing, repair, modification, overhaul, inspection, and performance verification.
latory	A breath whose settings and timing are preset; can be triggered by the ventilator, patient, or operator. The *840* Ventilator System allows you to select volume-controlled (VC) or pressure-controlled (PC) mandatory breaths.
latory type	The type of mandatory breath: volume control (VC) or pressure control (PC).
al inspiration	An OIM breath. Pressing the MANUAL INSP key on the *840* Ventilator System delivers one mandatory breath to the patient.
um-urgency	As defined by international standards organizations, an abnormal condition that requires prompt attention to ensure the safety of the patient. When a medium-urgency alarm is active, the yellow medium-urgency indicator (! !) flashes, the medium-urgency audible alarm (a repeating sequence of three tones) sounds, and the upper screen shows an alarm message.
	Minute (unit of time).
	Milliliter (unit of volume).
	Ventilatory mode, the algorithm that determines type and sequence of breath delivery. The *840* Ventilator System offers a choice of assist/control (A/C), spontaneous (SPONT), or synchronous intermittent mandatory ventilation (SIMV).
	Magnetic resonance imaging.

ms	Millisecond (unit of time).
NIST	Non-interchangeable screw thread, a standard for high pressure gas inlet fittings.
normal ventilation	The state of the ventilator when breathing is in progress and no alarms are active.
NOVRAM	Nonvolatile random access memory.
O_2%	Both an operator-set and monitored variable. The O_2% 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 that is delivered when the operator presses MANUAL INSP.
ongoing background checks	Continuously running tests during ventilation that assess the ventilator's electronics and pneumatics hardware.
OSC	Occlusion status cycling. A ventilation mode in effect during a severe occlusion. In this mode, the ventilator periodically attempts to deliver a pressure-based breath while monitoring the inspiration and expiration 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.)
$\overline{P}_{CIRC}$	Mean circuit pressure, a calculation of the measured average patient circuit pressure over an entire respiratory cycle.
$P_{CIRC\ MAX}$	Maximum circuit pressure, the maximum pressure during a breath, including the inspiratory and expiratory phases.
$P_{E\ END}$	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.
P_I	Inspiratory pressure, the operator-set inspiratory pressure at the patient wye (above PEEP) during a pressure control (PC) mandatory breath.

End inspiratory pressure, the pressure at the end of the inspiration phase of the current breath. If plateau is active, the displayed value reflects the level of end-plateau pressure.

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. Available in all modes.

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).

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}).

nt circuit — The entire inspiratory-expiratory conduit, including tubing, humidifier, and water traps.

nt problems — A definition used by the ventilator's safety net. Patient problems are declared when patient data is 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.

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.

Positive end expiratory pressure, the minimum level of pressure maintained in the patient circuit throughout ventilation. Both an operator-set and monitored variable. The level of PEEP is also called *baseline* pressure.

Patient-initiated mandatory breath, a breath that is triggered by patient inspiratory effort.

Power on self test, a self test that the ventilator runs to verify the integrity of ventilator electronics. The ventilator runs POST when it is powered on, following a power loss, or if the ventilator detects internal timing errors.

preventive maintenance	Procedures that keep the ventilator and its subassemblies in satisfactory operational condition by providing system inspection, detection, and prevention of failures. Procedures include fan and filter replacement, lubrication, calibration, etc.
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 and SIMV modes.
PSOL	Proportional solenoid valve.
RAM	Random access memory.
resistance	The flow-dependent pressure drop across a conduit. Measured in $cmH_2O/L/s$ or hPa/L/s.
s	Second (unit of time).
safety net	The ventilator's strategy for responding to patient problems and system faults.
safety ventilation	A mode of ventilation that becomes 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.
SandBox	*840* Ventilator System capability that allows you to preview settings before applying them to your patient.
service mode	A ventilator mode that provides a set of services tailored to the needs of testing and maintenance personnel. No ventilation is delivered while the ventilator is in the service mode.
SIMV	Synchronous 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.
SmartAlert	*840* Ventilator System alarm annunciation system which helps you to quickly determine the urgency and root cause of alarm conditions.

NT	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, and the breath can be augmented by support pressure.
taneous type	A setting that determines whether spontaneous breaths are pressure-supported (PS) or not (NONE).
	Short self test, a test that checks circuit integrity, calculates circuit compliance and filter resistance, and checks ventilator function. SST is intended to be run by the operator at intervals according to your institution's protocol.
	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.
	Safety valve open, an emergency state in which the ventilator opens the safety valve so that the patient can breathe room air unassisted by the ventilator. 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, both air and oxygen supplies are lost, or an occlusion is detected.
m 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). System faults are not usually self-correcting and are handled under the assumption that they can affect the ventilator's performance.
	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.
	Breath cycle.
	Expiratory time, the expiratory interval of a breath. Also the operator-set timing variable that determines the expiratory period for pressure-controlled (PC) mandatory breaths.

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) 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 inspiration 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.
technical alarm	An alarm that is triggered by the ventilator's ongoing background tests, and typically does not occur in the normal course of patient care.
V	Volts (unit of voltage).
$\dot{V}_{TRIG}$	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 ($\dot{V}_{SENS}$).
$\dot{V}_E$	Minute volume, the expiratory tidal volume normalized to unit time (L/min). The *840* Ventilator System estimates total minute volume based on the previous 60 seconds or eight breaths, whichever interval is shorter. The displayed value is compliance- and BTPS-compensated.
$\dot{V}_{MAX}$	Peak flow, a setting of the peak (maximum) flow of gas delivered during a VC mandatory breath. (Combined with tidal volume 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, the rate of flow inspired by the patient that triggers the ventilator to deliver a mandatory or spontaneous breath (when flow triggering is selected).

Tidal volume, the volume inspired and expired with each breath. The V_T delivered by the *840* Ventilator System 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).

Volt-amperes (unit of power).

Ventilator breathing system. Includes the part of the ventilator between the PSOL valve outlets and the *To patient* port; the patient circuit with tubing, filters, humidifier, and other accessories; and the part of the ventilator between the *From patient* port and the exhalation valve poppet.

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.

ator
erative

An emergency state that 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 unassisted by the ventilator. A qualified service technician must power up the ventilator and run EST before normal ventilation can resume.

Ventilator-initiated mandatory breath. A breath that is delivered at a time determined by the ventilator.

Symbols

Numerics

A

C

D

F

G

H

K

L

M

N

P

T

W