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Operator's Manual Addendum: Capnography

Puritan Bennett™

980 Series Ventilator

Copyright Information

1 Capnography ($ETCO_2$)

Operator's Manual Addendum

1.1 Overview

This addendum describes the operation of the Capnography option for the Puritan Bennett™ 980 Series Ventilator. The Capnography option monitors end-tidal carbon dioxide levels ($ETCO_2$) only.

The capnography sensor uses infrared absorption spectroscopy to measure mainstream $ETCO_2$ while avoiding contamination with patient secretions.

1.2 Product Description

The Capnography option must be used with either of the following components:

- $ETCO_2$ airway adapter (for $ETCO_2$ monitoring only). This adapter is available in neonatal/pediatric and pediatric/adult configurations. This sensor is for single-use only.
- Flow and CO_2 combination sensor (for use with neonatal patients, only). This component combines both a proximal flow transducer and an $ETCO_2$ built-in adapter. This sensor can be used when both NeoMode 2.0 and Capnography options are installed. This sensor is for single-use only.

The flow sensing component of the flow and CO_2 combination sensor is not required to be used during $ETCO_2$ monitoring. If the flow and CO_2 combination sensor is used for $ETCO_2$ monitoring only, the sensor must be connected to the ventilator's front panel in the location labeled Prox Flow, and the Proximal Flow option disabled.This combination sensor can be used when the Proximal Flow option is also in use so that flow sensing and $ETCO_2$ monitoring can both occur simultaneously. More information regarding the Proximal Flow option is available in Appendix E of the *Puritan Bennett™ 980 Ventilator System Operator's Manual* and NeoMode 2.0 details are described in the Appendix D of the *Puritan Bennett™ 980 Series Ventilator Operator's Manual*.

For general parameter and ventilator setup information, see Chapter 4 in the *Puritan Bennett™ 980 Ventilator Series Operator's Manual*.

1.3 Intended Use

The Capnography option is used for measuring the partial pressure of carbon dioxide in the exhaled gas of invasively ventilated, neonatal, pediatric, and adult patients at the breathing circuit wye.

1.4 Safety Symbol Definitions

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

Table 1-1. Safety Symbol Definitions

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

1.5 Safety Information

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

WARNING:
The ventilator offers a variety of breath delivery options. Throughout the patient's treatment, the clinician should carefully select the ventilation mode and settings to use for that patient, based on clinical judgment, considering the condition and needs of the individual patient, as they change from time to time, and considering the benefits, limitations and operating characteristics of each breath delivery option.

WARNING:
Explosion hazard. Do not use in the presence of flammable anesthetics.

WARNING:
Follow precautions for electromagnetic interference (EMI) to avoid unreliable ventilator readings.

WARNING:
Monitor the CO_2 waveform for elevated baseline. An erroneously elevated baseline can be caused by sensor problems.

WARNING:
If the CO_2 waveform appears abnormal, inspect the airway adapters and replace if needed.

WARNING:
$ETCO_2$ readings are intended only as an adjunct in patient assessment and must be used in conjunction with clinical signs and symptoms. Do not use $ETCO_2$ readings as a basis for changes to ventilator parameters without reference to clinical condition and independent monitors such as blood gas.

WARNING:
Do not use the flow and CO_2 combination sensor if there are kinks in the tubing.

WARNING:
Prior to patient ventilation, run SST with the exact configuration that will be used on the patient. This includes a patient circuit, airway adapter, and all accessories used with the patient circuit.See*To run SST* in Chapter 3 of the *Puritan Bennett™ 980 Series Ventilator Operator's Manual*.

WARNING:
Changing ventilator accessories can change the system resistance and compliance. Do not add or remove accessories after running SST.

WARNING:
Discontinue use if $ETCO_2$ monitoring fails to respond as described.

WARNING:
The flow and CO_2 combination sensor measures gas flow at the patient wye. A system leak, such as that caused by an uncuffed endotracheal tube or a damaged flow and CO_2 combination sensor may significantly affect flow-related readings.

WARNING:
Use only Covidien flow and CO_2 combination sensors, capnography sensors, and airway adapters with the Capnography option. Use of other sensors results in an "invalid sensor" message, a "capnography sensor inoperative" alarm, or erroneous readings.

WARNING:
To minimize the potential for condensation or secretions clogging the sensor's pneumatic lines, position the flow and CO_2 combination sensor exactly as described in this addendum.

WARNING:
Do not position the capnography sensor cable or flow and CO_2 combination sensor tubing in any manner that may cause entanglement or strangulation.

WARNING:
To reduce the risk of extubation or disconnection, do not apply tension to or pull on the capnography sensor or flow and CO_2 combination sensor tubing.

WARNING:
To reduce the risk of extubation or breathing circuit disconnection, do not rotate the flow and CO_2 combination sensor in the breathing circuit by pulling on the sensor's tubing.

WARNING:
The cable management clips supplied with each flow and CO_2 combination sensor must be used to mitigate risk of entanglement, kinking, or extubation that could lead to strangulation, hypercarbia, or hypoxemia.

WARNING:
Do not install the capnography sensor or flow and CO_2 combination sensor in the patient circuit if the sensor is not also connected to the BDU.

WARNING:
Excessive moisture in the flow and CO_2 combination sensor tubing may affect the accuracy of the measurements. Periodically check the sensor and tubing for excessive moisture or secretion build-up.

WARNING:
Disposable airway adapters are intended for single use only. Do not re-use these items. These sensors and adapters are not compatible with sterilization techniques.

WARNING:
Nitrous oxide, elevated levels of oxygen, helium, and halogenated hydrocarbons can influence the CO_2 measurement.

WARNING:
Inspect the airway adapter or flow and CO_2 combination sensor prior to use, and do not use if the adapter, sensor body, tubing, or connector are damaged or broken.

Caution:
Do not use aerosolized medications when employing CO_2 monitoring with either the airway adapter and capnography sensor or the flow and CO_2 combination sensor. Increased medication viscosity may contaminate the sensor windows and cause the sensor to fail prematurely.

Caution:
To prevent damage to cables or pneumatic lines, use the included cable management clips.

Caution:
Insert sensors in the ventilator circuit with the tubes upright to avoid the effects of excessive moisture.

Caution:
Ensure all connectors are properly connected, fully engaged, and free from moisture.

Caution:
To avoid possible damage to the ventilator or sensors, follow standard precautions for electrostatic discharge (ESD).

Note:
The flow and CO_2 combination sensor, capnography sensor, and airway adapters contain no user serviceable parts. Refer service to qualified service personnel.

Note:
Dispose of the flow and CO_2 combination sensor and disposable airway adapters in accordance with your institution's protocol.

Note:
The white-striped tubing of the flow sensor should always be proximal to the patient.

Note:
Position the flow and CO_2 combination sensor with its windows in a vertical, not horizontal position. This helps keep patient secretions from pooling on the windows.

1.6 Software Requirements

Purchased software options must be enabled after the option is purchased using an encrypted access code provided to you or the Customer Service Engineer (CSE).

To install software options

1. Enter Service mode. See To access Service mode in Chapter 3 of the *Puritan Bennett™ 980 Series Ventilator Operator's Manual*.
2. Touch the options button on the screen that appears.
3. Touch Installed Options.
4. Touch Update Options.
5. Enter the option access code on the virtual keyboard and touch Accept.
6. Confirm the option is installed by touching Installed Options.
7. Attach the software option label to the installed software options label located at the back of the ventilator.

1.7 Hardware Requirements

The following hardware is required:

- Option host card
- Capnography sensor (required for $ETCO_2$ measurement)
- Airway adapter suitable for the particular patient
- Flow and CO_2 combination sensor (neonatal circuit only and supports both proximal flow measurement and/or $ETCO_2$ measurement)

1.8 End Tidal CO_2 Monitoring Description

Note:
If the current vent type is NIV or vent type changes from invasive to NIV, the Capnography option is automatically disabled.

A capnography sensor is attached to an airway adapter or flow and CO_2 combination sensor which is installed at the patient circuit wye to measure end-tidal CO_2. The capnography sensor connects to the BDU via a connector located behind the door on the BDU's front panel. See *Figure 1-8.* on page *1-14*. Airway adapters are available in pediatric/adult and neonatal sizes.

When the option host card is installed in the ventilator, the card is the communication interface for the capnography system. Data measured by the capnography sensor are displayed on the GUI for monitoring purposes, not for ventilator control. When the ventilator has a capnography sensor installed and enabled, end-tidal CO_2 measurements are obtained and displayed on the GUI, and data are updated at the end of each exhalation. CO_2 data can be configured as a patient data parameter. If $ETCO_2$ is chosen as a patient data parameter, dashes (- -) appear if the $ETCO_2$ data value is unable to be displayed. The CO_2 waveform can be configured as a waveform layout, if desired. See *To configure the patient data displayed on the GUI* and *To configure waveforms and loops in* Chapter 3 of the *Puritan Bennett™ 980 Series Ventilator Operator's Manual*.

The time duration from enabling the $ETCO_2$ monitoring function to achieving specified accuracy is approximately 2 minutes due to the capnography sensor warm-up process.

1.8.1 $ETCO_2$ Monitoring Components

$ETCO_2$ monitoring components include:

Capnography sensor — The capnography sensor connects to the airway adapter or the flow and CO_2 combination sensor and contains the optics and electronics for $ETCO_2$ measurement.

$ETCO_2$ airway adapter — for $ETCO_2$ monitoring only. This adapter is available in neonatal/pediatric and pediatric/adult configurations. This sensor is for single-use only.

Flow and CO_2 combination sensor — This sensor and adapter combination is a single-use device which acts as a combination of a proximal flow sensor and an airway adapter (for use with neonatal patients, only). This component combines both a proximal flow transducer and an $ETCO_2$ built-in adapter. This sensor can be used for capnography when both NeoMode 2.0 and Capnography options are installed. This sensor is for single-use only.

Note:
Either the airway adapter or flow and CO_2 combination sensor are connected to the capnography sensor for $ETCO_2$ measurement only, or proximal flow and/or $ETCO_2$ measurement, respectively.

Use the airway adapters, flow and CO_2 combination sensor, and capnography sensor in the correct combination based upon the patient type and desired monitoring shown in the following tables.

Table 1-2. Endotracheal Tube Diameters

Item	Endotracheal tube inner diameter (ID), mm
Neonatal/pediatric airway adapters	≤4.0
Pediatric/adult airway adapters	≥4.5
Neonatal flow and CO_2 combination sensor	2.5 to 4.0

Table 1-3. Items Needed for $ETCO_2$ or Flow/Volume Monitoring

Desired monitoring	Items needed	Patient type
$ETCO_2$	Capnography sensor + neonatal/ pediatric airway adapter	Neonatal, pediatric
	Capnography sensor + pediatric/ adult airway adapter	Pediatric, adult
Flow and Volume Only	Flow and CO_2 combination sensor	Neonatal
	Proximal flow sensor[1]	Neonatal
$ETCO_2$ and Flow and Volume	Flow and CO_2 combination sensor and capnography sensor	Neonatal

1. See Appendix E in the *Puritan Bennett™ 980 Series Ventilator Operator's Manual.*

See *Part Numbers (1.17)* on page *1-32* to distinguish the components by color.

Figure 1-1. Capnography Sensor

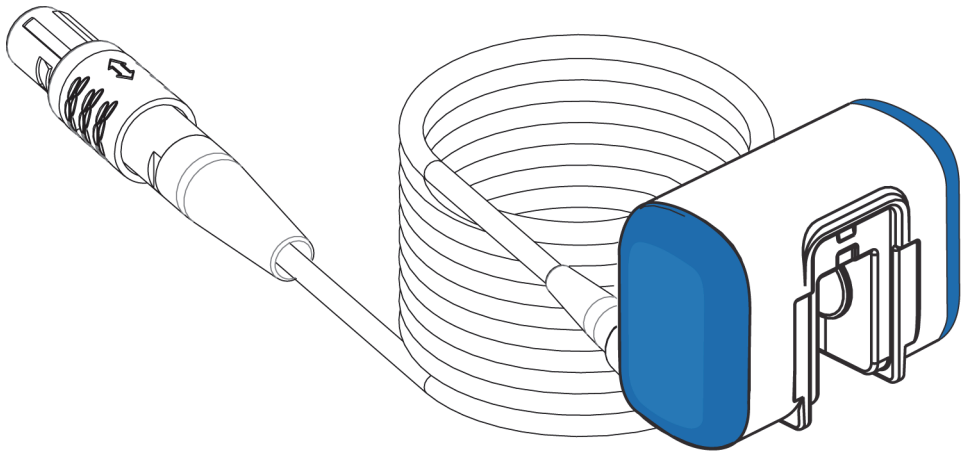

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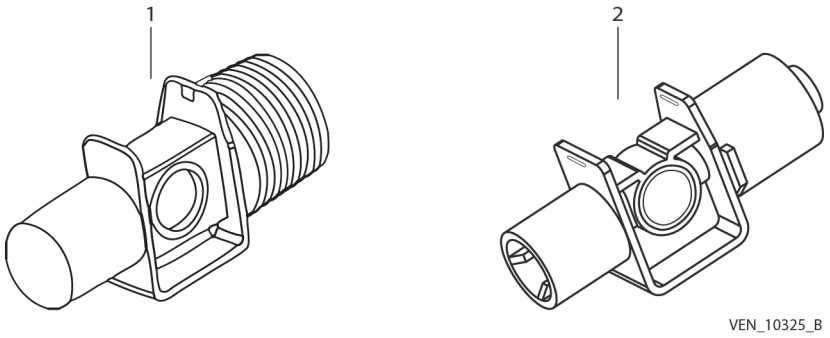
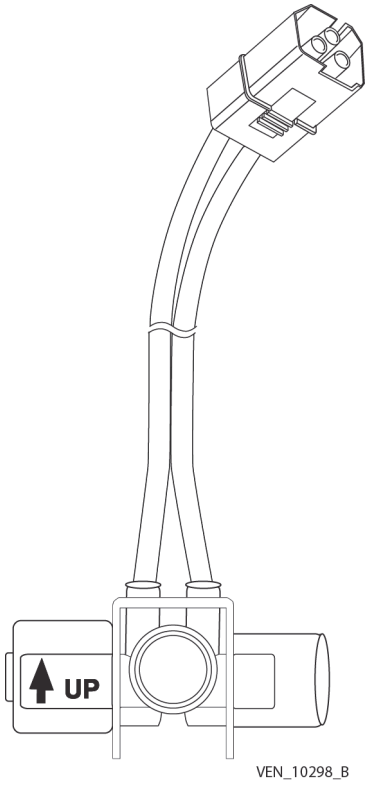
Figure 1-2. $ETCO_2$ Airway Adapters



1 Pediatric/adult $ETCO_2$ airway adapter 2 Neonatal/pediatric $ETCO_2$ airway adapter

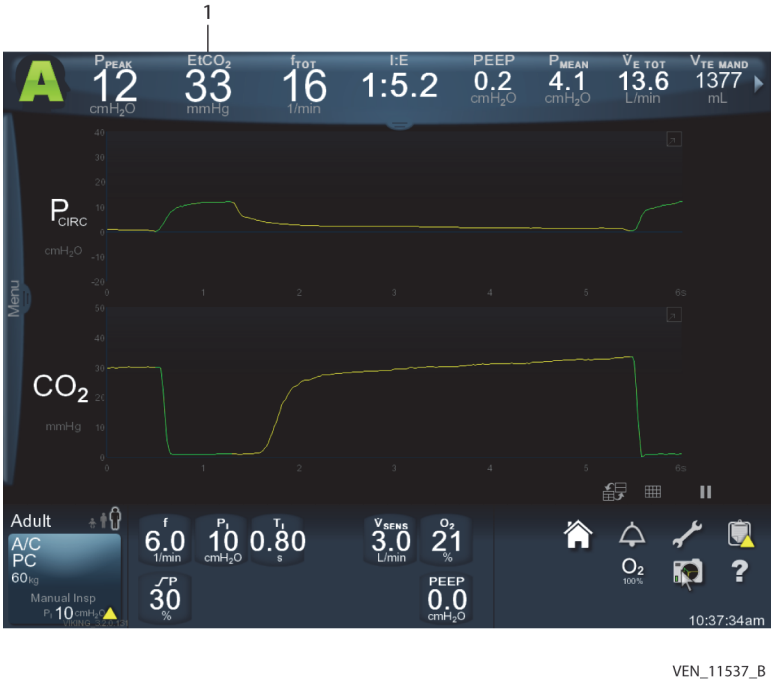
Figure 1-3. Flow and CO_2 Combination Sensor



1.9 On-screen Symbols

When the $ETCO_2$ monitoring function is enabled, measured $ETCO_2$ can be configured to display in the patient data banner.See *Vital Patient Data* in Chapter 3 of the *Puritan Bennett™ 980 Series Ventilator Operator's Manual* for information on configuring the GUI to display various patient data values. When $ETCO_2$ data are questionable or invalid, the data are not displayed.

Figure 1-4. Sample GUI Screen Showing $ETCO_2$ Data



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1 Patient data banner configured with $ETCO_2$

1.10 SST Requirements

SST is not required for $ETCO_2$ monitoring only, but in cases where the flow and CO_2 combination sensor is used for proximal flow measurement as well as $ETCO_2$ measurement, SST is required. SST must be performed with all circuit components in the configuration to be used on the patient in order for the ventilator to calculate the correct compliance and resistance.See *To run SST* in Chapter 3 of the *Puritan Bennett™ 980 Series Ventilator Operator's Manual* for complete instructions on how to run SST.

Note:
For SST, the capnography sensor does not need to be connected to the ventilator, but the flow and CO_2 sensor must connect to the ventilator's port labeled Prox Flow to avoid leaks.

1.10.1 Attaching the Flow and CO_2 Combination Sensor for SST

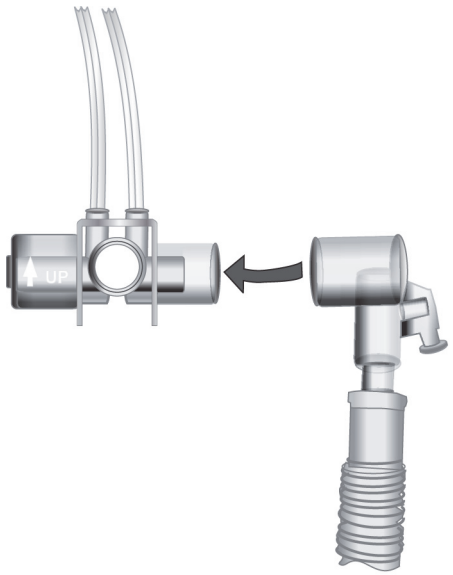
To attach the flow and CO_2 combination sensor to the patient circuit

1. Verify that the flow and CO_2 combination sensor, pneumatic lines and connector are not damaged.
2. Open the connector panel door and firmly attach the flow and CO_2 combination sensor connector to the receptacle in the BDU's front connector port labeled Prox Flow. See *Figure 1-8.* on page *1-14*.

3. Insert the **smaller**(15 mm diameter) end (opposite end of UP arrow) of the airway adapter portion of the flow and CO_2 combination sensor into the breathing circuit wye, as shown (*Figure 1-5.*). Ensure the sensor tubing is in the upward position.
4. To reposition, grasp the sensor plastic body. Do not rotate it by pulling on the tubing.
5. Confirm a tight connection.
6. Space the provided clips evenly to secure the sensor tubing to the breathing circuit.
7. Zero the adapter if it is new or if prompted by a message displayed on the ventilator's GUI. See *Zeroing the Sensor*, page 1-15.
8. Run SST. See *To run SST* in Chapter 3 of the *Puritan Bennett™ 980 Series Ventilator Operator's Manual*.

Note:
If using a heat-moisture exchanger (HME) on the endotracheal tube, place the sensor between the HME and the breathing circuit wye.

Figure 1-5. Attaching Flow and CO_2 Combination Sensor or Airway Adapter to Breathing Circuit Wye



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1.10.2 Attaching the airway adapter for SST

To attach the airway adapter for SST

1. Attach the capnography sensor and airway adapter so the **small** end of the airway adapter connects to the breathing circuit wye (*Figure 1-5.*). The airway adapter attaches the same way as the flow and CO_2 Combination sensor.

2. Run SST. See *To run SST* in Chapter 3 of the *Puritan Bennett™ 980 Series Ventilator Operator's Manual*.

1.11 Using the $ETCO_2$ Monitoring function

Ensure that SST has been run with all accessories installed in the ventilator breathing circuit.

Review and follow all warnings prior to patient ventilation with the $ETCO_2$ monitoring function. See *Safety Information*, page 1-2.

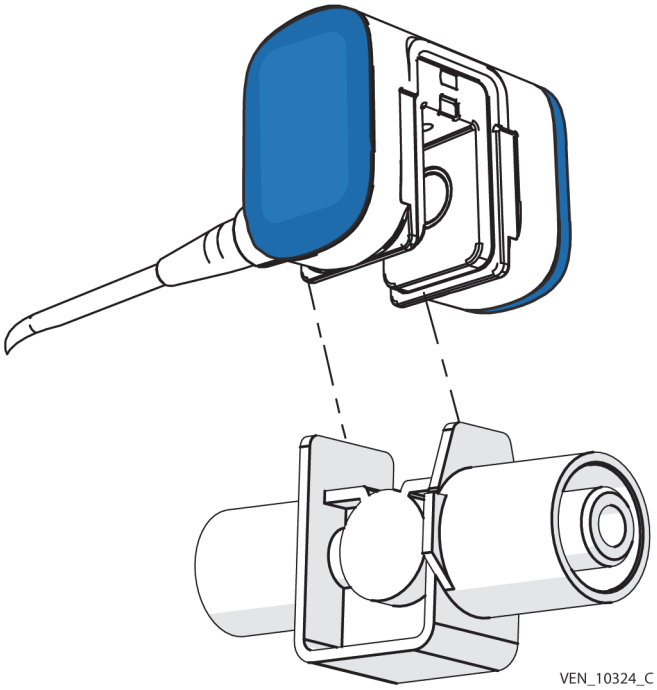
To connect the capnography sensor to the ventilator

1. Verify that the capnography sensor and connector are not damaged in any way.
2. Open the connector panel door and firmly attach the sensor connector to the receptacle in the BDU's front connector port labeled CO_2.

To attach the $ETCO_2$ airway adapter to the capnography sensor

1. Use an appropriate $ETCO_2$ airway adapter that matches the patient type (neonatal/pediatric or pediatric/adult) and the patient being ventilated.
2. Press the capnography sensor onto the $ETCO_2$ airway adapter, oriented so that the **smaller** end of the adapter can attach to the breathing circuit wye. The capnography sensor will "click" into place when properly seated.

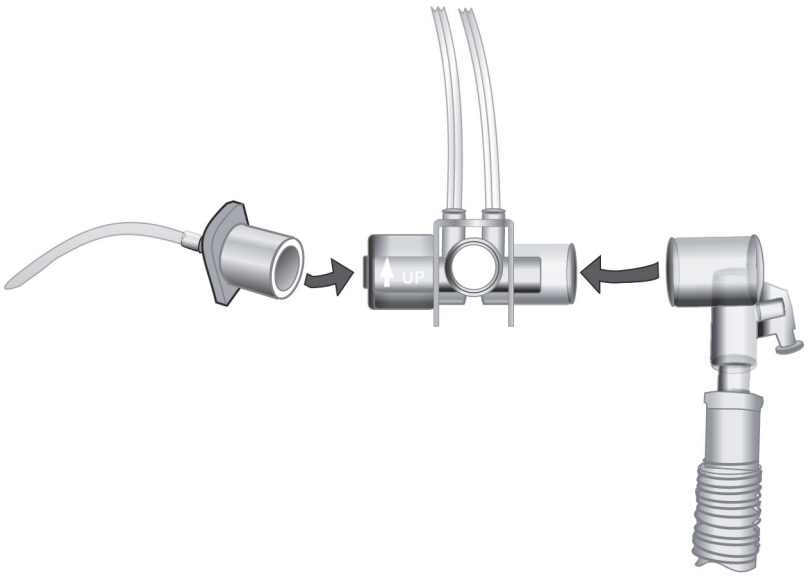
Figure 1-6. Connecting the Capnography Sensor to the $ETCO_2$ Airway Adapter



To attach the capnography sensor and airway adapter to the patient circuit

1. Attach the capnography sensor and airway adapter so the **small** end of the airway adapter connects to the breathing circuit wye, and the large end connects to the ET tube (*Figure 1-7.*). The capnography sensor and airway adapter connect the same way as the flow and CO_2 combination sensor.

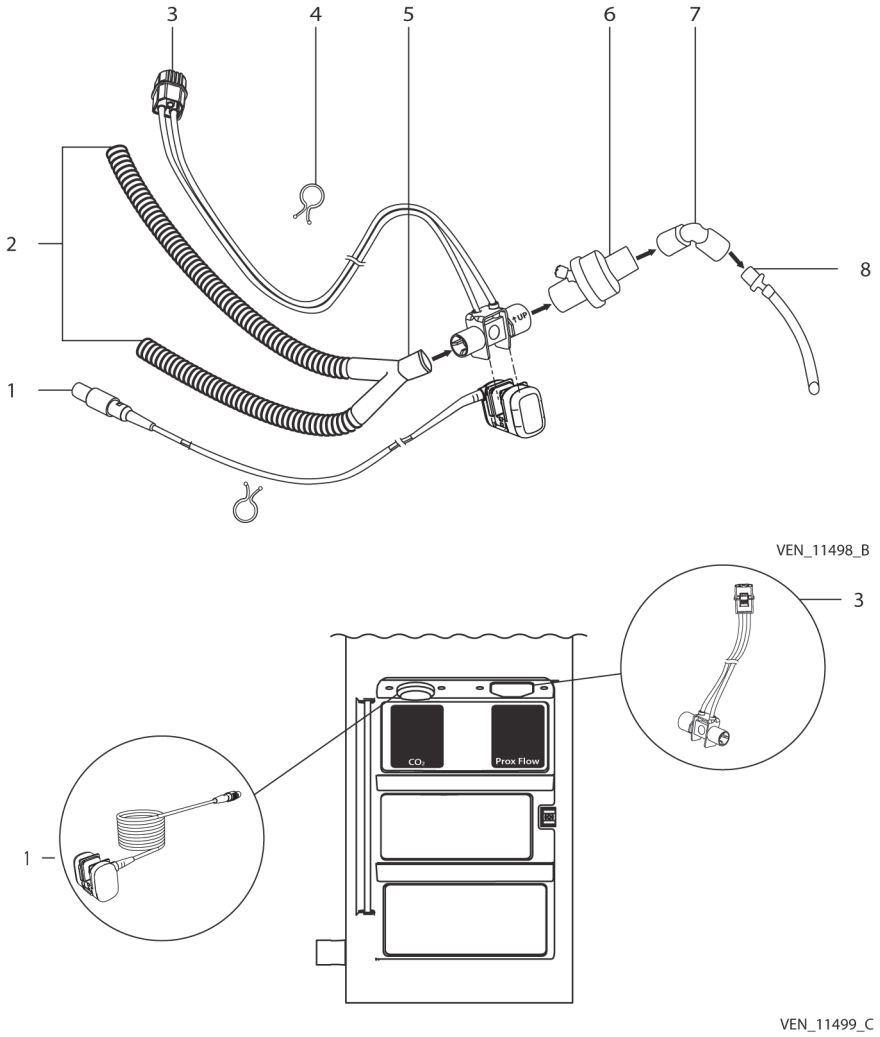
Figure 1-7. Connecting Breathing Circuit and the ET Tube



To attach the flow and CO_2 combination sensor to the capnography sensor

1. Snap the flow and CO_2 combination sensor into the capnography sensor as shown (*Figure 1-8.*) on page *1-14*.

Figure 1-8. Capnography Sensor Installation to Flow and CO_2 Combination Sensor and Ventilator



1	Capnography sensor (connect to BDU port labeled CO_2	5	Breathing circuit wye
2	Patient circuit inspiratory and expiratory limbs	6	HME
3	Flow and CO_2 combination sensor (connect to BDU port labeled Prox Flow)	7	Elbow (optional)
4	Cable management clip	8	Endotracheal tube

Note:
If using a heat-moisture exchanger (HME) on the endotracheal tube, place the flow and CO_2 combination sensor between the HME and the breathing circuit wye.

2. Ensure the sensor tubing is positioned in an upward direction, as shown in *Figure 1-8.* If the sensor needs repositioning, **DO NOT** rotate it by pulling on the tubing. Reposition as follows:

a. Grasp the sensor's plastic body with one hand and the breathing circuit wye with the other hand.
b. Rotate the sensor body and wye towards each other until the sensor tubing is upright.
c. Confirm a tight connection between the sensor and breathing circuit wye.

3. Use cable management clips to attach the sensor tubing to the breathing circuit tubing. Space the clips evenly along the length of the sensor tubing. Twist the ends of each clip to close. Ensure the appropriate clip size is used with the patient circuit in use.
4. Connect the capnography sensor to the ventilator as described and shown in *Figure 1-8.*
5. Connect the flow and CO_2 combination sensor to the BDU's front connector port labeled Prox Flow, as shown in *Figure 1-8.* on page *1-14*.

Note:
When the ventilator is set up for proximal flow operation, the flow and CO_2 combination sensor can be switched as necessary. There is no need to run SST after switching sensors unless the breathing circuit or other ventilator accessories have been changed.

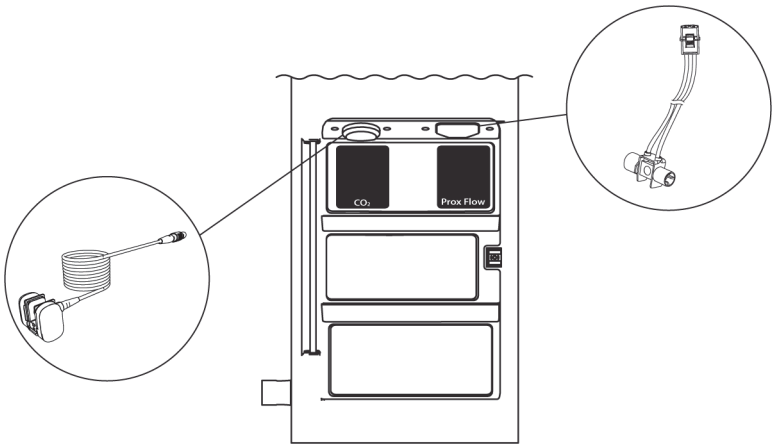
1.11.1 Zeroing the Sensor

WARNING:
If the sensor or adapter assembly zero process is not executed properly, the CO_2 waveform information may not be representative of actual exhaled CO_2.

If a problem is detected with the CO_2 measurement the GUI displays a message stating "CO_2 sensor zeroing required" or "Check CO_2 sensor adapter." Zeroing the sensor is typically done when switching between different airway adapters.

Before zeroing the sensor

1. Verify the capnography sensor is connected to the port labeled CO_2 on the ventilator.



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2. Connect the capnography sensor to a clean and dry airway adapter or flow and CO_2 combination sensor. See *Figure 1-6.* on page *1-12* or *Figure 1-8.* on page *1-14*. Ensure that the capnography sensor and airway adapter or flow and CO_2 combination sensor is motionless, exposed only to room air, and away from all sources of CO_2, including the ventilator, the patient's breath, and your breath.

To zero the sensor

1. Use the capnography sensor and airway adapter or flow and CO_2 combination sensor connected to the ventilator from the previous steps.
2. Wait 2 minutes before proceeding.
3. At the ventilator setup screen, touch the configure icon. A menu containing tabs appears.
4. Touch the Options tab. A screen appears containing Installed Options and CO_2 tabs.
5. Touch the CO_2 tab.
6. Follow zeroing setup instructions on the GUI screen.
7. Touch the Start button to zero the sensor. The length of time to zero the sensor is typically 15 to 20 seconds. During this time, ensure the sensor and adapter is not exposed to any form of CO_2.
8. Verify that the message on the screen indicates "CO_2 zeroing passed."
9. If message reads "Zeroing failed," ensure that all zeroing conditions are met and retest or change adapter.
10. Place the successfully zeroed sensor assembly in the patient circuit. See *Figure 1-5.* on page *1-11*.

1.11.2 Disabling or Enabling the Capnography Option

The Capnography option has two states: Enabled and Disabled.

Note:
If the Capnography option has been disabled or enabled, SST does not have to be re-run unless the breathing circuit or other breathing system accessories have been changed (including the flow and CO_2 combination sensor), removed, or added.

To disable or enable the capnography monitoring function

1. At the ventilator setup screen, touch the configure icon. A menu containing tabs appears.
2. Touch the Options tab. A screen appears containing Installed Options and CO_2 tabs.
3. Touch the CO_2 tab.
4. Touch Enabled or Disabled to enable or disable the Capnography option.

CO_2 Waveform

The CO_2 waveform appears when the Capnography option is enabled and the waveform's y-axis is configured to show CO_2. The CO_2 waveform displays the expired CO_2 value as measured and reported by the capnography sensor at the circuit wye.

Figure 1-9. CO_2 Waveform

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1.12 Accuracy Check

No user-performed calibration is necessary or possible, except for zeroing the sensor. An accuracy check of the capnography sensor should be performed once per year.

WARNING:
Before performing an accuracy check, ensure no patient is connected to the ventilator.

Before performing the accuracy check, ensure the Capnography option has been enabled. See *Disabling or Enabling the Capnography Option (1.11.2)* on page *1-17*.

Perform an accuracy check using the following items:

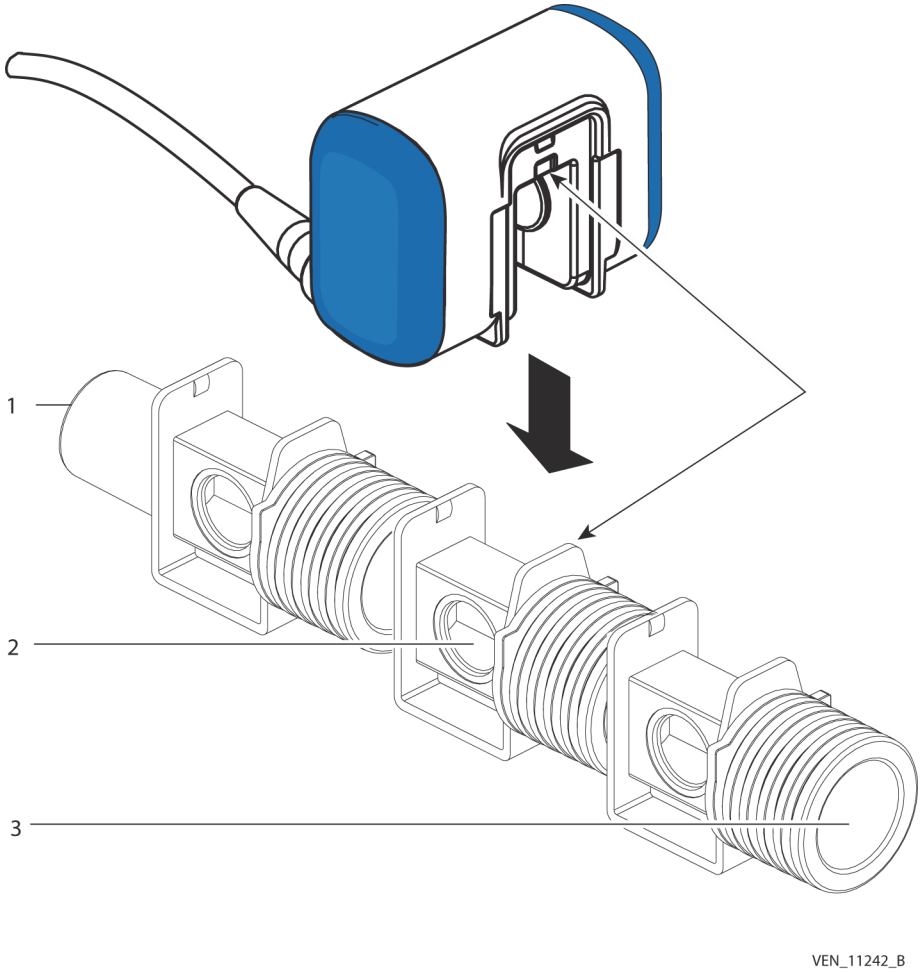
Table 1-4. Parts Required for Accuracy Check

Manufacturer	Description	Part number
Philips (formerly known as Respironics)	Gas regulator	6081-00
Air Liquide	Calibration gas [5% CO_2 with the balance being Nitrogen] (carton of 4)	T4507NM-4PD (USA)
Air Liquide	Calibration gas [5% CO_2 with the balance being Nitrogen] (sold by the can with a required minimum order of 6)	T4507SRI-PD (Other countries)
External barometer	For use in calculating the expected CO_2 value obtained during the accuracy check.	Local supplier

To perform an accuracy check

1. Allow the calibration gas time to reach room temperature (approximately 30 minutes depending upon the ambient storage temperature of the calibration gas).
2. Attach the capnography sensor to the ventilator at the connector port labeled CO_2 on the ventilator's front panel. Ensure the capnography sensor/adapters are not connected to the patient circuit.
3. Connect three identical airway adapters end-to-end to the gas regulator. This configuration is called a stack.

Figure 1-10. Airway Adapter Configuration

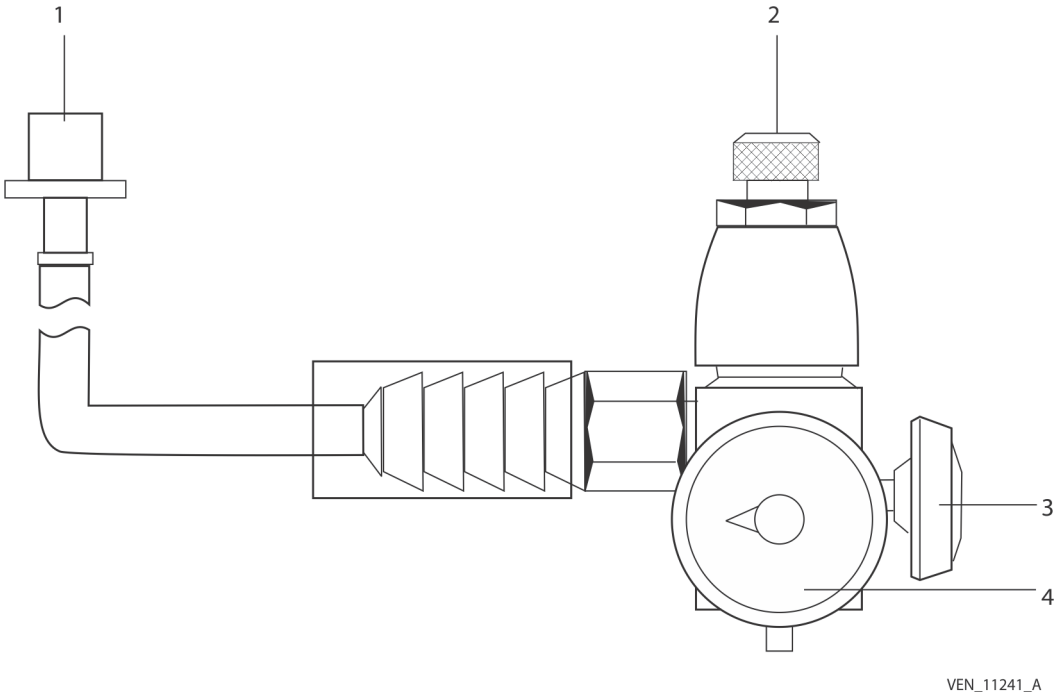


1	Top of stack (smaller diameter)	3	Bottom of stack (larger diameter)
2	Attach capnography sensor to middle airway adapter		

4. Turn on the ventilator and configure it for an adult circuit type, if not already configured. To change the circuit type, SST must be performed. See *To run SST* in Chapter 3 of the *Puritan Bennett™ 980 Series Ventilator Operator's Manual*.
5. Set the ventilator up for a new patient. The Quick Start settings may be used.
6. Set the oxygen concentration to 21%.
7. Connect a patient circuit to the ventilator and to a test lung. At the time the circuit and test lung are connected, the ventilator will sense a patient connection, and the waveforms display will appear on the GUI screen.
8. Change the waveform display to show CO_2 in mmHg, by double-tapping the y-axis parameter. A list of buttons appears with parameters.

9. Touch the CO_2 button. The waveform now shows CO_2 in mmHg.
10. Connect the capnography sensor to the middle airway adapter.
11. Zero the sensor. See *Zeroing the Sensor*, page 1-15.
12. Turn the gas regulator flow control valve off (turned fully clockwise).
13. Attach the gas regulator and hose assembly to the calibration gas cylinder.

Figure 1-11. Gas Regulator Attachment



1	Regulator output. Attach bottom of airway adapter stack (larger diameter) here	3	Flow control valve
2	Factory preset - do not adjust	4	Pressure gauge

14. Connect the gas regulator output to the bottom of the airway adapter stack described in step 3.
15. Provide a constant flow of the test gas (approximately 2 L/min) through the airway adapters by fully opening the valve, and allow the gas to flow for 30 seconds.
16. Touch the pause icon for the waveform and use the knob to move the cursor along the waveform. Read the CO_2 measurement appearing on the cursor.
17. Turn the test gas off.
18. Because the gas stabilized at room temperature, use the ambient temperature, pressure displayed when the option was enabled, and CO_2 measurements from the display, and compare with *Table 1-5.*

Note:
To use the table, locate the intersection of the pressure measurement in the Barometric pressure reading column, and the ambient temperature in the Gas temperature row. The intersection of pressure and temperature is the expected CO_2 measurement in mmHg.

Table 1-5. Expected CO_2 measurements (mm Hg) vs. Temperature and Pressure

Barometric pressure reading (mmHg)	Gas temperature (°C)						
	20	21	22	23	24	25	26
620	33.1	32.9	32.8	32.7	32.6	32.5	32.4
621	33.1	33.0	32.9	32.8	32.7	32.6	32.5
622	33.2	33.1	32.9	32.8	32.7	32.6	32.5
623	33.2	33.1	33.0	32.9	32.8	32.7	32.6
624	33.3	33.2	33.1	33.0	32.9	32.7	32.6
625	33.3	33.2	33.1	33.0	32.9	32.8	32.7
626	33.4	33.3	33.2	33.1	33.0	32.9	32.8
627	33.4	33.3	33.2	33.1	33.0	32.9	32.8
628	33.5	33.4	33.3	33.2	33.1	33.0	32.9
629	33.5	33.4	33.3	33.2	33.1	33.0	32.9
630	33.6	33.5	33.4	33.3	33.2	33.1	33.0
631	33.6	33.5	33.4	33.3	33.2	33.1	33.0
632	33.7	33.6	33.5	33.4	33.3	33.2	33.1
633	33.7	33.6	33.5	33.4	33.3	33.2	33.1
634	33.8	33.7	33.6	33.5	33.4	33.3	33.2
635	33.8	33.7	33.6	33.5	33.4	33.3	33.2
636	33.9	33.8	33.7	33.6	33.5	33.4	33.3
637	34.0	33.9	33.7	33.6	33.5	33.4	33.3
638	34.0	33.9	33.8	33.7	33.6	33.5	33.4
639	34.1	34.0	33.9	33.7	33.6	33.5	33.4
640	34.1	34.0	33.9	33.8	33.7	33.6	33.5
641	34.2	34.1	34.0	33.9	33.7	33.6	33.5
642	34.2	34.1	34.0	33.9	33.8	33.7	33.6
643	34.3	34.2	34.1	34.0	33.9	33.7	33.6
644	34.3	34.2	34.1	34.0	33.9	33.8	33.7

Table 1-5. Expected CO_2 measurements (mm Hg) vs. Temperature and Pressure (Continued)

Barometric pressure reading (mmHg)	Gas temperature (°C)						
	20	21	22	23	24	25	26
645	34.4	34.3	34.2	34.1	34.0	33.9	33.7
646	34.4	34.3	34.2	34.1	34.0	33.9	33.8
647	34.5	34.4	34.3	34.2	34.1	34.0	33.9
648	34.5	34.4	34.3	34.2	34.1	34.0	33.9
649	34.6	34.5	34.4	34.3	34.2	34.1	34.0
650	34.6	34.5	34.4	34.3	34.2	34.1	34.0
651	34.7	34.6	34.5	34.4	34.3	34.2	34.1
652	34.8	34.6	34.5	34.4	34.3	34.2	34.1
653	34.8	34.7	34.6	34.5	34.4	34.3	34.2
654	34.9	34.8	34.6	34.5	34.4	34.3	34.2
655	34.9	34.8	34.7	34.6	34.5	34.4	34.3
656	35.0	34.9	34.8	34.6	34.5	34.4	34.3
657	35.0	34.9	34.8	34.7	34.6	34.5	34.4
658	35.1	35.0	34.9	34.7	34.6	34.5	34.4
659	35.1	35.0	34.9	34.8	34.7	34.6	34.5
660	35.2	35.1	35.0	34.9	34.7	34.6	34.5
661	35.2	35.1	35.0	34.9	34.8	34.7	34.6
662	35.3	35.2	35.2	35.0	34.9	34.7	34.6
663	35.3	35.2	35.1	35.0	34.9	34.8	34.7
664	35.4	35.3	35.2	35.1	35.0	34.8	34.7
665	35.4	35.3	35.2	35.1	35.0	34.9	34.8
666	35.5	35.4	35.3	35.2	35.1	35.0	34.8
667	35.6	35.4	35.3	35.2	35.1	35.0	34.9
668	35.6	35.5	35.4	35.3	35.2	35.1	35.0
669	35.7	35.6	35.4	35.3	35.2	35.1	35.0
670	35.7	35.6	35.5	35.4	35.3	35.2	35.1
671	35.8	35.7	35.5	35.4	35.3	35.2	35.1
672	35.8	35.7	35.6	35.5	35.4	35.3	35.2
673	35.9	35.8	35.7	35.5	35.4	35.3	35.2
674	35.9	35.8	35.7	35.6	35.5	35.4	35.3

Table 1-5. Expected CO_2 measurements (mm Hg) vs. Temperature and Pressure (Continued)

Barometric pressure reading (mmHg)	Gas temperature (°C)						
	20	21	22	23	24	25	26
675	36.0	35.9	35.8	35.6	35.5	35.4	35.3
676	36.0	35.9	35.8	35.7	35.6	35.5	35.4
677	36.1	36.0	35.9	35.8	35.6	35.5	35.4
678	36.1	36.0	35.9	35.8	35.7	35.6	35.5
679	36.2	36.1	36.0	35.9	35.7	35.6	35.5
680	36.2	36.1	36.0	35.9	35.8	35.7	35.6
681	36.3	36.2	36.1	36.0	35.9	35.7	35.6
682	36.4	36.2	36.1	36.0	35.9	35.8	35.7
683	36.4	36.3	36.2	36.1	36.0	35.8	35.7
684	36.5	36.3	36.2	36.1	36.0	35.9	35.8
685	36.5	36.4	36.3	36.2	36.1	36.0	35.8
686	36.6	36.5	36.3	36.2	36.1	36.0	35.9
687	36.6	36.5	36.4	36.3	36.2	36.1	35.9
688	36.7	36.6	36.4	36.3	36.2	36.1	36.0
689	36.7	36.6	36.5	36.4	36.3	36.2	36.0
690	36.8	36.7	36.6	36.4	36.3	36.2	36.1
691	36.8	36.7	36.6	36.5	36.4	36.3	36.2
692	36.9	36.8	36.7	36.5	36.4	36.3	36.2
693	36.9	36.8	36.7	36.6	36.5	36.4	36.3
694	37.0	36.9	36.8	36.6	36.5	36.4	36.3
695	37.0	36.9	36.8	36.7	36.6	36.5	36.4
696	37.1	37.0	36.9	36.8	36.6	36.5	36.4
697	37.2	37.0	36.9	36.8	36.7	36.6	36.5
698	37.2	37.1	37.0	36.9	36.7	36.6	36.5
699	37.3	37.1	37.0	36.9	36.8	36.7	36.6
700	37.3	37.2	37.1	37.0	36.9	36.7	36.6
701	37.4	37.3	37.1	37.0	36.9	36.8	36.7
702	37.4	37.3	37.2	37.1	37.0	36.8	36.7
703	37.5	37.4	37.2	37.1	37.0	36.9	36.8
704	37.5	37.4	37.3	37.2	37.1	36.9	36.8

Table 1-5. Expected CO_2 measurements (mm Hg) vs. Temperature and Pressure (Continued)

Barometric pressure reading (mmHg)	Gas temperature (°C)						
	20	21	22	23	24	25	26
705	37.6	37.5	37.3	37.2	37.1	37.0	36.9
706	37.6	37.5	37.4	37.3	37.2	37.1	36.9
707	37.7	37.6	37.5	37.3	37.2	37.1	37.0
708	37.7	37.6	37.5	37.4	37.3	37.2	37.0
709	37.8	37.7	37.6	37.4	37.3	37.2	37.1
710	37.8	37.7	37.6	37.5	37.4	37.3	37.1
711	37.9	37.8	37.7	37.5	37.4	37.3	37.2
712	38.0	37.8	37.7	37.6	37.5	37.4	37.3
713	38.0	37.9	37.8	37.7	37.5	37.4	37.3
714	38.1	37.9	37.8	37.7	37.6	37.5	37.4
715	38.1	38.0	37.9	37.8	37.6	37.5	37.4
716	38.2	38.0	37.9	37.8	37.7	37.6	37.5
717	38.2	38.1	38.0	37.9	37.7	37.6	37.5
718	38.3	38.2	38.0	37.9	37.8	37.7	37.6
719	38.3	38.2	38.1	38.0	37.9	37.7	37.6
720	38.4	38.3	38.1	38.0	37.9	37.8	37.7
721	38.4	38.3	38.2	38.1	38.0	37.8	37.7
722	38.5	38.4	38.2	38.1	38.0	37.9	37.8
723	38.5	38.4	38.3	38.2	38.1	37.9	37.8
724	38.6	38.5	38.4	38.2	38.1	38.0	37.9
725	38.6	38.5	38.4	38.3	38.2	38.0	37.9
726	38.7	38.6	38.5	38.3	38.2	38.1	38.0
727	38.8	38.6	38.5	38.4	38.3	38.2	38.0
728	38.8	38.7	38.6	38.4	38.3	38.2	38.1
729	38.9	38.7	38.6	38.5	38.4	38.3	38.1
730	38.9	38.8	38.7	38.6	38.4	38.3	38.2
731	39.0	38.8	38.7	38.6	38.5	38.4	38.2
732	39.0	38.9	38.8	38.7	38.5	38.4	38.3
733	39.1	39.0	38.8	38.7	38.6	38.5	38.4
734	39.1	39.0	38.9	38.8	38.6	38.5	38.4

Table 1-5. Expected CO_2 measurements (mm Hg) vs. Temperature and Pressure (Continued)

Barometric pressure reading (mmHg)	Gas temperature (°C)						
	20	21	22	23	24	25	26
735	39.2	39.1	38.9	38.8	38.7	38.6	38.5
736	39.2	39.1	39.0	38.9	38.7	38.6	38.5
737	39.3	39.2	39.0	38.9	38.8	38.7	38.6
738	39.3	39.2	39.1	39.0	38.9	38.7	38.6
739	39.4	39.3	39.1	39.0	38.9	38.8	38.7
740	39.4	39.3	39.2	39.1	39.0	38.8	38.7
741	39.5	39.4	39.3	39.1	39.0	38.9	38.8
742	39.6	39.4	39.3	39.2	39.1	38.9	38.8
743	39.6	39.5	39.4	39.2	39.1	39.0	38.9
744	39.7	39.5	39.4	39.3	39.2	39.0	38.9
745	39.7	39.6	39.5	39.3	39.2	39.1	39.0
746	39.8	39.6	39.5	39.4	39.3	39.2	39.0
747	39.8	39.7	39.6	39.4	39.3	39.2	39.1
748	39.9	39.7	39.6	39.5	39.4	39.3	39.1
749	39.9	39.8	39.7	39.6	39.4	39.3	39.2
750	40.0	39.9	39.7	39.6	39.5	39.4	39.2
751	40.0	39.9	39.8	39.7	39.5	39.4	39.3
752	40.1	40.0	39.8	39.7	39.6	39.5	39.3
753	40.1	40.0	39.9	39.8	39.6	39.5	39.4
754	40.2	40.1	39.9	39.8	39.7	39.6	39.4
755	40.2	40.1	40.0	39.9	39.7	39.6	39.5
756	40.3	40.2	40.0	39.9	39.8	39.7	39.6
757	40.4	40.2	40.1	40.0	39.9	39.7	39.6
758	40.4	40.3	40.2	40.0	39.9	39.8	39.7
759	40.5	40.3	40.2	40.1	40.0	39.8	39.7
760	40.5	40.4	40.3	40.1	40.0	39.9	39.8
761	40.6	40.4	40.3	40.2	40.1	39.9	39.8
762	40.6	40.5	40.4	40.2	40.1	40.0	39.9
763	40.7	40.5	40.4	40.3	40.2	40.0	39.9
764	40.7	40.6	40.5	40.3	40.2	40.1	40.0

Table 1-5. Expected CO_2 measurements (mm Hg) vs. Temperature and Pressure (Continued)

Barometric pressure reading (mmHg)	Gas temperature (°C)						
	20	21	22	23	24	25	26
765	40.8	40.7	40.5	40.4	40.3	40.1	40.0
766	40.8	40.7	40.6	40.5	40.3	40.2	40.1
767	40.9	40.8	40.6	40.5	40.4	40.3	40.1
768	40.9	40.8	40.7	40.6	40.4	40.3	40.2
769	41.0	40.9	40.7	40.6	40.5	40.4	40.2
770	41.0	40.9	40.8	40.7	40.5	40.4	40.3
771	41.1	41.0	40.8	40.7	40.6	40.5	40.3
772	41.2	41.0	40.9	40.8	40.6	40.5	40.4
773	41.2	41.1	40.9	40.8	40.7	40.6	40.4
774	41.3	41.1	41.0	40.9	40.7	40.6	40.5
775	41.3	41.2	41.1	40.9	40.8	40.7	40.5
776	41.4	41.2	41.1	41.0	40.9	40.7	40.6
777	41.4	41.3	41.2	41.0	40.9	40.8	40.7
778	41.5	41.3	41.2	41.1	41.0	40.8	40.7
779	41.5	41.4	41.3	41.1	41.0	40.9	40.8

The following example reads an expected CO_2 value from the table above, when the pressure reading is 760 mmHg and temperature is 23°C:

To find the expected CO_2 value

1. Find the barometric pressure of 760 mmHg in the table.
2. Find the temperature of 23°C.
3. The expected CO_2 value is the intersection of those two values in the table, or 40.1 mmHg.

If for any reason the temperature and pressure values are not listed in the table above, use the following equation to calculate the expected CO_2 value:

$$CO_2(mmHg) = \frac{CO_2\ gas\ \% \times Barometric\ Pressure \times Gas\ Comp}{1 - (0.003 \times (35 - Temperature))}$$

where Gas Comp =

$$1 + (0.000865 \times (setO_2\ \% - O_2\ \text{gas}\ \%))$$

CO_2 gas is the percentage of CO_2 in the specified test gas, which is 5% or 0.05.

Pressure Reading is the pressure in mmHg from the waveform display.

Set CO_2% is the set CO_2 concentration on the ventilator which, for Gas Comp calculation purposes is 21.

O_2 gas%, which is zero, as there is no CO_2 in the specified test gas.

Temperature is the ambient temperature in °C.

The next example calculates the expected CO_2 value using the equation given above with barometric pressure of 759 mmHg and temperature of 19°C.

$$CO_2(mmHg) = \frac{0.05 \times 759 \times 1.018165}{1 - (0.003 \times (35 - 19))}$$

The expected CO_2 value equals 40.59 mmHg.

Dispose of calibration gas per the institution's protocol.

Note:
Gas Comp is always calculated to equal 1.018165 using the equation above, because the set O_2% should always equal 21 (from step 6 above) and the percentage of O_2 in the specified test gas is 0%.

1.13 Cleaning the Capnography Sensor

Note:
Allow the capnography sensor to cool to room temperature for 30 minutes before attempting to clean it.

Caution:

- Disconnect the capnography sensor from the BDU before cleaning
- Only the outside of the capnography sensor can be cleaned. Do not sterilize or immerse the capnography sensor in liquids, as cable and/or sensor damage could result.
- Do not attempt to sterilize the capnography sensor.

- Allow the capnography sensor to dry completely before reconnecting to the BDU and breathing circuit.

To clean the capnography sensor

1. Wipe with a cloth dampened with any of the cleaning agents listed in *Table 1-13.* on page *1-33*.
2. Wipe with a clean, water-dampened cloth to rinse and dry before use. Ensure that the sensor windows are clean and dry before reuse.

1.14 Alarms

Three alarm events are associated with the $ETCO_2$ feature:

- High $ETCO_2$ level (↑$ETCO_2$) where the measured $ETCO_2$ level is above the operator-set value.
- Low $ETCO_2$ level (↓$ETCO_2$) where the measured $ETCO_2$ level is below the operator-set value.
- Capnography sensor inoperative (a malfunction has occurred with the capnography sensor).

See Chapter 4 in the *Puritan Bennett™ 980 Series Ventilator Operator's Manual* for information on setting alarms. The ↑ and ↓ $ETCO_2$ alarms may be set during ventilator operation, only.

If any of the alarm conditions occur, the GUI displays an alarm message similar to the one shown in *Figure 1-12.* Follow the information contained in the remedy message and the prompt area to troubleshoot the alarm.

Figure 1-12. Alarm Message for Capnography Sensor Inoperative

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1.15 Messaging

Messages are displayed either in the Prompt area of the GUI (see the figure Areas of the GUI in Chapter 4 of the *Puritan Bennett™ 980 Series Operator's Manual*), in the capnography screen, or in the alarm banner.

Examples of messages include:

- CO_2 sensor ready
- CO_2 sensor warming up
- CO_2 sensor zeroing in progress
- CO_2 sensor zeroing passed
- Zeroing attempt rejected, verify procedure
- Capnography is currently disabled

The following messages occur in conjunction with the Capnography inoperative alarm banner:

  - CO_2 sensor not connected
  - Check CO_2 sensor adapter
  - Invalid CO_2 sensor
  - CO_2 sensor faulty
  - CO_2 sensor not ready
  - Zeroing failed. CO_2 sensor zeroing required.

1.16 CO_2 Specifications

The following tables describe the specifications for the capnography sensor.

Table 1-6. Ventilator Patient Data Displayed Range, Resolution, and Accuracy

Parameter	Range, resolution, accuracy
CO_2	Range: 0 mmHg to 150 mmHg Resolution: 0.1 mmHg for values 0 mmHg to 69 mmHg; 0.25 mm Hg for values 70 mm Hg to 150 mmHg Accuracy: 0 mmHg to 40 mmHg ±2 mmHg 41 mmHg to 70 mmHg ±5% of reading 71 mmHg to 100 mmHg ±8% of reading 101 mmHg to 150 mmHg ±10% of reading Temperature at 35°C (No degradation due to respiratory rate or I:E ratio.) Accuracy (short term drift): ≤0.8 mmHg over four hours Accuracy (long term drift): Accuracy specification maintained over 120 hours

Table 1-7. Ventilator Alarm settings Range and Resolution

Setting	Description	Range and resolution
High end tidal CO_2 alarm ($\overline{\uparrow}ETCO_2$)	The $\uparrow ETCO_2$ alarm indicates the measured end tidal CO_2 level is ≥ the set alarm limit.	Range: OFF or 10.0 mmHg to 150 mmHg and > $\downarrow ETCO_2$ alarm limit Resolution: 1.0 mmHg
Low end tidal CO_2 alarm ($\downarrow ETCO_2$)	The $\downarrow ETCO_2$ alarm indicates the measured end tidal CO_2 level is ≤ the set alarm limit.	Range: OFF or 5 mmHg to 60 mmHg and < $\overline{\uparrow}ETCO_2$ alarm limit Resolution: 1.0 mmHg

Table 1-8. Capnography Sensor Specifications

Parameter	Description	Specification
System response time	Time until 90% of step change of final CO_2 value is displayed	<60 ms
Sampling rate	Frequency of CO_2 measurements	100 Hz
Transducer type	N/A	Mainstream
Principle of operation		Non-dispersive infrared (NDIR) single beam optics, dual wave-length, no moving parts.
CO_2 calculation method	Peak of the expired CO_2 wave-form	BTPS
Water resistance	Category for liquid ingress	IPX4 (splash proof)
Interfering gases	Accuracy not affected by pres-ence of specified gas concentra-tions	0.1% ethanol 0.1% isopropanol 0.1% acetone 1% methane
Non-condensing humidity	N/A	Accuracy not affected

Table 1-8. Capnography Sensor Specifications

Parameter	Description	Specification
Respiratory rate (f)	Number of breaths per minute set by the operator	Range: 0 breaths/min to 150 breaths/min Accuracy: ±1 breath Accuracy not affected. No limitation on respiratory rate when monitoring CO_2.
I:E ratio	Ratio of inspiratory time to expiratory time	Accuracy not affected

Note:
The capnography sensor is equipped with automatic barometric pressure compensation.

Table 1-9. Neonatal/pediatric Single Use Airway Adapter Specifications

Parameter	Description	Specification
Dead space	The volume of air not included in the $ETCO_2$ measurement	<1 mL
Weight	N/A	9.1 g
Pressure drop	The difference in pressure from the inlet to the outlet at a specified flow rate	0.74 cmH_2O at 10 L/min
Color	N/A	Purple

Table 1-10. Pediatric/adult Single Use Airway Adapter Specifications

Parameter	Description	Specification
Dead space	The volume of air not included in the $ETCO_2$ measurement	<6 mL
Weight	N/A	7.7 g
Pressure drop	The difference in pressure from the inlet to the outlet at a specified flow rate	0.40 cmH_2O at 60 L/min
Color	N/A	Colorless, transparent

Table 1-11. Flow and CO_2 Combination Sensor Specifications

Parameter	Description	Specification
Dead space	The volume of air not included in the $ETCO_2$ measurement	<1 mL
Weight	Weight of the flow and CO_2 combination sensor	9.6 g

Table 1-11. Flow and CO_2 Combination Sensor Specifications (Continued)

Parameter	Description	Specification
Pressure drop	The difference in pressure from the inlet to the outlet at a specified flow rate	3.1 cmH_2O at 10 L/min
Color	N/A	Purple, transparent

Note:
The flow and CO_2 combination sensor is for neonatal use, only.

1.17 Part Numbers

Table 1-12. lists the part numbers for the $ETCO_2$ monitoring function individual components.

Table 1-12. Capnography Monitoring System Part Numbers

Item	Part number
Capnography sensor	10087409
Airway adapter, single-use pediatric/adult (package of 10) (colorless transparent)	10078387
Airway adapter, single-use neonatal/pediatric (package of 10) (purple transparent in color)	10078386
Flow and CO_2 combination sensor, single-use (package of 10)	10005002
CO_2 sensor cable (internal)	PT00088615

1.18 Cleaning Agents

Table 1-13. lists cleaners that are compatible with the capnography sensor.

Table 1-13. Capnography Sensor Compatible Cleaning Agents

Cleaning agent
Isopropyl alcohol 70%
A 10% aqueous solution of 6% chlorine bleach
Steris™* Coverage™* Spray HB
Clinell™* Universal Wipes
PDI™* Sani Cloth™* Bleach Germicidal Disposable Wipe
PDI™* Super Sani Cloth™* Germicidal Disposable Wipe
PDI™* Sani-Cloth™* Plus Germicidal Disposable Cloth
Whiteley Medical™* Speedy Clean™* Wipes
Vernacare™* Tuffie™* Disinfectant Wipes
Vernacare™* Tuffie™* 5 Universal Wipes
Accel™* TB Wipes
Bacillol™* 30 Foam
Bacillol™* AF Tissues
Caltech™* Dispatch™* Disinfectant Wipes
Hydrogen Peroxide
Meliseptol™* Wipes
Metrex™* CaviWipes 1™* Disinfecting Wipes
Oxivir™* Tb Wipes
Revital-Ox™* Resert™* XL HLD
Sporox™* II Sterilizing & Disinfecting Solution
Viraguard™* Hospital Disinfectant (Isopropanol 70%)
Virex™* TB Disinfectant
WipesPlus™* Disinfecting Wipes

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