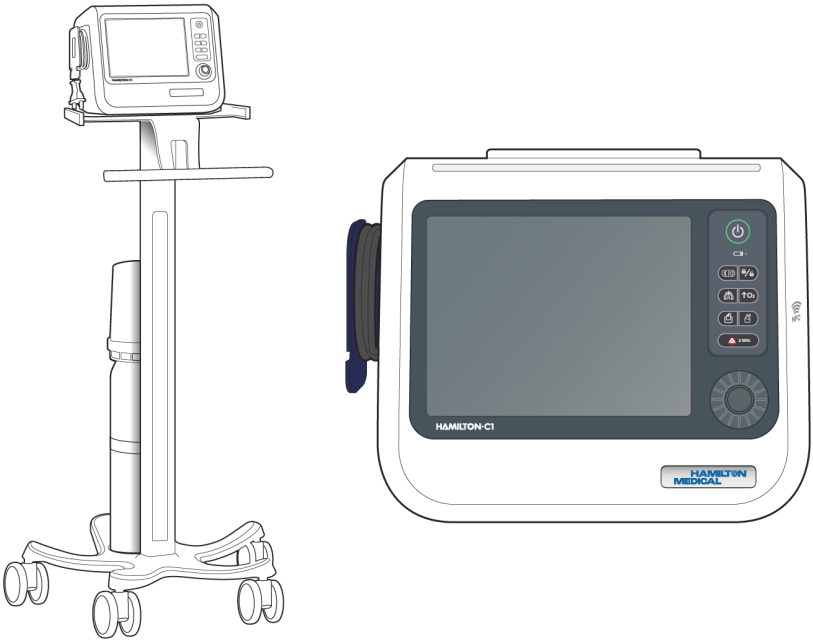

HAMILTON-C1/C1 neo

Operator's Manual

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HAMILTON MEDICAL

Operator's Manual

HAMILTON-C1/C1 neo

2025-05-27

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HAMILTON-C1 Documentation

Be sure to read the documentation *before* using the device or accessories.

This guide is part of a documentation suite[1] that includes, among others, the following documents.

Table 1. HAMILTON-C1 documentation suite

Document title	Description
Operator's Manual (this guide)	Provides detailed information about the setup and use of the HAMILTON-C1 ventilator.
Pulse Oximetry Instructions for Use, HAMILTON-C1/T1 (PN 624992)	Provides setup and use information for using SpO2 and related sensors with the ventilator.[2] The current version of the manual for software version 3.0.x also applies to software version 3.1.x.
Volumetric Capnography User Guide (PN 10107270)	Provides reference information for CO2 capnography.[2]
HAMILTON-H900 Instructions for Use (PN 624431)	Provides specifications, and setup and use information for the HAMILTON-H900 humidifier.[2]
Communication Interface User Guide (PN 627052)	Provides an overview of the communication interface, including how to connect the ventilator to external devices for data communication and support for nurse call remote alarms. The current version of the manual for software version 3.0.x also applies to software version 3.1.x.
EMC Declarations Guide (PN 10078283)	Provides emissions and EMC-related safety and use information. The current version of the manual for software version 3.0.x also applies to software version 3.1.x.
Service Manual (PN 624338)	Provides information about installing and setting up the medical equipment, as well as additional technical and servicing information for the ventilator.

[1] The user documentation provided by Hamilton Medical is developed in English. The manuals are translated into all other languages by ISO 9001- and 17100-certified translators.
[2] If option is installed.

Documentation downloads and training

To download the latest version of this manual or other documents, visit the Hamilton Medical Resource Center: https://www.hamilton-medical.com/Resource-center

Hamilton Medical offers the Hamilton Medical e-Academy, which provides a variety of learning modules free of charge. To register, go to: https://e-academy.hamilton-medical.com

A QR code on the ventilator provides a link to the Hamilton Medical Resource Center, where you can download this manual and related product documentation. See Section 10.15.

Conventions used in this guide

In this manual:

- Button and tab names are shown in a **bold** font.
- The notation **XX** > **XX** shows the sequence of buttons/tabs to touch to open the associated window.

  For example, the text "Touch **System** > **Settings**" means touch the **System** button, then touch the **Settings** tab.
- Window names are shown using the sequence of buttons/tabs used to open them.

  For example, "Alarms > Limits 2 window" means the window is accessed by touching the **Alarms** button, then the **Limits 2** tab.
- *Software version:* The software version for the ventilator is displayed in the System > Info window and should match the version on the title page of this manual.
- A green check mark ✓ or button XXX indicates a selected item or feature.
- The graphics shown in this manual may not exactly match what you see in your environment.
- Adult/Ped patient values and displays are shown in the illustrations.
- If the C1 neo option is enabled, the ventilator only provides Neonatal patient support. Some windows may show different content. In these cases, both versions of the window are shown in the manual.
- If the NIV-only option is enabled, the ventilator only provides noninvasive ventilation modes.[3] Some windows may show different content. In these cases, both versions of the window are shown in the manual.
- Some figures use callouts in a white circle with a blue border.

  (1) These figures may have an associated legend table, or may provide the legend in the figures title, if a single item. Callouts may be numeric or alphabetic. Callouts are *unrelated* to any nearby procedures and refer only to the figures themselves and their associated legend.
- Some figures use small dark blue callouts.

  (A) These callouts show the sequence of steps. They are *not* directly related to the numbering in the text of any associated procedure.

[3] Only for adult/pediatric patients.

- You can choose to display the APV modes using either the APVcmv / APVsimv nomenclature or the (S)CMV+ / SIMV+ nomenclature; the selection is set in Configuration, in the Modes > General > Philosophy window.
- IntelliSync+ is *not* available in all markets.
- Not all features or products are available in all markets.
- Product description and order number may differ depending on region.
- *Units of measure:* Pressure is indicated in cmH2O, length in cm, and temperature in degrees Celsius (°C). The units of measure for pressure and length are configurable.
- All patient-related pressure, volume, and flow measurements are expressed in BTPS (body temperature and pressure saturated).
- Pneumatic-related pressure, volume, and flow measurements are expressed in STPD (standard temperature and pressure dry).
- The term *USB drive* refers to a passive USB memory device, also known as a USB flash drive or USB memory stick.
- The terms *user* and *operator* are used interchangeably and refer to the operator of the device.

Safety messages are displayed as follows:

⚠ WARNING

A WARNING statement provides important information about a potentially hazardous situation which, if not avoided, could result in death or serious injury.

⚠ CAUTION

A CAUTION statement provides important information about a potentially hazardous situation which, if not avoided, may result in minor or moderate injury to the user or patient, or in damage to the medical device or other property.

NOTICE

A NOTICE provides additional information intended to avoid inconvenience during operation.

In tables, safety messages are indicated as follows:

⚠ WARNING!

⚠ CAUTION!

NOTICE!

⚠ CAUTION

Federal law restricts this device to sale by or on the order of a physician.

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Safety information

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1.1 Overview

This chapter provides safety information related to setting up and operating the HAMILTON-C1 ventilator, as well as providing service.

Be sure to review this Operator's Manual before using the ventilator and any accessories. Accessories include any and all consumables and other components used with the ventilator.

Be sure to read the Instructions for Use provided with any devices and accessories used with the ventilator before use.

Carefully review all sections of this safety chapter before setting up the ventilator and accessories, and ventilating the patient.

If you have questions about any of the information in this manual, contact your Hamilton Medical representative or technical service personnel.

1.2 Intended use, indications and contraindications for use

Intended use

The HAMILTON-C1 ventilator is intended to provide positive pressure ventilatory support to adults and pediatrics, and optionally infants and neonates.

Intended areas of use:

- Health care facilities
- During transfer of ventilated patients within the hospital

The HAMILTON-C1 ventilator is a medical device intended for use by qualified, trained personnel under the direction of a physician and within the limits of its stated technical specifications.

1.3 Electromagnetic susceptibility safety information

⚠ WARNING

- **MR UNSAFE.** Keep away from magnetic resonance imaging (MRI) equipment. The ventilator poses unacceptable risks to the patient, medical staff, or other persons within the MR environment.
- Correct function of the device may be impaired by the operation of high-frequency surgical equipment, microwaves, shortwaves, or strong magnetic fields in close proximity.
- Follow precautions for electrostatic discharge (ESD) and electromagnetic interference (EMI) to and from the ventilator and any connected devices and accessories.
- Use of accessories, transducers, and cables other than those specified by Hamilton Medical can result in increased electromagnetic emissions or decreased electromagnetic immunity of this equipment, and can result in improper operation.
- Ensure a minimum of 15 cm (6 in) distance between the HAMILTON-C1 and any 134.2 kHz RFID equipment.

- Portable RF communications equipment, including peripherals such as antenna cables and external antennas, should be placed no closer than 30 cm (12 in) to any part of the ventilator, including any specified cables. Otherwise, degradation of the performance of this equipment can occur.
- Certain RF transmitting devices (cellular phones, RFID equipment, walkie-talkies, cordless phones, paging transmitters, etc.) emit radio frequencies that could affect ventilator performance if operated too closely to the ventilator. Be aware of possible radio frequency interference if portable devices are operated in close proximity to the ventilator.
- The emissions characteristics of this equipment make it suitable for use in industrial areas and hospitals (CISPR 11, class A). If it is used in a residential environment (for which CISPR 11, class B is normally required) this equipment might not offer adequate protection to radio-frequency communication services. The user might need to take mitigation measures, such as relocating or reorienting the equipment.

The ventilator requires special precautions regarding electromagnetic compatibility (EMC). It must be installed and put into service according to the EMC information provided in the ventilator *EMC Declarations* (PN 10078283).

When using the optional integration with the HAMILTON-H900 humidifier, refer to the *EMC Declarations* for the device (PN 624539).

Portable and mobile RF communications equipment can affect the ventilator and all medical electrical equipment.

1.4 Fire and other hazards safety information

For device use instructions, see Chapters 3 and later.

⚠ WARNING

- It is *not* permitted to use flammable gases or anesthetic agents that pass through the ventilator, or to run the ventilator in insufficiently ventilated areas.
  Danger of fire! Only air and oxygen are allowed for use in the ventilator. Other gases may be added at the breathing circuit, external to the inspiratory port.
- To reduce the risk of fire, use only breathing circuit sets intended for use in oxygen-enriched environments. Do *not* use antistatic or electrically conductive tubing.
- It is *not* permitted to use the ventilator with helium or mixtures of helium. Such use might cause the ventilator to *not* function correctly, causing patient death or serious deterioration of health.
- During oxygen therapy, do *not* use near open flames. Danger of fire, which can result in burns or death. Do *not* allow open flames within two (2) meters of the equipment or any oxygen-carrying accessories.
- Do *not* use the ventilator with any equipment or high-pressure gas hoses that are worn or contaminated with oil or grease.

- Highly compressed oxygen together with flammable sources can lead to spontaneous explosions.
- In case of fire, immediately secure the patient's ventilatory needs, turn off the ventilator, and disconnect it from its gas and electrical sources.
- Do not lubricate any part of the equipment, connections, tubing, or accessories to avoid the risk of fire.
- Do *not* use if primary power cables are damaged.

1.5 General operation and setup safety information

This section provides the following safety information:

- General operation and setup
- Electrical: power and batteries
- Gas supply
- USB port

For device setup information, see Chapters 3 and 4.

For device operation details, see Chapters 5 through 11.

1.5.1 General operation and setup

Additional operation and setup-related safety information is presented in Section 1.6.

⚠ WARNING

- In case of ventilator failure, the lack of immediate access to appropriate alternative means of ventilation can result in patient death.
- An alternative means of ventilation *must* be available whenever the ventilator is in use. If a fault is detected in the ventilator or its life-support functions are in doubt, disconnect the ventilator from the patient and *immediately* start ventilation with an alternate device (for example, a resuscitation bag), using PEEP and/or increased oxygen concentration when appropriate. The ventilator *must* be removed from clinical use and serviced by Hamilton Medical authorized service personnel.
- Only use the ventilator, its components, accessories, and consumables according to the intended use and as described in the associated *Instructions for use*. Any other use might cause the ventilator to *not* function correctly, causing patient death or serious deterioration of health.
- Modifications to the device and any accessories are *not* permitted. Such use might cause the ventilator to *not* function correctly, causing patient death or serious deterioration of health.
- Use only Hamilton Medical-approved parts, spare parts, and accessories, including ventilator mounting solutions, that are specified in Chapter 14 and in the product e-catalog, or that are specified as being compatible with this ventilator. Doing so safeguards the patient, ensures proper ventilation operation, avoids degraded performance, and keeps your warranty in force.

- Additional equipment connected to medical electrical equipment must comply with the respective IEC or ISO standards. All configurations must comply with the requirements for medical electrical systems, IEC 60601-1, clause 16.
- Anybody connecting additional equipment to medical electrical equipment configures a medical system and is responsible for ensuring that the system complies with the requirements for medical electrical systems. Local laws take priority over the above-specified requirements. When developing a medical system, to ensure patient safety, a double safeguard is required for overall isolation between mains-supplied IEC 62368-approved external devices up to the applied part in accordance with IEC 60601-1.
- Only use the ventilator within the temperature range of 5°C to 40°C. Only use any components and accessories within the temperature range specified in their respective *Instructions for use*. Any use outside the stated temperature ranges might cause the ventilator to *not* function correctly and might impact the function of the components/accessories, causing patient death or serious deterioration of patient health.
- Ensure the oxygen source connected to the oxygen inlet is specified to operate within the limits of the ventilator specifications (see Section 15.3). Failure to do so may result in equipment damage, injury, or serious deterioration of health.
- The use of this equipment is restricted to one patient at a time.
- A HEPA inlet filter *must be* installed at the air intake. For details, see Section 12.4.1.
- An O2 sensor *must* be installed.
- The ventilator must *not* be used in a hyperbaric chamber. Such use might cause the ventilator to *not* function correctly, causing patient death or serious deterioration of health.
- If there is damage to any part of the ventilator, do *not* use the device. Technical service is required.
- Do *not* simultaneously touch conductive components or conductive parts of the ventilator enclosure and the patient.

⚠ CAUTION

- *Do NOT cover the ventilator or position it in such a way that the operation or performance of the ventilator is adversely affected.*
- *To prevent possible patient injury, do NOT block the holes at the back and side of the ventilator. These holes are vents for the fresh air intake and the cooling fan.*
- *Prior to use, check the stability of all connections.*

NOTICE

- Any incident with the device leading to serious patient injury, death, or a potential threat to public health must be reported to the manufacturer and the relevant authorities.
- The ventilator provides automatic barometric pressure compensation.
- Due to the ventilator's base flow, the exhaust gas output is larger than the patient's actual exhaled volume.

1.5.2 Electrical power and battery safety information

For details about power and battery use, see Sections 3.2 and 3.2.1.

⚠ WARNING

- To ensure grounding reliability, use a special hospital-grade receptacle.
- Ventilation stops if the battery is discharged or removed and no external power supply is connected.
- The HAMILTON-C1 does not require protective earth grounding, because it is a class II device, as classified according to IEC 60601-1.
- Only authorized personnel may check and replace batteries.
- Check the battery charge level before ventilating a patient and before unplugging the ventilator for transport or other purposes.
- The battery will *not* charge if the ambient temperature is above 43°C.

NOTICE

- Set up the ventilator in a location where the primary power supply is accessible.
- Only authorized service personnel may replace the power cable.
- Battery life indications are approximate. The actual battery operating time depends on ventilator settings, battery age, and level of battery charge. To ensure maximum battery life, maintain a full charge and minimize the number of complete discharges.
- To electrically isolate the ventilator electrical circuits from all poles of the primary power supply simultaneously, disconnect the power plug.

1.5.3 Gas supply safety information

Connection and usage information is provided in Sections 3.3 and Ensuring an adequate oxygen supply for patient transport. Specifications are provided in Section 15.3.

⚠ WARNING

- You must remove the low-pressure oxygen adapter before using high-pressure oxygen.
- Only connect the ventilator to an oxygen supply that complies with ISO 7396-1:2016+AMD1:2017.
- Visually verify proper attachment of the oxygen cylinder to the trolley. When using an oxygen cylinder, ensure that the Velcro straps attaching the cylinder to the trolley sufficiently overlap, and the cylinder is properly and securely attached to the trolley.

- It is the responsibility of the operator to ensure that the oxygen source is compatible with the rated range of pressure, flow rate, and oxygen concentration as marked on the equipment and indicated in this *Operator's Manual* (Section 15.3), as this can affect the performance of the equipment or pipeline system, which can consequently result in serious deterioration of health.

⚠ CAUTION

- *Always check the status of the oxygen cylinders or other supply before using the ventilator during transport.*
- *When using a 93% oxygen gas supply, the delivered oxygen may be lower than the set value.*

NOTICE

- To prevent damage to the ventilator, connect only clean, dry medical grade oxygen.
- When the ventilator is not in use, disconnect all gases.
- If you use gases from the cylinder, secure the cylinder to the trolley with the accompanying straps.

1.5.3.1 Low-pressure oxygen supply safety information

For information about working with a low-pressure oxygen supply, see Section 3.3.

⚠ CAUTION

- *To reduce the risk of fire:*

  – Do NOT use a low-pressure oxygen source that delivers a flow greater than 15 l/min.

  – Ensure adequate ventilation at the rear of the ventilator.

  – Turn off the oxygen source when the ventilator is not in operation.
- *To prevent possible patient injury when using the ventilator with an oxygen concentrator, do not use a humidifier. Any humidifier system supplied with the concentrator must be removed before using the ventilator.*
- *The Oxygen control on the ventilator is not active when low-pressure oxygen is used. It is the operator's responsibility to control the oxygen setting.*
- *To prevent possible patient injury, use low-pressure oxygen only in cases where the low-pressure source can provide an adequate level of oxygenation.*
- *To prevent possible patient injury, ensure that an emergency backup oxygen supply (for example, a cylinder) is available in case the low-pressure oxygen source fails.*

- *To calibrate the O2 sensor, disconnect all O2 supplies. Calibration is performed at a concentration of 21%.*
- *To protect the oxygen control system, do not supply both high- and low-pressure oxygen to the ventilator simultaneously.*

NOTICE

- Only use low-pressure hoses that comply with EN ISO 5359 to connect the device to the oxygen supply.
- Before starting ventilation, ensure that the selected gas source type, HPO or LPO[1], matches the connected gas source.

1.5.4 USB port safety information

⚠ WARNING

- During transfer of a ventilated patient, to prevent water intake, the ventilator USB port and RJ-45 Ethernet connector must be covered.
- Do *not* use the USB port to make a wireless connection of any kind.

NOTICE

- Before using the USB port, touch the ventilator to discharge any static electricity.
- Do *not* connect a USB hub to the USB port. Only one device may be connected at a time.
- The USB drive must be USB 1.1 compatible.
- During a file transfer, if you remove the USB drive before files are completely transferred, you *must* turn the ventilator off and on again to reset the USB port.
- You may connect only the following to the USB port:
  – a USB memory drive
  – Aerogen nebulizer

1.6 Setting up for ventilation safety information

This section provides safety information for the following:

- Patient breathing circuit sets, components, and accessories
- Performing preoperational check and testing
- Humidifier
- CO2 monitoring setup and operation
- Nebulization
- SpeakValve
- SpO2 monitoring setup and operation; see the *Pulse Oximetry Instructions for Use* (PN 624992)

For device and accessories preparation for use, see Chapters 3 and 4.

1.6.1 Patient breathing circuit sets, components, and accessories safety information

In addition to the information provided in this section, carefully review the information in Sections 1.4 and 1.5.

[1] Not available in all markets.

For breathing circuit set/component connection information, see Section 3.4. For placement/positioning information, see Section 3.4.5.

⚠ WARNING

- Discard the breathing circuit set if there is any sign of damage to any component or to the packaging, or it fails multiple preoperational checks.
- For each new patient, *always* use a new or reprocessed breathing circuit set to avoid cross contamination.
- Discard the expiratory valve set if there is any sign of damage to any component or to the packaging, or it fails multiple preoperational Leak tests.
- To prevent patient or ventilator contamination, always use a filter in the inspiratory gas path. If no inspiratory filter is used, the exhaled gas can contaminate the ventilator. If the ventilator becomes contaminated, have it serviced.
- During ventilation, regularly check any connected breathing system filters (ventilator-side inspiratory and expiratory filter, and patient-side HMEF), for increased resistance and blockage.
- Attaching components/assemblies to a breathing system can change the pressure gradient across the ventilator system, which can adversely affect ventilator performance. Such use might cause the ventilator to *not* function correctly, causing patient death or serious deterioration of health.
- Adding a breathing system filter, HMEF, or other accessories to the breathing circuit set can increase dead space and lead to higher resistance.
- Ensure that all of the components of the breathing circuit set, including but not limited to flow sensor and other accessories, match the associated intended use for the target patient group.

NOTICE

- Follow the manufacturer's *Instructions for use* for consumables and accessories, including masks.
- Any breathing system filter or additional accessories in the expiratory gas path may substantially increase flow resistance and impair ventilation.
- When adding components to the Hamilton Medical breathing circuit set configurations, do *not* exceed the inspiratory and expiratory resistance values of the ventilator breathing system as specified in Section 15.11, as required by ISO 80601-2-12.
- Pressure and volume measurement accuracy may be affected by using a breathing circuit set with high resistance. Accuracy was tested with the HAMILTON-C1 using the breathing circuit sets PN 260144 for adults, PN 260189 for pediatrics, and PN 151969 for neonates. Accuracy was tested with the HAMILTON-C1 neo using the breathing circuit set PN 151969 for neonates.
- The flow sensor tubes must be secured with the included clamp.

- To prevent inaccurate flow sensor readings, make sure the flow sensor is correctly installed and calibrated. The flow sensor tubes must *not* be kinked.
- During ventilation, secretions, occlusions, and/or condensation can build up in the flow sensor and circuit components. Position the flow sensor upright, with the patient end facing downward. Ideally, the flow sensor should be at a 45° or greater angle relative to the floor. See the *Breathing Circuit Positioning Guide* (PN ELO20180924N).

1.6.2 Preoperational check and tests safety information

For details on performing the preoperational check and tests, see Section 5.4.

⚠ CAUTION

- *To prevent possible patient injury, disconnect the patient from the ventilator before running the preoperational tests, and use another source of ventilatory support.*
- *To ensure the ventilator's safe operation, always run the preoperational check before using the ventilator on a patient.*
- *Do NOT use the ventilator until necessary repairs are completed and all preoperational tests have passed.*

NOTICE

- To ensure that all breathing circuit connections are leak-tight, perform the Leak test every time you connect a circuit or change a circuit part.
- If there is a mismatch between the selected patient group and the type of flow sensor connected, the calibration fails. Ensure you are using the correct flow sensor for the patient.

1.6.3 Humidifier safety information

For information about working with a humidifier, see Chapters 4 and 11.

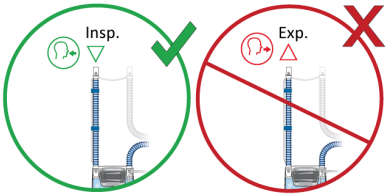
⚠ WARNING

- Before using a humidifier, review the *Instructions for use* as well as the *Instructions for use* provided with its accessories.
- Before using the humidifier on the patient, verify that the breathing circuit is correctly connected to the ventilator as follows:

  – The blue inspiratory limb is connected to the inspiratory port (*To patient*).

  – The white expiratory limb is connected to the expiratory port (*From patient*).

  Failure to connect the limbs to the proper ventilator ports can result in delivery of overheated gas to the patient.

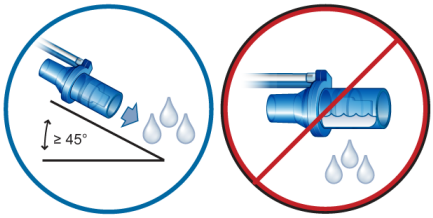


- To prevent possible patient injury and equipment damage, do *not* turn the humidifier on until the gas flow has started and is regulated. Turn the humidifier off before stopping gas flow.
- Adding attachments or other components/assemblies to a connected humidifier can change the pressure gradient across the ventilator, which can adversely affect ventilator performance. Such use might cause the ventilator to *not* function correctly, causing patient death or serious deterioration of health.
- Humidification can cause an occlusion and increased resistance of a connected inspiratory and expiratory filter. Check the filters frequently for increased resistance or blockage.
- Regularly check the water traps and the breathing circuit limbs for water accumulation. Empty as required.

⚠ CAUTION

When using active humidification, prevent water accumulation in the flow sensor by ensuring that the flow sensor is positioned at a ≥ 45° angle relative to the floor. Excess water can affect the flow sensor measurements and lead to inaccurate volume delivery, potentially resulting in hypoventilation.

Figure 1-1. Position flow sensor at an angle ≥ 45° relative to the floor



1.6.4 CO2 sensor setup and operation safety information

For information about setting up CO2 sensors, see Section 4.3.

⚠ WARNING

- **LoFlo sidestream CO2 sensor.** Do *not* use with patients who cannot tolerate the removal of 50 ml ±10 ml/min from their total minute volume. In adaptive modes (such as ASV, APVcmv, and APVsimv), the removal is fully compensated.
- **LoFlo sidestream CO2 sensor.** Use of devices containing PVC plasticized with DEHP should be limited to the amount of time treatment is medically necessary, especially for neonates and pregnant or nursing mothers.
- Do *not* combine the neonatal CO2 airway adapter and the adult flow sensor. Doing so can increase resistance, create artifact, or lead to hypoventilation, AutoPEEP, or overinflation.
- **LoFlo sidestream CO2 sensor.** Monitor the CO2 waveform (capnogram) on the ventilator display. If it appears abnormal, check the patient, settings, and the breathing circuit components, including the CO2 sensor sampling line. Adjust and replace components as appropriate.
- If the capnogram appears abnormal, inspect the adult/pediatric CO2 airway adapter and replace if needed.
- Connect the CO2 airway adapter according to your institution's policy and procedures. Connecting the airway adapter between the flow sensor and the endotracheal tube increases dead space and may contribute to incorrect volume measurements.
- Elevated baseline can be caused by sensor problems or by the patient's condition.
- Do *not* use any CO2 sensor/adapter if it appears to be damaged or if it fails to operate properly. Refer servicing to Hamilton Medical authorized personnel.
- In NIV and neonatal ventilation, leaks may influence the capnogram and the measured values.
- Always connect all components securely and check for leaks according to standard clinical procedures.
- Positioning of tubing and cables:
  – Do *not* position the cables or tubing in any manner that may cause patient entanglement or strangulation.
  – Support the tubing to avoid stress on the ET tube.
  – Do *not* apply excessive tension to any cable or tubing.
- During use, a system leak, such as that caused by an uncuffed ET tube or damaged airway adapter, may significantly affect sensor readings, including flow, volume, pressure, and other respiratory parameters.
- Leakages in the breathing or sampling system may cause the displayed CO2 values to be significantly under-reported (too low).

- Periodically check the sensor and tubing for excessive moisture or secretion build-up, and replace if needed. Excessive moisture can affect measurements.
- Keep all cleaning agents away from the CO2 sensor electrical connections.
- For the CO2 sensor/adapter, use only cleaning and disinfection agents that are recommended in Chapter 12.

⚠ CAUTION

- *Do NOT place the CO2 sensor directly on the patient's skin. It can burn the skin as the sensor may reach a temperature of 46°C (115°F).*
- *All devices are NOT protected against reanimation with a defibrillator. Disconnect the CO2 sensor before using a defibrillator on the patient.*
- *Always use the correct CO2 airway adapter for the patient group.*
  In adult patients, smaller geometrics increase airway resistance and induce low tidal volumes and AutoPEEP.
  In neonatal patients, larger geometrics impede effective CO2 removal and add dead space.
- *Do NOT use the CO2 components when they are wet or have exterior condensation. Condensation may harm the patient.*
- *Use during nebulization may influence the CO2 measurements. In addition, the medication can contaminate the airway adapter windows, causing the sensor to fail prematurely.*
- ***LoFlo sidestream CO2 sensor.***
  Remove the sampling kit sample cell from the module when not in use.
- ***LoFlo sidestream CO2 sensor.***
  Do NOT stick finger into the sample cell receptacle.

NOTICE

- Position airway adapters with windows in a vertical, *not* a horizontal, position. This helps keep patient secretions from pooling on the windows. If pooling occurs, remove the adapter, rinse with sterile water, and reconnect.
- Do *not* place the CO2 sensor/adapter between the ET tube and any connected airway adapter, as this may allow patient secretions to enter the tubing and block the adapter windows.
- The CO2 sensors and accessories that have contact with the patient are not made with natural rubber latex.
- Nitrous oxide, elevated levels of oxygen, helium, and halogenated hydrocarbons can influence the CO2 measurement.
- Do *not* combine the neonatal CO2 airway adapter and the adult flow sensor. Doing so can increase resistance, create artifact, or lead to hypoventilation, AutoPEEP, or overinflation.

1.6.5 Nebulization safety information

For information on setting up and working with a nebulizer, see Chapters 4 and 10.

⚠ WARNING

- Nebulization of drugs can cause an occlusion and increased resistance of a connected inspiratory and expiratory filter or HME/F. Check the breathing system filters frequently for increased resistance or blockage. Follow the manufacturer's *Instructions for use* of the breathing system filters.
- Connect the nebulizer in the inspiratory limb according to your institution's policy and procedures. Connecting the nebulizer between the flow sensor and the endotracheal tube increases dead space and causes incorrect volume measurements.
- Nebulization can affect the accuracy of CO2 measurements.
- The use of a pneumatic nebulizer adds gas to the ventilator breathing system, which can affect the accuracy of volume or flow measurements.
- Pneumatic nebulization affects the delivered oxygen concentration.

⚠ CAUTION

To prevent the expiratory valve from sticking due to nebulized medications, regularly check and clean or replace the expiratory valve membrane and/or any expiratory filter in the gas path.

NOTICE

- Pneumatic nebulization is disabled:
  - During neonatal ventilation (if needed, use an Aerogen nebulizer[1])
  - When using HiFlowO2 therapy
  - When using LPO
- Only use approved piezo nebulizers with the HAMILTON-C1.

[1] Aerogen nebulization is not supported for patients younger than 28 days old in the USA.

1.6.6 SpeakValve safety information

For details on working with a speaking valve (SpeakValve option), see Sections 4.7 and 10.9.

⚠ CAUTION

- *Do not leave the patient unattended when SpeakValve is turned ON and a speaking valve is connected to the patient.*
- *When SpeakValve is turned on:*

  – Apnea backup ventilation is disabled. When SpeakValve compatibility is turned off, Apnea backup ventilation returns to its previous settings.

  – Some alarm limits are changed and some alarms are disabled. For details, see Section 10.9.4.

  – Some changes apply to monitoring parameters. For details, see Section 10.9.3.

1.7 Ventilating the patient safety information

This section provides the following safety information:

- Specifying patient settings
- Neonatal ventilation
- Apnea backup
- Noninvasive ventilation

For information on ventilation settings, features, and procedures, see Chapters 5 through 11. Specifications are in Chapter 15.

1.7.1 Specifying patient settings safety information

For information on specifying patient settings, see Chapter 5.

⚠ WARNING

- It is the clinician's responsibility to ensure that all ventilator settings are appropriate, even when "automatic" features, such as ASV, or default settings are used.
- To prevent possible patient injury:

  – Make sure the ventilator is set up for the appropriate patient group with the appropriate breathing circuit components.

  – For each patient group, make sure you select the correct patient sex and height (Adult/Ped) or weight (Neonatal). Correct entries help prevent hyper- or hypo-ventilation.

1.7.2 Neonatal ventilation safety information

In addition to the information provided in this section, carefully review the information in Sections 1.6 and 1.7.

For information on setting up the ventilator for neonatal patients, see Chapter 6.

⚠ WARNING

Prolonged exposure to high oxygen concentrations may cause irreversible blindness and pulmonary fibrosis in pre-term neonates. Be especially careful when performing oxygen enrichment.

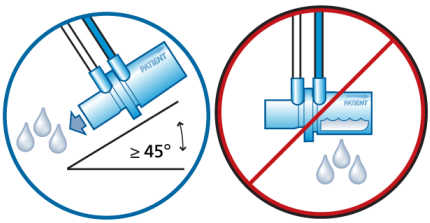
⚠ CAUTION

- *Make sure the correct type of expiratory valve for your patient is installed:*

  – Ensure the Neonatal patient group is selected on the ventilator when using the neonatal expiratory valve. It cannot be used with the Adult/Ped group.

  – You must use a neonatal expiratory valve for neonates.
- *To prevent increased CO2, do NOT use an adult airway adapter for neonates as it will increase dead space.*
- *To determine appropriate tidal and minute volumes for neonatal patients, you must consider (anatomic) dead space. Artificial airways (for example, Y-piece, flow sensor, ET tube, CO2 airway adapter) increase the dead space.*
- *When using active humidification, prevent water accumulation in the flow sensor by ensuring that the flow sensor is positioned at a ≥ 45° angle relative to the floor. Excess water can affect the flow sensor measurements and lead to inaccurate volume delivery, potentially resulting in hypoventilation.*

Figure 1-2. Position flow sensor at a ≥ 45° angle relative to the floor



NOTICE

- When switching between the Adult/Ped. and the Neonatal patient groups, you must perform the Leak test and calibrate the flow sensor.
- You must use an appropriate adapter to connect the mainstream CO2 neonatal airway adapter to a neonatal flow sensor.

1.7.2.1 Working with nCPAP modes

For details about the nCPAP modes and noninvasive ventilation, see Chapter 7.

NOTICE

- In nCPAP and nCPAP-PC modes, starting O2 enrichment or changing the Oxygen setting sets the flow to 10 l/min for 60 seconds. The flow then returns to its previous setting.
- The Flow sensor calibration needed alarm may be generated when changing to and from nCPAP modes.
- Apnea backup, trigger detection, disconnection detection, and volume measurements are not available in nCPAP modes.

1.7.3 Apnea backup safety information

For information about apnea backup ventilation, see Section 5.6.3.

⚠ CAUTION

We recommend you enable Apnea backup ventilation whenever a mode that allows spontaneous breathing is selected. Apnea backup is enabled by default.

1.7.4 Noninvasive ventilation safety information

For information about working with NIV modes, see Chapter 7 and Section 10.6.

NOTICE

- As a precaution, while noninvasive ventilation is in use, you must be prepared to intubate the patient and start invasive ventilation at any time.
- The use of a mask or HMEF can increase dead space. Always comply with the mask or HMEF manufacturer's instructions.
- The Vt high: breath terminated alarm is inactive in noninvasive modes.

1.7.5 Using high flow oxygen therapy safety information

For information on working with high-flow oxygen therapy, see Section 10.5.

⚠ WARNING

- High flow oxygen therapy is suitable only for spontaneously breathing patients.
- There is a risk of fire associated with oxygen enrichment during oxygen therapy. Do *not* use the equipment or accessories near sparks or open flames.
- Use only interfaces intended for high flow oxygen therapy that allow the patient to exhale, such as a nonocclusive high-flow nasal cannula, tracheal adapter, or tracheal mask. This is important because exhalation through the expiratory valve is not possible when using high flow oxygen therapy.
- Do *not* use high flow oxygen therapy with a nasal mask, facial mask, a helmet with a dual limb breathing circuit, or any interface that increases patient dead space volume. Ensure the interface allows the patient to exhale.
- Use only water-based lotions or salves that are oxygen compatible before and during oxygen therapy. Never use petroleum-based or oil-based lotions or salves to avoid the risk of fire and burns.

- Risk of fire! When the device is turned on but not in use, do *not* leave a nasal cannula or mask on bed coverings or chair cushions; oxygen makes materials more flammable. Turn device off when not in use to prevent oxygen enrichment.
- Ensure the ventilator's gas pipeline system does not exceed the pipeline design flow capacity. If the system exceeds the flow capacity, it can interfere with the operation of other equipment using the same gas source.
- To prevent disconnection of the tubing or tubing system during use, especially during ambulatory use, only use tubes with a retention force in conformance with ISO 5367 or ISO 80601-2-74.
- The ventilator is a high-flow device that can operate with flows above 100 l/min and with a high oxygen concentration (not applicable on HAMILTON-C1 neo).[1]

⚠ CAUTION

- *During high flow oxygen therapy, active humidification is required.*
- *Any connected humidifier must conform to ISO 80601-2-74.*

1.7.6 Volume targeted modes safety information

NOTICE

- The minimum inspiratory pressure (Ppeak – PEEP) in VS, APVcmv, and APVsimv modes is 5 cmH2O. Be aware that a small set tidal volume with high lung compliance may lead to higher-than-expected tidal volumes.
- Ensure Plimit is set appropriately for adaptive modes. This setting provides a safety pressure limit for the device to appropriately adjust the inspiratory pressure necessary to achieve the target tidal volume.

  The maximum available inspiratory pressure (Plimit), is indicated by a blue line on the pressure waveform display.

  If Plimit is set too low, there may not be enough margin for the device to adjust its inspiratory pressure to deliver the target tidal volume.

[1] In some markets, the maximum possible Flow setting may be different.

1.8 Monitoring and alarms safety information

For information about monitoring ventilation/therapy, see Chapter 8.

For information about working with alarms, see Chapter 9.

⚠ WARNING

To prevent possible patient injury, make sure the alarm limits are appropriately set before you place the patient on the ventilator.

⚠ CAUTION

- *The HAMILTON-C1 oxygen monitoring function can be disabled. Ensure that an alternative means of oxygen monitoring is always available and enabled to reduce the possibility of patient death or serious deterioration of health.*
- *To ensure that oxygen monitoring is always fully functional, replace an exhausted or missing O2 sensor as soon as possible or use an external monitor that complies with ISO 80601-2-55.*
- *Carefully set alarm limits according to the patient's condition. Setting limits too high or too low defeats the purpose of the alarm system.*

NOTICE

- It is recommended that additional independent monitoring devices, including pulse oximeters measuring SpO2 and CO2 sensors, be used during mechanical ventilation. The operator of the ventilator must still maintain full responsibility for proper ventilation and patient safety in all situations.
- The HAMILTON-C1 is *not* intended to be a comprehensive vital sign monitor for patients on life-support equipment. Patients on life-support equipment should be appropriately monitored by qualified medical personnel and suitable monitoring devices.
- Do *not* pause the audible alarm when leaving the patient unattended.
- The factory default alarm limit settings are set in line with the selected patient group, allowing for unattended monitoring. These settings, however, can *never* replace individual review of the patient and adjustment of alarm limits based on their condition.
- The use of an alarm monitoring system does *not* give absolute assurance of warning for every type of issue that may arise with the ventilator. Alarm messages may *not* pinpoint a problem exactly; the exercise of clinical judgment is necessary.

- Alarm conditions, including technical faults/events, that are *not* directly related to a physiological sensor (CO2, SpO2) do *not* affect the function of any attached physiological sensor, including the values of any associated CO2, SpO2, and pulse-rate measurements. Real-time waveforms on the ventilator provide a method for assessing the displayed numeric values.
- The alarm limits Auto function is *not* available during neonatal ventilation.

1.9 Using the trolley safety information

For information about working with the trolley, see Section 2.2.4.

⚠ WARNING

- To prevent possible personal injury and equipment damage, including tipping:

  – Lock the trolley's wheels when parking the ventilator.

  – Take care when crossing thresholds.
- To prevent accidental extubation, check the patient tubing support arm joints and secure as necessary.

1.10 Maintenance safety information

This section provides the following safety information:

- General maintenance, cleaning, and disinfection
- Preventive maintenance
- O2 sensor

1.10.1 General maintenance, cleaning, and disinfection safety information

For detailed cleaning/disinfection information for the device and components, including procedures and agents, see Chapter 12.

⚠ WARNING

- Reprocessing of Hamilton Medical single-use products can affect the product properties and may cause injury to the patient. For example, a change to the surface structure during reprocessing may lead to a change in the tear strength or cause actual cracking.
  Furthermore, an altered surface structure may result in a microbial aggregation of spores, allergens, and pyrogens, for example, or cause an increase in the number of particles released as a result of chemical changes in the material properties.
- To reduce the risk of cross-contamination, regularly clean and replace the fan filter. For details, see Table 12-5.

- To prevent patient exposure to sterilizing agents and to prevent premature deterioration of parts, sterilize parts using only the techniques recommended in Chapter 12 and in any associated *Reprocessing guide* or *Instructions for use* provided with each part.
- Hamilton Medical does *not* assume any liability for the proper functioning of single-use items if they are reprocessed and reused by the user.
- Always use caution when handling inspiratory and expiratory breathing system filters and HMEFs to minimize the risk of viral or bacterial contamination, or physical damage. Follow the manufacturer's *Instructions for use* of the breathing system filter and HMEF.
  Dispose of used filters immediately after use. Follow your hospital procedures for disposal.
- Follow the cleaning, disinfection, and sterilization procedures for each component as described in this guide and in the cleaning agent manufacturer's *Instructions for use*.
- Always disconnect the device and any accessories, including CO2 sensor/adapter, from electrical power before cleaning and disinfection to reduce the risk of electric shock.

⚠ CAUTION

- *Do NOT sterilize or immerse the CO2 sensor in liquids.*
- *Do NOT attempt to sterilize the interior components of the ventilator.*
- *Do NOT attempt to sterilize the entire device with ETO gas.*
- *Incorrect concentrations or residence times of sterilization agents may lead to bacterial resistance.*
- *To prevent premature deterioration of parts, make sure the disinfecting chemical is compatible with the part material. Use only EPA-registered/approved cleaning and disinfection solutions, as approved by your institution's protocol, after each patient use, according to the cleaning agent manufacturer's Instructions for use.*
- *Intrusion of fluids, or immersing parts in fluids, will damage the device.*
- *Do NOT pour fluids onto the device surfaces.*
- *Do NOT use abrasives materials (for example, steel wool or silver polish), hard brushes, pointed instruments, or rough materials on surfaces.*
- *Thoroughly rinse all patient- or airway-contact components to ensure removal of residual cleaning/disinfection agents.*
- *Cleaning and disinfection agent residues can cause blemishes.*

NOTICE

For specific information on cleaning, disinfecting, and sterilizing autoclavable (reusable) accessories and components, refer to the appropriate *Reprocessing guide* and *Instructions for use* provided with each part.

1.10.2 Preventive maintenance safety information

For detailed preventive maintenance information and instructions, see Chapter 12.

NOTICE

- Dispose of all parts removed from the device according to your institution's protocols. Comply with all local, state, and federal regulations with respect to environmental protection, especially when disposing of the electronic device or parts of it.
- We recommend that you document all maintenance procedures.
- It is *not* allowed to perform service or maintenance on the device while a patient is connected.
- If no viral or bacterial breathing system filter is used on the inspiratory port, the device *must* be considered contaminated and *must* be serviced.

1.10.3 O2 sensor safety information

⚠ CAUTION

If an O2 sensor is not installed, use an external oxygen monitor complying with ISO 80601-2-55 to verify that the set oxygen concentration is being delivered to the patient. Be sure to cover the O2 sensor port with the provided cover.

NOTICE

- Replace the O2 sensor with a genuine Hamilton Medical O2 sensor only; otherwise, oxygen measurement will *not* function and permanent oxygen-related alarms may be generated.
- To prevent leakage within the ventilator, make sure an O2 sensor is installed at all times, even if you use an external monitor or disable oxygen monitoring.
- Keep the oxygen sampling site free of other gases to avoid affecting oxygen sampling.

1.11 Service and testing safety information

- To ensure proper servicing and to prevent possible physical injury, *only* Hamilton Medical authorized service personnel may service the ventilator and related accessories/devices using information provided in the ventilator *Service Manual*.
- The manufacturer can *only* be responsible for the safety, reliability, and performance of the ventilator if *all* of the following requirements are met:
  - Appropriately qualified, trained healthcare professionals carry out assembly operations, extensions, readjustments, modifications, maintenance, or repairs.
  - The electrical installation of the relevant room complies with the appropriate requirements.
  - The ventilator system is used in accordance with the ventilator *Operator's Manual*.
  - Do *not* attempt service procedures other than those specified in the ventilator *Service Manual*.
  - Follow the infection prevention policies and reprocessing regulations, including the reprocessing intervals, of the health-care facility.
  - Follow the national infection prevention policies and reprocessing regulations.
  - Use validated procedures for reprocessing the external surfaces of the device.
  - Reprocessing is performed by personnel who have specialist knowledge in the reprocessing of medical devices and who have read and understood this document.
  - Follow the manufacturer's instructions for cleaning and disinfection methodologies and reprocessing of the device.
- Any attempt to modify the ventilator hardware or software without the express written approval of Hamilton Medical automatically voids all warranties and liabilities.

2
System overview

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2.4 Navigating the display and controls 63

2.1 Overview

The HAMILTON-C1 ventilator system comprises the following main components:

- Ergonomic design featuring integrated monitor with touch screen display and integrated alarm lamp
- Ventilation unit for gas mixing and control, and patient breathing circuit set for gas delivery and exchange
- Oxygen monitoring using a galvanic sensor
- High-pressure (HPO) and low-pressure oxygen (LPO) supply connections
- Optional integration with hospital network
- Optional connections to a humidifier, nebulizer, SpO2 and CO2 sensors, and external data interfaces
- Trolley or shelf mount

The ventilator system offers the following main features:

- *Monitoring:* Real-time waveforms, numerical monitoring, trends, loops, and Intelligent panels showing the patient's real-time breathing status, ventilator dependence, and targets, CO2 and SpO2 measurements (when enabled)
- Alarms and on-screen troubleshooting help
- Configurable startup settings for each patient group
- Remote access to the HAMILTON-H900 humidifier controls and status
- Support for pneumatic and Aerogen nebulization

The NIV-only option, when enabled, configures the HAMILTON-C1 ventilator to provide only noninvasive ventilation. The HAMILTON-C1 with the NIV-only option is dedicated exclusively to noninvasive ventilation; only modes and features applicable to noninvasive ventilation are supported.

The HAMILTON-C1 neo is a HAMILTON-C1 ventilator on which the neo option is enabled. The HAMILTON-C1 with the neo option is dedicated exclusively to neonatal ventilation; only modes and features applicable to neonatal ventilation are supported.

The intended position of the device user is directly facing whichever part/side of the device with which they are interacting.

2.1.1 Standard features and options

The ventilator offers a robust set of standard equipment and features, as well as optional modes and features for the supported patient groups.

Table 2-1 lists software configuration and options.

Table 2-2 lists equipment (hardware) and options.

Table 2-1. Software configuration and options

Function	Patient group	
	Adult/Ped	Neonatal[1,2]

Note the following:

- When the C1 neo option is activated, only the Neonatal patient group, associated modes, and features are supported.
- When the NIV-only option is activated, only the noninvasive modes and features are supported.

Standard: X Option: O Not applicable: --

Patient groups	X	O
Modes		
Intelligent ventilation mode		
ASV®	X	--
Volume-targeted, pressure-controlled modes		
APVcmv / (S)CMV+	X	X
APVsimv / SIMV+	X	X
Volume Support (VS)	X	X
Pressure-controlled modes		
DuoPAP, APRV	O	O
PCV+	X	X
PSIMV+	X	X
SPONT	X	X
Noninvasive modes		
NIV, NIV-ST	O	O
nCPAP, nCPAP-PC	--	O

[1] Applies only to devices with serial number > 6000.
[2] Not available in all markets.

Function	Patient group	
	Adult/Ped	Neonatal[1,2]
Other functions		
NIV-only	O	--
Flow trigger	X	X
IntelliSync®+[3]	O	--
On-screen help	X	X
CPR ventilation	X	X
Suctioning tool	X	--
HiFlowO2	O	O
SpeakValve	O	--
Hamilton Connect Module[4]	O	O
Trends/Loops	O	O

Table 2-2. Equipment (hardware) configuration and options

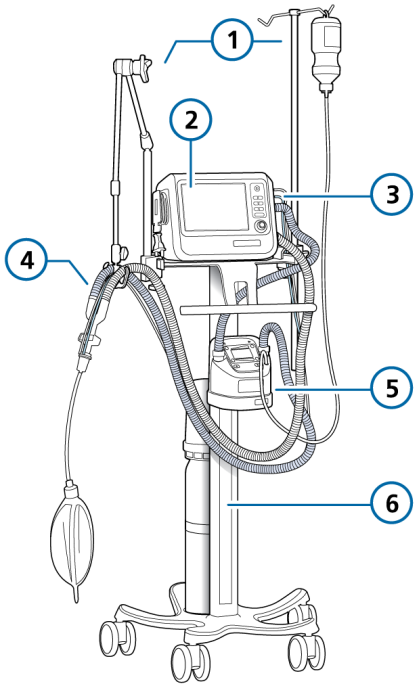
Functions	HAMILTON-C1
Standard: X Option: O	
Trolley or shelf mount solution	O
Communication board: CO2/Nurse Call/COM, CO2/SpO2/COM[1], or CO2/SpO2/Humidifier & COM1[5]	O
USB port	X
RJ-45 Ethernet port[6]	X
Communication protocols: Hamilton, Hamilton P2, GALILEO compatible, DrägerTestProtocol, Philips VueLink Open, Hamilton Block protocol	O
HAMILTON-H900 humidifier integration	O

[1] Applies only to devices with serial number > 6000.
[2] Not available in all markets.
[3] Available for HAMILTON-C1 PN 1610010.
[4] Available for HAMILTON-C1 PN 1610010.
Available for the HAMILTON-C1 PN 161001 with SN > 6000 with the Hamilton Connect Module (HCM) Upgrade kit.
[5] RS-232 connection over the /COM1 port is only available when using the communication Y-cable (PN 10077038).
[6] The RJ-45 ethernet port is for internal use only.

2.2 Physical descriptions

This section provides an overview of the ventilator, breathing circuit sets, and trolley.

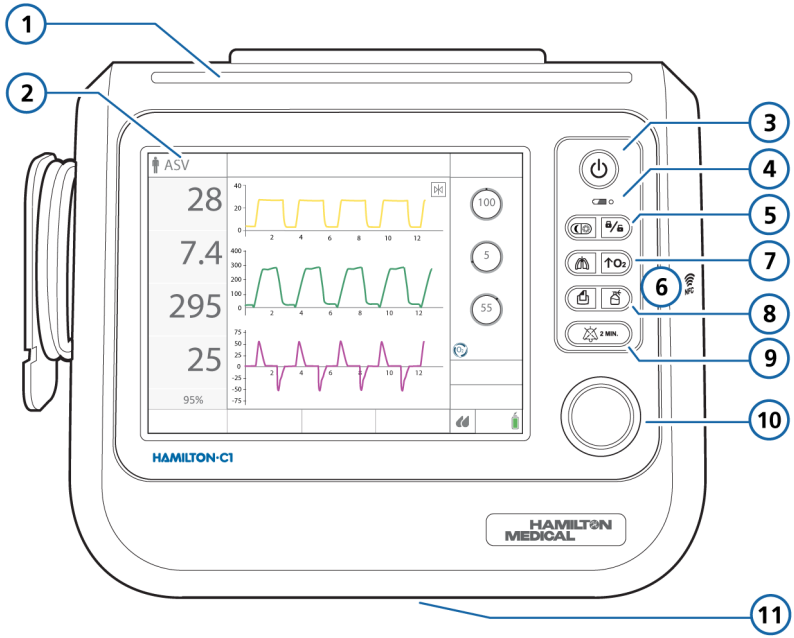
Figure 2-1. HAMILTON-C1 with accessories



1	Support arm and water bottle holder	4	Breathing circuit set
2	Display and controls	5	Humidifier
3	Breathing circuit set connections	6	Trolley

2.2.1 About the ventilator

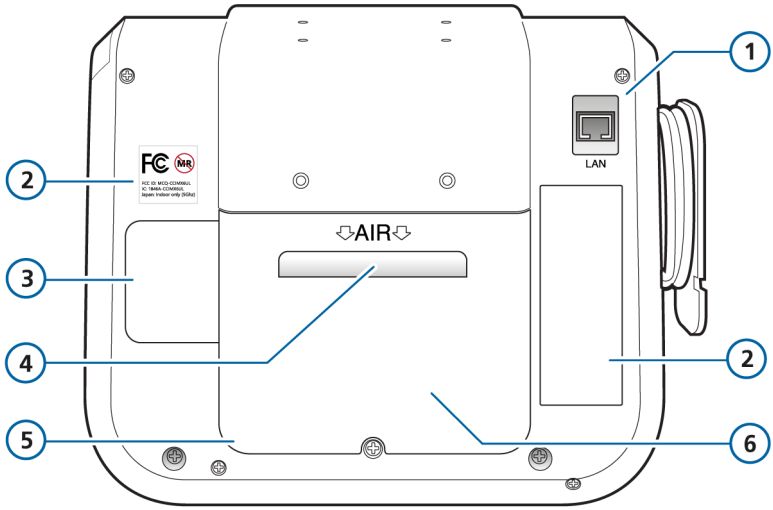
Figure 2-2. Front view, HAMILTON-C1/C1 neo ventilators



1	Alarm lamp	7	Manual breath key/O2 enrichment key
2	Touch screen display	8	Print screen key/Nebulizer key
3	Power/Standby key	9	Audio pause key
4	Battery charge indicator	10	Press-and-Turn (P&T) knob
5	Day/Night key[1]/Screen lock/unlock key	11	Expiratory valve bleed port (under the ventilator) *Do not obstruct*
6	Near-field communication (NFC) connection area[2]		

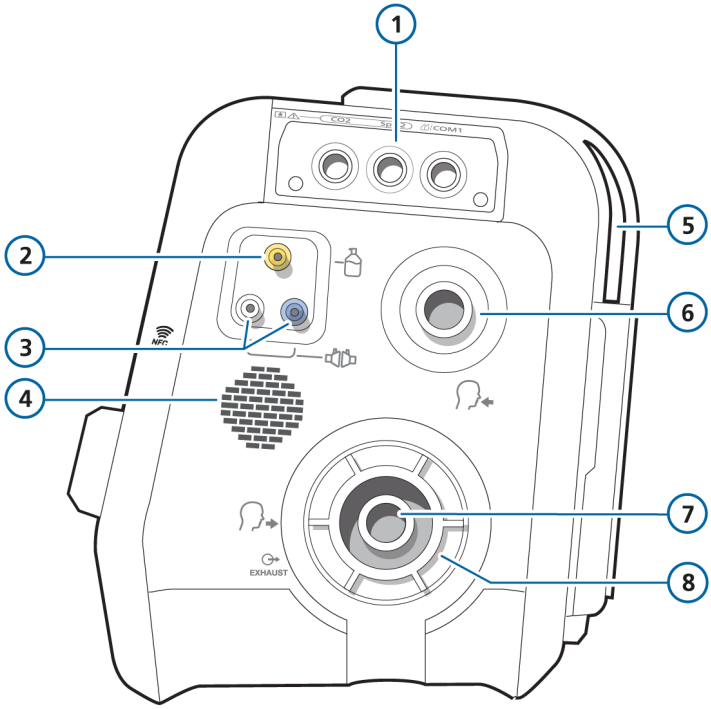
[1] Applies only to devices with serial number > 6000.
[2] May not be available on older devices. Contact your Hamilton Medical technical representative for details.

Figure 2-3. Rear view, ventilator



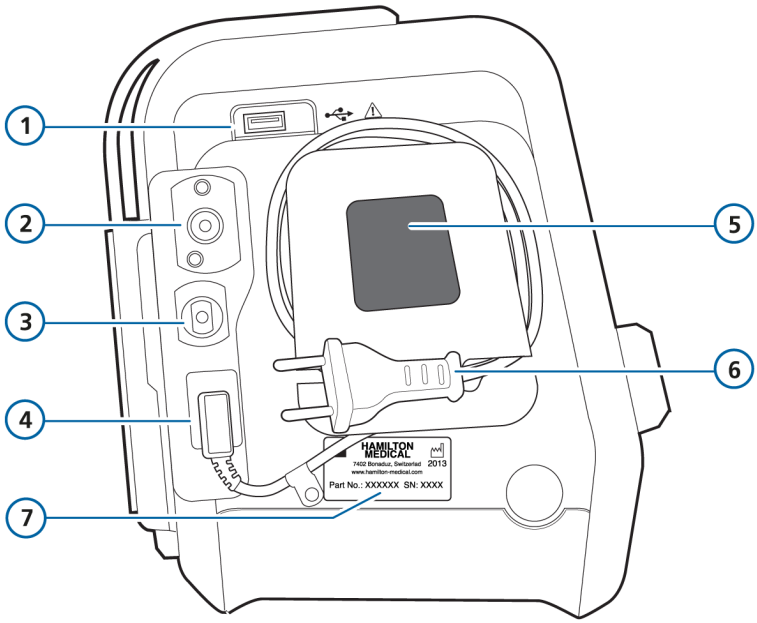
1	RJ-45 Ethernet connector (under the cover)	4	Air intake and dust filter *Do not obstruct*
2	Device labels	5	Rear cover
3	O2 sensor (under the cover)	6	HEPA air inlet filter (under the cover)

Figure 2-4. Side view, with breathing circuit connections



1		Communication board (optional)	5		Cooling air outlet
2		Pneumatic nebulizer port	6		*To patient* inspiratory port
3		Flow sensor connection ports	7		*From patient* expiratory port
4		Loudspeaker	8		Expiratory valve set

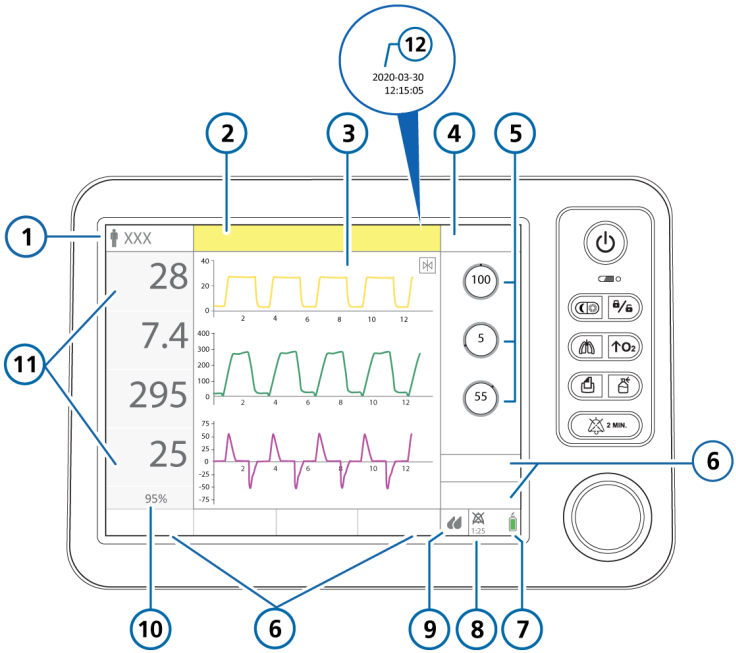
Figure 2-5. Side view, with gas connections



1	USB port (under the cover)	5	Cooling air intake and dust filter
2	High-pressure oxygen DISS or NIST inlet fitting	6	AC power cord with retaining clip
3	Low-pressure oxygen connector	7	Serial number label
4	Power socket		

2.2.2 About the main display

Figure 2-6. Main display



1	Patient group symbol and active mode	7	Power source and battery status
2	Message bar (color coded)	8	Audio pause indicator and countdown timer[1]
3	Configurable graphic display (full-length waveforms shown)	9	Humidifier quick access icon
4	Modes button	10	Measured SpO2 value[2]
5	Main controls for the active mode	11	Main monitoring parameters (MMPs)
6	Window buttons: Alarms, Controls, Monitoring, Tools, Events, System	12	Date and time

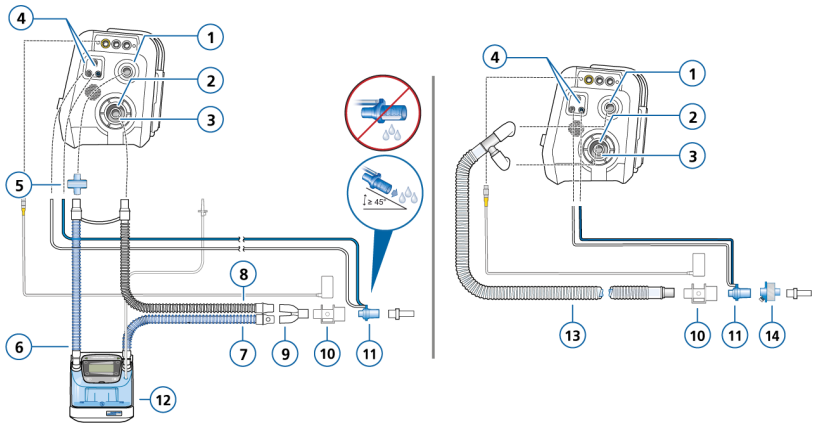
[1] When Audio pause is active, the connectivity icons are not displayed.
[2] When SpO2 sensor enabled.

2.2.3 About the patient breathing circuits sets

Figure 2-7. Adult/pediatric breathing circuits[1]

Adult/Ped: Dual limb with humidifier

Adult/Ped: Coaxial with HMEF



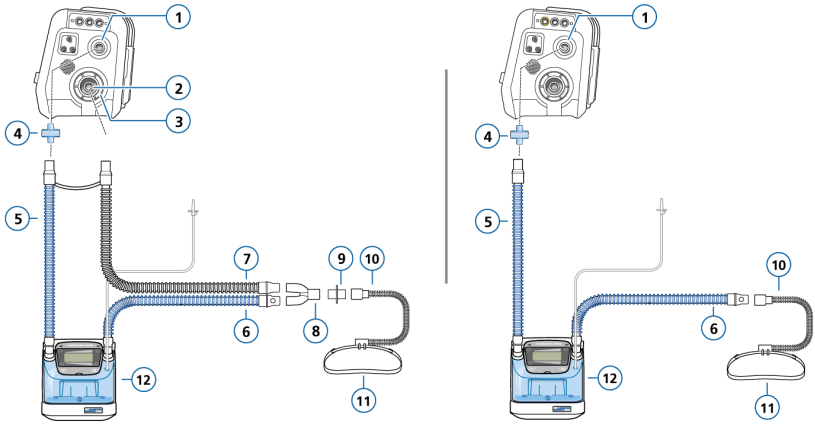
1	Inspiratory port (*To patient*)	8	Heated expiratory limb
2	Expiratory port (*From patient*)	9	Y-piece
3	Expiratory valve set	10	CO2 sensor/airway adapter
4	Flow sensor connection ports	11	Flow sensor
5	Inspiratory filter	12	Humidifier
6	Inspiratory limb to humidifier	13	Coaxial inspiratory/expiratory limb
7	Heated inspiratory limb with temperature sensor, to patient	14	Heat and moisture exchanger filter (HMEF)

[1] Some connection adapters may be required. See the breathing circuit set *Instructions for use*.

Figure 2-8. Adult/pediatric breathing circuits: high flow oxygen therapy[1]

Adult/Ped: Dual limb, high flow oxygen therapy

Adult/Ped: Single limb, high flow oxygen therapy



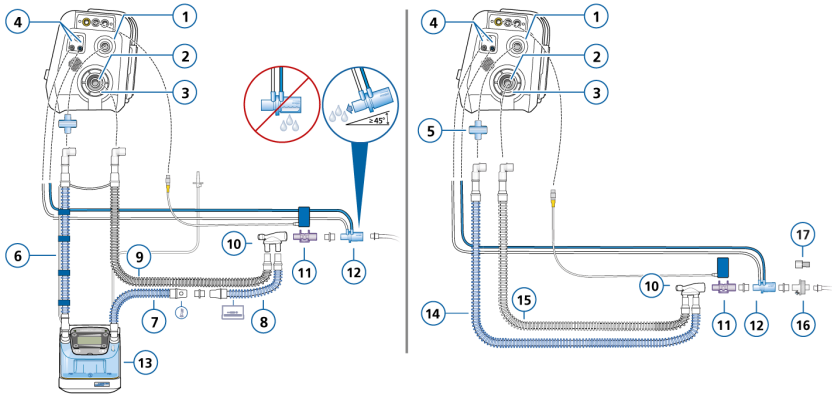
1	Inspiratory port (*To patient*)	7	Heated expiratory limb
2	Expiratory port (*From patient*)	8	Y-piece
3	Expiratory valve set	9	Adapters (various)
4	Inspiratory filter	10	Nasal cannula
5	Inspiratory limb to humidifier	11	Attachment strap
6	Heated inspiratory limb with temperature sensor, to patient	12	Humidifier

[1] Some connection adapters may be required. See the breathing circuit set *Instructions for use*.

Figure 2-9. Neonatal breathing circuits[1]

Neonatal/pediatric: Dual limb, active humidification with humidifier

Neonatal/pediatric: Dual limb, passive humidification with HME/F

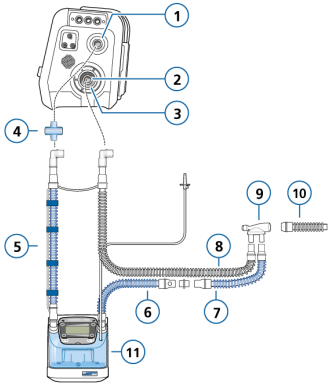


1	Inspiratory port (*To patient*)	10	Y-piece
2	Expiratory port (*From patient*)	11	CO2 sensor/airway adapter[1]
3	Expiratory valve set	12	Neonatal flow sensor
4	Flow sensor connection ports	13	Humidifier
5	Inspiratory filter	14	Inspiratory limb
6	Inspiratory limb to humidifier	15	Expiratory limb
7	Heated inspiratory limb with temperature sensor, to patient	16	Heat and moisture exchanging filter (pediatric HMEF)
8	Unheated inspiratory limb extension, for use in incubator[1]	17	Heat and moisture exchanger (neonatal HME)
9	Heated expiratory limb		

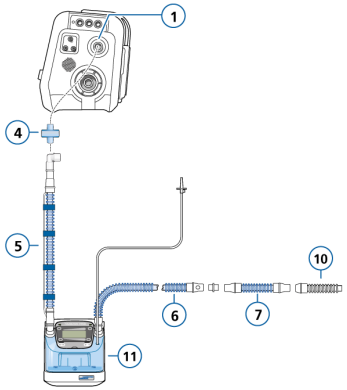
[1] Some connection adapters may be required. See the breathing circuit set *Instructions for use*.

Figure 2-10. Neonatal breathing circuits: high flow oxygen therapy[1]

Neonatal/pediatric: Dual limb, high flow oxygen therapy



Neonatal/pediatric: Single limb, high flow oxygen therapy

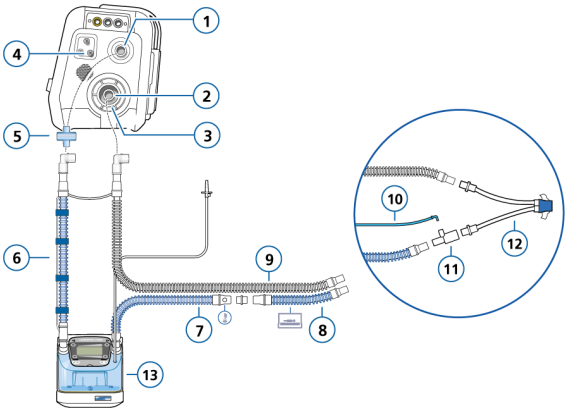


1	Inspiratory port (*To patient*)	7	Unheated inspiratory limb extension, for use in incubator
2	Expiratory port (*From patient*)	8	Heated expiratory limb
3	Expiratory valve set	9	Y-piece
4	Inspiratory filter	10	Connection to patient interface (options not shown)
5	Inspiratory limb to humidifier	11	Humidifier
6	Heated inspiratory limb with temperature sensor, to patient		

[1] Some connection adapters may be required. See the breathing circuit set *Instructions for use*.

Figure 2-11. Neonatal breathing circuit: nCPAP, nCPAP-PC[1]

Neonatal: nCPAP, nCPAP-PC



1	Inspiratory port (*To patient*)	8	Unheated inspiratory limb extension, for use in incubator[1]
2	Expiratory port (*From patient*)	9	Heated expiratory limb
3	Expiratory valve set	10	Pressure line
4	Flow sensor connection port (blue) for pressure line	11	T-piece, connect tubing to blue flow sensor connection port
5	Inspiratory filter	12	nCPAP generator, connected to mask or nasal prongs
6	Inspiratory limb to humidifier	13	Humidifier
7	Heated inspiratory limb with temperature sensor, to patient		

[1] Some connection adapters may be required. See the breathing circuit set *Instructions for use*.

2.2.4 About the trolley and mounting variations

The HAMILTON-C1 can optionally be ordered with a trolley or a shelf mount solution. The trolley has space for one oxygen cylinder.

2.2.4.1 Preparing the trolley for transport within the hospital

Before proceeding, review the safety information in Chapter 1.

⚠ WARNING

- *Only* the components listed in this section are approved for intrahospital transport.
- Use of additional items can result in the trolley tipping over.
- The ventilator must be attached to the trolley using the locking bolt. Ensure the device is securely attached to the trolley before use.

If using a HAMILTON-C1 trolley, the ventilator and its components, as well as the trolley, **must be** configured and positioned as follows during transport within the hospital:

- The ventilator and oxygen cylinders must be securely attached to the trolley.
- *Only* the following components are allowed to be connected during transport:
  - Breathing circuit set
  - Tubing support arm
  - Flow sensor (or pressure line)
  - CO2 sensor (mainstream or sidestream)
  - O2 cylinder
  - HME/F, inspiratory and expiratory filters
  - SpO2 sensor, including Masimo adapter
  - Humidifier
  - Water bottle
  - Water feed tube for water bottle
  - Water bottle holder
  - Basket

2.3 Turning the ventilator on and off

To ensure the Event log records all events properly, do the following:

- When entering Standby, wait at least 30 seconds before turning off the ventilator.
- After turning off the ventilator, wait at least 3 seconds before turning the ventilator back on.

To turn on the ventilator

▸ Press ⏻ (Power/Standby).

The ventilator runs a self-test. The self-test includes testing the alarm system, including the speaker, buzzer, and alarm lamp.

After a short time, the Standby window is displayed.

Proceed with setting up the ventilator and patient, as appropriate.

If the startup process does not complete successfully when turning on the ventilator, proceed as follows.

To turn on the ventilator if startup is not successful

1. Turn off the ventilator by pressing and holding ⏻ for about 10 seconds.
2. Turn the ventilator on again by pressing ⏻.

Figure 2-12. Power/Standby key (1)

To turn off the ventilator

1. Press ⏻ to open the Activate Standby window during active ventilation.
2. Touch **Activate standby** to confirm.
   The ventilator enters Standby.
3. Press and hold ⏻ for about 3 seconds to turn off the ventilator.

The ventilator turns off.

In the event of a technical fault or the device will not turn off

▸ Press and hold ⏻ for about 10 seconds to turn off the ventilator.

2.4 Navigating the display and controls

Use the touch screen and the Press-and-turn knob (referred to as the *P&T knob*) to access data and specify settings.

You interact with the HAMILTON-C1 user interface as follows:

- Touch elements on the display to open windows and make and confirm selections.
- Use the P&T knob to select, specify, and confirm selections. A selected item is highlighted in yellow.

This section describes how to navigate the interface.

2.4.1 Accessing features and functions

To open a window

- Do either of the following to open a window:
  - Touch the button and any needed tabs.
  - Turn the P&T knob to move the cursor to the button or tab, then press the P&T knob.

To close a window

- Do any of the following to close a window:
  - Touch the window button again.
  - Touch the [X] button.
  - Turn the P&T knob to move the cursor to the [X] button, then press the P&T knob.

2.4.2 Adjusting controls

Specifying settings involves *activating* a control, *adjusting* a value, and *confirming* the setting.

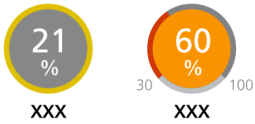
To adjust a control setting

1. **Activate** the control by doing either of the following:
   - Touch the control to select and activate it; the selected control has a yellow outline.
   - Turn the P&T knob to move the cursor to the control; the selected control has a yellow outline. Press the P&T knob to activate it.

   The activated control is orange (Figure 2-13).
2. **Adjust** the value by turning the P&T knob to increase or decrease the value. The orange dot indicates the dynamic limit.
3. **Confirm** the setting by doing either of the following:
   - Touch the control again.
   - Press the P&T knob.

The new setting is immediately applied.

Figure 2-13. Control status: selected (left), activated (right)



2.4.3 Selecting list items

Some selections are presented in a scrollable list.

To select a list item

1. In a list, touch the scroll bar to select and activate it.
2. Turn the P&T knob to scroll through the list, and when the desired selection is highlighted, press the knob to select it.

2.4.4 Using shortcuts

The ventilator provides shortcuts for some key functions.

Table 2-3. Shortcuts

Touch Quick access icon/ shortcut on main display ...	To display the ...
, , or	Controls > Patient window
Active mode (top left of display)	Modes window
Any MMP	Alarms > Limits 1 window
SpO2 value (under MMPs)	Alarms > Limits 2 window
Any graphic (waveform, loop, trend, Intelligent panel)	Graphics selection window
(any displayed battery icon)	System > Info 1 window
2017-08-07 07:11:58	System > Settings > Date & Time window
or 1:40	Alarms > Buffer window
Alarm message in the Alarms > Buffer window	On-screen alarm troubleshooting help
	System > Settings > Humidifier window[1]
[2]	System > Settings > Connectivity window When an Audio pause is active, the connectivity icon is *not* displayed.

[1] If connected to the /COM1 port on the ventilator.
[2] If the option is installed. Not available in all markets.

3
Preparing the ventilator

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3.3 Connecting the oxygen supply 70
3.4 Setting up the patient breathing circuit set 71

3.1 Overview

Preparing the ventilator for use comprises the following steps:

To ...	See ...
Connect to a power source.	Section 3.2
Connect the oxygen supply.	Section 3.3
Set up the patient breathing circuit, including performing the preoperational check.	Section 3.4
Connect external devices and sensors.	Chapter 4
Turn on the ventilator.	Section 2.3
Select the patient group, mode, and alarm limits, and enter patient data.	Chapter 5

3.2 Connecting to a power source

Before proceeding, review the safety information in Chapter 1.

NOTICE

Only use power supply cords that are compliant with IEC 60601-1 requirements. Additional national standards and requirements may apply.

To connect the ventilator to a primary power supply

- Connect the ventilator to an outlet that supplies AC power.

  Make sure the power cord is well seated into the ventilator socket and secured with the power cord retaining clip to prevent unintentional disconnection.

Always check the reliability of the primary power outlet before plugging in the ventilator. The charge icon above the battery shows that the ventilator is plugged in and the battery is charging.

3.2.1 Using battery power

A mandatory backup battery protects the ventilator from low power or failure of the primary power source.

When the primary power source fails, the ventilator automatically switches to operation on backup battery with no interruption in ventilation. An alarm sounds to signal the switch-over. Silence the alarm to confirm notification of the power system change and reset the alarm.

If battery power is completely lost, a buzzer sounds continuously for at least two minutes.

The battery is charged whenever the ventilator is connected to primary power, whether or not it is turned on. The battery indicator on the device (Figure 3-1) shows the charge status of the battery.

The battery and power source symbols in the bottom right corner of the display show the power source in use. See Table 3-1.

Figure 3-1. Power source indicators on display

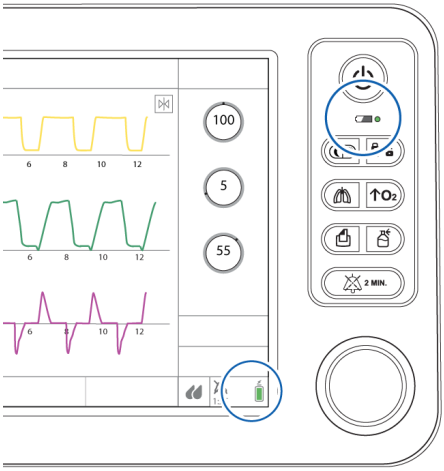


Table 3-1. Battery/power state

Power icon on display	Battery status
	Device is plugged into primary power and the battery is charging.
	Device is running on battery power and battery is fully charged.
	Battery is partially charged.
	Battery has less than 10% charge left.
	Battery is either defective or not installed.

Table 3-2. Battery charge indicator on ventilator, overview

Indicator on venti-lator	Battery status
1	*Solid green:* The indicated battery (1 shown) is fully charged and the device is connected to primary power, even when the ventilator is turned off.
1	*Flashing green:* Flashes to show that the device is connected to a primary power source and the indi-cated battery is charging, even when the ventilator is turned off.
1	*Not lit:* Dark to show the indi-cated battery is not charging (the device is running on battery power and is not connected to a primary power source or the battery is overheated).

If the battery is not fully charged, recharge it by connecting the ventilator to the primary power source. For details, see Section 15.4.

3.3 Connecting the oxygen supply

Before proceeding, review the safety information in Chapter 1.

Oxygen for the HAMILTON-C1 can be provided by a high- or low-pressure source.

High-pressure oxygen, provided by a central gas supply or a gas cylinder, is supplied through DISS or NIST male gas fittings. With the optional cylinder holder, you can mount an oxygen cylinder to the trolley.

If you use the cylinder, it must be secured to the trolley with the accompanying straps.

Low-pressure oxygen is provided by a concentrator or liquid cylinder.

The selected setting is active until manually changed or the ventilator is restarted.

3.3.1 Using a low-pressure oxygen supply

Using the low-pressure oxygen supply[1] involves two steps:

- Connecting the supply to the ventilator (Section 3.3.2)
- Selecting the source type on the ventilator (Section 3.3.3)

3.3.2 Connecting the oxygen supply to the ventilator

To connect the oxygen supply to the ventilator

- Connect the oxygen hose to the HAMILTON-C1's high-pressure or low-pressure oxygen inlet fitting (Figure 2-5).

See Section 3.3.3 for details on selecting the oxygen source on the device.

3.3.3 Selecting the oxygen source type

Before starting ventilation, be sure to select the appropriate oxygen source. By default, the ventilator is set to high-pressure oxygen (HPO).

You set the source in Standby.

To select the oxygen source

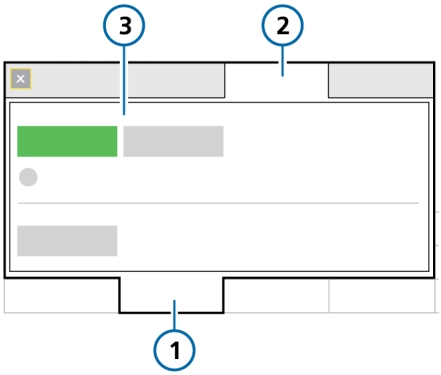
1. In Standby mode, touch **Tools** > **Utilities**.
2. Touch the appropriate button for the desired oxygen source.

   – Select **HPO mode** for high-pressure oxygen (default).

   – Select **LPO mode** for low-pressure oxygen (see Section 3.3.1).
3. Close the window.

[1] Not available in all markets.

Figure 3-2. Selecting the oxygen source



1	Tools	3	HPO mode, LPO mode
2	Utilities		

3.4 Setting up the patient breathing circuit set

Before proceeding, review the safety information in Chapter 1.

Connecting the breathing circuit comprises the following steps.

For neonatal ventilation, see Chapter 6.

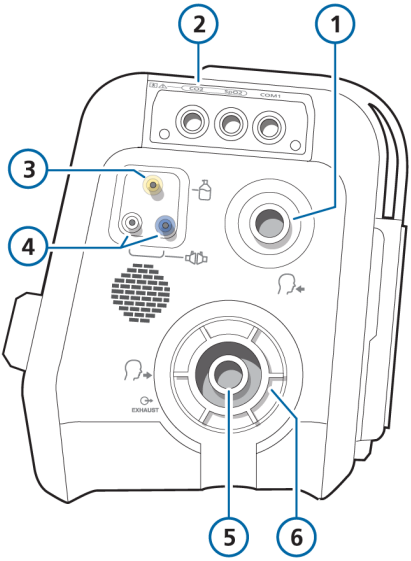
To ...	See ...
Select the appropriate breathing circuit set and components.	Section 3.4.2
Install the expiratory valve set.	Section 3.4.3
Assemble the breathing circuit set, and connect it to the ventilator.	Section 3.4.4
Adjust the position of the breathing circuit after connection.	Section 3.4.5
Change breathing circuit components during ventilation	Section 3.4.6
Connect external devices and sensors.	Chapter 4
Perform any required tests, calibrations, and the preoperational check.	Chapter 5

3.4.1 Breathing circuit set connections on the ventilator

Figure 3-3 illustrates the key ports on the ventilator for connecting the breathing circuit set.

For breathing circuit diagrams, see Section 2.2.3.

Figure 3-3. Key connection ports



1	Inspiratory port (*To patient*)	4	Flow sensor connection ports
2	Communication board (optional)	5	Expiratory port (*From patient*)
3	Nebulizer port	6	Expiratory valve set

3.4.2 Breathing circuit set components

Select the correct breathing circuit parts for your patient.

For neonatal ventilation, see Chapter 6.

Table 3-3. Breathing circuit component specifications

Patient data/ Component	Adult	Pediatric
Patient height (cm)	> 130	30 to 150
IBW (kg)	> 30	3 to 48
Breathing circuit limb ID (mm)[1]	15 to 22	10 to 22
Flow sensor	Adult/Ped	Adult/Ped
CO2 airway adapter	Adult/Ped[2]	Adult/Ped[2]

[1] When using coaxial breathing sets, follow the manufacturer's recommendations for each patient group.
[2] When tracheal tube ID > 4 mm.

3.4.2.1 Using breathing system filters

⚠ WARNING

To prevent patient or ventilator contamination, always use a filter in the inspiratory gas path. If no inspiratory filter is used, the exhaled gas can contaminate the ventilator. If the ventilator becomes contaminated, have it serviced.

NOTICE

When connecting a breathing system filter to the inspiratory or expiratory port, pay special attention to the fit and seal of the filter to the port, in particular with filters that offer additional connectors (such as a Luer connector on the filter housing).

For proper function, it is important that all components in the breathing circuit set are properly positioned and securely connected.

Before proceeding, review the safety information in Chapter 1.

Inspiratory filter

To prevent patient or ventilator contamination, be sure to connect a breathing system filter in the inspiratory gas path.

For neonatal patients, use a neonatal-pediatric heat and moisture exchanger (HME), which contributes less dead space to the circuit, together with an inspiratory filter connected at the ventilator inspiratory port.

If no inspiratory filter or heat and moisture exchanging filter (HME/F) is used, the exhaled gas can contaminate the ventilator.

If you are not using a filter in the inspiratory gas path, either ventilator-side on the inspiratory port or a patient-side HME/F, and an Exhalation obstructed alarm is generated, the ventilator may be contaminated. Have the ventilator serviced.

Expiratory filter

Before using an expiratory filter with nebulization, review the safety information in Section 1.6.5.

An expiratory filter is not technically required on the HAMILTON-C1. The expiratory valve design prevents internal ventilator components from coming into contact with the patient's exhaled gas, preventing any cross-contamination. However, your institution's protocol for certain circumstances may require the use of an expiratory filter for infection control.

If you use an expiratory filter, place it on the patient side of the expiratory valve set. Monitor closely for increased expiratory circuit resistance. RCexp (expiratory time constant) monitors the rate at which the lungs empty. See Section 8.4.1.

An Exhalation obstructed alarm may also indicate excessive expiratory circuit resistance. If the Exhalation obstructed alarm occurs repeatedly, remove the expiratory filter immediately. If you otherwise suspect increased expiratory circuit resistance, replace with a new, low resistance expiratory filter to eliminate it as a potential cause.

Heat and moisture exchanging filter (HMEF)

Use an HMEF when ventilating with an unheated coaxial breathing circuit set.

The HMEF combines the filtration efficiency of a breathing system filter with passive humidification – moisture capture and return from patient's exhaled gas.

For neonatal patients, use a neonatal-pediatric heat and moisture exchanger (HME), which contributes less dead space to the circuit, together with an inspiratory filter connected at the ventilator *To patient* inspiratory port.

3.4.2.2 Using a speaking valve in the breathing circuit

A speaking valve allows certain tracheostomized adult and pediatric patients to communicate verbally.

SpeakValve compatibility is an option available for Adult/Ped invasive ventilation when using any of the following modes: PCV+, PSIMV+, and SPONT.

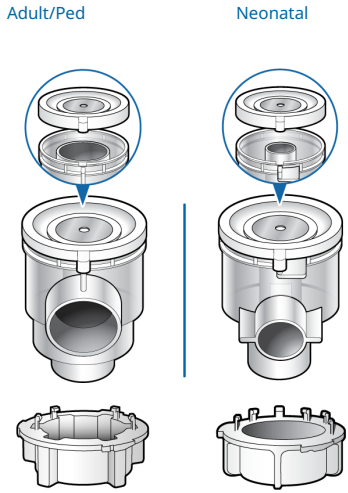
For setup details, see Section 4.7. For details about working with SpeakValve, see Section 10.9.

3.4.3 Installing/removing the expiratory valve set

This section describes how to assemble/install, and remove/disassemble the expiratory valve set.

Be sure to install the correct expiratory valve for the selected patient group.

Figure 3-4. Comparison between the Adult/Ped and Neonatal expiratory valves

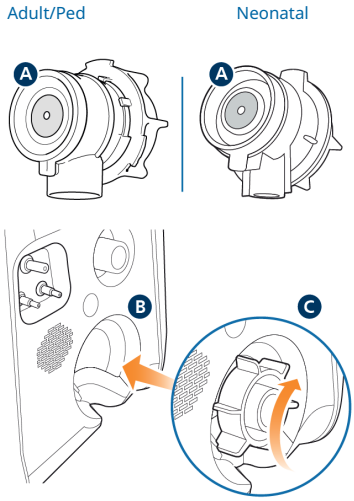


To assemble/install the expiratory valve set

Refer to Figure 3-5.

1. Remove the safety cover.
2. Ensure the membrane is properly aligned with the expiratory valve housing and the metal plate faces up (**A**).
3. Position the expiratory valve set in the expiratory port (**B**) and twist the locking ring clockwise until it locks into place (**C**).

Figure 3-5. Installing the expiratory valve set



To remove and disassemble the expiratory valve set

1. Remove the expiratory valve set from the expiratory port on the ventilator.
2. Holding the expiratory valve housing, remove the silicone membrane (**A** in Figure 3-5) by lifting it up and away.
3. Dispose of the expiratory valve appropriately.

   A used component must be handled as contaminated. Follow all local, state, and federal regulations with respect to waste management and environmental protection when disposing of used parts.

3.4.4 Assembling and connecting the patient breathing circuit set

Assemble the appropriate breathing circuit set for your patient. Commonly used standard breathing circuit configurations are illustrated in Section 2.2.3.

For neonatal setup, see Chapter 6.

3.4.4.1 Connecting the flow sensor

NOTICE

To prevent inaccurate flow sensor readings, make sure the flow sensor is correctly connected. The flow sensor tubes must *not* be kinked.

Before proceeding, review the safety information in Chapter 1.

To connect a flow sensor to the breathing circuit

1. Insert a flow sensor into the breathing circuit in front of the patient connection (Figure 3-6).

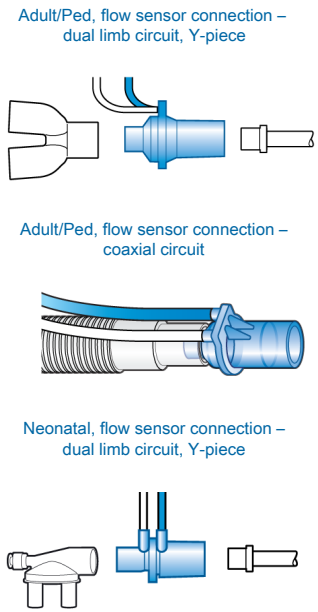
   See also the breathing circuit diagrams in Section 2.2.3.

2. Attach the blue and clear tubes to the flow sensor connection ports on the ventilator (Figure 3-3).

   The blue tube attaches to the blue connection port. The clear tube attaches to the white connection port.

3. Calibrate the flow sensor and perform the Leak test. See Section 5.4.

Figure 3-6. Connecting the flow sensor to the Y-piece or circuit



3.4.4.2 Use of adult/pediatric flow sensor with neonatal/pediatric breathing circuits

With small pediatric patients whose IBW is below 20 kg, using an adult/pediatric breathing circuit can generate too much dead space, resulting in ineffective ventilation.

For these patients, consider using a neonatal/pediatric breathing circuit with an adult/pediatric flow sensor instead.

To use an adult/pediatric flow sensor with a neonatal/pediatric breathing circuit

1. Verify that the Adult/Ped patient group is selected.
2. Verify that the patient IBW is below 20 kg.
3. Set up the ventilator for adult/pediatric ventilation with the adult/pediatric flow sensor, but connect a neonatal/pediatric breathing circuit.
4. Perform the Leak test, calibrate the flow sensor, and perform other preoperational checks. See Section 5.4.
5. Connect the patient.
6. Start ventilation.

3.4.5 Positioning the breathing circuit set and device

NOTICE

- To prevent water accumulation in the flow sensor and tubing, position the flow sensor tubing on top of the flow sensor.
- Ensure there is no undue stress placed on any tubing or cables.

After assembly, position the breathing circuit so that the hoses will *not* be pushed, pulled, or kinked as a result of a patient's movement, transport, or other activities, including scanner bed operation and nebulization.

The next step is to perform all required tests, calibrations, and the preoperational check. See Chapter 5.

3.4.6 Changing breathing circuit set components during ventilation

During ventilation, it may be necessary to add components to the breathing circuit, or to change existing components. To do so in the safest manner for the patient and personnel, we recommend following this general process:

To change the breathing circuit set components during ventilation

1. Enter Standby.
2. Provide alternative respiratory support for the patient.
3. Change or add components, in accordance with your institution's standards and protocols. See Section 1.5.1 for important safety information.
4. Perform the preoperational check (Section 5.4).
5. Re-connect the patient.
6. Resume ventilation.
7. Verify settings.

4

Setting up external devices and sensors

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4.1 Overview

The HAMILTON-C1 supports a variety of external devices and sensors for ventilation, including:

- Humidifier
- CO2 monitoring sensors
- Pulse oximetry (SpO2 monitoring) sensors
- Nebulizers
- SpeakValve

This chapter describes how to set them up for ventilation.

4.2 Setting up a humidifier

Before proceeding, review the safety information in Chapter 1.

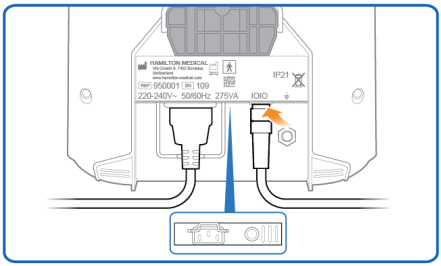
When used with the optional HAMILTON-H900 humidifier, the ventilator supports remote access to the humidifier controls and status.[1,2]

Other humidifiers are supported, without the integration. To connect a non-Hamilton Medical humidifier, refer to the manufacturer's *Instructions for use*.

To connect the HAMILTON-H900 humidifier to the ventilator

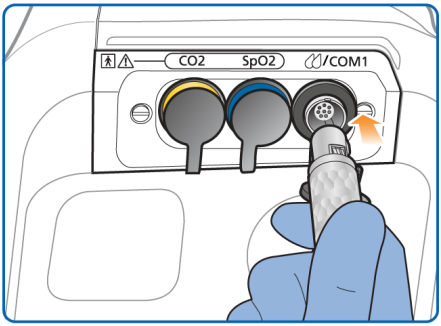
1. Attach the humidifier to the trolley, if appropriate. See the *Installation Guide for HAMILTON-H900 Humidifier on HAMILTON-C1/T1 Trolley* (PN 10099119).
2. Connect a potential equalization cable to the humidifier and to a grounding socket at your facility.
3. Plug the humidifier into primary power.
4. Connect the communication cable:
   – Connect one end of the cable to the humidifier (Figure 4-1).
   – Connect the other end of the cable to the /COM1 port on the communication board (Figure 4-2).

Figure 4-1. Connect communication cable to the humidifier



[1] Not available in all markets.
[2] Supported for HAMILTON-H900 software version 1.05b and later.

Figure 4-2. Connect HAMILTON-H900 to the ventilator



For additional details about:

- Connecting the humidifier to the breathing circuit, see Section 2.2.3.
- Working with the humidifier, see the *HAMILTON-H900 Instructions for use*.
- Controlling the humidifier from the ventilator, see Chapter 11.

4.3 Setting up CO2 monitoring

Before proceeding, review the safety information in Chapter 1.

CO2 monitoring data is helpful for the assessment of the patient's airway integrity or ensuring proper endotracheal tube placement, among other applications.

Two CO2 measurement options are available: mainstream and sidestream. Which option you use depends on the clinical setting.[1] For calibration information, see Section 5.4.

Enabling CO2 measurement on the ventilator requires enabling the CO2 hardware (in Configuration) and enabling the sensor.

Table 4-1. CO2 measurement overview

For details about ...	See ...
Enabling the CO2 hardware	Section 13.12.3
Mainstream CO2 measurement, connection, and use	Section 4.3.1
Sidestream CO2 measurement, connection, and use	Section 4.3.2
Enabling the CO2 sensor	Section 4.5

[1] The volumetric capnogram is only available when using a mainstream CO2 sensor.

4.3.1 Mainstream CO2 measurement

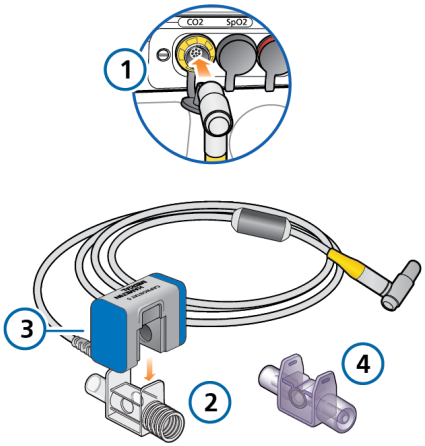
The CO2 monitoring option comprises the following components (shown in Figure 4-3): communication board, airway adapter, and CO2 sensor.

The sensor generates infrared light and beams it through the airway adapter to a detector on the opposite side. CO2 from the patient, flowing through the mainstream airway adapter, absorbs some of this infrared energy.

The system determines the CO2 concentration in the breathing gases by measuring the amount of light absorbed.

The ventilator displays CO2 measurements as numeric values, waveforms, trends, and loops.

Figure 4-3. Mainstream CO2 monitoring components and assembly



1	Communication board with CO2 connection port	3	CO2 sensor
2	Airway adapter (Adult/Ped.)	4	Airway adapter (Neonatal)

4.3.1.1 Connecting the mainstream CO2 sensor

Before proceeding, review the safety information in Chapter 1.

⚠ CAUTION

When using active humidification, prevent water accumulation in the CO2 airway adapter by ensuring that it is positioned at a ≥ 45° angle relative to the floor. Excess water can affect the sensor measurements.

NOTICE

You must use an appropriate adapter to connect the mainstream CO2 neonatal airway adapter to a neonatal flow sensor.

Ensure the CO2 sensor and airway adapter are clean and dry before connection.

To set up mainstream CO2 monitoring

Refer to Figure 4-3.

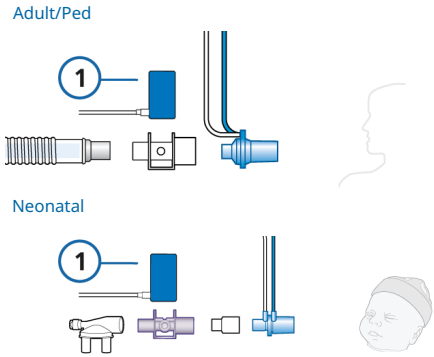
1. Connect the sensor cable to the CO2 connection port (**1**) on the ventilator.
2. Attach the CO2 sensor (**3**) to the airway adapter (**2**), aligning the arrows on both components.

   Press the components together until they click.
3. If needed, connect the potential equalization USB cable to the USB port and a grounding socket at your facility.[1]
4. When connecting a CO2 sensor for the first time, perform the zero calibration of the sensor/airway adapter, if needed, as described in Section 5.4.5.
5. Connect the sensor/adapter to the breathing circuit proximal to the patient, in a vertical position. See Figure 4-4.

   Do *not* place the airway adapter between the ET tube and any connected adapter, as this may allow patient secretions to accumulate in the adapter.[2]

   The cable side of the sensor should face away from the patient.
6. Secure the cable safely out of the way.

Figure 4-4. Connecting CO2 sensor/airway adapter (1) to breathing circuit



To verify the quality of the connection

- Check the capnogram (CO2 waveform) on the ventilator display.

  If CO2 levels are higher than expected, check the patient condition. If you determine that the patient's condition is not contributing, calibrate the sensor (Section 5.4.5).

[1] Recommended in all cases. Not required when the device is running on DC or battery power, or when the communication Y-cable to HAMILTON-H900 and RS-232 is in use.
[2] You can connect the CO2 sensor in front of or behind the flow sensor according to your institution's protocol.

To disconnect the sensor cable from the ventilator

- Pull back on the connector sheath and disengage from the connection port on the ventilator.

4.3.2 Sidestream CO2 measurement

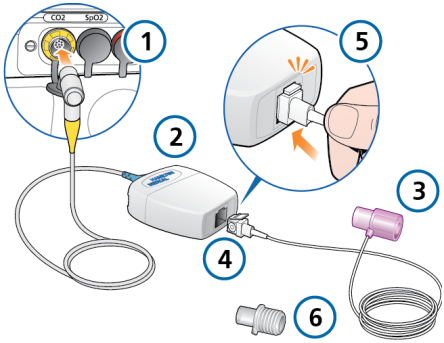
The LoFlo CO2 module is a sidestream CO2 monitoring system comprising the following components (shown in Figure 4-5): communication board, airway sampling adapter, sampling cell, and CO2 module.

The module generates infrared light and beams it through the sample cell to a detector on the opposite side. CO2 from the patient that is aspirated into the sample cell absorbs some of this energy. The system uses a sampling rate of 50 ml/min.

The system determines CO2 concentration in the breathing gases by measuring the amount of light absorbed.

The ventilator displays CO2 measurements as numeric values, waveforms, trends, and loops.

Figure 4-5. Sidestream CO2 monitoring components and assembly



1	Communication board with CO2 connection port	4	Sampling cell
2	CO2 module	5	Connecting sampling cell to module
3	Airway sampling adapter (Neonatal)	6	Adapter ID15/ OD15

4.3.2.1 Connecting the sidestream CO2 sensor

⚠ WARNING

Connect the CO2 airway adapter according to your institution's policy and procedures. Connecting the airway adapter between the flow sensor and the endotracheal tube increases dead space and may contribute to incorrect volume measurements.

Before proceeding, review the safety information in Chapter 1.

To set up CO2 sidestream monitoring

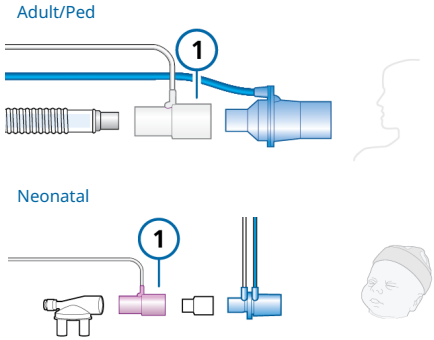
Refer to Figure 4-5.

1. Connect the CO2 module cable to the CO2 connection port (**1**) on the ventilator.
2. Insert the sample cell (**4**) into the CO2 module (**2**). The sample cell clicks into place.

   Inserting the sample cell into the module automatically starts the sampling pump. Removing the cell turns the pump off.
3. If needed, connect the potential equalization USB cable to the USB port and a grounding socket at your facility.[1]
4. Perform the zero calibration of the adapter, if necessary, as described in Section 5.4.5 before connecting it to the breathing circuit.
5. Connect the adapter between the inspiratory limb and the flow sensor (or between the inspiratory limb and HMEF, if used). See Figure 4-6.

   The sampling line should face away from the patient.
6. Secure the sampling line safely out of the way.

Figure 4-6. Connecting CO2 adapter (**1**) to the breathing circuit[2]



To remove the sample cell

1. Remove the airway adapter from the breathing circuit.
2. Press down on the locking tab and remove the sample cell from the CO2 module.

[1] Recommended in all cases. Not required when the device is running on DC or battery power, or when the communication Y-cable to HAMILTON-H900 and RS-232 is in use.
[2] If the option is installed and activated.

4.4 Setting up SpO2 monitoring

The HAMILTON-C1 supports input of SpO2 and related pulse oximetry data, and provides integrated monitoring and data display.

Enabling SpO2 measurement on the ventilator requires enabling the SpO2 hardware (in Configuration) and enabling the SpO2 sensor.

Table 4-2. SpO2 measurement overview

For details about ...	See ...
Activating the SpO2 hardware	Section 13.12.3
Enabling the SpO2 sensor	Section 4.5
Working with SpO2 data	*Pulse Oximetry Instructions for Use*

4.5 Enabling sensors

Before proceeding, review the safety information in Chapter 1.

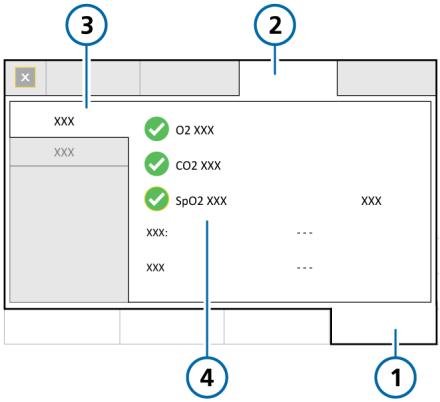
In addition to hardware activation for CO2 and SpO2 measurement (Section 13.12.3), the O2, CO2, and/or SpO2 sensors must be individually enabled for monitoring data to be available.

To enable sensor monitoring

1. Touch **System** > **Sensors** > **On/Off**.
2. Select the appropriate checkboxes (O2 sensor, CO2 sensor, SpO2 sensor) to enable/disable the monitoring functions, as desired.

The ventilator always enables O2 monitoring upon restart.

Figure 4-7. System > Sensors > On/Off window



1	System	3	On/Off
2	Sensors	4	O2 sensor, CO2 sensor[1], SpO2 sensor[1]

[1] If the option is installed and activated.

4.6 Setting up nebulization

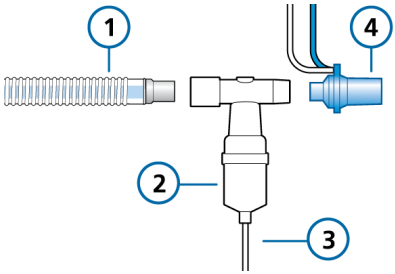
The HAMILTON-C1 supports the use of Aerogen and pneumatic nebulizers for adult and pediatric patients.[1]

For neonatal patients, use an Aerogen nebulizer system[2]; the use of pneumatic nebulizers is *not* supported. For Aerogen connection and device details, refer to the manufacturer's *Instructions for use*.

To connect a pneumatic nebulizer to the breathing circuit set

1. Connect the nebulizer to the breathing circuit as shown in Figure 4-8.
2. Connect the nebulizer tubing to the Nebulizer port on the ventilator (Figure 2-4).

Figure 4-8. Connecting a pneumatic nebulizer[3]



1	Breathing circuit (coaxial shown)	3	Nebulizer tubing to ventilator
2	Nebulizer	4	Flow sensor

For additional details, refer to the manufacturer's Instructions for use.

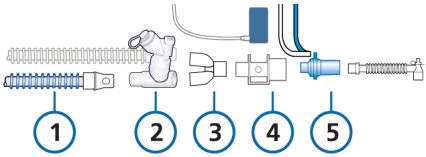
To connect an Aerogen nebulizer to the breathing circuit set

1. Connect the nebulizer to the breathing circuit as appropriate. See Figure 4-9.
2. Connect the nebulizer USB cable to the ventilator USB port or an external power supply.

For nebulizer details and operation, see Section 10.8.

The following figure presents a nebulizer placement example. For other placement options, see the *Nebulizer positioning guidelines* (ELO2020-124-TW), available in the Hamilton Medical Resource Center (https://www.hamilton-medical.com/Resource-center), and the manufacturer's *Instructions for use*.

Figure 4-9. Connecting an Aerogen nebulizer



1	Inspiratory limb	4	CO2 airway adapter/sensor (optional)
2	Aerogen nebulizer	5	Flow sensor
3	Y-piece		

[1] See the Hamilton Medical e-catalog for compatible devices.
[2] Aerogen nebulization is not supported for patients younger than 28 days old in the USA.
[3] Not applicable when the HAMILTON-C1 neo option is enabled and the ventilator is dedicated to neonatal ventilation.

4.7 Setting up a speaking valve

⚠ CAUTION

- *Do not leave the patient unattended when SpeakValve is turned ON and a speaking valve is connected to the patient.*
- *When SpeakValve is turned on:*

  – Apnea backup ventilation is disabled. When SpeakValve compatibility is turned off, Apnea backup ventilation returns to its previous settings.

  – Some alarm limits are changed and some alarms are disabled. For details, see Section 10.9.4.

  – Some changes apply to monitoring parameters. For details, see Section 10.9.3.

A speaking valve allows certain tracheostomized adult and pediatric patients to communicate verbally, in addition to numerous other clinical benefits.

Table 4-3 describes the steps required to set up the patient for ventilation with a speaking valve.

Table 4-3. Speaking valve patient setup

To ...	See ...
Connect the speaking valve	
Select a compatible mode.	Section 10.9
Turn on (activate) SpeakValve compatibility.	Section 4.7.1
Deflate the tracheostomy cuff.	
Connect the speaking valve to the breathing circuit set and patient.	Section 4.7.2
Review control settings and alarm limits.	Section 10.9.4 and Chapter 5
Start ventilation.	
Remove the speaking valve	
Remove speaking valve from the breathing circuit.	
Turn off (deactivate) SpeakValve compatibility.	Section 4.7.3
Inflate the tracheostomy cuff.	
Review control settings and alarm limits.	Section 10.9.4 and Chapter 5

4.7.1 Activating SpeakValve compatibility

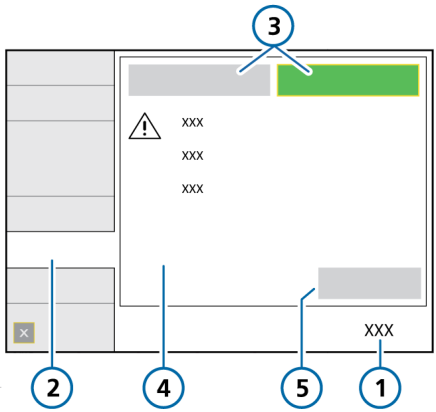
NOTICE

If PEEP > 0, auto-triggering can occur while using a speaking valve.

SpeakValve compatibility is available only in the following modes: PCV+, PSIMV, and SPONT. See Section 10.9.

By default, speaking valve compatibility is deactivated (OFF).

Figure 4-10. Controls > SpeakValve window



1	Controls	4	Important safety information
2	SpeakValve	5	Apply
3	SpeakValve ON, SpeakValve OFF		

To activate the use of a speaking valve with the ventilator

1. Touch **Controls** > **SpeakValve**.

   Be sure to carefully read the safety information displayed in the window.

2. Be sure to do the following:

   – Deflate the tracheostomy cuff.

   – Connect a speaking valve.

3. To activate compatibility, touch **SpeakValve ON**, then touch **Apply**.

   Consider setting PEEP to 0 while compatibility is activated.

As long as compatibility is activated, the message SpeakValve ON is active and the following safety messages are shown in the SpeakValve window:

The tracheostomy cuff must be completely deflated prior to connecting a speaking valve.

Disconnection alarms and the Inspiratory limitation alarm are disabled. The Vt alarms are based on VTI. The ExpMinVol alarm limits are set to OFF. Apnea backup ventilation is disabled.

4.7.2 Connecting a speaking valve to the breathing circuit set

Connect the speaking valve between the flow sensor and the patient interface.

Pay careful attention to any safety information and requirements for cuff deflation.

For connection details, refer to the speaking valve manufacturer's *Instructions for use*.

4.7.3 Deactivating SpeakValve compatibility

In some cases, compatibility is automatically deactivated. See Section 10.9.1.

To deactivate speaking valve compatibility

1. Touch **Controls** > **SpeakValve**.
2. Touch **SpeakValve OFF**, then touch **Apply**.
3. Be sure to do the following:
   – Remove the speaking valve from the breathing circuit.
   – Inflate the tracheostomy cuff.

When compatibility is deactivated (OFF), the following safety messages are shown in the SpeakValve window:

Remove the speaking valve, deactivate speaking valve compatibility, and inflate the tracheostomy cuff.

All alarms are enabled. The Vt alarms are based on VTE.

Apnea backup ventilation is enabled.

Upon deactivation, alarms and monitoring parameters return to their previous operation, and the ExpMinVol alarm limits are reset based on the patient's IBW.

For details, see Sections 10.9.3 and 10.9.4.

4.8 Connecting to external devices

You can connect the ventilator to a patient monitor, PDMS (patient database management system), or computer using the communication port on the communication board, if installed. For details, see the *Communication Interface User Guide*, available in the Hamilton Medical Resource Center (https://www.hamilton-medical.com/Resource-center).

For additional information see:

- For details about selecting a communication protocol for use with the communication board, see Section 13.3.3.
- For details about configuring connectivity settings, including Connectivity configuration file import/export and Hamilton Connect Module firmware update, see Section 13.10.[1]

[1] Only available for use if the Hamilton Connect Module is activated.

5
Specifying ventilation settings

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5.1 Process overview

This section explains how to set up the HAMILTON-C1 for ventilation on an individual patient. Connecting power and oxygen supplies, and setting up the breathing circuit set are covered in Chapter 3.

Setting up ventilation parameters generally comprises the following steps.

Table 5-1. Setting up the ventilator for use, overview

To ...	See ...
Select the patient group, enter patient data, and select a Quick Setup	Sections 5.2 and 5.3
Perform preoperational check (calibrations and tests)	Section 5.4
Select the ventilation mode	Section 5.5
Review and adjust control settings	Section 5.6
Review and adjust alarm limits	Section 5.7
Start ventilation	Section 5.8

5.2 Selecting the patient group

Before proceeding, review the safety information in Chapter 1.

The HAMILTON-C1 supports the following patient groups: Adult/Ped. (adult and pediatric patients) and Neonatal.

Table 5-2. Patient groups

Adult/Ped.[1]	Neonatal
Sex: Male, Female	Weight: 0.2 to 30 kg
Height: 30 to 250 cm	Minimum delivered tidal volume: 2 ml
IBW: 3 to 139 kg	
Minimum delivered tidal volume: 20 ml	

To select the patient group and initial settings

1. In the Standby window (Figure 5-1), touch the desired patient group tab:
   - **Neonatal**
   - **Adult/Ped**[1]
   - **Last patient.** Reuse the last active ventilator parameters.

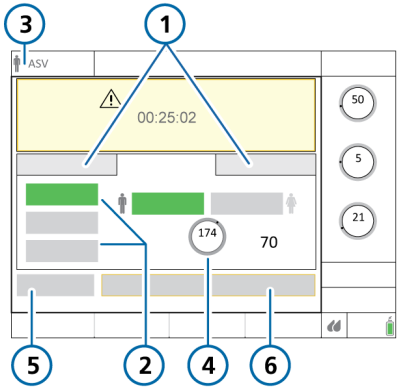
   The icon for the selected patient group appears to the left of the mode name at the top left of the display (Figure 2-6).
2. For a new patient, touch the desired Quick setup button (Section 5.2.1).

The settings saved with the selected Quick setup are loaded and displayed, in addition to the default patient sex/height/IBW (Adult/Ped) or weight (Neonatal).

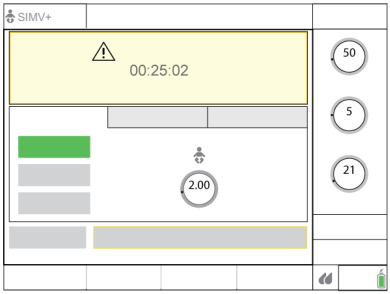
[1] Not applicable when the HAMILTON-C1 neo option is enabled and the ventilator is dedicated to neonatal ventilation.

Figure 5-1. Patient group options in Standby window

HAMILTON-C1



HAMILTON-C1 neo option enabled



1	Patient group tabs	4	Sex/height/IBW (or Weight for Neonatal) for selected Quick setup
2	Quick setups	5	Preop check
3	Selected mode and patient group	6	Start ventilation[1]

5.2.1 About Quick setups: preconfigured settings

For each of the patient groups, you can define up to three different default configurations, referred to as Quick setups.

During patient setup, you can then quickly preconfigure the ventilator per your standard protocols, and modify settings as needed.

Each Quick setup defines:

- A ventilation mode
- Mode control settings
- Graphic display selections
- Alarm limit settings
- Vent Status panel settings
- Vt/IBW (Adult/Ped) or Vt/kg (Neonatal)
- Specified humidifier settings (if connected)
- Default CPR ventilation settings

The Quick setups are defined in Configuration (Chapter 13).

[1] When HiFlowO2 is selected: Start therapy; when CPR ventilation is active: Start CPR.

5.3 Entering patient data

⚠ CAUTION

Entering the correct patient data ensures safe ventilation settings for start up, Apnea backup, and Safety ventilation/Safety mode.

Before proceeding, review the safety information in Chapter 1.

Specifying the correct patient data is particularly important, as the ventilator uses this data as a basis for some calculations and initial mode control settings.

- For the Adult/Ped patient group, the ventilator uses sex and patient height to calculate the ideal body weight (IBW).

  The following control settings are based on IBW: Vt, Rate, T low, T high, and TI, and Apnea backup and safety settings.

- For Neonatal patients, the ventilator uses the patient body weight.

  The following parameters are set based on Weight: Vt, Rate, T low, T high, TI, and TI max, and Apnea backup and safety settings.

To enter patient data

- In the Standby window (Figure 5-1):

  – **Adult/Ped.** Specify the patient sex and height. The device calculates the patient IBW.

  – **Neonatal.** Specify the patient weight.

5.4 Performing the preoperational check, tests, and calibrations

The preoperational check calibrations and tests are performed in Standby, without any connected patient.

The tests and calibrations described in this section help verify the safety and reliability of the ventilator.

These tasks include (see Table 5-3):

- Leak test
- Flow sensor calibration
- O2 sensor calibration
- CO2 sensor calibration
- Alarm tests

Make sure these tests and calibrations are successful before you return the ventilator to clinical use.

If a test fails, troubleshoot the ventilator as indicated or have the ventilator serviced.

Test results are stored in memory, including when the ventilator is turned off. This allows the ventilator to be checked and kept in storage, ready for use.

The time and date of the last test are displayed in the System > Tests & calib window. Ensure the last performed preoperational test is valid for your patient.

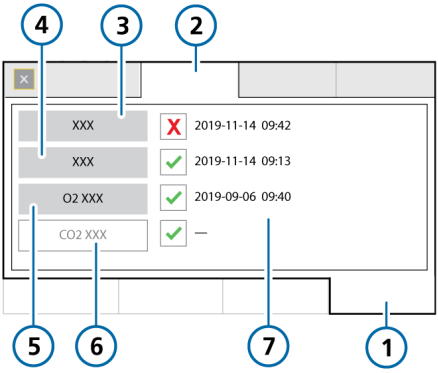
Table 5-3. When to perform tests and calibrations

Test or calibration	When to perform
Preoperational check	When connecting a new breathing circuit set to the ventilator.
Flow sensor/circuit calibration and Leak test	After connecting a new breathing circuit or component (including a flow sensor or pressure-monitoring line).
Daily/regular checks	Perform the following tests daily or according to your institution's protocols: 1. Turn on the ventilator. 2. Ensure that the preoperational check has been successfully completed as indicated by the following (Section 5.4.1): – Green checkmarks in the Tests & calib window. – The last test date is valid. 3. Check the battery status. 4. Perform a visual inspection of the integrity of the device and breathing circuit set. 5. Turn off the ventilator.
Before starting ventilation	With the already tested breathing circuit set connected, including HME/F and/or other components, perform the Leak test.
O2 sensor calibration	After installing a new O2 sensor or when a related alarm occurs.
CO2 sensor/adapter zero calibration (mainstream/sidestream)	Required after connecting a CO2 sensor or when a related alarm occurs. Recommended after switching between different airway adapter types.
Alarm tests	As desired

To access tests and calibration functions

1. Do either of the following:
   – Touch **System** > **Tests & calib**.
   – In the Standby window, touch **Preop check**.
2. Touch the button for the desired operation.

Figure 5-2. System > Tests & calib window



1	System	5	O2 sensor
2	Tests & calib	6	CO2 sensor
3	Leak test (shown uncalibrated)	7	Time and date of last test/calibration
4	Circuit or Flow sensor, depending on selected mode		

5.4.1 Performing the preoperational check

Before proceeding, review the safety information in Chapter 1.

For details about performing the preoperational check with neonatal ventilation, see Section 6.2.

When to perform

Before connecting a new patient to the ventilator.

To perform the preoperational check

1. Use a setup as described below.
2. Perform all of the steps in Table 5-4.

To ensure that the ventilator functions according to specifications on your patient, perform the preoperational check using the breathing circuit that will be used on the patient.

For a test breathing circuit setup, you need:

- *Breathing circuit:* Adult/pediatric, ID10 to ID22
- *Flow sensor:* Adult/pediatric, with calibration adapter
- *Test lung:* Demonstration lung, connective tubing between flow sensor and lung

When a test is complete:

☑ indicates the component is calibrated and ready.

☒ indicates the calibration was unsuccessful.

The preoperational check comprises the following steps.

Table 5-4. Preoperational check, overview

	Do or observe...	Verify ...
1	Connect ventilator to primary power and an oxygen supply.	
2	Assemble the patient breathing circuit.	The breathing circuit is assembled correctly.
3	Turn on the ventilator.	During the self test, the alarm lamp flashes yellow and red in sequence.
4	With the ventilator in Standby, touch **Preop check** in the Standby window.	The System > Tests & calib window opens.
5	Perform the Leak test.	The test passes. See Section 5.4.2.
6	Calibrate the flow sensor.	The calibration is successful. See Section 5.4.3.
7	If necessary, run the O2 sensor calibration.	The calibration is successful. See Section 5.4.4.
8	If necessary, run the CO2 sensor zero calibration.	The zero calibration is successful. See Section 5.4.5.
9	Generate test alarms.	The corresponding alarm message is displayed in the message bar. See Section 5.4.6. Note that patient alarms are suppressed in Standby.

5.4.2 Performing the breathing circuit set Leak test

Before proceeding, review the safety information in Chapter 1.

To perform the Leak test

1. Set up the ventilator for ventilation, complete with breathing circuit and flow sensor.
2. Touch **System** > **Tests & calib**.
3. Touch **Leak test**.

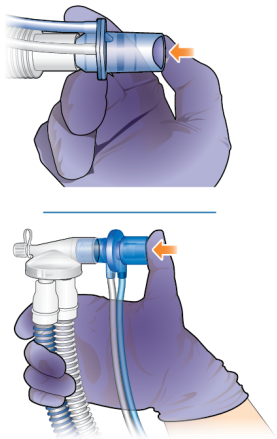
   The text Disconnect patient is now displayed.
4. Disconnect the breathing circuit at the patient side of the flow sensor. Do not block the open end of the flow sensor.

   The text Block breathing circuit is now displayed.
5. Block the opening (wearing a glove is recommended). See Figure 5-3.

   Ensure the opening is fully blocked. Failure to do so may result in test failure.

   The text Reconnect breathing circuit is now displayed.
6. Connect the patient.
7. When the test is complete, verify that there is a checkmark ☑ in the Leak test checkbox.

Figure 5-3. Block the flow sensor opening when prompted



To cancel the test while it is in progress

- Touch **Leak test** again.

In case of test failure

If the test fails, ☒ is displayed in the Leak test checkbox.

Ensure that you have performed all steps of the test correctly. If so, perform the following checks, repeating the Leak test after each one, until the test is successful:

- Check the breathing circuit for a disconnection between the ventilator and the flow sensor, or for other large leaks (for example, breathing circuit, humidifier).
- Check that the flow sensor and expiratory valve set are properly seated.
- If the test still fails, replace the expiratory valve set.
- If the test still fails, replace the breathing circuit.

If the problem still persists, have the ventilator serviced.

5.4.3 Calibrating the adult/pediatric flow sensor

This calibration checks and resets the calibration points specific to the flow sensor in use, and measures the circuit resistance. The measured value determines the required resistance compensation during ventilation.

Ensure you are using the correct flow sensor for the selected patient group. If there is a mismatch, calibration fails.

For details about calibrating a neonatal flow sensor, see Section 6.2.1.

When to perform

After connecting a breathing circuit or component.

Flow sensor calibration involves three components:

- Flow sensor
- Component in the breathing circuit directly following the flow sensor
- Calibration adapter

To calibrate an adult/pediatric flow sensor

1. Calibrate the flow sensor in Standby, with *no* patient connected.
2. Connect the flow sensor to the breathing circuit (Figure 5-4).
3. Connect the *next* component in the circuit to the flow sensor (Figure 5-5).

   Depending on your setup, this could be, for example, an HMEF, nebulizer, CO2 sensor, or the flex tube.

   Do *not* connect any more components at this time. You will be prompted to connect the calibration adapter once the calibration process starts.
4. In the Standby window, touch **Preop check**.

   The System > Tests & calib window is displayed.
5. Touch **Flow sensor**.

   A help guide is shown on the display, providing an overview of the calibration process.
6. Touch **Start** to begin calibration.

   To close the guide without starting calibration, touch **Cancel**.
7. When prompted on the display, attach the calibration adapter to the component connected to the flow sensor and flip all three of them together 180° so the adapter is directly connected to the breathing circuit (Figure 5-6).
8. When prompted, flip the flow sensor/component/adapter 180° again, so the flow sensor is directly connected to the breathing circuit, and remove the calibration adapter (Figure 5-7).
9. When calibration is complete, verify that there is a checkmark ☑ in the Flow sensor checkbox.
10. When successful, finish assembling the breathing circuit, and continue with other tests or ventilation.

Figure 5-4. Connect the flow sensor

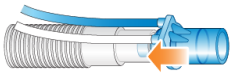


Figure 5-5. Connect the next component

Figure 5-6. Attach adapter, flip components

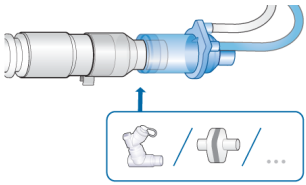
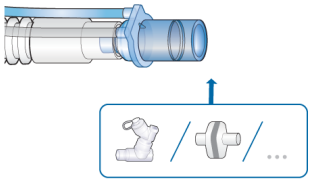


Figure 5-7. Flip components, remove adapter



To cancel an ongoing calibration

- Touch **Flow sensor** again.

In case of calibration failure

If the calibration fails, ☒ is displayed in the Flow sensor checkbox.

Ensure that you have performed all steps of the test correctly. If so, perform the following checks, repeating the calibration after each one, until calibration is successful:

- Ensure that the flow sensor is appropriate for the selected patient group.
- Check the breathing circuit for a disconnection between the ventilator and the flow sensor, or for other large leaks (for example, breathing circuit, humidifier).
- Check that the flow sensor and expiratory valve set are properly seated.
- If the calibration still fails, replace the flow sensor.
- If the calibration still fails, replace the expiratory valve set.

If the problem persists, have the ventilator serviced.

5.4.4 Calibrating the O2 sensor

⚠ CAUTION

When using an oxygen supply < 99% (HPO) or low pressure oxygen (LPO), calibrate the O2 cell at 21%. This information is displayed in the Calibration window.

NOTICE

When using LPO, disconnect the oxygen supply during calibration.

Calibrate the O2 sensor if either of the following occur:

- ☒ is displayed in the O2 sensor checkbox (Figure 5-2)
- The O2 sensor calibration needed alarm is generated.

To perform O2 sensor calibration

1. Using the information in Table 5-5, set the Oxygen control as appropriate to calibrate the sensor using either 21% or 100% oxygen.

   For example, to calibrate during active ventilation with 100% oxygen, ensure the Oxygen control is set to 22% or higher.
2. Touch **System** > **Tests & calib**.
3. Touch **O2 sensor**.
4. When calibration is complete, verify that there is a checkmark ☑ in the O2 sensor checkbox.

Table 5-5. Oxygen concentration during O2 sensor calibration

Standby or active ventilation	Gas source connection status	Set Oxygen to ...
100% oxygen calibration[1]		
Standby	HPO Connected	any
Active ventilation[2]	HPO Connected	> 21%
21% oxygen calibration		
When the oxygen supply is less than 99%, you must disconnect the oxygen supply before calibration.		
Standby	LPO Disconnected	21%
Active ventilation	HPO Connected	21%
Active ventilation	LPO Disconnected	21%

In case of calibration failure

If the calibration fails, a red ☒ is displayed in the O2 sensor checkbox.

Perform the following checks, repeating the calibration after each one, until calibration is successful:

- Ensure a Hamilton Medical O2 sensor is installed.
- If the second calibration attempt fails, replace the O2 sensor.

If the problem persists, have the ventilator serviced.

5.4.5 Performing a zero calibration of the CO2 sensor/adapter

Before proceeding, review the safety information in Chapter 1.

⚠ CAUTION

- *Always perform zero calibration with the CO2 sensor (mainstream) or CO2 module (sidestream) connected to the airway adapter.*
- *Be sure NOT to cover both ends of the airway adapter with your fingers.*

The CO2 adapter zero calibration compensates for optical differences between airway adapters and for sensor drift.

Note that the CO2 sensors are calibrated at the factory; you only need to zero the adapters as described next.

Zero calibration requirements for sidestream CO2 sensors

You only need to perform a zero calibration with sidestream CO2 sensors when the CO2 calibration needed alarm is generated.

Zero calibration requirements for mainstream CO2 sensors

Perform a zero calibration in the following cases:

- With the first use of the sensor
- When changing between airway adapter types (for example, from single use to reusable)
- When the CO2 calibration needed alarm is generated

[1] Calibrating at 100% improves the stability of measurements at higher oxygen concentrations during use.
[2] Only for adult/pediatric patients.

To ensure all CO2 is dissipated, wait 2 minutes to perform the zero calibration after removing the adapter from the patient's airway.

To perform zero calibration of the CO2 sensor/adapter

Zero calibration is performed with the CO2 sensor and airway adapter connected to each other, *disconnected from the breathing circuit and the patient*.

1. Connect the CO2 sensor (**1** mainstream) or the CO2 module (**2** sidestream) to the CO2 port on the ventilator (Figure 5-8), and ensure CO2 monitoring is enabled.

   If this is the first time the CO2 sensor is connected, wait at least 2 minutes for the device to warm up.

2. Attach the CO2 sensor to the airway adapter (**1** mainstream) or snap the CO2 sensor into the CO2 module (**2** sidestream) (Figure 5-9).

   Zero calibration is performed with the sensor and airway adapter connected to each other, disconnected from the breathing circuit and the patient.

   Keep these components away from all sources of CO2, including the patient's and your own exhaled breath, as well as the ventilator exhaust port.

3. Touch **System** > **Tests & calib**.
4. Touch **CO2 sensor**.

   Do *not* move the components during calibration.

5. When the zero calibration is complete, verify that there is a checkmark ☑ in the CO2 sensor checkbox.

Figure 5-8. Connecting the components

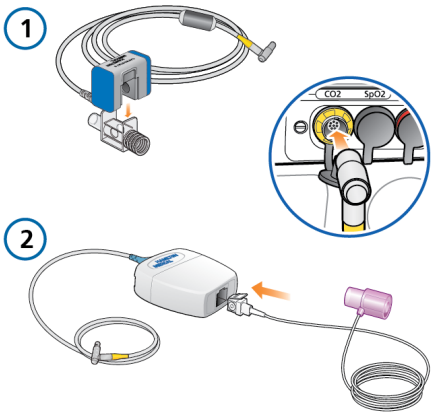
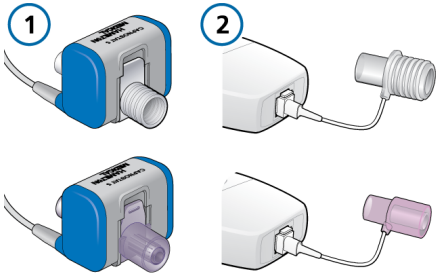


Figure 5-9. Sensor and adapter connected for calibration



In case of zero calibration failure

If the zero calibration fails, ☒ is displayed in the CO2 sensor checkbox.

Perform the following checks, repeating the zero calibration after each one, until it is successful:

- Check the airway adapter and clean if necessary.
- If the zero calibration still fails, ensure there is no source of CO2 near the airway adapter.
- If the zero calibration still fails, connect a new adapter.
- If the zero calibration still fails, connect a new CO2 sensor (mainstream) or CO2 module (sidestream).

If the problem persists, have the ventilator serviced.

5.4.6 Testing the alarms

During ventilator startup, the HAMILTON-C1 performs a self-test that also verifies proper alarm function, including generation of an audible alarm sound. You are *not* required to perform additional alarm tests.

If desired, you can test any adjustable alarm by manually changing the set limit such that the ventilator exceeds or fails to reach the set limit, thereby generating the associated alarm. For details on setting alarm limits, see Section 5.7.

5.4.6.1 Testing the Loss of external power alarm

You can optionally test the Loss of external power alarm as follows.

To test the alarm

1. Ensure a battery is installed in the ventilator.
2. Turn on the ventilator.
3. Unplug the ventilator from the primary power outlet.

   Verify that the low-priority Loss of external power alarm is generated, indicating that the device is running on battery power.
4. Reconnect the power cord to the primary power outlet.

The low-priority Loss of external power alarm disappears.

5.4.6.2 Testing the Exhalation obstructed alarm

To test the Exhalation obstructed alarm

1. Block the expiratory valve exhaust port during active ventilation.
2. Observe the pressure rise.
3. Verify that the Exhalation obstructed alarm is activated.

5.5 Selecting the ventilation mode

The active ventilation mode is displayed at the top left corner of the display together with the selected patient group.

When first starting to ventilate a patient, the mode associated with the selected Quick setup is pre-selected. You can change it, if needed.

For details about each of the modes, see Chapter 7.

To select a mode

1. Do either of the following (see Figure 5-10):

   – Touch the mode name (**1**) at the top left of the display.

   – Touch **Modes** (**2**) at the top right of the display.

2. In the Modes window, touch the desired mode, then touch **Confirm**.

   The **Confirm** button is only displayed after you select a different mode in the window.

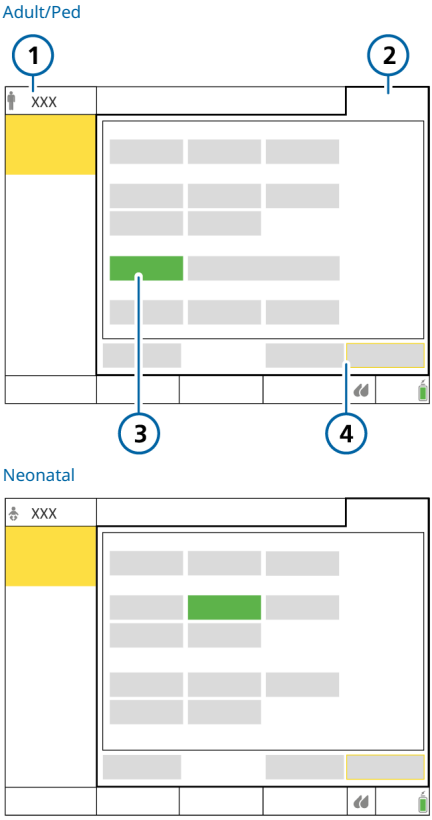
   The Controls window opens.

3. Review and, if needed, adjust the control settings (Figure 5-12), then touch **Confirm** to enable the new mode.

   After you touch **Confirm**, the mode changes at the end of the current breath cycle.

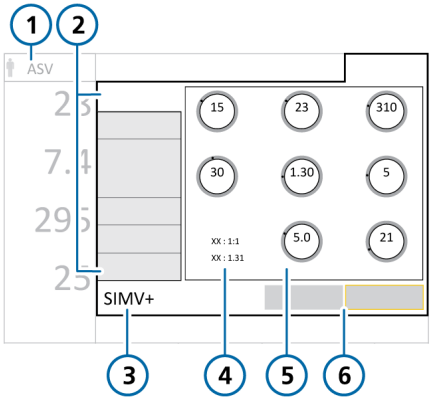
   Without confirmation, the window closes after a short time and the currently active mode remains in place.

Figure 5-10. Modes window, changing modes



1	Active mode, patient group	3	New mode
2	Modes	4	Cancel/Confirm

Figure 5-11. Controls window, changing modes



1	Active mode, patient group	4	Values depending on mode
2	Tabs: Basic, More, Apnea, Patient, Speak-Valve	5	Mode controls
3	New mode	6	Cancel/Confirm

5.6 Reviewing and adjusting therapy settings

You specify ventilation settings in the Controls window tabs: Basic, More, Apnea. The **Patient** tab provides access to patient data during ventilation.

Which tabs are available depends on which mode is selected, as well as whether you are in Standby or active ventilation.

In addition, the window changes slightly depending on whether you are changing settings for the active mode or you are changing modes.

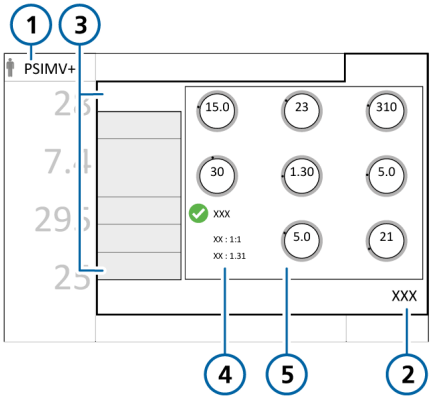
To change the control settings for the active mode

1. Touch **Controls**, and select and adjust settings as needed. See Figure 5-12.

   The change takes effect on the next breath.

2. Touch **More** to enable/disable Sigh, if needed.[1]
3. If applicable, touch **Apnea** and select or deselect Backup as needed.
4. If you need to change basic patient data, touch **Patient** and adjust settings as needed. See Section 5.3.

Figure 5-12. Controls window, settings for active mode



1	Active mode, patient group	4	Values depending on mode (I:E, TE, TI)
2	Controls	5	Mode controls
3	Tabs: Basic, More, Apnea, Patient, SpeakValve		

[1] Not applicable when the HAMILTON-C1 neo option is enabled and the ventilator is dedicated to neonatal ventilation.

5.6.1 About Plimit and related pressure-control settings

The pressure limit setting (Plimit) defines the maximum allowed pressure to apply during ventilation. This setting is available in the Controls > Basic window (Figure 5-12).[1]

The Plimit control setting is directly related to the high Pressure alarm limit, in that changing one of these settings automatically changes the other: The high Pressure alarm limit is always 10 cmH2O greater than Plimit.

Depending on the selected mode, the following control parameters can be used to set pressure: ΔPcontrol, ΔPinsp, ΔPsupport, or P high.

The total inspiratory pressure to be applied is defined as follows:

- ΔPcontrol + PEEP/CPAP
- ΔPsupport + PEEP/CPAP
- ΔPinsp + PEEP/CPAP
- P high[2]

If the total inspiratory pressure setting exceeds Plimit, the ventilator only delivers pressure equal to Plimit. The ventilator cannot deliver the set pressure and the Pressure limitation alarm is generated. When this conflict occurs, the Plimit control is highlighted in yellow in the Controls window and the Check Plimit alarm is generated.

During active adjustment, you may see the pressure or Plimit controls turn yellow, indicating that total inspiratory pressure exceeds Plimit with the proposed settings. Adjust the pressure-related settings to resolve the conflict.

The following examples illustrate each of these cases.

Example 1: Pressure control setting adjustments exceed Plimit

Assume the control parameters are set as follows:

Plimit	32 cmH2O
ΔPcontrol	25 cmH2O
PEEP/CPAP	5 cmH2O
Total inspiratory pressure	30 cmH2O (ΔPcontrol + PEEP/CPAP in this example)

The total inspiratory pressure of 30 cmH2O is below Plimit. The ventilator delivers the total inspiratory pressure as set.

[1] Not available in (S)CMV+ / APVcmv mode.
[2] In DuoPAP and APRV modes, P high defines the total inspiratory pressure to be delivered. PEEP/CPAP does not need to be accounted for.

If you increase ΔPcontrol to 30 cmH2O, the total inspiratory pressure, which is now 35 cmH2O, exceeds Plimit and the following occurs:

1. Plimit (**1** in Figure 5-13) is highlighted in yellow, indicating that total inspiratory pressure exceeds Plimit.
2. Either decrease the pressure control settings or increase Plimit to ensure that Plimit is equal to or greater than the total inspiratory pressure setting.

   When Plimit (**1** in Figure 5-14) meets this condition, it is no longer highlighted in yellow.

Figure 5-13. Total inspiratory pressure exceeds Plimit

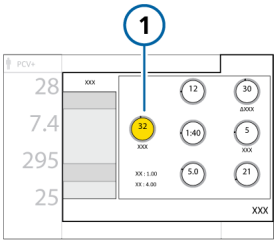
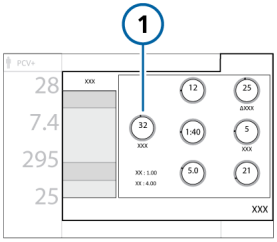


Figure 5-14. Total inspiratory pressure no longer exceeds Plimit



Example 2: Plimit setting adjustment is below total inspiratory pressure

Assume the control parameters are set as follows:

Plimit	32 cmH2O
ΔPcontrol	25 cmH2O
PEEP/CPAP	5 cmH2O
Total inspiratory pressure	30 cmH2O (ΔPcontrol + PEEP/CPAP in this example)

The total inspiratory pressure of 30 cmH2O is below Plimit. The ventilator delivers the total inspiratory pressure as set.

If you decrease Plimit to 25 cmH2O, the total inspiratory pressure of 30 cmH2O exceeds Plimit and the following occurs:

1. The currently active Plimit control that you are adjusting (**1** in Figure 5-15) is shown in orange.

   The pressure controls are highlighted in yellow (**2**) if the total inspiratory pressure exceeds Plimit, indicating there is a conflict.
2. Upon confirming the new Plimit setting, Plimit (**1** in Figure 5-16) is highlighted in yellow, indicating there is a conflict. The pressure controls return to their default color.
3. Either decrease the pressure control settings or increase Plimit to ensure that Plimit is equal to or greater than the total inspiratory pressure setting.

   When Plimit (**1** in Figure 5-17) meets this condition, it is no longer highlighted in yellow.

Figure 5-15. Plimit control is active, total inspiratory pressure exceeds Plimit

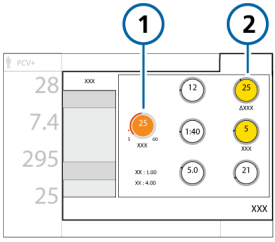


Figure 5-16. Total inspiratory pressure still exceeds Plimit

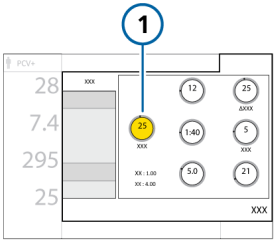
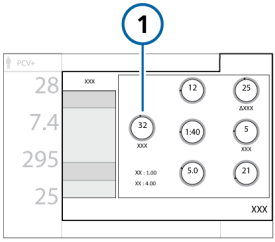


Figure 5-17. Total inspiratory pressure no longer exceeds Plimit



5.6.2 About the trigger types

Before proceeding, review the safety information in Chapter 1.

You can select the conditions that cause the ventilator to trigger inspiration (Section 5.6.2.1) based on flow or using the IntelliSync+ trigger.[1]

You can also select the conditions that cause the ventilator to trigger expiration (Section 5.6.2.2) based on flow or using the IntelliSync+ trigger.[1]

For details about IntelliSync+, see Section 5.6.2.3.

[1] If the IntelliSync+ option is installed.

5.6.2.1 Selecting the inspiratory trigger type

You can select the inspiratory trigger type to use.

Table 5-6. Inspiratory trigger types

Trigger type, symbol on waveform	Description
Flow trigger (F) ▲	The patient's inspiratory flow triggers the ventilator to deliver a breath. When selected, the **F** indicator under the control is green.
IntelliSync+[1,2] (I) ▲	The ventilator monitors incoming sensor signals from the patient and reacts dynamically to initiate inspiration in real time. When selected, the **I** indicator under the control is green, and the control itself is blue, displaying the text *IntelliSync+*.

To specify the inspiratory trigger type and setting

1. Touch **Controls**.

   The Controls > Basic window opens.

2. Touch the desired Trigger selection button below the control (**1** in Figure 5-18).

   The buttons are labeled **F** (flow trigger) and **I** (IntelliSync+). The selected trigger type is shown in green.

   If IntelliSync+ is selected, the control turns blue and shows the text, **IntelliSync+**, indicating the ventilator is dynamically adjusting the setting in real-time.

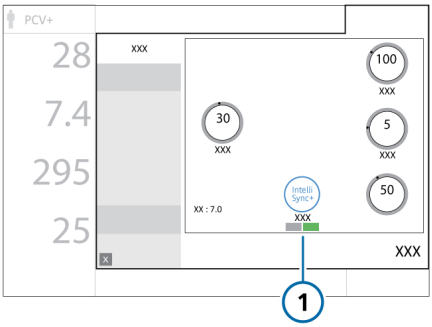
3. If Flow trigger is selected, adjust the Trigger setting as needed.

Note the following:

- Changing the setting during the inspiratory or expiratory phase affects the next breath.
- If the trigger is set higher than the patient's efforts can achieve, a breath cannot be triggered. Reset the trigger to an achievable value, adjusting the sensitivity of the trigger to the patient's ability.

[1] If the IntelliSync+ option is installed.
[2] Not available in all markets.

Figure 5-18. Inspiratory trigger controls



5.6.2.2 Selecting the expiratory trigger type

You can select the expiratory trigger type to use.

Table 5-7. Expiratory trigger types

Trigger type	Description
ETS (E)	The percent of peak inspiratory flow at which the ventilator cycles from inspiration to exhalation. When selected, the **E** indicator under the control is green.
IntelliSync+ (I)[1]	The ventilator monitors incoming sensor signals from the patient and reacts dynamically to initiate expiration in real time. When selected, the **I** indicator under the control is green, and the control itself is blue, displaying the text *IntelliSync+*.

[1] If the IntelliSync+ option is installed.

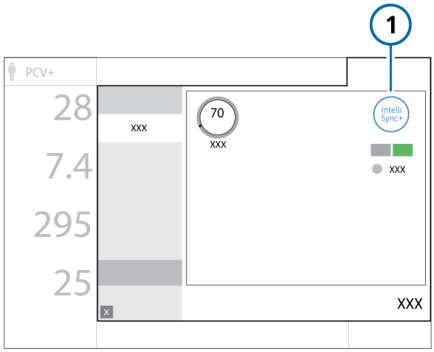
To specify the expiratory trigger type and setting

1. Touch **Controls** > **Basic**.
2. Touch the desired expiratory trigger selection button below the control (**1** in Figure 5-19).

   The buttons are labeled **ETS** and **I** (IntelliSync+). The selected option is shown in green.

   If IntelliSync+ is selected, the control turns blue and shows the text, **IntelliSync+**, indicating the ventilator is dynamically adjusting the setting in real-time.
3. If ETS is selected, adjust the ETS setting as needed.

Figure 5-19. Expiratory trigger controls



5.6.2.3 About IntelliSync+

⚠ CAUTION

- *When using IntelliSync+, observe the waveforms and ensure that the ventilator cycles into inspiration/expiration in synchrony with the patient's attempts to inhale/exhale.*
- *When asynchrony or oscillations (for example, cardiogenic oscillations) are observed, or IntelliSync+ causes patient discomfort, change the trigger type.*

Limitations for use

IntelliSync+ is designed for use with all adult and pediatric patients weighing 10 kg or more.

You can use IntelliSync+[1] as the inspiratory trigger, expiratory trigger, or both. IntelliSync+ is available for adult and pediatric patients in the following ventilation modes:

- IntelliSync+ inspiratory trigger: in all ventilation modes except HiFlowO2 therapy and CPR ventilation
- IntelliSync+ expiratory trigger: in all ventilation modes except APVcmv, PCV+, APRV, HiFlowO2 therapy, and CPR ventilation

When a patient is spontaneously breathing, analysis of the waveforms on the ventilator can reveal the patient's efforts. This analysis is performed by the clinician at the bedside, where ventilation settings can be adjusted to improve patient-ventilator synchrony.

[1] Not available in all markets.

IntelliSync+ is based on a mathematical model that is designed to identify a patient's spontaneous breathing efforts, just as an experienced clinician would observe when determining treatment.

By analyzing waveforms on the ventilator, IntelliSync+ identifies the patient's attempts to inhale/exhale and triggers the ventilator to initiate inspiration or expiration, as appropriate. IntelliSync+ continuously performs this analysis in real-time, and thereby can react to changing patient conditions, breath by breath.

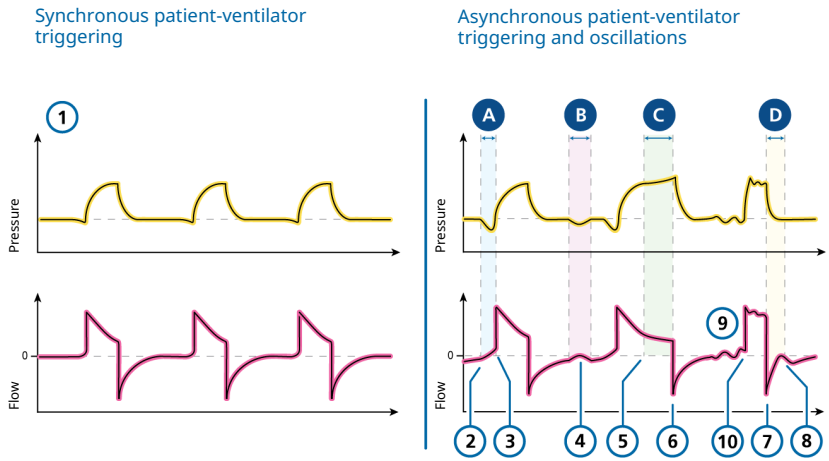
When IntelliSync+ is enabled, it is important that the ventilator trigger inspiration/expiration is in synchrony with the patient's efforts. If the ventilator is not applying breaths synchronously, change the trigger type (Section 5.6.2).

You can observe the trigger timing by reviewing the pressure and flow waveforms. Figure 5-20 provides a visual example of synchronous and asynchronous patient-ventilator triggering.[1]

Oscillations can also cause IntelliSync+ to inappropriately trigger (Figure 5-20). If oscillations are observed in the waveforms, change the trigger type.

[1] For further information about patient-ventilator synchrony, Hamilton Medical provides additional resources, including white papers and quick references, available at www.hamilton-medical.com.

Figure 5-20. Patient-ventilator trigger synchrony and asynchrony when using IntelliSync+



1 Waveforms showing patient-ventilator trigger synchrony in both the inspiratory and expiratory phases

A. Delayed triggering[1]

2 Patient inspiratory effort

3 Ventilator initiates inspiration

B. Ineffective effort

4 Patient inspiratory effort fails to trigger inspiration

C. Delayed cycling[1]

5 Patient muscles relax (indicating readiness to exhale)

6 Ventilator initiates expiration

D. Early cycling[1]

7 Ventilator initiates expiration

8 Indication of early expiration by the ventilator (bump in expiratory flow due to ongoing patient inspiratory effort)

Other

9 Oscillations

10 Auto trigger (caused by oscillations)

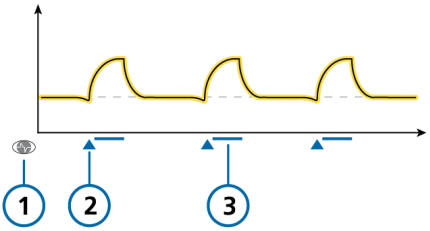
[1] *Triggering* refers to the inspiratory trigger; *Cycling* refers to the expiratory trigger.

IntelliSync+ indicators on the ventilator

When active, is shown on the uppermost waveform on the display.

Additional symbols are shown on the waveform, indicating the patient trigger and inspiratory time, depending on whether IntelliSync+ is selected as the inspiratory and/or expiratory trigger.

Figure 5-21. IntelliSync+ symbols on the waveform



1 IntelliSync+ symbol

2 Blue patient inspiratory trigger symbol[2]

3 Blue bar indicating inspiratory time[1]

5.6.3 About Apnea backup ventilation

Before proceeding, review the safety information in Chapter 1.

The HAMILTON-C1 provides Apnea backup ventilation, a mechanism that minimizes possible patient injury due to apnea or cessation of respiration. Apnea backup is available in the following modes:

Table 5-8. Modes and their backup modes

Selected mode	Backup mode
APVsimv, VS, DuoPAP, APRV, SPONT	APVsimv / Off
NIV	PCV+ / Off
NIV (NIV-only option enabled)	NIV-ST / Off

Apnea backup ventilation enabled

Apnea backup provides ventilation after the apnea time passes with no breath attempts detected. The apnea time is set in the Alarms window using the Apnea time control.

When this occurs, the ventilator automatically and immediately switches into Apnea backup ventilation.

It generates a low-priority alarm, displays the alarm Apnea ventilation, and provides ventilation using the settings specified in Section 7.1.2.

When set to Automatic, the control setting for the Apnea backup mode depends on the IBW (or Weight for neonates) of the patient.

[1] When IntelliSync+ is selected as the expiratory trigger.
[2] When IntelliSync+ is selected as the inspiratory trigger.

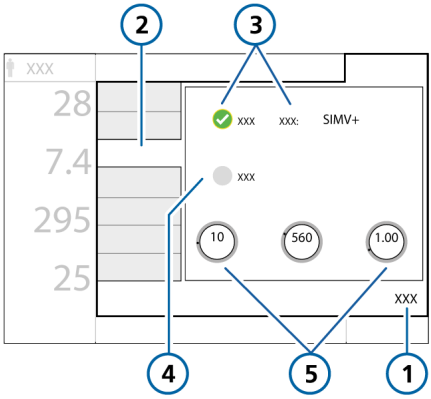
To change the Apnea backup control settings

1. Touch **Controls** > **Apnea**.
2. Clear the Automatic checkbox.

   The settings controls are enabled.
3. Change the values as desired.

   The changes take effect immediately.

Figure 5-22. Controls > Apnea window



1	Controls	4	Automatic check box
2	Apnea	5	Control settings corresponding to the mode
3	Backup check box and mode		

If the patient triggers two consecutive breaths, the ventilator reverts to ventilation in the original support mode and at the original settings, and displays the message, Apnea ventilation ended.

Once Apnea backup ventilation is enabled or disabled, it retains this status in all applicable modes. Apnea backup ventilation requires no clinician intervention, although you can freely change the mode during Apnea backup ventilation, either switching to a new mode or accepting the backup mode as the new mode.

Apnea backup ventilation disabled

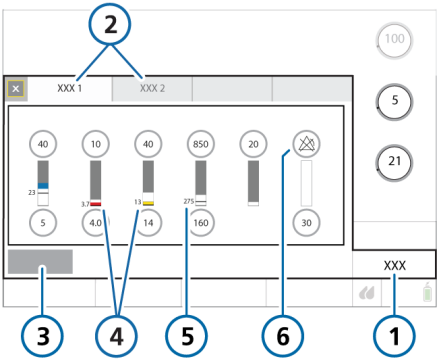
When Apnea backup is disabled, the high-priority Apnea alarm is generated when apnea occurs and there is no patient trigger within the operator-set interval.

5.7 Setting alarm limits

Before proceeding, review the safety information in Chapters 1 and 9.

You can access the Alarms window and change alarm settings at any time during noninvasive or invasive therapy.

Figure 5-23. Alarms > Limits 1 window



1	Alarms	4	Red or yellow bar (depending on alarm priority) indicates the monitored value is out of range
2	Limits 1, 2	5	Current monitored value
3	Auto[1, 2]	6	Alarm Off symbol when an alarm limit is set to Off

To review and adjust alarms

1. Either touch the **Alarms** button or touch an MMP on the left of the display.

   The Alarms > Limits 1 window is displayed (Figure 5-23).

2. To set an alarm limit individually, touch the alarm control and adjust the value.

   Repeat for any other alarm.

3. Access additional alarm settings by touching the **Limits 2**, and if used, **Limits 3** tabs.

   The ventilator displays (Alarm Off symbol) when an alarm limit is set to Off.

   For details about the Oxygen alarm limits, see Section 5.7.1.

4. To set alarm limits automatically, touch **Auto**[2,3] in the Limits 1 window.

   Selecting **Auto** automatically sets alarm limits around the current monitoring parameter values except for the Vt and Apnea alarm limits.[4] These alarm limits remain unchanged, and must be set manually to the desired level.

   Note that some automatic settings are not appropriate under all clinical conditions. Check the validity of the settings as soon as possible.

5. Close the window.

The following table briefly describes each of the adjustable ventilator alarms. Additional details are available in Table 15-12.

For SpO2-related alarms, see the *Pulse Oximetry Instructions for Use* (PN 624992).

[1] Not available during neonatal ventilation.
[2] Not available in all markets.
[3] Not available during neonatal ventilation.
[4] SpO2-related alarms are not automatically set.

Table 5-9. Adjustable alarms

Alarm	Definition
Apnea time	The maximum time allowed from the beginning of one inspiration to the beginning of the next inspiration. If the patient does not trigger a breath during this time: • A low-priority alarm sounds if Apnea backup is enabled. Apnea ventilation begins. • A high-priority alarm sounds if Apnea backup is disabled Not applicable in nCPAP or nCPAP-PC modes, or during HiFlowO2.
ExpMinVol (low and high)	Low and high expiratory minute volume. If either limit is reached, a high-priority alarm is generated. Not applicable in nCPAP or nCPAP-PC modes. For alarm details when using a speaking valve, see Table 10-1. During CPR ventilation, alarm limits are automatically set to their minimum and maximum allowed limits. See Table 15-12.
Flow	Only active in nCPAP and nCPAP-PC modes. The High Flow alarm is generated when the limit is reached.
fTotal (low and high)	Low and high monitored total breath rate (fTotal), including both spontaneous and mandatory breaths. If either limit is reached, a medium-priority alarm is generated. Not applicable in nCPAP or nCPAP-PC modes. During CPR ventilation, alarm limits are automatically set to their minimum and maximum allowed limits. See Table 15-12.
Oxygen (low and high)	Low and high monitored oxygen concentration (Oxygen). If either limit is reached, a high-priority alarm is generated. Applies only when low-pressure oxygen is used or the Set Oxygen alarm limits manually checkbox is selected with HPO.
PetCO2 (low and high)	Low and high monitored PetCO2. If either limit is reached, a medium-priority alarm is generated. During CPR ventilation, alarm limits are automatically set to their minimum and maximum allowed limits. See Table 15-12.

Alarm	Definition
Pressure (low and high)	Low and high monitored pressure at the patient airway (Ppeak). If the high Pressure limit is reached or the device fails to reach the low Pressure limit, a high-priority alarm is generated. When pressure reaches the Plimit setting (high Pressure limit minus 10 cmH2O), inspiratory pressure is limited to this setting; the pressure is not increased further. If the delivered pressure is the same as the set high Pressure alarm limit, the device aborts the breath and reduces the pressure to PEEP level. Sigh breaths are an exception to this rule. In this case, the ventilator may apply inspiratory pressure up to 3 cmH2O below the high Pressure alarm limit.
Vt (low and high)	Low and high expiratory tidal volume, for two consecutive breaths. If either limit is reached, a medium-priority alarm is generated. When the delivered Vt is > 1.5 times the set upper Vt alarm limit, the Inspiratory volume limitation alarm is generated. In this case, the device stops the inspiratory breath and reduces the pressure to PEEP level. The APV controls reduce the pressure for the next breath by 3 cmH2O. During CPR ventilation, alarm limits are automatically set to their minimum and maximum allowed limits. See Table 15-12.

5.7.1 About the Oxygen alarm limits

How the device sets the Oxygen alarm limits depends on the gas source used (LPO or HPO) and associated option settings.

Oxygen alarm limits are set as follows.

Table 5-10. Setting Oxygen alarm limits in LPO and HPO modes

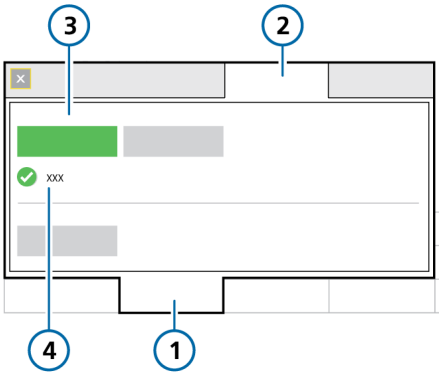
Gas source	Setting Oxygen alarm limits
LPO	Always manually. The Oxygen alarm limit controls are enabled in the Alarms window and are manually adjusted, as appropriate.
HPO	By default, automatically. The Oxygen high/low alarms are, by default, automatically set to the current Oxygen setting ± 5 (absolute value). The Oxygen alarm limit controls are disabled in the Alarms window. To set them manually, select the Set Oxygen alarm limits manually option, as described next.
The minimum lower alarm limit is 18%.	

To enable manual adjustment of Oxygen alarm limits in HPO mode

1. Touch **Tools** > **Utilities**.
2. Select HPO mode as the gas source.
3. To set the Oxygen alarm limits yourself, touch the Set Oxygen alarm limits manually checkbox.

   When selected, the Oxygen alarm limit controls are enabled in the Alarms window. You can now set the limits as desired.
4. To have the limits set automatically, ensure the checkbox is clear.

Figure 5-24. Setting Oxygen alarm limits manually with HPO



1	Tools	3	Gas source: HPO mode
2	Utilities	4	Set Oxygen alarm limits manually checkbox selected

5.8 Starting ventilation

Before starting ventilation, review the patient information in the Standby window and ensure it is correct.

To start ventilation

- Do one of the following:
  - In Standby, press the Power/Standby key.
  - In Standby, touch **Start ventilation**.
  - Using the P&T knob, move the cursor to the **Start ventilation** button, and press the P&T knob.

  When using HiFlowO2, the button is labeled **Start therapy**.

  When CPR ventilation is active, the button is labeled **Start CPR**.

Ventilation starts.

5.8.1 Ensuring an adequate oxygen supply for patient transport

⚠ WARNING

Before transporting the patient, ensure the oxygen supply is adequate by checking the O2 consumption parameter (in the System > Info window) and ensuring it is adequate for your estimated travel time and current oxygen capacity.

Use the appropriate calculation method (see Table 5-11) to estimate total oxygen requirements for the patient.

Before transporting the patient you must ensure that you have enough oxygen for the journey.

Be sure to:

- Review current oxygen consumption (Section 5.8.1.1)
- Calculate the patient's estimated oxygen requirement (Section 5.8.1.2)

For neonatal patients, use Method III (Section 5.8.1.2.3).

For information about estimated oxygen consumption relative to minute volume, see Section 15.12.3.

5.8.1.1 Reviewing current oxygen consumption

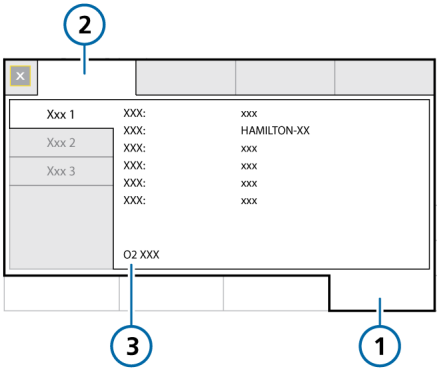
NOTICE

- O2 consumption data is not available with low-pressure oxygen (LPO).
- When initially starting ventilation, the O2 consumption parameter is calculated and displayed after 2.5 minutes.

The current oxygen consumption rate is displayed in the O2 consumption parameter in the System > Info window (Figure 5-25).

The O2 consumption rate is updated every breath and shows the average rate over the last five (5) minutes, after the initial 2.5 minutes of ventilation.

Figure 5-25. System > Info window, O2 consumption



1	System	3	O2 consumption
2	Info		

5.8.1.2 Calculating estimated oxygen consumption

⚠ WARNING

The oxygen consumption of a nebulizer attached to the device is not included in the O2 consumption parameter value. To calculate it, use Method IV (Section 5.8.1.2.4).

NOTICE

- The oxygen consumption calculation is not intended to affect therapy decisions and should be used solely to estimate the amount of oxygen required for the duration of transport, *before* connecting the ventilator to the patient.
- The calculations provided here are valid only for systems without leaks at the patient end.

  For systems with leaks (for example, ventilating with a mask), oxygen consumption will be higher.
- The calculations show the result in liters per minute (l/min). You must multiply the result by the planned duration of transport for the final estimate.

The calculation method for estimating oxygen consumption depends on the patient height and weight, and nebulizer use, as listed in the following table.

Table 5-11. Overview of O2 consumption calculation methods

For ...	Applicable for ...	See ...
Method I[1]	Smaller patients: ≤ 70 cm, IBW ≤ 8 kg	Section 5.8.1.2.1
Method II[1]	Larger patients: > 70 cm, IBW > 8 kg	Section 5.8.1.2.2
Method III	Neonates: Patient group on the ventilator is set to Neonatal.	Section 5.8.1.2.3
Method IV (nebulizer in use)	Additional amount to add to the result of Method I or II to account for the nebulizer oxygen use.	Section 5.8.1.2.4

All of the methods require the following information for the calculation:

- ExpMinVol setting (l/min)
- Oxygen setting (%)
- I:E setting, if using a nebulizer
- Planned duration of transport

The patient height and IBW (or Weight for neonatal patients) determine which of the calculation methods to use (Table 5-11).

[1] Not applicable when the HAMILTON-C1 neo option is enabled and the ventilator is dedicated to neonatal ventilation.

5.8.1.2.1 Method I. Overall oxygen consumption for smaller patients

Method I[1] is for smaller patients with height ≤ 70 cm, IBW ≤ 8 kg, in liters per minute (l/min).

For neonatal patients, use *Method III*[2] (Section 5.8.1.2.3).

Table 5-12. Calculating O2 consumption using Method I for smaller patients

	Calculation	Result and example
	To calculate estimated oxygen consumption using Method I: O2 cons. = [(ExpMinVol * 2) + 3 l/min] * [(FiO2 - 20.9) / 79.1]	
1	Replace *ExpMinVol* and *FiO2* in the equation with the current patient values.	*Example uses:* ExpMinVol = 2 l/min Oxygen (FiO2) = 60%
2	Solve the equation.[3]	The result is the estimated oxygen consumption in liters per minute (l/min). *Example.* O2 consumption = ((2 * 2) + 3) l/min * (60 - 20.9) / 79.1 O2 consumption = 7 l/min * 0.494 O2 consumption = 3.5 l/min
3	Multiply the result by the planned duration of transport, in minutes.	The final result is the estimated oxygen requirement, in liters, for the specified length of time. *Example.* Transport duration = ~60 minutes *Example result.* Required O2 for transport = ~3.5 * 60 = **210 liters**

[1] Not applicable when the HAMILTON-C1 neo option is enabled and the ventilator is dedicated to neonatal ventilation.
[2] If the patient group on the ventilator is set to Neonatal, be sure to use Method III for the calculation. This is important because the base flow is fixed at 4 l/min for neonatal patients and at 3 l/min for adult/pediatric patients.
[3] The * 2 is to account for compressible volume in the breathing circuit. See Section 15.12.3.

5.8.1.2.2 Method II. Overall oxygen consumption for larger patients

Method II[1] is for larger patients, with height > 70 cm, IBW > 8 kg in liters per minute (l/min).

For neonatal patients, use *Method III*[2] (Section 5.8.1.2.3).

Table 5-13. Calculating O2 consumption using Method II for larger patients

Calculation		Result and example
		To calculate estimated oxygen consumption using Method II: O2 cons. = [(ExpMinVol + 3 l/min)] * [(FiO2 - 20.9) / 79.1]
1	Replace *ExpMinVol* and *FiO2* in the equation with the current patient values.	*Example uses:* ExpMinVol = 2 l/min Oxygen (FiO2) = 60%
2	Solve the equation.	The result is the estimated oxygen consumption in liters per minute (l/min). *Example.* O2 consumption = (2 + 3) l/min * (60 - 20.9) / 79.1 O2 consumption = 5 l/min * 0.494 O2 consumption = 2.5 l/min
3	Multiply the result by the planned duration of transport, in minutes.	The final result is the estimated oxygen requirement, in liters, for the specified length of time. *Example.* Transport duration = ~60 minutes *Example result.* Required O2 for transport = ~2.5 l/min * 60 = **150 liters**

[1] Not applicable when the HAMILTON-C1 neo option is enabled and the ventilator is dedicated to neonatal ventilation.
[2] If the patient group on the ventilator is set to Neonatal, be sure to use Method III for the calculation. This is important because the base flow is fixed at 4 l/min for neonatal patients and at 3 l/min for adult/pediatric patients.

5.8.1.2.3 Method III. Overall oxygen consumption for neonatal patients

Method III is for neonatal patients. Use this method when the Neonatal patient group is selected on the ventilator.

This method is required because the base flow is fixed at 4 liters per minute (l/min) for neonatal patients, and at 3 liters per minute (l/min) for adult and pediatric patients.

Table 5-14. Calculating O2 consumption using Method III for neonatal patients

Calculation		Result and example
		To calculate estimated oxygen consumption using Method III: O2 cons. = [(VolMinExp * 2) + 4 l/min] * [(FiO2 - 20.9) / 79.1]
1	Replace *ExpMinVol* and *FiO2* in the equation with the current patient values.	*Example uses:* ExpMinVol = 0.5 l/min Oxygen (FiO2) = 60%
2	Solve the equation.[1]	The result is the estimated oxygen consumption in liters per minute (l/min). *Example.* O2 consumption = ((0.5*2) + 4) * (60 - 20.9) / 79.1 O2 consumption = 5 l/min * 0.494 O2 consumption = 2.5 l/min
3	Multiply the result by the planned duration of transport, in minutes.	The final result is the estimated oxygen requirement, in liters, for the specified length of time. *Example.* Transport duration = ~60 minutes *Example result.* Required O2 for transport = ~2.5 * 60 = **150 liters**

[1] The * 2 is to account for compressible volume in the breathing circuit. See Section 15.12.3.

5.8.1.2.4 Method IV. Nebulizer oxygen consumption

Method IV calculates nebulizer oxygen consumption. The result of this calculation is added to the result of Method I or II.

Table 5-15. Calculating O2 consumption with a nebulizer

Calculation	Result and example
To calculate estimated oxygen consumption using Method IV: Neb. O2 cons. = 8 l/min * (Insp time / total breath time)	
1 Calculate the ventilation oxygen requirement using Method I or II. See Sections 5.8.1.2.1 and 5.8.1.2.2.	*Example uses:* Method I ExpMinVol = 2 l/min Oxygen (FiO2) = 60% Transport duration = 30 minutes *Example result.* O2 consumption = 3.5 l/min Required O2 for transport = ~3.5 * 30 = **105 liters**
2 Calculate the nebulizer oxygen requirement.	Replace *Insp Time / total breath time* with the current patient I:E value. *Example.* I:E = 1:3 The inspiration time is one-quarter (0.25) of the total breath time. Neb. O2 cons. = 8 * 0.25 = 2 l/min.
3 Multiply the result of step 2 by the planned nebulization duration.	The result is the oxygen requirement for the nebulizer *only*. *Example.* Neb. O2 cons. = 2 l/min Transport duration = ~30 minutes *Example result.* Required O2 for nebulizer during transport = ~2 * 30 = **60 liters**
4 Add the results from steps 1 and 3.	This gives you the total estimated oxygen requirement for the duration of transport and the specified nebulization time. *Example.* Required O2 for nebulizer during transport = 60 liters Required O2 for transport = 105 liters *Example result.* Total required O2 for transport = 105 + 60 = **165 liters**

5.9 Stopping ventilation (Standby)

⚠ WARNING

When in Standby, the ventilator does *not* automatically resume ventilation when the patient is reconnected. You must manually restart ventilation.

NOTICE

- Patient alarms are suppressed in Standby.
- Acoustic patient alarms are suppressed for 30 seconds after starting ventilation from Standby.

Standby is a waiting state that lets you maintain ventilator settings while the ventilator is not performing any ventilatory functions.

To stop ventilation and place the ventilator in Standby

1. Press and quickly release ⏻ (Power/Standby) while the ventilator is turned on (Figure 10-2).

   The Activate Standby window opens (Figure 5-26).

2. Touch **Activate standby**.

   The Standby window opens (Figure 5-27).

A timer shows the elapsed time the ventilator has been in Standby.

Note that, if another window is open on the display, the elapsed time appears in a small yellow box on the left side of the Standby window.

Figure 5-26. Activate Standby window

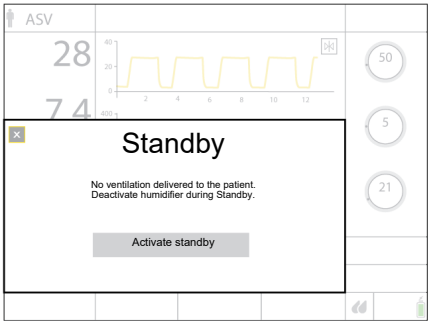
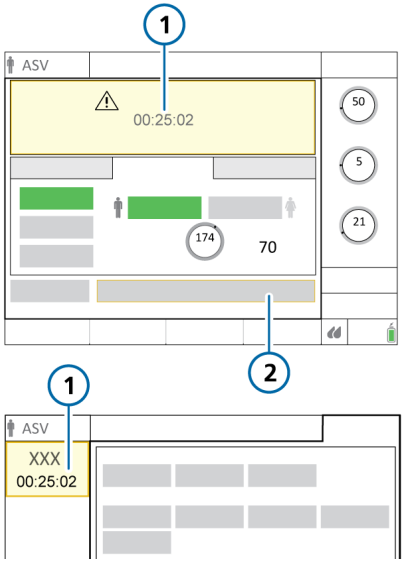


Figure 5-27. Standby window



1	Elapsed time in Standby	2	Start ventilation[1]

[1] When HiFlowO2 is selected: Start therapy; when CPR ventilation is active: Start CPR.

To end Standby and start ventilation

- Do either of the following:
  - Touch **Start ventilation**[1].
  - Press and quickly release ⏻.

Ventilation resumes with the previous settings.

To enter Standby and stop ventilation

1. Press the Power/Standby key.
2. In the confirmation window, touch **Activate standby**.

The device enters Standby (Figure 5-1). The yellow counter shows the time elapsed in Standby.

5.10 About the control parameters

Table 5-16 provides a brief description of the ventilator's control parameters, also referred to as *control settings*. You can review and adjust these settings in various locations, depending on their function.

Table 15-8 in the *Specifications* chapter provides the control parameter ranges and default settings, including accuracy.

For a comparison of Hamilton Medical ventilation-related terminology with ISO 19223:2019, see Section 15.5.

[1] When HiFlowO2 is selected: Start therapy; when CPR ventilation is active: Start CPR.

Table 5-16. Control parameters, defined

Parameter	Definition
%MinVol[1]	Percentage of minute volume to be delivered in ASV mode. The ventilator uses the %MinVol, Pat. height, and sex settings to calculate the target minute ventilation. Add 20% per degree of body temperature > 38.5°C (101.3°F).
Apnea backup	A function that provides ventilation after the adjustable apnea time passes without breath attempts. If Automatic is enabled, control parameters are calculated based on the patient's IBW (Adult/Ped patient group) or Weight (Neonatal patient group). Applies in APVsimv, SPONT, DuoPAP, APRV, VS, and NIV modes. *Be sure to review the safety information in Chapter 1*.
ETS	*See* Trigger, expiratory.
Flow	In HiFlowO2, Flow is the continuous and constant flow of medical gas to the patient in liters per minute.
Flow trigger	*See* Trigger, inspiratory.
HAMILTON-H900 related parameters	Displayed when a HAMILTON-H900 humidifier is connected and the option is installed. See Section 11.1.7.
I:E	Ratio of inspiratory time to expiratory time. Applies to mandatory breaths, and in APVsimv/APVcmv and PCV+ modes.
IBW[1] (kg)	Ideal body weight. A calculated value using height and sex, used in calculations for ASV and startup ventilation settings for adult and pediatric patients.
IntelliSync+ trigger	*See* Trigger, inspiratory and Trigger, expiratory.
Oxygen	Oxygen concentration to be delivered.
P high	The high pressure setting in APRV and DuoPAP modes. Absolute pressure, independent of set PEEP.
P low	The low pressure setting in APRV mode.
Pat. height[1]	Patient height. Used to compute ideal body weight (IBW) for adult and pediatric patients.

[1] Not applicable when the HAMILTON-C1 neo option is enabled and the ventilator is dedicated to neonatal ventilation.

Parameter	Definition
PEEP/CPAP	Positive end expiratory pressure and continuous positive airway pressure, baseline pressures applied during the expiratory phase. Applies to all breaths, except in APRV mode and with HiFlowO2.
Plimit	The maximum allowed pressure to apply during ventilation. Does not apply in nCPAP and nCPAP-PC modes, with Sigh breaths, or in HiFlowO2. Changing Plimit or the high Pressure alarm limit automatically changes the other: the high Pressure alarm limit is always 10 cmH2O greater than Plimit. When adjusting the pressure controls, the ventilator indicates when the total inspiratory pressure (including PEEP/CPAP) exceeds Plimit. For details, see Section 5.6.1. In ASV mode[1], Plimit must be at least 15 cmH2O above PEEP/CPAP for the ASV controller to function correctly.
P-ramp	Pressure ramp. The rate at which pressure rises to meet the set value. The P-ramp setting lets you fine-tune the initial flow output during a pressure-controlled or pressure-supported breath to match the ventilator flow to the patient's demand. Applies to all breaths. Notes: • Short P-ramp settings (0 to 50 ms) provide higher initial flow rates and result in faster attainment of the target pressure. This may benefit patients with elevated respiratory drive. • Setting the P-ramp too high, especially in combination with a small ET tube (high resistance), may result in a noticeable pressure overshoot during the early stage of inspiration and generation of a Pressure limitation alarm. • Setting the P-ramp too high may prevent the ventilator from attaining the set inspiratory pressure. A square (rectangular) pressure profile is the goal. • P-ramp is not available during CPR ventilation.
Rate	Respiratory frequency or number of breaths per minute.
Sex[1]	Sex of patient. Used to compute ideal body weight (IBW) for adult and pediatric patients.

[1] Not applicable when the HAMILTON-C1 neo option is enabled and the ventilator is dedicated to neonatal ventilation.

Parameter	Definition
Sigh[1]	When Sigh is activated, every 50th breath is applied using one of the following settings: • In pressure-controlled modes, the pressure delivered is > 10 cmH2O above the currently set ΔPcontrol or ΔPinsp. • In volume-controlled modes, the tidal volume delivered is 150% of the current tidal volume (Vt) setting. During Sigh breaths, the Pressure and Vt alarm limits remain in effect to help protect the patient from excessive pressures and volumes. Not available for neonatal patients, in DuoPAP or APRV modes, or with HiFlowO2.
T high	Length of time at the higher pressure level, P high, in DuoPAP and APRV modes.
T low	Length of time at the lower pressure level, P low, in APRV mode.
TI	Inspiratory time, the length of time to deliver gas for inspiration at the ΔPcontrol or Vt setting. Used with Rate to set the breath cycle time. Applies in PCV+, APVcmv, APVsimv, PSIMV+, NIV-ST, and nCPAP-PC modes. In PCV+ and APVcmv modes, TI can be controlled by Rate and TI or by the I:E ratio (set in Configuration). All other modes are controlled by Rate and TI.

[1] Not applicable when the HAMILTON-C1 neo option is enabled and the ventilator is dedicated to neonatal ventilation.

Parameter	Definition
TI max	Maximum inspiratory time for flow-cycled breaths in the following modes: • All patient groups: NIV and NIV-ST • Neonatal patient group: APVsimv, VS, PSIMV+, DuoPAP, and SPONT In Configuration, you can enable the TI max control setting for the following modes: • Adult/Ped patient group: APVsimv, VS, PSIMV+, DuoPAP, and SPONT For all patient groups, the switchover from inspiration to exhalation in spontaneous breaths is normally controlled by the ETS setting. If gas leakage is significant, however, the set cycle may never be reached. The TI max setting provides a backup so inspiration can be terminated. The ventilator switches over to exhalation when the set TI max is reached. When speaking valve compatibility is activated (ON), the TI max control setting is available in PSIMV+ and SPONT modes, in the Controls > More window regardless of whether it is enabled in Configuration.
Trigger, expiratory	The ventilator offers the following expiratory trigger types: ETS and IntelliSync+[1,2], which apply to all breaths. For details on selecting the trigger to use, see Section 5.6.2. **ETS** (expiratory trigger sensitivity) The percent of peak inspiratory flow at which the ventilator cycles from inspiration to exhalation. Increasing the ETS setting results in a shorter inspiratory time. The ETS setting lets you match the inspiratory time of pressure-supported breaths to the patient's neural timing. **IntelliSync+** With IntelliSync+, the ventilator monitors incoming sensor signals from the patient and reacts dynamically to initiate inspiration and expiration in real time.

[1] If the IntelliSync+ option is installed.
[2] Not available in all markets.

Parameter	Definition
Trigger, inspiratory	The ventilator offers the following trigger types: Flow and IntelliSync+[1], which apply to all breaths. For details on selecting the trigger to use, see Section 5.6.2. If the trigger is set higher than the patient is able to meet, a breath cannot be triggered. Reset the trigger to an achievable value, adjusting the sensitivity of the trigger to the patient's ability. All inspiratory trigger types are disabled during CPR ventilation. **Flow** The patient's inspiratory flow that triggers the ventilator to deliver a breath. **IntelliSync+** With IntelliSync+, the ventilator monitors incoming sensor signals from the patient and reacts dynamically to initiate inspiration and expiration in real time.
Vt/kg	Tidal volume per weight.
Vt	Tidal volume delivered during inspiration in APVcmv, APVsimv, and VS modes.
Weight	Actual body weight. Used only with neonates.
ΔPcontrol	The pressure (additional to PEEP/CPAP) to apply during the inspiratory phase in PCV+ and PSIMV+ modes.
ΔPinsp	Pressure (additional to PEEP/CPAP) to apply during the inspiratory phase. Applies in PSIMV+PSync and NIV-ST modes.
ΔPsupport	Pressure support for spontaneous breaths in SPONT, NIV, APVsimv, PSIMV+, and DuoPAP modes. It is the pressure (additional to PEEP/CPAP) to apply during the inspiratory phase. Pressure support helps the patient counteract the flow resistance of the breathing circuit and endotracheal tube. It compensates for the decreasing tidal volume and rising respiratory rate of a spontaneously breathing patient.

[1] If the IntelliSync+ option is installed.

6
Specifying neonatal settings

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6.1 Setting up for neonatal ventilation

Before proceeding, review the safety information in Chapter 1.

Setting up for neonatal ventilation comprises the following steps:

To ...	See ...
On the ventilator, select the patient group and specify weight.	Section 6.1.1
Install the expiratory valve.	Section 3.4.3
Select and assemble the appropriate breathing circuit and components.	Section 6.1.2
Adjust the position of the breathing circuit.	Section 6.1.2.6
Connect external devices.	Chapter 4
Perform the preoperational check and any required tests and calibrations.	Sections 6.2 and 5.4
Select the ventilation mode.	Sections 6.3 and 5.5

6.1.1 Setting the patient group and weight

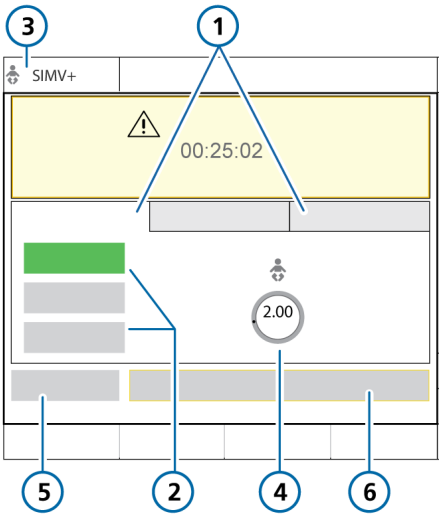
⚠ CAUTION

Entering the correct patient data ensures safe ventilation settings for start up, Apnea backup, and Safety ventilation/Safety mode.

You select the patient group and weight in the Standby window when first setting up the ventilator for the patient.

You can edit this information during ventilation, if needed, in the Patient window.

Figure 6-1. Neonatal Standby window



1 Patient group tabs (Neonatal selected)
2 Quick setup buttons
3 Selected mode and patient group
4 Weight
5 Preop check
6 Start ventilation[1]

[1] When HiFlowO2 is selected: Start therapy; when CPR ventilation is active: Start CPR.

To select the patient group

1. In the Standby window, touch the **Neonatal** tab. See Figure 6-1.
2. Touch the appropriate Quick setup button.

   By default, they are labeled **Neonatal 1**, **Neonatal 2**, and **Neonatal 3**. The Quick setup names and settings are defined in Configuration. For details, see Section 5.2.1.
3. Touch the Weight control and set the patient's body weight.

   By default, the weight is set to 2 kg.

You can now select the ventilation mode, if the desired mode is not already selected.

6.1.2 Setting up the patient breathing circuit set

Setting up a neonatal breathing circuit comprises the following steps:

Table 6-1. Assembling the breathing circuit

To ...	See ...
Select the breathing circuit components	Section 6.1.2.1
Connect the neonatal breathing circuit	Section 6.1.2.2
Connect the neonatal flow sensor	Section 6.1.2.4
Connect the pressure line (nCPAP, nCPAP-PC modes)	Section 6.1.2.5
Position the breathing circuit	Section 6.1.2.6

6.1.2.1 Selecting the breathing circuit components

Select the correct breathing circuit and components for your patient from Table 6-2.

Table 6-2. Neonatal breathing circuit part specifications

Patient group/Component	Specification
Patient group	Neonatal
Weight (kg)	0.2 to 30
Breathing circuit tube ID (mm)	10 to 12
Flow sensor	Neonatal
Pressure line	Neonatal
CO2 airway adapter	Neonatal

6.1.2.2 Connecting the neonatal breathing circuit

Figures 2-9 through 2-11 in Chapter 2 show typical neonatal breathing circuit configurations.

6.1.2.3 Working with the expiratory valve

The process is the same as for adult and pediatric patients. See Section 3.4.3.

6.1.2.4 Connecting the neonatal flow sensor

Note the following:

- Use a Hamilton Medical neonatal flow sensor to ventilate your neonatal patient.
- Do *not* use an adult/pediatric flow sensor.
- The neonatal flow sensor adds 1.3 ml of dead space.

To connect the neonatal flow sensor

1. For all modes except nCPAP and nCPAP-PC, connect a flow sensor between the Y-piece of the breathing circuit and the patient connection. See Figure 6-2.

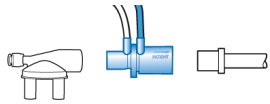
   When using the nCPAP and nCPAP-PC modes, remove the flow sensor and use the pressure-monitoring line with the breathing circuit (Section 6.1.2.5).

   Note that during calibration you place the flow sensor proximal to the patient.

   HiFlowO2 does not require the use of a flow sensor.
2. Connect the blue and clear tubes to the flow sensor connection ports on the ventilator.

   The blue tube attaches to the blue connection port. The clear tube attaches to the white connection port.
3. Calibrate the flow sensor and perform the Leak test. See Section 6.2.

Figure 6-2. Connect flow sensor between the Y-piece and patient interface

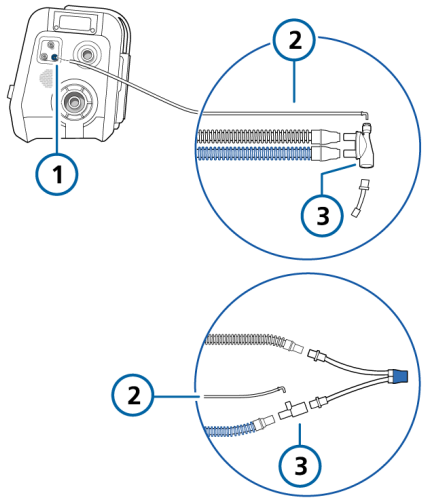


6.1.2.5 Connecting the pressure-monitoring line

Use the pressure line with the breathing circuit when using the nCPAP or nCPAP-PC modes. Do *not* use a flow sensor.

The pressure is measured by a built-in T-piece adapter in the inspiratory line, close to the patient, or (if available) over the optional pressure measuring connection at the Y-piece of the breathing circuit.

Figure 6-3. Connecting the pressure line



1	Pressure line connection port (blue)	3	T-piece, Y-piece
2	Pressure line		

To connect the pressure-monitoring line

1. Using an adapter, connect the pressure line to the small inlet at the top of the T- or Y-piece, whichever is used. See Figure 6-3.
2. Connect the pressure line to the blue flow sensor connection port on the ventilator.
3. Calibrate the breathing circuit and perform the Leak test.

6.1.2.6 Positioning the breathing circuit

After assembly, position the breathing circuit so that the hoses will *not* be pushed, pulled, or kinked as a result of a patient's movement, transport, or other activities, including scanner bed operation and nebulization.

6.2 Performing the preoperational check, tests, and calibrations

Before proceeding, review the safety information in Chapter 1.

The following sections in this chapter provide information that is specific to neonatal ventilation, and is intended as a supplement to the information provided in Chapter 5.

For details about when to perform the tests, and about the full preoperational check process, see Section 5.4.

When to perform

Before connecting a new patient to the ventilator or after changing the flow sensor and/or breathing set.

To perform the preoperational check

1. Use a setup as described in Table 6-2.
2. Perform all of the steps in Table 6-3.

To ensure that the ventilator functions according to specifications on your patient, perform the preoperational check using the breathing circuit that will be used on the patient.

For a test breathing circuit setup, you need:

- *Breathing circuit:* Neonatal, ID10 to ID12
- *Flow sensor:* Neonatal, with calibration adapter
- *Pressure line.* For use in nCPAP and nCPAP-PC modes
- *Test lung:* Demonstration lung, connective neonatal tubing between flow sensor and lung (an IngMar neonatal lung model is recommended)

When a test is complete:

☑ indicates the component is calibrated and ready.

☒ indicates the calibration was unsuccessful.

Table 6-3. Preoperational check, overview

To ...	See ...
Perform the preoperational check	Section 5.4 in Chapter 5
Perform the Leak test	Section 5.4.2 in Chapter 5
Calibrate the neonatal flow sensor	Section 6.2.1
In nCPAP modes, calibrate the breathing circuit	Section 6.2.2
Perform other calibrations, as needed	Section 5.4 in Chapter 5

6.2.1 Calibrating the neonatal flow sensor

Calibrate the flow sensor after connecting a new flow sensor or whenever the Flow sensor calibration needed alarm is generated.

A flow sensor is required for all modes except nCPAP or nCPAP-PC modes or when using HiFlowO2. Before proceeding, ensure you have the calibration adapter available.

To calibrate a neonatal/pediatric flow sensor

1. Calibrate the flow sensor in Standby, with no patient connected.
2. Make sure that the Neonatal patient group is selected, a neonatal flow sensor is connected, and the calibration adapter is available.
3. Set up the ventilator for ventilation, connecting the flow sensor to the Y-piece.
4. In the Standby window, touch **Preop check**.

   The System > Tests & calib window is displayed.
5. Touch **Flow sensor**.
6. When prompted on the display, attach the calibration adapter to the patient end of the flow sensor (Figure 6-4).
7. When prompted, flip the flow sensor and calibration adapter together 180° so the adapter is directly connected to the Y-piece (Figure 6-5).
8. When prompted, flip the flow sensor/adapter 180° again, so the flow sensor is directly connected to the Y-piece, and remove the calibration adapter (Figure 6-6).
9. When calibration is complete, verify that there is a checkmark ☑ in the Flow sensor checkbox.
10. When successful, finish assembling the breathing circuit, and continue with other tests or ventilation.

Figure 6-4. Attach adapter

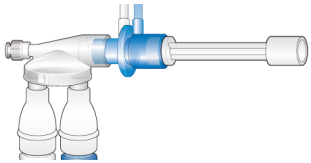


Figure 6-5. Flip components

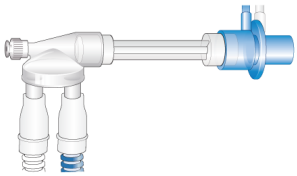
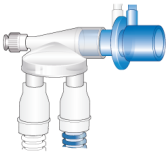


Figure 6-6. Flip components, remove adapter



To cancel an ongoing calibration

- Touch **Flow sensor** again.

In case of calibration failure

If the calibration fails, ☒ is displayed in the Flow sensor checkbox.

Perform the following checks, repeating the calibration after each one, until calibration is successful:

- Ensure that the flow sensor is appropriate for the selected patient group.
- Check the breathing circuit for a disconnection between the ventilator and the flow sensor, or for other large leaks (for example, breathing circuit, humidifier).
- Check that the correct flow sensor is connected, and that the flow sensor and expiratory valve/membrane are properly seated.
- If the calibration still fails, replace the flow sensor.
- If the calibration still fails, replace the expiratory valve membrane.
- If the calibration still fails, replace the expiratory valve set.

If the problem persists, have the ventilator serviced.

6.2.2 Calibrating the neonatal breathing circuit (nCPAP and nCPAP-PC modes)

The nCPAP and nCPAP-PC modes use a pressure line in the breathing circuit to measure the inspiratory pressure. Do *not* use a flow sensor.

This calibration ensures that the breathing circuit resistance compensation is accurate.

To calibrate the circuit with the pressure line

1. Touch **System** > **Tests & calib**.
2. Touch **Circuit**.

   If you have not already disconnected the patient, the text Disconnect patient is displayed.
3. Disconnect patient as follows:

   – If using a Y-piece, disconnect the breathing circuit from the patient.

   – If using a T-piece, disconnect the interface from the patient.
4. Follow the instructions displayed in the message line.
5. When calibration is complete, verify that there is a checkmark ☑ in the Circuit checkbox.
6. When successful, finish assembling the breathing circuit, and continue with other tests or ventilation.

To cancel an ongoing calibration

- Touch **Circuit** again.

In case of calibration failure

If the calibration fails, ☒ is displayed in the Circuit checkbox.

Perform the following checks, repeating the calibration after each one, until calibration is successful:

- Check the breathing circuit for a disconnection between the ventilator and the pressure line, or for other large leaks (for example, breathing circuit, humidifier).
- Check that the pressure line and expiratory valve set is properly seated.
- If the calibration fails, replace the pressure line.
- If the calibration still fails, replace the breathing circuit and expiratory valve set.

If the problem persists, have the ventilator serviced.

6.3 Selecting the ventilation mode

The neonatal modes available on the ventilator are either pressure controlled or adaptive (pressure regulated and volume targeted).

Note that the ventilator generates a continuous and constant base flow from the inspiratory outlet to the expiratory outlet during the later part of exhalation.

The base flow is set to a fixed 4 l/min for neonatal patients.

For the list of supported modes and details about each one, see Chapter 7.

To select the ventilation mode

- See Section 5.5.

6.4 Setting the patient weight for ventilation

For neonates, the ventilator uses actual body weight (instead of a calculated IBW), set in the Weight control.

Specifying the correct weight is particularly important as the ventilator uses this data as the basis for some calculations and mode control settings. By default, neonatal weight is set to 2 kg.

To set up the patient, see Section 6.1.1.

6.5 Alarms for neonatal ventilation

Note that the following adjustable alarms use patient Weight to set the initial alarm limits:

- Tidal volume, high and low (Vt)
- Minute volume, high and low (ExpMinVol)

Be sure to set the correct patient Weight in the Standby window before starting ventilation. See Section 6.1.1.

6.6 O2 enrichment for neonates

The applied oxygen concentration during the enrichment maneuver is increased to 125% of the current Oxygen setting.

For additional details on performing O2 enrichment, see Chapter 10.

7
Ventilation modes

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7.1 Overview

The HAMILTON-C1 offers a full range of ventilation modes that provide full and partial ventilatory support.

The primary aims of mechanical ventilation are:

- Elimination of CO2
- Oxygenation
- Decreased work of breathing
- Patient synchronization

The detailed mode descriptions provided in this chapter illustrate how the controls work to achieve these goals.

For a comparison of Hamilton Medical ventilation-related terminology with ISO 19223:2019, see Section 15.5.

In this manual, we refer to the APV modes using the APVcmv / APVsimv nomenclature. You can select the format to use in Configuration (Section 13.4.2).

7.1.1 Breath types and timing options

Hamilton Medical ventilators support two main breathing methods: mandatory breaths and spontaneous breaths.

Mandatory breaths. The start of inspiration (triggering) is determined by the ventilator or the patient. The end of inspiration (cycling) is determined by the ventilator.

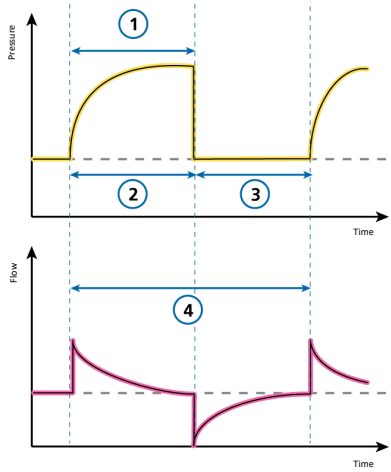
Spontaneous breaths. The start of inspiration (triggering) and end of inspiration (cycling) is determined by the patient. The patient breathes independently or receives support from the ventilator.

The ventilator controls mandatory breath timing using a combination of inspiratory time (TI) and Rate.

For some modes, you can set the ventilator to use any of the following combinations to control breath timing: I:E or TI.

To select the breath timing to use, see Section 13.4.1.

Figure 7-1. Breath timing parameters



1	TI	4	Rate
2, 3	I:E ratio		

Note that in the breath patterns shown in this chapter, we show I:E. What is actually displayed on your device depends on the breath timing selection on the ventilator.

7.1.2 Ventilation modes

The choice of mode is a medical decision that depends on the patient's CO2 elimination, oxygenation, activity, and breathing effort.

A ventilation mode combines breath type, breath sequence, and control variables.

The following tables provide an overview of the available ventilation modes.

Table 7-1. HAMILTON-C1 ventilation modes, description and applicable patient group

Mode name	ISO 19223 mode name	Patient group	Mode
Volume-targeted modes, adaptive pressure controlled			
APVcmv / (S)CMV+	A/C-vtPC	All	Breaths are volume targeted and mandatory.
APVsimv / SIMV+	SIMV-vtPC\PS	All	Volume-targeted mandatory breaths can be alternated with pressure-supported spontaneous (patient-triggered) breaths.
VS	CSV-vtPS	All	Breaths are spontaneous and deliver a set tidal volume to support patient-triggered breaths.
Pressure-controlled modes			
PCV+	A/C-PC	All	All breaths, whether triggered by the patient or the ventilator, are pressure-controlled and mandatory.
PSIMV+	SIMV-PC\PS	All	Mandatory breaths are pressure controlled. Mandatory breaths can be alternated with pressure-supported spontaneous (patient-triggered) breaths.
DuoPAP	SIMV-PC\PS	All	Mandatory breaths are pressure controlled. Spontaneous breaths can be triggered at both pressure levels.
APRV	IMV-PC	All	Spontaneous breaths can be continuously triggered. The pressure release between the pressure levels contributes to ventilation.
SPONT	CSV-PS	All	Every breath is spontaneous (patient-triggered), with or without pressure-support.

Mode name	ISO 19223 mode name	Patient group	Mode
Intelligent ventilation			
ASV[1]	n/a[2]	Adult/Ped	Operator sets %MinVol, PEEP, and Oxygen. Rate, tidal volume, inspiratory pressure, and I:E ratio are based on physiological input from the patient.
Noninvasive modes			
NIV	CSV-PS	All	Every breath is spontaneous (patient-triggered), with or without pressure-support.
NIV-ST	SIMV-PC	All	Every breath is spontaneous as long as the patient is breathing above the set rate. A backup rate can be set for mandatory breaths.
nCPAP	CPAP	Neonatal	Demand flow Nasal Continuous Positive Airway Pressure.
nCPAP-PC	CSV-PC	Neonatal	Breaths are pressure controlled and mandatory.

[1] Not applicable when the HAMILTON-C1 neo option is enabled and the ventilator is dedicated to neonatal ventilation.
[2] EN ISO 19223 is not applicable as this therapy is *not* reflected in the standard.

Figure 7-2. Ventilation modes/settings overview

Mode type	Intelligent Ventilation	Volume targeted, adaptive pressure control			Pressure controlled						Noninvasive				
Mode	ASV ***	APVcmv	APVsimv	VS	PCV+	PSIMV+ PSync	PSIMV+	DuoPAP	APRV	SPONT	NIV	NIV-ST	nCPAP**	nCPAP-PC **	HiFlow O2
Timing	--	Rate	Rate	--	Rate	Rate	Rate	Rate	T low	--	--	Rate	--	Rate	--
	--	*	TI	--	*	TI	TI	T high	T high	--	--	TI	--	TI	--
Mandatory breaths	--	Vt	Vt	--	ΔPcontrol	ΔPinsp	ΔPcontrol	P high	P high	--	--	ΔPinsp	--	ΔPinsp	--
Spontaneous breaths	--	--	ΔPsupport	Vt	--	ΔPinsp	ΔPsupport	ΔPsupport	--	ΔPsupport	ΔPsupport	ΔPinsp	--	--	--
	ETS	--	ETS	ETS	--	ETS	ETS	ETS	--	ETS	ETS	ETS	--	--	--
	--	--	--	--	--	--	--	--	--	--	TI max	TI max	--	--	--
Baseline press. PEEP/CPAP	X	X	X	X	X	X	X	X	P low	X	X	X	X	X	--
Trigger	X	X	X	X	X	X	X	X	X	X	X	X	--	--	--
P-ramp	X	X	X	X	X	X	X	X	X	X	X	X	--	X	--
Plimit	X	X	X	X	X	X	X	X	X	X	X	X	--	--	--
Oxygen	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Sex***	X	X	X	X	X	X	X	X	X	X	X	X	--	--	--
Pat. height***	X	X	X	X	X	X	X	X	X	X	X	X	--	--	--
Mode specific	%MinVol	--	--	--	--	--	--	--	--	--	--	--	--	--	Flow
Sigh***	X	X	X	X	X	X	X	--	--	X	X	X	--	--	--
Apnea backup	--	--	APVsimv	APVsimv	--	--	--	APVsimv	APVsimv	APVsimv	PCV+	--	--	--	--

* I:E, TI ** Neonatal only *** Adult/Ped only – N/A X applies to this mode

7.2 Volume-targeted modes, adaptive pressure control

The following modes are volume targeted, with adaptive pressure control:

- APVcmv / (S)CMV+
- APVsimv / SIMV+
- Volume Support (VS)

You can choose to display the APV modes using either the APVcmv / APVsimv nomenclature or the (S)CMV+ / SIMV+ nomenclature. The selection is set in Configuration, in the Modes > General > Philosophy window (see Section 13.4).

NOTICE

- The minimum inspiratory pressure (Ppeak – PEEP) in VS, APVcmv, and APVsimv modes is 5 cmH2O. Be aware that a small set tidal volume with high lung compliance may lead to higher-than-expected tidal volumes.
- Ensure Plimit is set appropriately for adaptive modes. This setting provides a safety pressure limit for the device to appropriately adjust the inspiratory pressure necessary to achieve the target tidal volume.

  The maximum available inspiratory pressure (Plimit), is indicated by a blue line on the pressure waveform display.

  If Plimit is set too low, there may not be enough margin for the device to adjust its inspiratory pressure to deliver the target tidal volume.

7.2.1 APVcmv / (S)CMV+ mode

APVcmv stands for *adaptive pressure ventilation with controlled mandatory ventilation*. This mode is also referred to as (S)CMV+, which stands for *synchronized controlled mandatory ventilation*.

You can choose to display the APV modes using either the APVcmv nomenclature or the (S)CMV+ nomenclature; the selection is set in Configuration, in the Modes > General > Philosophy window (see Section 13.4).

(S)CMV+ is a volume-targeted pressure-controlled ventilation mode. It functions similarly to conventional volume-controlled mode of ventilation, except that pressure is the control variable rather than flow. Pressure is adjusted between breaths to achieve the target tidal volume.

The breath can be triggered by the ventilator or by the patient. If the breath is triggered by the patient, the inspiratory rate may increase.

The ventilator uses the Plimit setting (high Pressure alarm limit minus 10 cmH2O) as a safety boundary for its inspiratory pressure adjustment, and does not exceed this value. An exception is Sigh breaths[1], when the ventilator may apply inspiratory pressures 3 cmH2O below the high Pressure alarm limit.

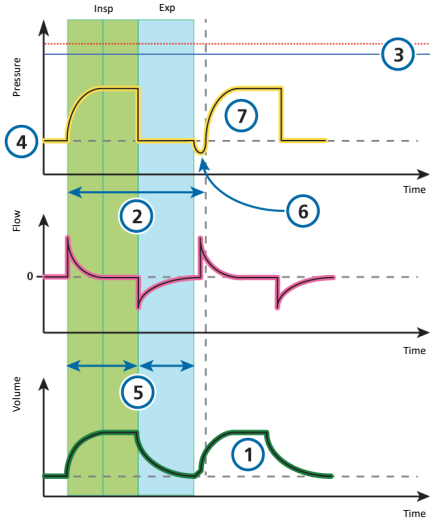
Breaths in (S)CMV+ mode are volume-targeted and mandatory, delivered at the lowest possible pressure depending on lung conditions.

The operator sets the target tidal volume (Vt).

The ventilator delivers the set target volume (Vt) at a preset rate. The patient can trigger mandatory breaths between preset rate breaths.

[1] Not applicable when the HAMILTON-C1 neo option is enabled and the ventilator is dedicated to neonatal ventilation.

Figure 7-3. APVcmv / (S)CMV+ mode: Breathing pattern and controls



Ventilator controls

CO2 elimination

1	Vt	3	Plimit
2	Rate		Sigh[1] *(not shown)*

Oxygenation

4	PEEP	5	I:E[2]
	Oxygen *(not shown)*		

Patient synchronization

6	Trigger	7	P-ramp

[1] Not applicable when the HAMILTON-C1 neo option is enabled and the ventilator is dedicated to neonatal ventilation.
[2] Depending on the selected breath timing philosophy.

7.2.2 APVsimv / SIMV+ mode

APVsimv stands for *adaptive pressure ventilation with synchronized intermittent mandatory ventilation*. This mode is also referred to as SIMV+, which stands for *synchronized intermittent mandatory ventilation plus.*

You can choose to display the APV modes using either the APVsimv nomenclature or the SIMV+ nomenclature; the selection is set in Configuration, in the Modes > General > Philosophy window (see Section 13.4).

The SIMV+ mode combines attributes of the (S)CMV+ and SPONT modes, delivering volume-targeted mandatory breaths or pressure-supported spontaneous (patient-triggered) breaths.

SIMV+ mode ensures that the set target volume is delivered during the mandatory breaths.

After the mandatory breath is delivered, the patient is free to take any number of spontaneous breaths for the remainder of the APV breath interval.

The ventilator uses the Plimit setting (high Pressure alarm limit minus 10 cmH2O) as a safety boundary for its inspiratory pressure adjustment, and does not exceed this value. An exception is Sigh breaths[1], when the ventilator may apply inspiratory pressures 3 cmH2O below the high Pressure alarm limit.

Each breath interval includes mandatory time (Tmand) and spontaneous time (Tspont).

- If the patient triggers a breath during Tmand, the ventilator immediately delivers a mandatory breath.
- If the patient triggers a breath during Tspont, the ventilator delivers a spontaneous pressure-supported breath.

If the patient does not trigger a breath during Tspont, the ventilator automatically delivers a mandatory breath at the end of Tmand.

In this mode, parameters for both mandatory and spontaneous breath types are set.

- The tidal volume (Vt) setting defines the delivered volume of mandatory breaths.
- Rate and I:E define the timing of the breath cycle for mandatory breaths.
- For spontaneous breaths:

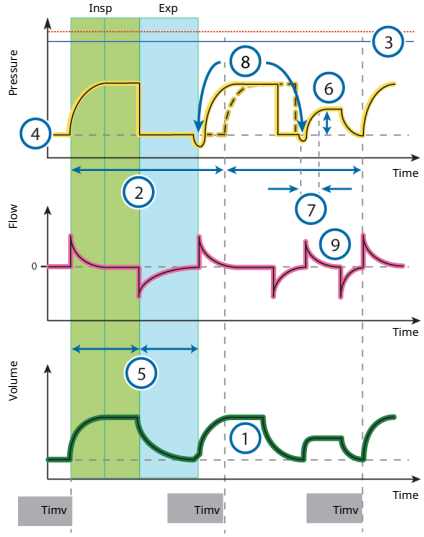
  – ΔPsupport defines the pressure support above PEEP.

  – ETS affects the inspiratory timing of the breaths.

  – TI max can limit the inspiratory time.[2]

[1] Not applicable when the HAMILTON-C1 neo option is enabled and the ventilator is dedicated to neonatal ventilation.
[2] TI max is only available for adult/pediatric patients if it is enabled in Configuration (Section 13.4.4). It is always available for neonates.

Figure 7-4. APVsimv/SIMV+: Breathing patterns and controls



Ventilator controls

CO2 elimination

1	Vt	3	Plimit
2	Rate		Sigh[1] *(not shown)*
6	ΔPsupport		

Oxygenation

4	PEEP		Oxygen *(not shown)*
5	I:E[2]		

Patient synchronization

7	P-ramp	9	ETS
8	Trigger		

[1] Not applicable when the HAMILTON-C1 neo option is enabled and the ventilator is dedicated to neonatal ventilation.
[2] Depending on the selected breath timing philosophy.

7.2.3 Volume Support (VS)

Breaths in VS mode are volume-targeted and spontaneous. Pressure is adjusted between breaths to achieve the target tidal volume.

The ventilator uses the Plimit setting (high Pressure alarm limit minus 10 cmH2O) as a safety boundary for its inspiratory pressure adjustment, and does not exceed this value. An exception is Sigh breaths[1], when the ventilator may apply inspiratory pressures 3 cmH2O below the high Pressure alarm limit.

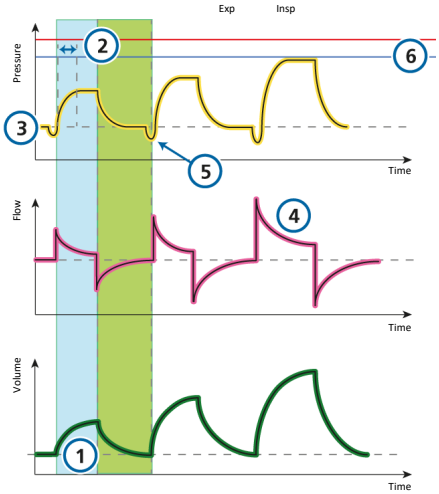
To achieve the set tidal volume, the device decreases support when the patient's breathing activity increases, and conversely, increases support when the patient's inspiratory efforts decrease.

In this mode, the patient initiates all breaths.

- The tidal volume (Vt) setting defines the delivered volume.
- The P-ramp setting controls the speed with which the ventilator arrives at the desired pressure.
- ETS affects the inspiratory timing of the supported breaths.

  The inspiratory time can also be limited by TI max.[2]

Figure 7-5. Volume Support mode: Breathing pattern and controls



1	Vt	4	ETS
2	P-ramp	5	Trigger
3	PEEP	6	Plimit (blue line)

[1] Not applicable when the HAMILTON-C1 neo option is enabled and the ventilator is dedicated to neonatal ventilation.
[2] TI max is only available for adult/pediatric patients if it is enabled in Configuration (Section 13.4.4). It is always available for neonates.

7.3 Pressure-controlled modes

The following modes are pressure-controlled:

- PCV+
- PSIMV+
- PSIMV+ with PSync
- SPONT
- DuoPAP
- APRV

7.3.1 PCV+ mode

PCV+ stands for *pressure-controlled ventilation*.

Breaths in PCV+ mode are pressure controlled and mandatory.

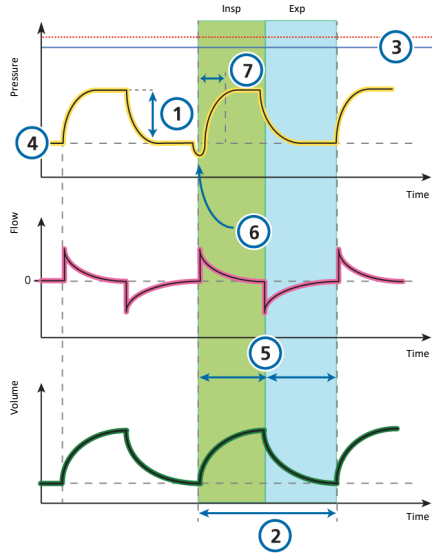
The ventilator delivers a constant level of pressure, so the volume depends on the pressure settings, the inspiration time, and the resistance and compliance of the patient's lungs.

In PCV+ mode, parameters are set only for mandatory breaths.

- The pressure control (ΔPcontrol) setting defines the applied pressure above PEEP.
- Rate and I:E define the timing of the breath cycle.
- The P-ramp setting controls the speed with which the ventilator arrives at the desired pressure.

This mode is available for use with a speaking valve.

Figure 7-6. PCV+ mode: Breathing pattern and controls



Ventilator controls

CO2 elimination

1	ΔPcontrol	3	Plimit
2	Rate		Sigh[1] *(not shown)*

Oxygenation

4	PEEP	5	I:E[2]
	Oxygen *(not shown)*		

Patient synchronization

6	Trigger	7	P-ramp

[1] Not applicable when the HAMILTON-C1 neo option is enabled and the ventilator is dedicated to neonatal ventilation.
[2] Depending on the selected breath timing philosophy.

7.3.2 PSIMV+ mode

PSIMV+ stands for *pressure-controlled synchronized intermittent mandatory ventilation*.

PSIMV+ mode has two options: with and without PSync. For a description of PSIMV+ with active PSync, see Section 7.3.3.

In PSIMV+ mode, the mandatory breaths are PCV+ breaths. These can be alternated with spontaneous (patient-triggered) breaths.

Each SIMV breath interval includes mandatory time (Tmand) and spontaneous time (Tspont).

- If the patient triggers a breath during Tmand, the ventilator immediately delivers a mandatory breath.
- If the patient triggers a breath during Tspont, the ventilator delivers a spontaneous, pressure-supported breath.
- If the patient does not trigger a breath during Tspont, the ventilator automatically delivers a mandatory breath at the end of Tmand.

In PSIMV+ mode, parameters for both mandatory and spontaneous breath types are set.

- For mandatory breaths, the pressure control (ΔPcontrol) setting defines the applied pressure above PEEP.

  Rate and I:E define the timing of the breath cycle.
- For spontaneous breaths:

  – ΔPsupport defines the pressure support above PEEP.

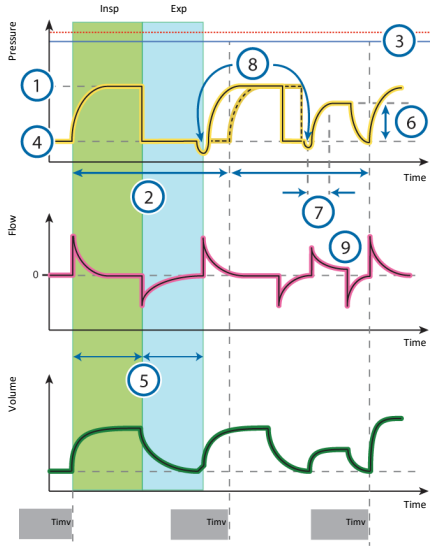
  – ETS affects the inspiratory timing of the breaths.

  – TI max can limit the inspiratory time.[1]

This mode is available for use with a speaking valve.

[1] TI max is only available for adult/pediatric patients if it is enabled in Configuration (Section 13.4.4). It is always available for neonates.

Figure 7-7. PSIMV+ mode: Breathing pattern and controls



Ventilator controls

CO2 elimination

1 ΔPcontrol

2 Rate

Sigh[1] *(not shown)*

3 Plimit

6 ΔPsupport

Oxygenation

4 PEEP

5 I:E[2]

Oxygen *(not shown)*

Patient synchronization

7 P-ramp

8 Trigger

9 ETS

[1] Not applicable when the HAMILTON-C1 neo option is enabled and the ventilator is dedicated to neonatal ventilation.
[2] Depending on the selected breath timing philosophy.

7.3.3 PSIMV+ mode with PSync

PSIMV+ stands for *pressure-controlled synchronized intermittent mandatory ventilation*.

PSIMV+ mode has two options: with and without PSync. For a description of PSIMV+ without active PSync, see Section 7.3.2.

If the patient triggers a breath, the ventilator delivers a spontaneous breath supported at the ΔPinsp setting.

If the patient does not trigger a breath, the ventilator automatically delivers a mandatory breath at the ΔPinsp setting.

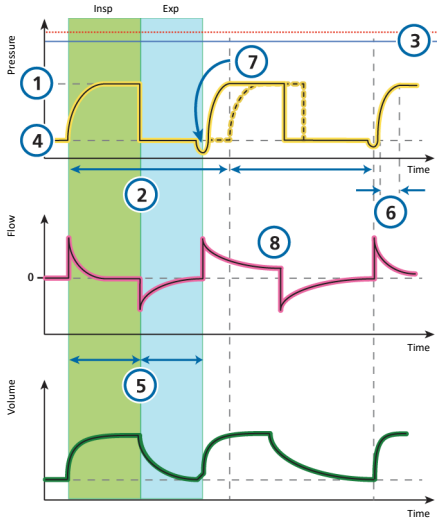
In PSIMV+ mode, parameters for both mandatory and spontaneous (patient-triggered) breath types are set.

- The ΔPinsp setting defines the applied pressure above PEEP for mandatory and spontaneous (patient-triggered) breaths.
- Rate and TI define the breath timing for mandatory breaths.
- For spontaneous (patient-triggered) breaths:

  – ETS affects the inspiratory timing of the breaths.

  – TI max can limit the inspiratory time.[1]

Figure 7-8. PSIMV+ with PSync mode: Breathing pattern and controls



Ventilator controls

CO2 elimination

1	ΔPinsp	3	Plimit
2	Rate		Sigh[2] *(not shown)*

Oxygenation

4	PEEP	5	I:E[3]
	Oxygen *(not shown)*		

Patient synchronization

6	P-ramp	8	ETS
7	Trigger		

[1] TI max is only available for adult/pediatric patients if it is enabled in Configuration (Section 13.4.4). It is always available for neonates.
[2] Not applicable when the HAMILTON-C1 neo option is enabled and the ventilator is dedicated to neonatal ventilation.
[3] Depending on the selected breath timing philosophy.

7.3.4 SPONT mode

SPONT stands for *spontaneous mode*; it delivers spontaneous breaths.

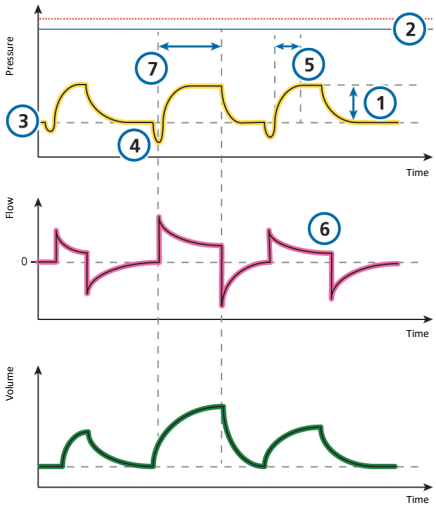
When pressure support is set to zero, the ventilator functions like a conventional CPAP system.

- The pressure support (ΔPsupport) setting defines the applied pressure during inspiration.
- The PEEP setting defines the PEEP applied during expiration.
- ETS affects the inspiratory timing of the breaths.

  The inspiratory time can also be limited by TI max.[1]

This mode is available for use with a speaking valve.

Figure 7-9. SPONT mode: Breathing pattern and controls



Ventilator controls

CO2 elimination

1	ΔPsupport	2	Plimit
	Sigh[2] *(not shown)*		

Oxygenation

3	PEEP		Oxygen *(not shown)*

Patient synchronization

4	Trigger	6	ETS
5	P-ramp	7	TI max

[1] TI max is only available for adult/pediatric patients if it is enabled in Configuration (Section 13.4.4). It is always available for neonates.

[2] Not applicable when the HAMILTON-C1 neo option is enabled and the ventilator is dedicated to neonatal ventilation.

7.3.5 DuoPAP mode

DuoPAP stands for *duo positive airway pressure*.

DuoPAP is a type of pressure ventilation designed to support spontaneous breathing on two alternating levels of CPAP.

In this mode, the ventilator switches automatically and regularly between two operator-selected levels of positive airway pressure or CPAP.

Cycling between the levels is triggered by DuoPAP timing settings or by patient effort.

In DuoPAP, the switch-over[1] between the two levels is defined by the pressure settings, P high and PEEP/CPAP, and the time settings, T high and Rate.

Note the following:

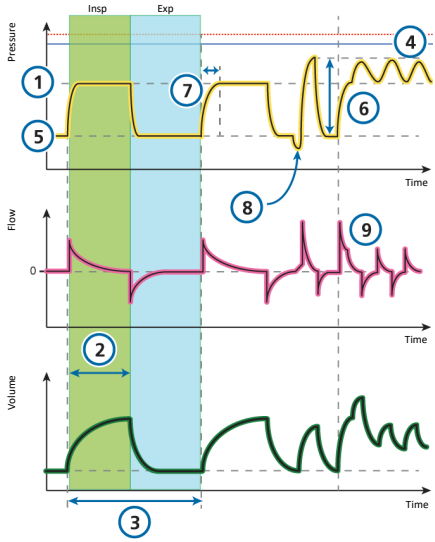
- At conventional settings and in the absence of spontaneous breathing, DuoPAP resembles PCV+.
- As you decrease the rate, keeping T high short relative to the time at the lower pressure level, the mode looks more like PSIMV+, with spontaneous breaths following mandatory breaths.
- If T high is set to almost the breath cycle time with just enough time at the low level to allow full or near-full exhalation, this mode looks like APRV (Section 7.3.6).

Pressure support can be set to assist spontaneous breaths in DuoPAP, whether they occur at the PEEP/CPAP or P high level.

ΔPsupport is set relative to (above) PEEP/CPAP, which means that spontaneous breaths at the P high level are supported only when this target pressure is greater than P high.

[1] The switch-over from PEEP to P high is synchronized to the patient's efforts in the Synchronization window.

Figure 7-10. DuoPAP mode: Breathing pattern and controls



Ventilator controls

CO2 elimination

1	P high	3	Rate
2	T high	4	Plimit
6	ΔPsupport		

Oxygenation

5	PEEP		Oxygen *(not shown)*

Patient synchronization

7	P-ramp[1]	9	ETS
8	Trigger		

[1] Pressure rise time to P high and ΔPsupport.

7.3.6 APRV mode

APRV stands for *airway pressure release ventilation*.

Set airway pressure P high is transiently released to a lower level P low, after which it is quickly restored to reinflate the lungs.

For a patient who has no spontaneous breathing efforts, APRV is similar to pressure-controlled inverse ratio ventilation.

APRV allows spontaneous breathing at any time during the respiratory cycle.

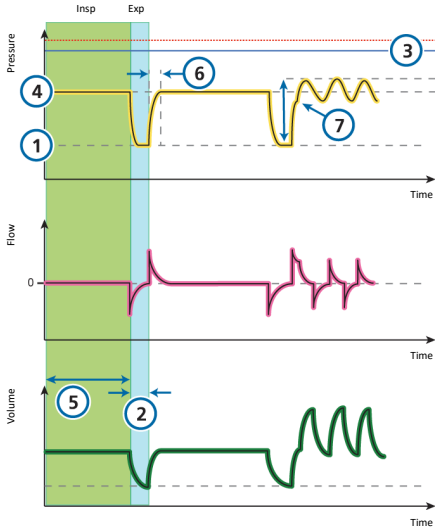
APRV is an independent mode. When changing modes, the pressure and timing settings from any other mode are not transferred to APRV, and vice versa.

When switching to APRV for the first time, the initial timing and pressure settings proposed are based on IBW (Weight for neonatal patients) as shown in the following table.

Table 7-2. Default settings for APRV

IBW / Weight (kg)	P high / P low (cmH2O)	T high (s)	T low (s)
0.2 to 2.99	20 / 5	1.4	0.2
3 to 5.9	20 / 5	1.7	0.3
6 to 8.9	20 / 5	2.1	0.3
9 to 20.9	20 / 5	2.6	0.4
21 to 39	20 / 5	3.5	0.5
40 to 59	20 / 5	4.4	0.6
> 60	20 / 5	5.4	0.6

Figure 7-11. APRV mode: Breathing pattern and controls



Ventilator controls

CO2 elimination

1 P low
2 T low
3 Plimit

Oxygenation

4 P high[1]
5 T high
Oxygen *(not shown)*

Patient synchronization

6 P-ramp (to P high)
7 Trigger[2]

[1] With prolonged T high settings and short T low settings, the P high setting in effect becomes the PEEP level.
[2] Only used to count spontaneous breaths or to monitor patient activity.

7.4 Intelligent Ventilation

ASV® is an adaptive pressure-controlled, volume-targeted Intelligent Ventilation mode.

ASV mode is only available for adult/ pediatric patients.

7.4.1 ASV mode

ASV stands for *Adaptive Support Ventilation®*.

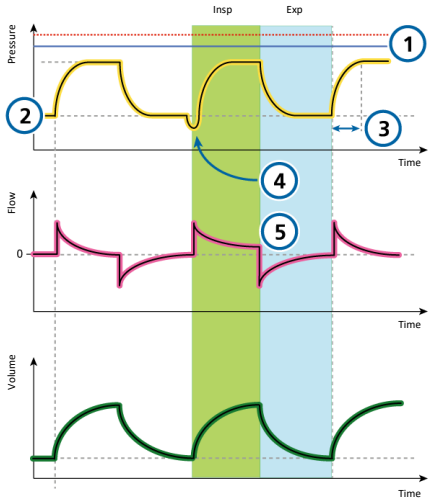
ASV maintains an operator-preset, minimum minute ventilation independent of the patient's breathing activity.

The target breathing pattern (tidal volume and respiratory rate) is calculated by the ventilator, based on the assumption that the optimal breathing pattern results in the least work of breathing, and the minimal force of breathing (driving pressure). For initial settings, see Table 7-3.

ASV adjusts inspiratory pressure and mandatory rate on a breath-by-breath basis taking into account the changing patient lung mechanics (resistance, compliance, RCexp) and applying lung-protective strategies to meet the targets.

A decrease in pressure limitation (Plimit) will follow with a decrease in tidal volume (Vt) and an increase in Rate.

Figure 7-12. ASV mode: Breathing pattern and controls



Ventilator controls

CO2 elimination

1 Plimit Sigh *(not shown)*

%MinVol *(not shown)*

Oxygenation

2 PEEP Oxygen *(not shown)*

Patient synchronization

3 P-ramp 5 ETS

4 Trigger

ASV maintains a **preset minimum minute ventilation**:

- Automatically adjusts for changing patient conditions between active and passive states
- Mandatory breaths are pressure controlled
- Spontaneous breaths are pressure supported
- Prevents tachypnea
- Prevents AutoPEEP
- Prevents dead space ventilation
- Does not exceed a ΔPinsp pressure of **10 cmH2O below the upper pressure limit**
- Does not exceed a pressure limit of 10 cmH2O below the upper pressure limit

The operator sets the %MinVol, PEEP, and Oxygen.

For details about working with ASV, see Section 7.7.

Table 7-3. ASV mode initial breath pattern settings

Patient group	IBW (kg)	ΔPinsp (cmH2O)	TI (s)	Initial rate (b/min)
Pediatric	3 to 5	15	0.4	30
	6 to 8	15	0.6	25
	9 to 11	15	0.6	25
	12 to 14	15	0.7	20
	15 to 20	15	0.8	20
	21 to 23	15	0.9	20
	24 to 29	15	1	20
	> 30	15	1	20
Adult	10 to 29	15	1	20
	30 to 39	15	1	18
	40 to 59	15	1	15
	60 to 89	15	1	15
	90 to 99	18	1.5	15
	> 100	20	1.5	15

7.4.1.1 ASV and ASV 1.1

ASV 1.1 is the default setting for the ASV mode. The previous version of ASV is also available on the device, and can be selected in Configuration.

ASV 1.1 follows the low tidal volume recommendation (Bellani G, et al. JAMA 2016) and brings additional features and changes:

- Increased target rate and reduced tidal volumes and driving pressure for the majority of patients compared to standard ASV.
- In cases of high time constants and high minute volumes, Vt max is limited to 15 ml/kg.

For details about working with ASV, see Section 7.7.

7.5 Noninvasive modes

⚠ CAUTION

Hamilton Medical ventilators provide noninvasive ventilation through a helmet EXCEPT for CPAP therapy. The turbine-driven ventilators provide higher continuous flow levels, and the air supply is provided by filtered room air (with a HEPA air inlet filter) with ambient humidity.

The following modes are noninvasive:

- NIV
- NIV-ST
- nCPAP
- nCPAP-PC

The NIV and NIV-ST modes are implementations of noninvasive positive pressure ventilation (NPPV).

nCPAP and nCPAP-PC are neonatal modes that offer nasal continuous positive airway pressure - and intermittent positive pressure support through a nasal interface (mask or prongs) for infants and neonates.

For details about working with noninvasive modes, see Section 7.6.

7.5.1 NIV mode

NIV stands for *noninvasive ventilation*.

NIV mode delivers spontaneous breaths with or without pressure support.

NIV is designed for use with a mask or other noninvasive patient interface.

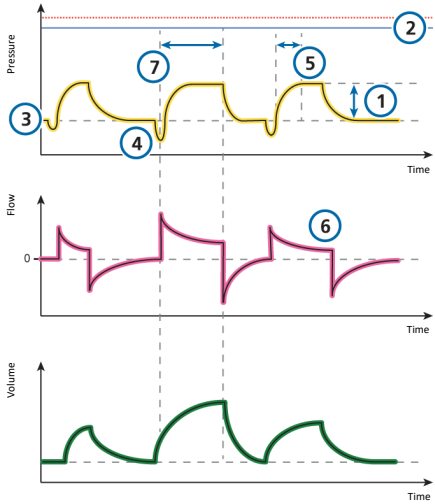
When pressure support is set to zero, the ventilator functions like a conventional CPAP system.

- The pressure support (ΔPsupport) setting defines the applied pressure during inspiration.
- ETS affects the inspiratory timing of the breaths.

  The inspiratory time can also be limited by TI max.
- The PEEP setting defines the PEEP applied during expiration.

For additional details about working with noninvasive modes, see Section 7.6.

Figure 7-13. NIV mode: Breathing pattern and controls



Ventilator controls

CO2 elimination

1	ΔPsupport	2	Plimit
	Sigh[1] *(not shown)*		

Oxygenation

3	PEEP		Oxygen *(not shown)*

Patient synchronization

4	Trigger	6	ETS
5	P-ramp	7	TI max

[1] Not applicable when the HAMILTON-C1 neo option is enabled and the ventilator is dedicated to neonatal ventilation.

7.5.2 NIV-ST mode

NIV-ST stands for *spontaneous/timed noninvasive ventilation*.

NIV-ST mode delivers time-cycled or flow-cycled breaths. Every patient trigger results in a flow-cycled, pressure-supported breath.

If the rate of patient-triggered breaths falls below the set mandatory Rate, time-cycled breaths are delivered at the set Rate and timing.

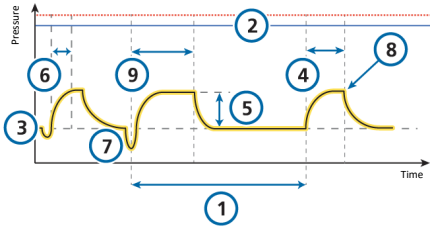
If the patient triggers a breath during the breath interval, the ventilator immediately delivers a spontaneous breath. If the patient does not trigger an inspiration during this time, the ventilator initiates a mandatory breath according to the set Rate.

This mode requires that you set the parameters needed for both mandatory and spontaneous breath types.

- The inspiratory pressure setting, ΔPinsp, defines the applied pressure for both mandatory and spontaneous breaths.
- The Rate and TI (inspiratory time) control settings define the breath timing.
- For spontaneous breaths, the ETS setting affects the inspiratory timing of the breaths.

  The inspiratory time can also be limited by TI max.

Figure 7-14. NIV-ST mode: Breathing pattern and controls



Ventilator controls

CO2 elimination

1	Rate	2	Plimit
5	ΔPinsp		Sigh[1] *(not shown)*

Oxygenation

3	PEEP	4	TI
	Oxygen *(not shown)*		

Patient synchronization

6	P-ramp	8	ETS
7	Trigger	9	TI max

[1] Not applicable when the HAMILTON-C1 neo option is enabled and the ventilator is dedicated to neonatal ventilation.

7.5.3 The nCPAP modes

⚠ CAUTION

Consider setting the Flow alarm limit to an appropriate level above the current monitored peak to be able to detect leaks and disconnection of the patient interface.

nCPAP stands for *nasal continuous positive airway pressure*.

The HAMILTON-C1 offers two nCPAP modes: nCPAP and nCPAP-PC, described in detail in the following sections.

About the Flow and Insp Flow parameters

In these modes, the Flow and Insp Flow parameters monitor average and peak flow, respectively, as described in the following table.

Table 7-4. Flow parameters in nCPAP modes

Parameter (unit)	nCPAP mode	nCPAP-PC mode
Flow (l/min)	Average flow, updated every second.	Average flow during expiration, updated each breath.
	Displayed in the Monitoring window.	
Insp Flow (l/min)	Peak flow during inspiration, measured every second. Insp Flow is a main monitoring parameter (MMP) and is always displayed.	

About the High Flow alarm

In both modes, the High Flow alarm monitors the inspiratory flow and can help to detect disconnection of the patient interface. When the flow exceeds the set limit, the High Flow alarm is generated and the system reduces the delivered flow. As a result, the delivered pressure may also be reduced.

To minimize the incidence of this alarm, observe the Insp Flow values and set the flow limit to a value above the average Insp Flow reading plus a known minimum leakage.

7.5.3.1 nCPAP mode

nCPAP stands for *nasal continuous positive airway pressure*.

This mode applies CPAP over a nasal interface (mask or prongs). Leaks are compensated due to the set High Flow limit.

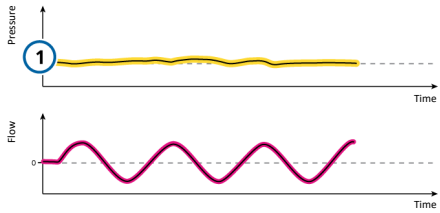
The nCPAP mode works with the following parameters:

- Control settings: PEEP/CPAP and Oxygen
- Monitored parameters: Insp Flow and Flow

For details about the parameters and flow-related alarms, see Sections 7.5.3, 5.10, and 9.4.

When a manual breath is applied, the pressure changes to PEEP + 5 cmH2O for a period of 0.4 seconds, or so long as the key is pressed, to a maximum of 15 seconds. When the manual breath is completed, the pressure returns to the set PEEP/CPAP level.

Figure 7-15. nCPAP mode: Breath pattern and controls



1 PEEP

7.5.3.2 nCPAP-PC mode

nCPAP-PC stands for nasal continuous positive airway pressure - pressure control.

This mode delivers, in addition to the set CPAP, intermittent, time-cycled, and pressure-controlled breaths. This results in a biphasic breathing pattern.

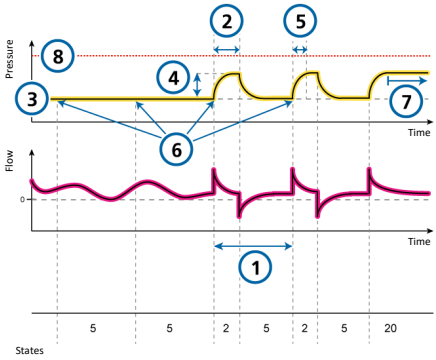
The patient can also breathe freely at both pressure levels. The inspiratory flow follows the respiratory effort of the patient on both pressure levels. Leaks are compensated due to the set High Flow limit.

The following parameters are used in the nCPAP-PC mode: Rate, ΔPcontrol, TI, P-ramp, PEEP/CPAP, Oxygen

When a manual breath is applied, the pressure changes to the ΔPcontrol setting for the length of time set by the TI (inspiratory time) or so long as the key is pressed, to a maximum of 15 seconds. When the manual breath is completed, the pressure returns to the set PEEP/CPAP level.

For details about the parameters, see Section 5.10.

Figure 7-16. nCPAP-PC mode: Breathing pattern and controls



1	Rate	5	P-ramp
2	TI	6	Mandatory trigger
3	PEEP	7	Manual breath key pressed
4	ΔPcontrol	8	Pressure limitation

7.6 Working with noninvasive modes

⚠ CAUTION

If you place an additional component, such as an HMEF, between the flow sensor and the patient, the additional resistance limits the ventilator's ability to identify disconnection at the patient. To correctly identify a patient disconnection, be sure to appropriately set the lower limit of the Pressure alarm, as well as the Volume alarm limits, and carefully monitor the patient's SpO2 and, if available, PetCO2 values.

This section provides an overview of noninvasive ventilation requirements, contraindications for use, and important information about settings and alarms.

When using noninvasive positive pressure ventilation (NPPV), use a noninvasive patient interface, for example a mask, rather than an invasive conduit.

7.6.1 Required conditions for use

Before proceeding, review the safety information in Chapter 1.

The following requirements **must be met** to use noninvasive ventilation:

- The patient must be able to trigger the ventilator and must have regular spontaneous breaths.

  Noninvasive ventilation is intended to provide supplemental ventilatory support to patients with regular spontaneous breaths.
- The patient must be conscious.
- The patient must be able to maintain an adequate airway.
- Intubation must be possible at any time.
- The mask or interface is a good fit.

7.6.2 Contraindications

⚠ CAUTION

- *To prevent possible patient injury, do NOT use noninvasive ventilation on patients with no or irregular spontaneous breaths. Noninvasive ventilation is intended to provide supplemental ventilatory support to patients with regular spontaneous breaths.*
- *To prevent possible patient injury, do NOT attempt to use noninvasive ventilation on intubated patients.*

Using noninvasive ventilation is contraindicated if **any** of the following conditions are met:

- The patient does not have the drive to breathe
- Partial or complete airway obstruction
- Gastrointestinal bleeding
- Anatomic or subjective intolerance of NIV interface
- Patient is unable to cooperate or protect airway

7.6.3 Potential adverse reactions

The following reactions to noninvasive ventilation are possible:

- Aspiration, gastric insufflation
- Increase of intracranial pressure (ICP)
- Decrease of arterial pressure
- CO2 rebreathing
- Claustrophobia
- Discomfort
- Dyssynchrony
- Skin or conjunctiva lesions

7.6.4 Control settings in noninvasive ventilation

⚠ WARNING

- The exhaled volume from the patient can differ from the measured exhaled volume due to leaks around the mask.
- Peak pressures exceeding 33 cmH2O may increase the risk of aspiration due to gastric insufflation. When ventilating with such pressures, consider using an invasive mode.

When a significant leak occurs, the inspiratory flow can never fall below ETS, thereby preventing the ventilator from cycling into exhalation and resulting in endless inspiration. The TI max setting provides an alternate way to cycle into exhalation. When inspiration lasts longer than TI max, the ventilator cycles into exhalation.

Ensure the TI max setting is sufficiently long to give ETS the chance to cycle the ventilator.

- Adjusting the TI max setting increases or decreases the allowable inspiratory time.
- Increasing ETS above the default 25% allows the ventilator to cycle to terminate inspiration at a higher flow, to accommodate larger leaks.

Other controls require special attention:

- Carefully observe the patient/ventilator interaction.
- Carefully adjust the trigger setting to prevent autotriggering (trigger threshold is set too low) or missed patient efforts (trigger threshold is set too high).
- Adjust ΔPsupport or ΔPinsp to obtain appropriate tidal volumes.
- The leakage in noninvasive modes can reduce the actual applied PEEP and give rise to autotriggering.
- Adjust PEEP further, considering oxygenation and AutoPEEP.

7.6.5 Alarms in noninvasive ventilation

Due to the changing and unpredictable amount of leakage, volume alarms are less meaningful in noninvasive modes than in other modes. Alarms are based on the returned expiratory gas volume measured at the flow sensor; this value can be significantly lower than the delivered tidal volume, because the delivered tidal volume is the sum of the displayed VTE and the leakage volume.

To avoid nuisance volume alarms, set the low Vt and ExpMinVol alarms to a low level.

As the noninvasive modes are pressure-controlled modes, however, be sure to pay attention to the pressure-related alarms. If the defined PEEP and inspiratory pressure can be maintained, the ventilator is compensating the gas leak sufficiently.

7.6.6 Monitored parameters in noninvasive ventilation

NOTICE

- The following numeric monitoring parameters *cannot* be used for reliable analysis of patient conditions: ExpMinVol, RCexp, Rinsp, Insp Flow, AutoPEEP, and Cstat.
- Continuous monitoring of clinical parameters and patient comfort is critically important.
- The parameters VTE NIV, MinVol NIV, MVSpont NIV, and MVLeak are leak compensated, and are used in noninvasive modes. These parameters are estimations and may not reflect exact values.

Due to the leakage at the patient interface, displayed exhaled volumes in the noninvasive modes can be substantially smaller than the delivered volumes.

The flow sensor measures the delivered volume and the exhaled tidal volume; the ventilator displays the difference as VLeak in percent (%), and as MVLeak in l/min. Use VLeak and MVLeak to assess the fit of the mask or other noninvasive patient interface.

While a leak at the patient interface influences the tidal volume measurement, leaks in the breathing circuit itself do not influence the tidal volume measurement.

In addition to other clinical parameters, TI, Ppeak, PEEP/CPAP, I:E, fTotal, Pmean, and fSpont can be used to assess the patient's ventilatory status.

7.6.7 Additional notes about using noninvasive ventilation

Due to some unique characteristics, consider the following points when using noninvasive ventilation.

IntelliTrig function

To synchronize, IntelliTrig compensates for leaks and resistance between the ventilator and the patient, and with each breath, it measures the leakage at the patient interface (mask).

With this information, IntelliTrig adjusts the trigger mechanism, reducing the influence of leakage and the changing breath pattern on the operator-set trigger sensitivity.

Maintaining PEEP and preventing autotriggering

Significant leakage can be present in noninvasive ventilation, which can serve to reduce the actual applied PEEP and give rise to autotriggering. If you cannot reach the set PEEP, check the mask fit.

Inspect mask fit and position

Inspect the mask position regularly and adjust as necessary. React promptly and appropriately to any alarms.

The ventilator's VLeak parameter provides one indicator of mask fit.

To verify that the mask fits properly, ensure that the leakage value shown in the Monitoring window (VLeak, MVLeak) is acceptable.

To monitor leakage during ventilation, set the low limit of the Pressure alarm to a value near the set pressure for ventilation (PEEP + ΔPinsp/ΔPsupport). When excessive leaks are present, the ventilator may not be able to reach the set pressure, and generates an alarm.

7.7 Working with ASV

ASV is indicated for passive and spontaneously breathing adult and pediatric patients.

7.7.1 Contraindications

The use of ASV mode is contraindicated with the following:

- Infants and neonates
- If there is a high leakage (NIV or broncho-pleural fistula)
- Irregular respiratory drive (Cheyne-Stokes respiration)

7.7.2 Setting up ASV on the ventilator

To set up the ventilator using ASV

1. Touch **Modes**.
2. Touch **ASV**, then touch **Confirm**.
3. Set the controls as appropriate:

   – %MinVol: Set a value that results in the same minute volume as a previous mode, if applicable.

   – PEEP, Oxygen, Trigger, ETS, P-ramp: Set according to clinical requirements and the patient condition.
4. Review and adjust alarm limits.

   Set the high Pressure alarm limit to an appropriate value.

   The maximum peak pressure delivered in ASV (Plimit) is 10 cmH2O below the high Pressure alarm limit or equal to the Plimit setting.

   The maximum peak pressure for ASV can be also set using the Plimit control in the Controls window.

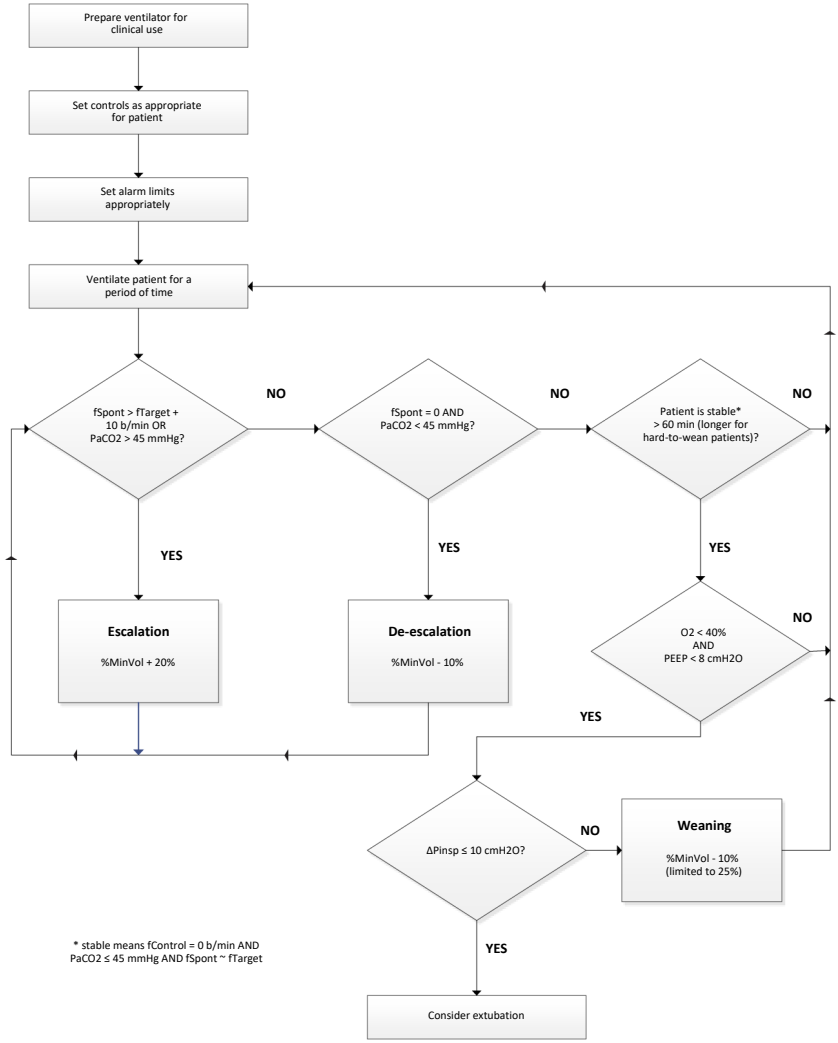
   Changing the Plimit value also changes the high Pressure limit. For details, see Section 5.6.1.
5. Connect the patient to the ventilator and start ventilation.

The ventilator initiates several test breaths.

The device automatically selects the values for respiratory rate (fTotal), inspiratory time (TI), and inspiratory pressure (ΔPinsp) based on the calculated IBW and as specified in Table 7-3.

7.7.3 Clinical workflow with ASV

Figure 7-17. Clinical use of ASV



7.7.4 Maintaining adequate ventilation

⚠ WARNING

To change the minute volume setting, always use the %MinVol control. Do *not* manipulate the patient height setting to achieve the desired IBW to control minute volume.

Once ASV is started, the ventilator calculates an optimal breath pattern and associated target values for tidal volume and rate according to the rules in ASV and the set %MinVol to achieve the targets. Depending on whether the patient is passive or actively breathing, the ventilator delivers pressure-controlled or pressure-supported breaths in compliance with a lung-protective strategy. For details, see Section 7.7.8.4.

Once the calculated targets are reached, the result of the ventilation needs to be assessed. All monitored parameters can be used for this purpose.

However, to assess respiratory acid-base status, it is recommended that arterial blood gases be measured and minute ventilation be adjusted accordingly.

Table 7-5 provides examples of how to adjust the %MinVol setting.

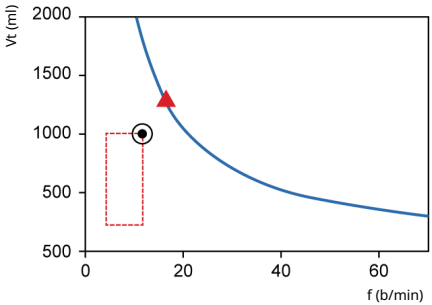
Table 7-5. Blood gas and patient conditions and possible adjustments for ASV

Condition	%MinVol change
Normal arterial blood gases	None
High PetCO2 or PaCO2	Increase %MinVol Pay attention to inspiratory pressures
Low PaCO2	Decrease %MinVol Pay attention to mean pressures and oxygenation status
High respiratory drive	Consider increase in %MinVol Consider sedation, analgesia, or other treatments
Low O2 saturation	None Consider increase in PEEP/CPAP and/or Oxygen

7.7.5 Reviewing alarm settings

It is *not* possible to select a %MinVol that is incompatible with the lung-protective rules that govern ASV (for a detailed description, see Section 7.7.8.4). As a consequence, ASV tries to achieve the maximum possible ventilation and activates the ASV: Cannot meet target alarm.

Figure 7-18. Example of high %MinVol setting incompatible with the lung-protective rules strategy



7.7.6 Monitoring ASV

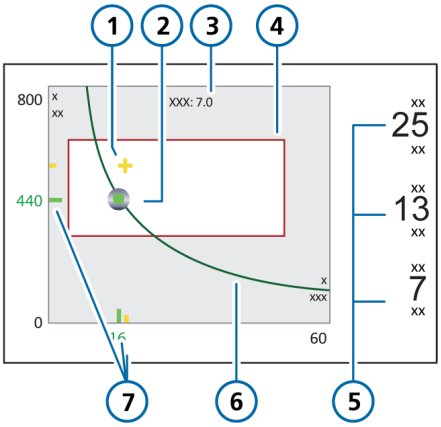
ASV interacts with the patient continuously. Whenever the patient's respiratory mechanics change, ASV adjusts to this change. Whenever the patient's breathing activity changes, ASV adjusts the settings.

The ASV graph, shown in Figure 7-19, provides a real-time graphical view of the patient status relative to the set target. For details about the graph, see Section 8.4.3.

For details on displaying the ASV graph and ASV monitoring values, see Section 8.4.

To monitor progress over time, it is recommended that you plot trends for ΔPinsp, fTotal, and fSpont. Review these trends, together with the %MinVol setting to gain insight into the patient's ventilatory status. Table 7-6 provides interpretations of typical ventilatory patterns.

Figure 7-19. ASV Graph panel



1	Patient symbol: intersection of current measured tidal volume and rate	5	ΔPinsp: Inspiratory pressure set by ventilator fControl: Machine rate fSpont: Spontaneous breath rate
2	Target point: Intersection of target tidal volume and target rate	6	Minute volume curve
3	Target minute volume	7	Current measured point (in yellow) and target value (in green)
4	Safety frame		

7.7.7 Weaning

Weaning patients from the ventilator is a clinical task that requires experience and involves more than just ventilation issues. This section does not intend to provide clinical information other than that needed to operate the ventilator using ASV mode.

ASV always allows patients to take spontaneous breaths. Episodes of spontaneous breathing can occur and are supported by ASV even within a period of fully controlled ventilation. In other words, weaning can start with ASV so early that it may go unrecognized clinically. It is therefore important to monitor the spontaneous efforts of the patient over time.

The weaning progress can be monitored in the trends display when inspiratory pressure (ΔPinsp), total rate (fTotal), and spontaneous rate (fSpont) are plotted.

It may be necessary to reduce the %MinVol setting to 70% or even lower to "motivate" the patient to resume spontaneous breathing. If a patient can sustain minutes or even hours with a low %MinVol setting, it does not mean that weaning is complete. In fact, the %MinVol setting must always be interpreted in conjunction with the level of ΔPinsp needed to achieve the set minute ventilation. Only if ΔPinsp and fControl are at their minimum values can weaning be assumed to be complete.

Table 7-6. Interpretation of breathing pattern at lower than 100 %MinVol setting

ΔPinsp	fControl	fSpont	Interpretation
> 10	> 10	0	*Danger of hypoventilation.* Check arterial blood gases and consider increasing %MinVol.
> 10	0	Acceptable	*Enforced weaning pattern.* Check arterial blood gases and patient respiratory effort. Consider decreasing or increasing %MinVol accordingly.
< 8	0	Acceptable	*Unsupported breathing.* Consider extubation.
> 10	0	High	*Dyspnea.* Consider increasing %MinVol and other clinical treatments. Check for autotriggering.

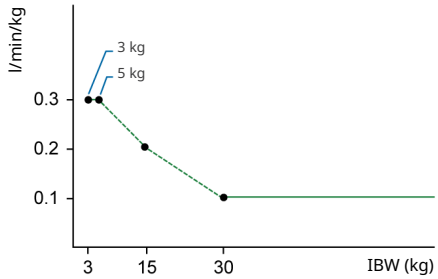
7.7.8 Functional overview

The following sections provide a brief overview of how ASV manages ventilation.

7.7.8.1 Normal minute ventilation

ASV defines normal minute ventilation according to the graph in Figure 7-20.

Figure 7-20. Normal minute ventilation as a function of predicted body weight (IBW)



For patients with an IBW of 30 kg or more, minute ventilation is calculated as 0.1 l/kg * IBW (solid line).

For patients with an IBW below 30 kg, the value is indicated by the dotted line in the previous figure.

Minute ventilation for a 15 kg patient is calculated as

0.2 l/kg * 15 kg = 3 l/min

For example, for an IBW of 70 kg, normal minute ventilation corresponds to 7 l/min.

7.7.8.2 Compensation for changes in apparatus dead space

Dead space is calculated as 2.2 ml per kilogram (kg) IBW. This dead space is a nominal value that is valid, on average, for intubated patients whose endotracheal tube is connected to the Y-piece of the ventilator by a standard catheter mount.

Changes in alveolar dead space due to ventilation/perfusion mismatch must be compensated using the MinVol control.

If this dead space is altered by an artificial airway configuration, such as the use of a heat and moisture exchanging filter (HMEF) or nonstandard tubing, modify the MinVol setting to take into account the added or removed dead space.

7.7.8.3 Targeted minute ventilation

When you choose ASV, you must select an appropriate minute ventilation for the patient. Minute ventilation is set with the %MinVol control, which, together with the patient height, determines the total minute ventilation in liters per minute (l/min).

A %MinVol setting of 100% corresponds to normal minute ventilation (Section 7.7.8.1). A setting below or above 100% corresponds to minute ventilation lower or higher than normal.

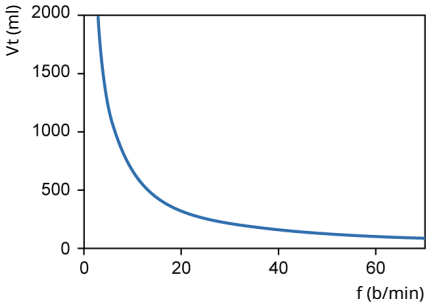
From the %MinVol, the target minute ventilation (in l/min) is calculated as:

Ideal body weight (in kg) x NormMinVent (in l/kg/min) x (%MinVol/100)

where NormMinVent is the normal minute ventilation. See Figure 7-20.

For example, with a %MinVol = 100 and an IBW = 70 kg, a target MinVol of 7 l/min is calculated. This target can be achieved with a number of combinations of tidal volume (Vt) and respiratory rate (f). This is shown in Figure 7-21, where all possible combinations of Vt and f lie on the bold line, the target minute volume curve.

Figure 7-21. MinVol = 7 l/min



7.7.8.4 Lung-protective strategy

Not all combinations of Vt and f shown in Figure 7-21 are safe for the patient. The high tidal volumes will overdistend the lungs, and the small tidal volumes cannot produce alveolar ventilation at all.

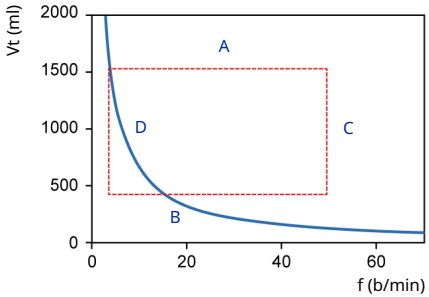
Another risk lies in inadequate respiratory rates. High rates can lead to dynamic hyperinflation or breath stacking, resulting in AutoPEEP. Low rates can lead to hypoventilation and apnea. Therefore, it is necessary to limit the number of possible combinations of Vt and f.

When limits are imposed on the possible combinations of Vt and f, ASV uses a double strategy:

- The operator input for ASV determines the absolute boundaries.
- Internal calculations based on patient measurements further narrow the limits to counteract possible operator errors and to follow changes of respiratory system mechanics.

The effect of the strategy is shown in Figure 7-22 and explained in the subsequent sections.

Figure 7-22. Lung-protective rules strategy



A: High tidal volume limit

The tidal volume applied by ASV is limited (see A in Figure 7-22) by three operator settings: high Pressure alarm limit, high Vt alarm limit, and patient height.

Note the following:

- You must set the high Pressure limit before connecting a patient to the ventilator. The maximum pressure applied in the ASV mode is 10 cmH2O below the high Pressure alarm limit.
- Additionally, the target volume is limited to 150% of the high Vt alarm limit, and pressure support is limited such that the inspired volume does not exceed the high Vt alarm limit in mechanical breaths for more than a few breaths.
- If you set the Pressure alarm limit to a very high pressure, say 60 cmH2O, the target volume is limited by the second criterion: 15 ml/kg.
- Check the Vt high setting to make sure the target minute ventilation can be reached in passive patients.

B: Low tidal volume limit

You must use caution with low tidal volumes to avoid insufficient alveolar ventilation.

The determining parameter for alveolar ventilation is dead space (VDaw). Tidal volume value must always be greater than the VDaw value. It is widely accepted that a first approximation of dead space can be obtained by the following simple equation[1]:

VDaw = 2.2 * IBW

ASV calculates the lower limit for tidal volume based on the following equation: IBW * 4.4 ml/kg. The multiplying factor is calculated to be at least twice the dead space.

C: High rate limit

The maximum rate (C in Figure 7-22) is derived from the operator-set %MinVol and the calculated IBW, which is calculated from the operator-set patient height (Pat. height). The equation used to calculate the maximum rate is:

fmax = target MinVol / minimum Vt

However, if you choose an excessively high %MinVol of 350%, the maximum rate becomes 77 b/min. To protect the patient against such high rates, ASV employs a further safety mechanism, which takes into account the patient's ability to exhale.

A measure of the ability to exhale is the expiratory time constant (RCexp). To achieve a nearly complete exhalation to the equilibrium point of the respiratory system (90% of the maximum potential volume change), an expiratory time of at least 2 * RCexp is theoretically required.

For this reason, ASV calculates the maximum rate based on the principle of giving a minimum inspiratory time equal to 1 * RCexp and a minimum expiratory time equal to 2 * RCexp, which results in these equations:

fmax = 60 / (3 x RCexp) = 20 / RCexp
fmax ≤ 60 b/min

This limit applies to the respiratory rate of the ventilator only, *not* to the respiratory rate of the patient.

D: Low rate limit

The lowest target rate (see D in Figure 7-22) is predefined according to the IBW (Table 7-3).

[1] Radford 1954

7.7.8.5 Optimal breath pattern

Although the lung-protective rules strategy limits possible combinations of Vt and f, ASV prescribes an explicit target combination. Using the example in Figure 7-22, this shows considerable room for selection within the dotted rectangle. The selection process is an exclusive feature of ASV.

The device works on the assumption that the optimal breath pattern is identical to the one a totally unsupported patient will choose naturally (assuming the patient is capable of maintaining the pattern).

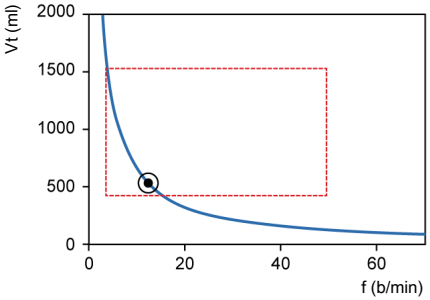
It is common knowledge that the choice of breathing pattern is governed by either work of breathing or the force needed to maintain a pattern. ASV calculates the optimal rate based on the operator-set %MinVol and the calculated IBW, as well as on the measurement of RCexp (Section 7.4.1).

Once the optimal rate is determined, the target Vt is calculated as follows:

Vt = target MinVol / optimal rate

Figure 7-23 shows the position of the target breathing pattern as well as the safety limits imposed by the lung-protective rules strategy. The rectangle shows the safety limits; the circle shows the target breath pattern.

Figure 7-23. Anatomy of the ASV target graphics window



7.7.8.6 Initial breaths: How ASV starts

How do you achieve the target values for a given patient if you do not know whether or not the patient can breathe spontaneously? For this purpose, ASV uses a predefined rate according to the calculated IBW (Table 7-3).

Patient-triggered breaths are pressure supported and flow-cycled, or the transition to exhalation is made based on IntelliSync+, if selected.

If the patient does not trigger the breath, the delivery of the breath is time cycled, with a preset pressure.

The following controls are operator-set (manual):

- PEEP/CPAP
- Oxygen
- P-ramp
- ETS
- Trigger type and sensitivity

The following controls are adjusted automatically by ASV, and cannot be adjusted by the operator:

- *Mandatory breath rate:* to change total respiratory rate
- *Inspiratory pressure level:* to change inspiratory volume
- *Inspiratory time:* to allow gas flow into the lungs
- Startup breath pattern

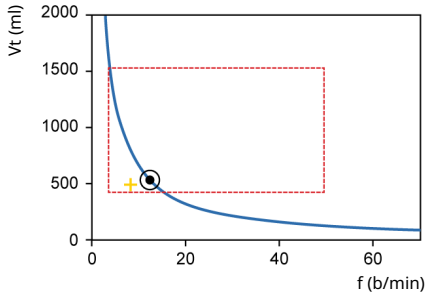
To safely start ASV, you set the patient height and sex, which are then used to calculate the IBW.

Upon starting ventilation, after some initial test breaths are delivered, the resulting rate and tidal volume are measured and compared with the target values. ASV then responds to the differences between the current and target tidal volumes, as well as the current and target rates.

7.7.8.7 Approaching the target

Figure 7-24 shows a possible scenario after the initial test breaths. The current breath pattern, which is plotted as the patient symbol, shows clear deviation from the target. ASV's task is to move the patient symbol as close to the circle as possible.

Figure 7-24. Example after three initial breaths



The patient symbol marks the actual measured value for Vt and Rate.

To achieve the target, ASV uses the following strategy:

- If actual Vt < target Vt, the inspiratory pressure is increased.
- If actual Vt > target Vt, the inspiratory pressure is decreased.
- If actual Vt = target Vt, the inspiratory pressure is left unchanged.
- If actual rate < target rate, the fControl rate is increased.
- If actual rate > target rate, the fControl rate is decreased.
- If actual rate = target rate, the fControl rate is left unchanged.

As a result, the patient symbol in Figure 7-24 moves toward the circle. The current Vt is calculated as the average of inspiratory and expiratory volumes. This definition compensates in parts for leaks in the breathing circuit, including the endotracheal tube.

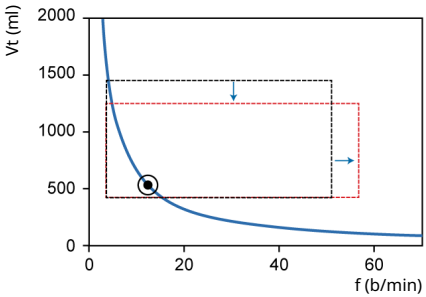
7.7.8.8 Dynamic adjustment of lung protection

The operator preset values are not changed by ASV, and the corresponding safety limits remain as defined in the previous sections. However, if the respiratory system mechanics change, the safety limits change accordingly, as defined in Section 7.7.8.4. The safety limits are updated on a breath-by-breath basis.

For example, if the lungs stiffen, the high Vt limit is lowered proportionally, and the high rate limit is increased.

This dynamic adjustment ensures that ASV applies a safe breathing pattern at all times. In graphical terms, the dotted rectangle changes as shown in Figure 7-25.

Figure 7-25. Lung-protective limits



Lung-protective limits are changed dynamically and according to the respiratory system mechanics.

However, the limits set by the operator are never violated.

7.7.8.9 Dynamic adjustment of optimal breath pattern

After it is calculated, the optimal breath pattern is revised with each breath according to the RCexp measurements. A new target breathing pattern is calculated using ASV algorithms. The targets do not change under steady-state conditions. However, if the patient's respiratory system mechanics change, the target values also change.

7.8 Special conditions

The following ventilator modes/states may be observed under certain error conditions:

Table 7-7. Special conditions overview

For details about ...	See ...
Sensor Failure mode	Section 7.8.1
Safety ventilation/ Safety mode	Section 7.8.2
Ambient state	Section 7.8.3

7.8.1 Sensor Failure mode

When there is a problem with the flow sensor that lasts for more than three breath cycles, the External flow sensor failed alarm is generated and the ventilator switches to Sensor Failure mode. Ventilation continues in PCV+ mode.[1]

Once the alarm is reset, the ventilator exits Sensor Failure mode and returns to ventilation with the previous mode and settings.

For details about the External flow sensor failed alarm, see Section 9.4.

[1] If the NIV-only option is enabled (Section 10.6), ventilation continues in NIV-ST mode.

The following conditions apply to ventilation in Sensor Failure mode:

- The ventilator changes to PCV+ mode.[1]
- Internal ventilator pressure (Pvent) is displayed instead of airway pressure (Paw).
- Monitoring parameters related to the flow sensor measurement are shown in gray, indicating they are inaccurate.
- The message Sensor Failure mode ventilation initiated is recorded in the Event log.

7.8.2 Safety ventilation/Safety mode

In the event of certain technical failures, the ventilator switches to Safety ventilation. This gives you time to arrange for corrective actions, including organizing a replacement ventilator.

If these conditions occur when using HiFlowO2, the ventilator switches to Safety mode.

The following conditions apply to ventilation in Safety ventilation:

- The ventilator does not monitor patient inputs in Safety ventilation.
- In Safety ventilation, the blower runs constantly to create inspiratory pressure (ΔPinsp) (Tables 7-6 and 7-7).

  In Safety mode, the blower creates a constant pressure of 5 cmH2O at the inspiratory port.
- In Safety ventilation, the expiratory valve switches system pressure levels between PEEP and inspiratory pressure.
- You must turn off ventilator power to exit Safety ventilation.

Settings in Safety ventilation

Table 7-8. Safety ventilation settings, Adult/Ped[2]

IBW (kg)	ΔPinsp (cmH2O)	Rate (b/min)	Oxygen (%)
3 to 5.9	15	35	> 21%
6 to 8.9	15	30	> 21%
9 to 19.9	15	25	> 21%
20 to 30	15	20	> 21%
31 to 39	15	17	> 21%
40 to 59	15	15	> 21%
60 to 89	15	12	> 21%
90 to 99	18	12	> 21%
≥ 100	20	12	> 21%
PEEP is set to the PEEP of the previous mode and the I:E ratio is 1:4.			

[1] If the NIV-only option is enabled (Section 10.6), ventilation continues in NIV-ST mode.
[2] Safety ventilation settings apply when any mode *other than* HiFlowO2 therapy is selected.

Table 7-9. Safety ventilation settings, Neonatal[1]

Weight (kg)	ΔPinsp (cmH2O)	Rate (b/min)	Oxygen (%)
< 1.26	15	60	> 21%
1.26 to 2.99	15	45	> 21%
3.0 to 5.9	15	35	> 21%
6.0 to 8.9	15	30	> 21%
9.0 to 19.9	15	25	> 21%
> 20	15	20	> 21%
PEEP is set to the PEEP of the previous mode and the I:E ratio is 1:3.			

7.8.3 Ambient state

If the technical fault alarm is serious enough to possibly compromise safe ventilation, the ventilator enters the Ambient state.

The following conditions apply to ventilation in the Ambient state:

- The inspiratory channel and expiratory valves are opened, letting the patient breathe room air unassisted.
- Provide alternative respiratory support immediately.
- You must turn off ventilator power to exit the Ambient state.

[1] Safety ventilation settings apply when any mode *other than* HiFlowO2 therapy is selected.

8
Monitoring ventilation

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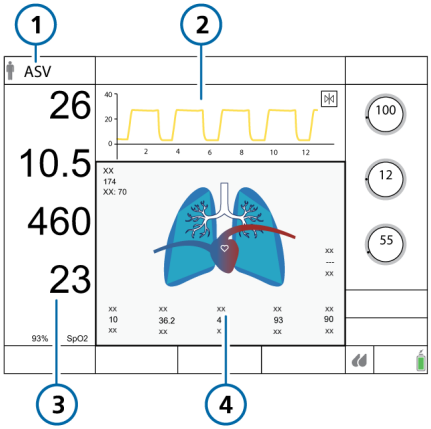
8.1 Overview

You can configure how to view patient data during ventilation, including viewing data numerically and graphically in a combination of waveforms, loops, trends, and Intelligent Panels to suit your institution's needs (Figure 8-1).

Data is also available in the Monitoring window, which you can access at any time without affecting breath delivery.

For the list of monitored parameters, see Section 8.5.

Figure 8-1. Main display



1	Current mode	3	Main monitoring parameters (MMP) (Section 8.2.1)
2	Pressure/time waveform, configurable (Section 8.3.2)	4	Graphic display, configurable (Section 8.3)

8.2 Viewing numeric patient data

Numeric patient data is readily available as follows:

- The main display prominently shows the configured main monitoring parameters (MMPs). See Section 8.2.1.
- The Monitoring window provides access to all of the parameter data. See Section 8.2.2.

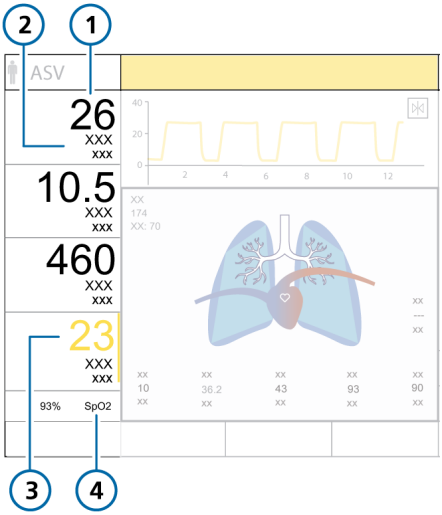
8.2.1 About the main monitoring parameters (MMPs)

The MMPs are the numerical monitoring parameters shown on the left side of the display. Every displayed parameter shows the following elements: the current value, name, and unit of the monitoring parameter.

The MMPs that are displayed, as well as their sequence on the display, can be changed in Configuration (Section 13.5). Any of the monitored parameters can be displayed as an MMP. As a result, MMPs may differ between individual ventilators.

An MMP is normally displayed in white. When directly related to an active alarm, the MMP is shown in yellow or red, corresponding to the alarm priority. In addition, a colored bar appears to the right of the affected MMP (Figure 8-2). After the alarm resets, the affected MMP returns to white and the bar is removed.

Figure 8-2. MMP components



1	MMP value	3	Parameter associated with an active alarm
2	Parameter name/units	4	Measured SpO2 value*

** If SpO2 sensor is enabled and connected*

8.2.2 Viewing patient data in the Monitoring window

The Monitoring window provides access to monitored parameter data as follows:

- The **General** tab (Figure 8-3) provides access to ventilation parameter values.
- When enabled, the **CO2** and **SpO2** tabs provide access to CO2- and SpO2-related data, respectively.

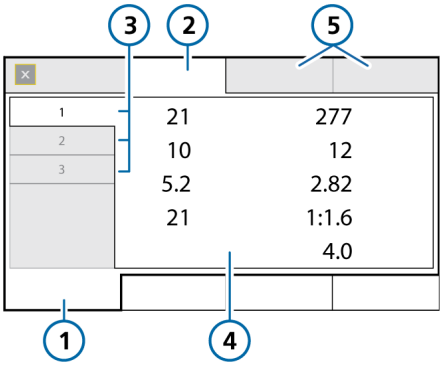
To display the Monitoring window

1. Touch **Monitoring**.

   The Monitoring > General window is displayed.

2. Touch the desired tab to view the associated information.

Figure 8-3. Monitoring > General window



1	Monitoring	4	Parameter values
2	General	5	CO2 and SpO2 (if enabled)
3	1, 2, 3 tabs		

8.3 Viewing graphical patient data

The HAMILTON-C1 can show waveforms, as well as graphic and Intelligent panels on the lower portion of the display.

The following table shows the options for each graphic type.

Table 8-1. Graphical view options

Graphic type/Options	
Waveforms (data values plotted against time)	
• Pressure	• PCO2[1]
• Flow	• FCO2[1]
• Volume	• Plethysmogram[2]
• Off	
Graphics (Intelligent panels)	
• Dynamic Lung[3]	• ASV Graph[4]
• Vent Status	
Trends	
1-, 6-, 12-, 24-, or 72-h[5] trend data for a selected parameter or combination of parameters	
Loops	
• Pressure/Volume	• Volume/PCO2[1]
• Pressure/Flow	• Volume/FCO2[1]
• Volume/Flow	

8.3.1 Selecting display options

You can change the graphics at any time.

To change the contents of a graphic panel or waveform

1. Touch the area of the display to change.

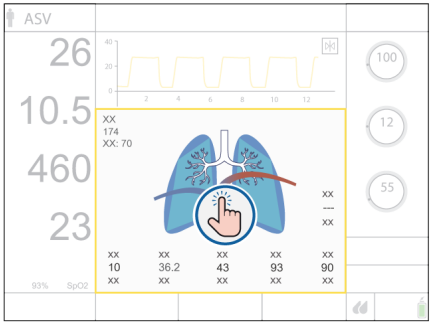
   The selected panel is highlighted in yellow (Figure 8-4).

   The graphics selection window appears, displaying the current selection (Figure 8-5).

2. Touch the desired option to select it, or touch a tab (**Trends**, **Loops**, **Graphics**, **Waveforms**) to access additional options.

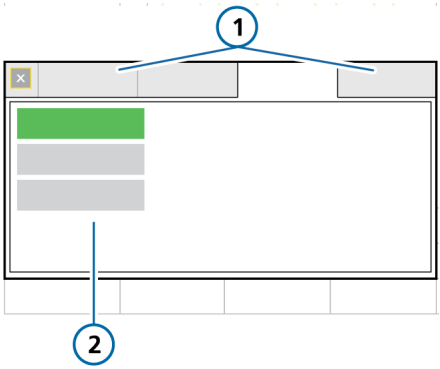
After making a selection, the window closes automatically, and the display adjusts to the new selection.

Figure 8-4. Selected panel outlined in yellow



[1] CO2 option required.
[2] SpO2 option required.
[3] Only for adult/pediatric patients.
[4] Only in ASV mode.
[5] 72-hour trend not available in all markets

Figure 8-5. Graphics selection window



1	Trends, Loops, Graphics, Waveforms	2	Available options

8.3.2 Working with waveforms

The ventilator can plot pressure, volume, and flow against time, in addition to other data as listed in Table 8-1.

The waveforms provide an ongoing real-time graphical view of the selected parameters over multiple breaths. As a result, they also provide a way to assess the numerical monitored parameter values.

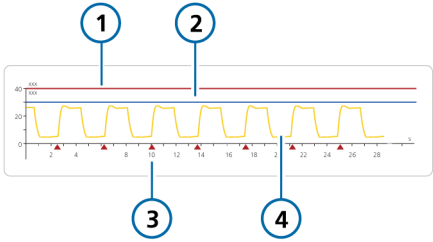
8.3.2.1 Waveform views

You can show up to three waveforms on the display. For details, see Section 8.3.2.3.

8.3.2.2 About the Pressure/time (Paw) graph

The blue pressure limit line shows the maximum pressure that the ventilator will apply, which you can set using the Plimit control. The high Pressure alarm limit is shown as a red line. The high Pressure alarm limit is always 10 cmH2O greater than Plimit.

Figure 8-6. Pressure/time graph

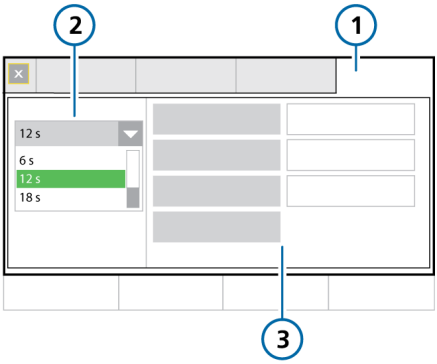


1	High Pressure alarm limit	3	Patient trigger indicator
2	Plimit	4	Airway pressure (Paw) waveform

8.3.2.3 Displaying waveforms

You select waveform display options in the Waveforms window.

Figure 8-7. Graphics selection > Waveforms window



1	Waveforms	3	Available options
2	Time scale		

To select a waveform

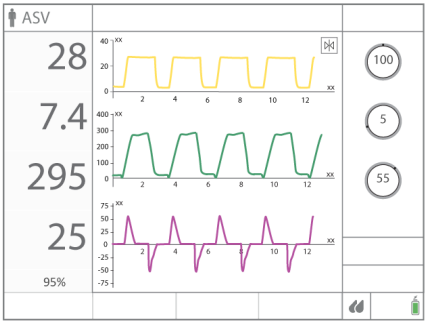
1. Touch the area of the display where you wish to show a waveform or touch the waveform to change (Section 8.3.1).

   The graphics selection window appears (Figure 8-5).
2. If needed, touch the **Waveforms** tab.
3. If needed, change the time scale to apply to all waveforms.
4. Touch the waveform type to display.

   To leave the area blank, touch **Off**. You must display at least one waveform in the top portion of the display.

   Once the selection is made, the window closes and the selected waveform is displayed.

Figure 8-8. Waveform display



8.3.2.4 Changing the waveform time scale

Scaling refers to the values of the x- and y-axis of a waveform or a loop. In the waveforms displayed on the ventilator, the x-axis represents time, while the y-axis can represent a variety of parameters, including pressure, flow, or volume.

You can set the time scale (x-axis values) of the waveforms; your selection applies to all displayed waveforms.

A scale value refers to the length of the x-axis. For example, a scale value of 24 means that the x-axis displays the waveform from 0 to 24 seconds.

The HAMILTON-C1 offers the following time scale options, in seconds:

- Adult/Ped: 6, 12, 18, 24, 30
- Neonatal: 3, 6, 12, 18, 24

To change the time scale

1. Touch a waveform.

   The Waveforms window opens.

2. On the left of the window, touch the Time scale dropdown arrow, and using the P&T knob, find and select the desired entry; press the knob to confirm the selection.

Your selection applies to all displayed waveforms.

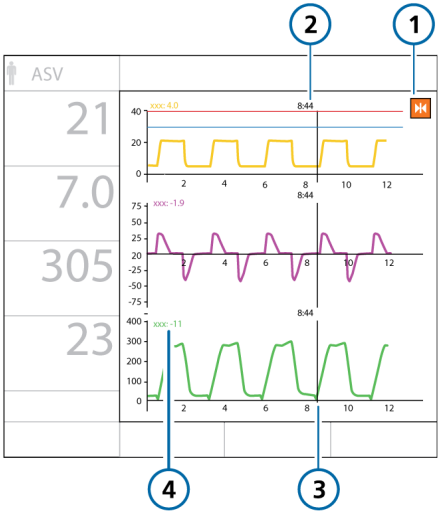
8.3.2.5 Freezing and reviewing waveforms and trends

You can temporarily freeze the display of waveforms and trends. After 30 seconds of inactivity, they are automatically unfrozen.

When Freeze is enabled, any displayed waveforms and trend graphs are frozen, allowing you to scroll through them for a detailed review. The Freeze function is time-synced across the displayed graphs.

Note that when Freeze is enabled, only the Freeze button is available on the display.

Figure 8-9. Freezing waveforms



1	Freeze button	3	Cursor
2	Time at cursor	4	Value at cursor (same color as the waveform)

To freeze waveforms and trends

1. Touch the **Freeze** button (**1** in Figure 8-9).

   Any displayed waveforms and Trend graphs are frozen, and cursor bars are displayed.

2. To scroll through the graphics for analysis, turn the P&T knob clockwise or counter-clockwise.

   The cursor bars move to the right and to the left.

3. To unfreeze the display, touch the **Freeze** button again or press the P&T knob.

The display returns to displaying real-time data and all of the elements on the display are available.

8.3.3 Working with Trend graphs

Trend data includes all data since the ventilator was turned on for a selected parameter for the past 1, 6, 12, 24, or 72 hours.

From the time the ventilator is turned on, it continuously stores up to 72 hours of monitored parameter data in its memory, including when in Standby. This data is deleted upon setting up a new patient.

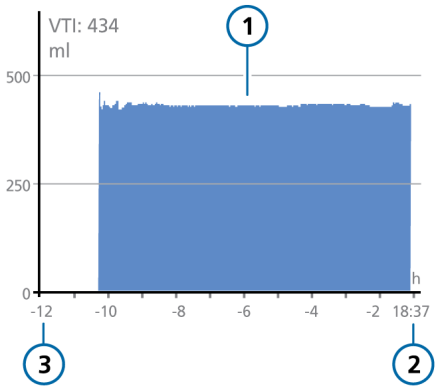
You can also freeze trend graphs and examine them more closely. When trends are frozen, the panel shows the time and the corresponding value of the monitored parameter. For details on using (Freeze) to freeze trends, see Section 8.3.2.5.

For details on freezing a trend, see the previous section.

Most monitoring parameters can be trended. The following parameters are trended in combination:

- Ppeak/PEEP
- ExpMinVol/MVSpont
- fTotal/fControl
- VDaw/VTE
- VTE/Vtalv
- SpO2/Oxygen
- SpO2/FiO2 (if supported on your device)

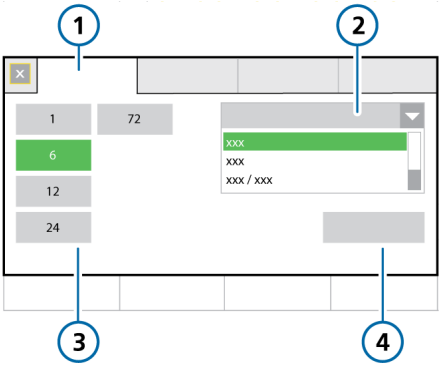
Figure 8-10. Trend panel



1	Trend graph	3	Elapsed time relative to present
2	Current time		

8.3.3.1 Displaying trends

Figure 8-11. Graphics selection > Trends window



1	Trends	3	Trend time, in hours
2	Parameter list	4	Confirm

To display trends

1. Touch the graphics area at the bottom half of the display (Section 8.3.1).
2. In the graphics selection window, touch the **Trends** tab (Figure 8-11).
3. Select the parameter(s) to trend.
4. Touch the desired trend time.
5. Touch **Confirm**.

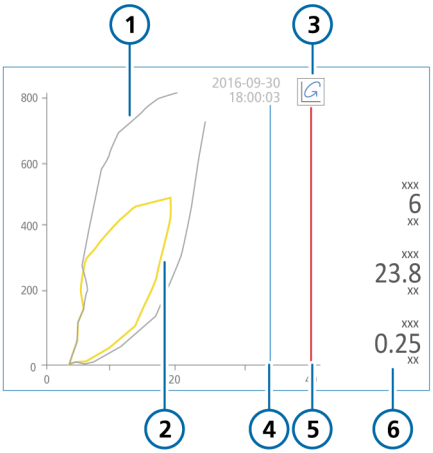
The selected trend information is displayed (Figure 8-10).

8.3.4 Working with loops

The HAMILTON-C1 can display a dynamic loop based on the following parameter combinations:

- Pressure/Volume
- Pressure/Flow
- Volume/Flow
- Volume/PCO2[1]
- Volume/FCO2[1]

Figure 8-12. Loops panel, Pressure/Volume loop displayed

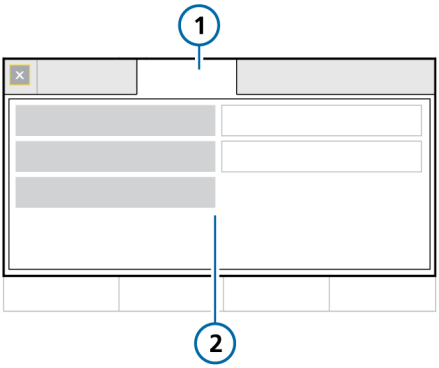


1	Stored reference loop	4	Plimit (high Pressure alarm limit − 10 cmH2O)[2]
2	Current loop	5	High Pressure alarm limit[2]
3	Loop reference button	6	Key parameters

[1] CO2 option required.

8.3.4.1 Displaying loops

Figure 8-13. Graphics selection > Loops window



1	Loops	2	Parameter options

To display loops

1. Touch the graphics area at the bottom half of the display (Section 8.3.1).
2. In the graphics selection window, touch the **Loops** tab.
3. Touch the parameter combination to display.

The selected combination is displayed (Figure 8-12).

8.3.4.2 Storing loops

You can store a loop to use as a reference, for comparison purposes.

To store a new loop

- In the Loop display (Figure 8-12), touch (Loop reference) to store the loop curve with the current date and time.

The previous and current characteristics are shown. Any previously stored loop is discarded.

8.4 Working with Intelligent panels

On the HAMILTON-C1 neo, you can show the Vent Status Intelligent panel on the ventilator display.

On the HAMILTON-C1, you can show any of the following Intelligent panels on the ventilator display:

- Dynamic Lung
- Vent Status
- ASV Graph

The Intelligent panels are all displayed using the graphics selection window **Graphics** tab.

8.4.1 Dynamic Lung panel: real-time ventilation status

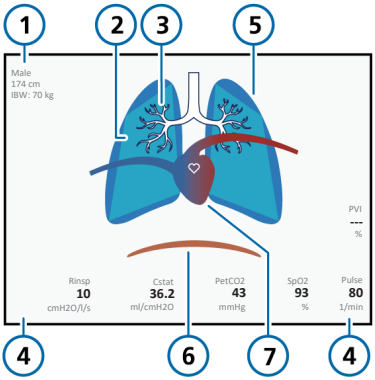
The Dynamic Lung[1] shows an up-to-date visual representation of key ventilation data (Figure 8-14). It visualizes tidal volume, lung compliance, patient triggering, and resistance in real-time.

In addition to the graphic representation, the panel shows numeric data for key parameters. If all values are in a normal range, the panel is framed in green.

The Dynamic Lung comprises the following components:

- Mechanical breath
- Respiratory compliance
- Airway resistance
- Patient triggering
- SpO2 data (if installed and enabled)

Figure 8-14. Dynamic Lung panel



1	Sex, height, IBW	5	Representation of breaths and tidal volume
2	Representation of lung compliance	6	Patient trigger (diaphragm)
3	Representation of airway resistance	7	Heart and pulse display*
4	Monitored parameter values		

* *If SpO2 sensor enabled and connected.*

Mechanical breaths, with tidal volume

The mechanical breath is shown as a set of lungs that expand and contract in synchrony with ventilator breath delivery, showing the delivered tidal volume (Vt) in real-time. The lung size displayed is relative to the “normal” size for the patient’s height.

A Disconnection alarm is indicated by a deflated lung. An Exhalation obstructed alarm is indicated by an over-inflated lung.

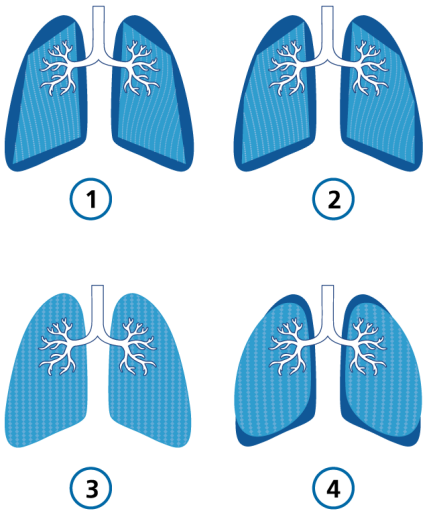
[1] Only for adult/pediatric patients.

The movement and shape of the lungs allow you to quickly verify that the ventilator is ventilating the patient.

Respiratory compliance

Respiratory compliance is a measure of the lung's ability to stretch and expand. Compliance is illustrated by the contour lines of the lung, as shown in Figure 8-15. The best possible approximation to static measurement is provided with the Cstat parameter.

Figure 8-15. Examples of lung compliance (Cstat) illustrated in the Dynamic Lung

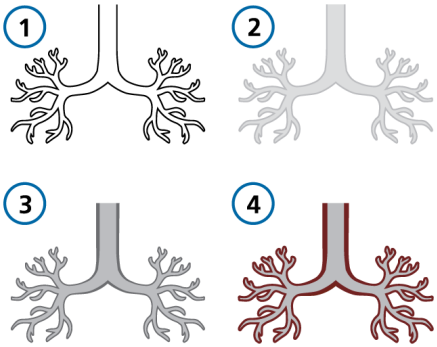


1	Very low compliance	3	Normal compliance
2	Low compliance	4	High compliance

Airway resistance

Airway resistance refers to the total resistance imposed by the patient's airway as well as the artificial airway, such as an endotracheal tube or tracheostomy tube. Airway resistance is illustrated by the size and color of the tracheobronchial tree, as shown in Figure 8-16. The resistance measurement is provided with the Rinsp parameter.

Figure 8-16. Examples of resistance shown by the bronchial tree of the Dynamic Lung



1	Resistance information is unavailable	3	Moderately high resistance
2	Normal resistance	4	High resistance

Patient trigger

If a patient trigger is detected, an illustration of the diaphragmatic muscle appears briefly at the beginning of inspiration, as shown in Figure 8-14. This allows you to quickly see whether the breath is patient triggered.

SpO2 data

If the SpO2 option is enabled and a sensor is connected, the Dynamic Lung panel shows a heart and big vessel illustration superimposed on the lungs. The heart beats in synchrony with the patient's pulse rate.

For details about SpO2 measurement, see the *Pulse Oximetry Instructions for Use*.

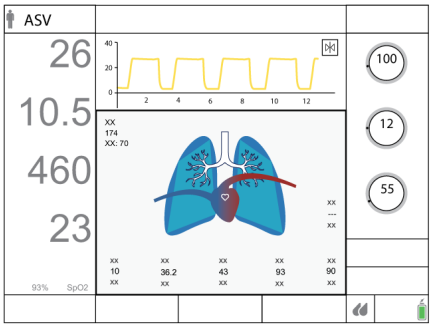
8.4.1.1 Displaying the Dynamic Lung

To display the Dynamic Lung

1. Touch the graphics area at the bottom half of the display (Section 8.3.1).
2. In the graphics selection window, touch the **Graphics** tab (Figure 8-5).
3. Touch **Dynamic Lung**.

The Dynamic Lung panel is displayed (Figure 8-17).

Figure 8-17. Dynamic Lung panel in display



8.4.2 Vent Status panel: real-time ventilator dependence status

The Vent Status panel (Figure 8-18) displays six parameters related to the patient's ventilator dependence, in the areas of oxygenation, CO2 elimination, and patient activity.

A floating indicator moving up and down within the column shows the value for a given parameter.

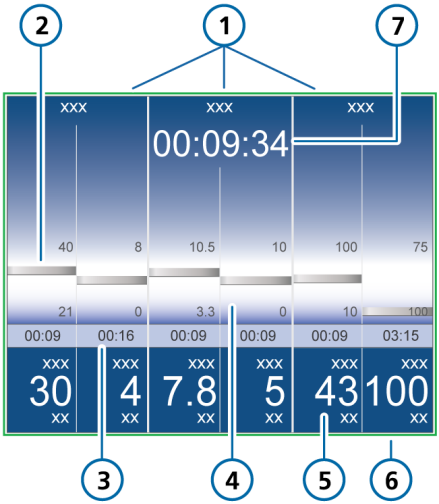
When the indicator is in the white (weaning) zone, a timer starts, showing how long that value has been in the weaning zone. When all values are in the weaning zone, the Vent Status panel is framed in green, indicating that weaning should be considered. A timer appears, recording the length of time all values have been in the weaning zone (Figure 8-18).

The panel is updated breath by breath.

Table 8-2 describes the parameters shown in the Vent Status panel.

You can configure the weaning zone ranges for these parameters in Configuration. To set the values, see Section 13.7.1.

Figure 8-18. Vent Status panel



1 Group title

2 Monitored value, graphic (floater)

3 Elapsed time value has been in weaning zone

4 Weaning zone with user-configurable limits

5 Monitored value, numeric

6 Green outline indicating all values are in the weaning zone

7 Elapsed time all values have been in weaning zone

Table 8-2. Vent Status parameters

Parameter (unit)	Definition
For additional details, including ranges and accuracy, see Table 15-8.	
Oxygen (%)	Oxygen setting.
PEEP (cmH2O)	PEEP/CPAP setting.
MinVol (l/min)	Normal minute ventilation (see Section 7.7).
ΔPinsp (cmH2O)	Inspiratory pressure, the target pressure (additional to PEEP/CPAP) applied during the inspiratory phase.
RSB[1] (1 / (l*min))	Rapid shallow breathing index. The total breathing frequency (fTotal) divided by the exhaled tidal volume (VTE).
%fSpont (%)	Spontaneous breath percentage. The moving average of the percentage of spontaneous breaths over the last 10 total breaths.

[1] Weaning zone defaults are based on normal values < 100/(l*min) for adult patients. Default values can be changed in Configuration.

8.4.2.1 Displaying the Vent Status panel

To display the Vent Status panel

1. Touch the graphics area at the bottom half of the display (Section 8.3.1).
2. In the graphics selection window, touch the **Graphics** tab (Figure 8-5).
3. Touch **Vent Status**.

The Vent Status panel is displayed (Figure 8-18).

8.4.3 ASV Graph panel: real-time patient condition and targets

Available in ASV mode, the ASV Graph shows how the adaptive lung controller moves toward its targets. The graph shows both the target and real-time patient data for tidal volume, frequency, pressure, and minute ventilation.

Figure 7-19 in Chapter 7 describes the graph in detail.

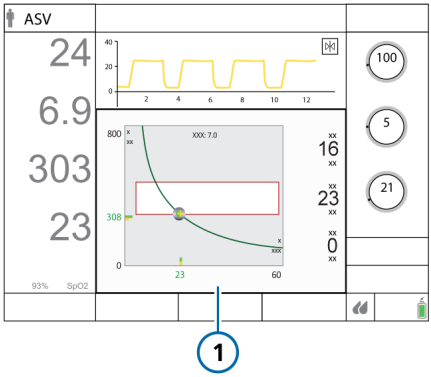
8.4.3.1 Displaying the ASV Graph

To display the ASV Graph

1. Touch the graphics area at the bottom half of the display (Section 8.3.1).
2. In the graphics selection window, touch the **Graphics** tab (Figure 8-5).
3. Touch **ASV Graph**.

The ASV Graph is displayed (Figure 8-19).

Figure 8-19. ASV Graph panel (1)



8.5 About the monitoring parameters

The following table provides a list of the ventilator's monitored parameters.

You can review all parameter values in the Monitoring window (Section 8.2.2). The display of monitored parameters is updated every breath or is time driven.

For parameter specifications, see Section 15.7.

For details about SpO2-related parameters, see the *Pulse Oximetry Instructions for use*.

For a comparison of Hamilton Medical ventilation-related terminology with ISO 19223:2019, see Section 15.5.

Table 8-3. Monitored parameters

Parameter (unit)	Definition
Pressure	
AutoPEEP (cmH2O)	The difference between the set PEEP and the calculated total PEEP within the lungs. AutoPEEP is the abnormal pressure generated by air "trapped" in the alveoli due to inadequate lung emptying. Ideally, it should be zero. AutoPEEP is calculated using the LSF method applied to the entire breath. Actively breathing patients can create artifacts or noise, which can affect the accuracy of these measurements. When AutoPEEP is present, volutrauma or barotrauma might develop. In active patients, AutoPEEP may present an extra workload to the patient. AutoPEEP or air trapping may result from an expiratory phase that is too short, which may be observed under the following conditions: • Delivered tidal volume too large • Expiratory time too short or respiratory rate too high • Circuit impedance too high or expiratory airway obstruction • Peak expiratory flow too low AutoPEEP is also referred to as *intrinsic PEEP*.
Driving pressure, ΔP (cmH2O)	A calculated value showing the ratio of tidal volume to static compliance, which reflects the difference between Pplateau and PEEP.
PEEP/CPAP (cmH2O)	Monitored PEEP/CPAP. The airway pressure at the end of exhalation. Measured PEEP/CPAP may differ slightly from the set PEEP/CPAP, especially in spontaneously breathing patients.

Parameter (unit)	Definition
ΔPinsp (cmH2O)	Inspiratory pressure, the automatically calculated target pressure (additional to PEEP) applied during the inspiratory phase. Also displayed in the Vent Status panel. Not all modes use the ΔPinsp parameter. Rather, this target pressure is set using the following parameters, depending on the selected mode: • APVcmv, APVsimv, ASV: Automatically calculated target pressure • PCV+: ΔPcontrol setting • PSIMV+PSync, NIV-ST: ΔPinsp setting • SPONT, NIV: ΔPsupport setting • APRV, DuoPAP: P high setting
Pmean (cmH2O)	Mean airway pressure. The absolute pressure, averaged over the previous breath cycle.
Ppeak (cmH2O)	Peak airway pressure. The highest pressure during the previous breath cycle. It is influenced by airway resistance and compliance. Ppeak may differ noticeably from alveolar pressure if airway resistance is high. This value is always displayed.
Pplateau (cmH2O)	Plateau or end-inspiratory pressure. The pressure measured at the end of inspiration when flow is at or close to zero.
Pprox (cmH2O)	The airway pressure at the proximal patient interface. Displayed only in HiFlowO2 when a flow sensor is connected.
Flow	
Exp Flow (l/min)	Peak expiratory flow.
Flow (in HiFlowO2) [1] (l/min)	The set flow of gas to the patient when using HiFlowO2.

[1] Only displayed as an MMP; not displayed in the Monitoring window.

Parameter (unit)	Definition
Flow (in nCPAP/ nCPAP-PC) (l/min)	Only active in nCPAP and nCPAP-PC modes. Displays the current flow as follows: • In nCPAP mode, this value is the average flow, updated every second. • In nCPAP-PC mode, this value is the average flow during expiration, updated every breath. Displayed in the Monitoring window. Flow is affected by the setting of the Flow alarm. See Chapter 9.
Insp Flow (l/min)	Peak inspiratory flow, spontaneous or mandatory. Measured every breath.
Volume	
ExpMinVol MinVol NIV (l/min)	Expiratory minute volume. The moving average of the monitored expiratory volume per minute over the last 8 breaths. ExpMinVol changes to MinVol NIV in noninvasive modes. MinVol NIV is an adjusted parameter taking leakage into account.
MVSpont MVSpont NIV (l/min)	Spontaneous expiratory minute volume. The moving average of the monitored expiratory volume per minute for spontaneous breaths, over the last 8 mandatory and spontaneous breaths. In noninvasive ventilation modes, MVSpont is replaced by MVSpont NIV. MVSpont NIV is an adjusted parameter taking leakage into account.
VLeak (%) MVLeak (l/min)	Due to the leakage at the patient interface, displayed exhaled volumes in the noninvasive modes can be substantially smaller than the delivered volumes. The flow sensor measures the delivered volume and the exhaled tidal volume; the ventilator displays the difference as VLeak in % and as MVLeak in l/min, averaged over the past 8 breaths. VLeak/MVLeak can indicate leaks on the patient side of the flow sensor. They do not include leakage between the ventilator and the flow sensor. Use VLeak and MVLeak to assess the fit of the mask or other noninvasive patient interface.

Parameter (unit)	Definition
VTE VTE NIV (ml)	Expiratory tidal volume, the volume exhaled by the patient. It is determined from the flow sensor measurement, so it does not show any volume added due to compression or lost due to leaks in the breathing circuit. If there is a gas leak on the patient side, the displayed VTE may be less than the tidal volume the patient actually receives. In noninvasive ventilation modes, VTE is replaced by VTE NIV. VTE NIV is an adjusted parameter taking leakage into account
VTESpont (ml)	Spontaneous expiratory tidal volume, the volume exhaled by the patient. If there is a gas leak on the patient side, the displayed VTESpont may be less than the tidal volume the patient actually receives. Only displayed for spontaneous breaths.
VTI (ml)	Inspiratory tidal volume, the volume delivered to the patient, determined from the flow sensor measurement. If there is a gas leak on the patient side, the displayed VTI may be larger than the displayed VTE.
Vt/IBW Vt/Weight (kg)	Tidal volume is calculated according to ideal body weight (IBW) for adult/pediatric patients and according to the actual body weight for neonatal patients.
Time	
fControl (b/min)	Mandatory breath frequency. The moving average of machine-delivered breaths per minute over the last 8 total breaths.
fSpont (b/min)	Spontaneous breath frequency. The moving average of spontaneous breaths per minute over the last 8 total breaths.
fTotal (b/min)	Total breathing frequency. The moving average of the patient's total breathing frequency over the last 8 breaths, including both mandatory and spontaneous breaths. When the patient triggers a breath or the operator initiates a breath, fTotal may be higher than the Rate setting.
I:E	Inspiratory:expiratory ratio. Ratio of the patient's inspiratory time to expiratory time for every breath cycle. This includes both mandatory and spontaneous breaths. I:E may differ from the set I:E ratio if the patient breathes spontaneously.

Parameter (unit)	Definition
TE (s)	Expiratory time. In mandatory breaths, TE is measured from the start of exhalation until the set time has elapsed for the switch to inspiration. In spontaneous breaths, TE is measured from the start of exhalation, as dictated by the ETS setting, until the patient triggers the next inspiration. TE may differ from the set expiratory time if the patient breathes spontaneously.
TI (s)	Inspiratory time. In mandatory breaths, TI is measured from the start of breath delivery until the set time has elapsed for the switch to exhalation. In spontaneous breaths, TI is measured from the patient trigger until the flow falls to the ETS setting for the switch to exhalation. TI may differ from the set inspiratory time if the patient breathes spontaneously.
Other calculated and displayed parameters	
CPR Timer	Displayed as an MMP during CPR ventilation, shows how long CPR ventilation has been on. For details, see Section 10.10.
Cstat (ml/cmH2O)	Static compliance of the respiratory system, including lung and chest wall compliances, calculated using the LSF method. Cstat can help diagnose changes in elastic characteristics of the patient's lungs. Actively breathing patients can create artifact or noise, which can affect the accuracy of these measurements.
Oxygen (%)	Oxygen concentration of the delivered gas. It is measured by an O2 sensor in the inspiratory pneumatics. This parameter is not displayed if the O2 sensor is not installed, is defective, is not a genuine Hamilton Medical part, or if oxygen monitoring is disabled.

Parameter (unit)	Definition
P0.1 (cmH2O)	Airway occlusion pressure. The pressure drop during the first 100 ms when a breath is triggered. P0.1 indicates the patient's respiratory drive and patient inspiration effort. P0.1 applies only to patient-triggered breaths. A P0.1 value of -3 cmH2O indicates a strong inspiratory effort, and a value of -5 cmH2O indicates an excessive effort, possibly because the patient is "air hungry" (peak inspiratory flow or total ventilatory support is inadequate) or has an excessive drive. If P0.1 is below -3 cmH2O: • Increase pressure or volume settings (depending on mode) • Increase %MinVol (ASV mode only) • Shorten P-ramp
PTP (cmH2O*s)	Inspiratory pressure time product. The measured pressure drop required to trigger the breath multiplied by the time interval until the PEEP/CPAP level is reached at the beginning of inspiration. PTP is valid for patient-triggered breaths only, and indicates work by the patient to trigger the breath. The work depends on: • The intensity of the patient's effort • The trigger sensitivity • The volume and resistance of the breathing circuit PTP does not indicate total patient work but is a good indicator of how well the ventilator is adjusted for the patient. If PTP values increase, do the following: • Increase trigger sensitivity • Decrease P-ramp

Parameter (unit)	Definition
RCexp (s)	Expiratory time constant. The rate at which the lungs empty, as follows: Actual TE, % emptying 1 x RCexp, 63% 2 x RCexp, 86.5% 3 x RCexp, 95% 4 x RCexp, 98% RCexp is calculated as the ratio between VTE and flow at 75% of the VTE. Normal values in intubated adult patients: • Short, < 0.6 seconds: restrictive disease (ARDS, atelectasis, chest wall stiffness) • Normal, 0.6 to 0.9 seconds: normal compliance and resistance, or combined decreased compliance and increased resistance • Long, > 0.9 seconds: obstructive disease (COPD, asthma), bronchospasm, ET tube obstruction, or incorrect positioning Use RCexp to set the optimum TE (Goal: TE ≥ 3 x RCexp): • *With passive patients:* Adjust Rate and I:E • *With active patients:* Increase ΔPsupport and/or ETS to achieve a longer TE These actions may reduce the incidence of AutoPEEP.
Rinsp (cmH2O / (l/s))	Resistance to inspiratory flow caused by the endotracheal tube and the patient's airways during inspiration. It is calculated using the LSF method applied to the inspiratory phase. Also displayed in the Dynamic Lung panel. Actively breathing patients can create artifact or noise, which can affect the accuracy of these measurements.

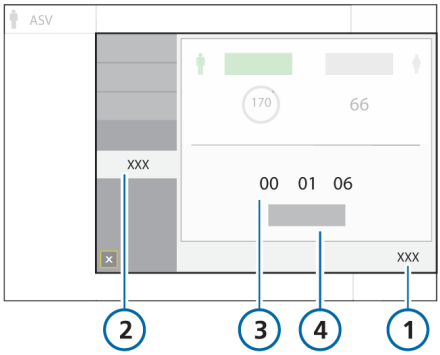
Parameter (unit)	Definition
RSB (1 / (l*min))	Rapid shallow breathing index. The total breathing frequency (fTotal) divided by the exhaled tidal volume (VTE). Because a patient with dyspnea typically takes faster and shallower breaths than a non-dyspnoeic patient, RSB is high in the dyspnoeic patient and low in the non-dyspnoeic patient. RSB is often used clinically as an indicator of a ventilated patient's readiness for weaning. RSB is only significant for spontaneously breathing patients weighing more than 40 kg and is only shown if 80% of the last 25 breaths were spontaneous.
Ventilation time	Displayed in the Controls > Patient window, shows how long the patient has been ventilated. For details, see Section 8.6.
Humidifier related	
T Y-piece (°C)	*For HAMILTON-H900 humidifier only*. See Table 11-5.
T humidifier (°C)	*For HAMILTON-H900 humidifier only*. See Table 11-5.
CO2 related	
FetCO2 (%)	Fractional end-tidal CO2 concentration. Permits assessment of PaCO2 (arterial CO2). Note that it is inaccurate in pulmonary embolism. Available when a CO2 sensor is connected and enabled.
PetCO2 (mmHg)	End-tidal CO2 pressure. The maximum partial pressure of CO2 exhaled during a tidal breath (just before the start of inspiration). It represents the final portion of air that was involved in the exchange of gases in the alveolar area, thus providing a reliable index of CO2 partial pressure in the arterial blood under certain circumstances. PetCO2 does not reflect PaCO2 in the case of a pulmonary embolism. Available when a CO2 sensor is connected and enabled.

Parameter (unit)	Definition
slopeCO2 (%CO2/l)	Slope of the alveolar plateau on the FCO2 / Volume curve. Available when a CO2 mainstream sensor is connected and enabled.
V'alv (l/min)	Alveolar minute ventilation. Permits assessment of actual alveolar ventilation (as opposed to minute ventilation). Valv * f (normalized to 1 min) Available when a CO2 mainstream sensor is connected and enabled.
V'CO2 (ml/min)	CO2 elimination. Net exhaled volume of CO2 per minute. Permits assessment of metabolic rate (for example, it is high with sepsis) and treatment progress. Available when a CO2 mainstream sensor is connected and enabled.
VDaw (ml)	Airway dead space. Gives an effective, in-vivo measure of volume lost in the conducting airways. A relative increase in dead space points to a rise in respiratory insufficiency and can be regarded as an indicator of the current patient situation. Patients with high dead space values are at particular risk if the muscles also show signs of fatigue. Available when a CO2 mainstream sensor is connected and enabled.
VDaw/VTE (%)	Airway dead space fraction at the airway opening. Available when a CO2 mainstream sensor is connected and enabled.
VeCO2 (ml)	Exhaled CO2 volume, updated breath by breath. Available when a CO2 mainstream sensor is connected and enabled.
ViCO2 (ml)	Inspired CO2 volume, updated breath by breath. Available when a CO2 mainstream sensor is connected and enabled.
Vtalv (ml)	Alveolar tidal ventilation. VTE - VDaw Available when a CO2 mainstream sensor is connected and enabled.

8.6 Viewing patient ventilation time

The Controls > Patient window displays a timer that shows how long the patient has been ventilated.

Figure 8-20. Ventilation time



1	Controls	3	Ventilation time (days, hours, minutes)
2	Patient	4	Reset

The timer records time as follows:

- The timer starts when you start ventilation.
- When you enter Standby, the timer pauses. It picks up again from the last value when you exit Standby and return to active ventilation.
- When you set up a new patient in the Standby window, and start ventilation, the timer resets to 0.
- When you select **Last patient** in the Standby window, the timer continues from the last total time recorded.
- When you touch **Reset**, the timer resets to 0.

When the timer is reset, an entry is made to the Event log recording the time of the reset, as well as how long the ventilator had been running prior to the reset.

To reset the timer to 0

1. Touch **Controls**.
2. In the Controls window, touch the **Patient** tab.
3. Touch **Reset**.

The timer starts again at 00d 00h 00min.

9
Responding to alarms

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9.1 Overview

Operator-adjustable and nonadjustable alarms together with a visual alarm indicator notify you of conditions that require your attention.

These alarms are categorized as high, medium, or low priority, as described in Table 9-1. The ventilator's visual alarm indications are described in Figure 9-1.

Additional alarms conditions are associated with technical fault and technical note alarms, as well as informational messages.

You can view active alarms in the alarm buffer (Figure 9-2). Information about the alarm is also stored in the Event log. Informational messages are *not* stored in the Event log.

Alarms are indicated in the color associated with the alarm priority as follows:

- The alarm lamp on top of the ventilator lights and flashes.
- The message bar on the ventilator display is shown in color and displays the alarm text.
- An MMP associated with an active alarm is shown in color, together with a colored bar to the right of the affected parameter.
- In the Monitoring window, a parameter associated with an active alarm is shown in the associated color.
- Any affected parameter shown in the Dynamic Lung is shown in color.
- The Humidifier quick access icon is shown in the associated color when a related alarm is active.
- The alarm text is displayed in the alarm buffer.

In the event of certain technical failures, the ventilator switches to Safety ventilation (Section 7.8). This gives you time to arrange for corrective actions, including organizing a replacement ventilator.

When an alarm condition is serious enough to possibly compromise safe ventilation, the device defaults to the Ambient state (Section 7.8). The ventilator immediately stops gas flow to the patient. The release valve and expiratory valve are opened, letting the patient breathe room air unassisted.

When reviewing alarms, you can access on-screen alarm troubleshooting help in the Alarms > Buffer window. See Section 9.2.1.

For details on setting alarm limits, see Section 5.7.

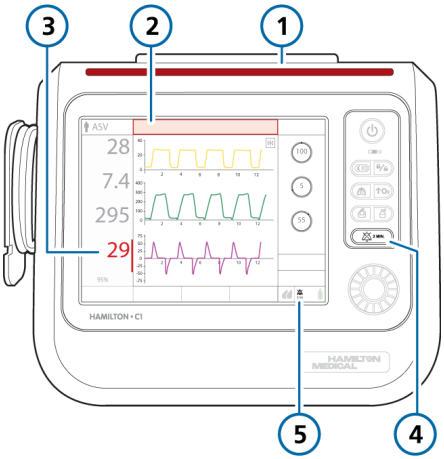
Table 9-1 describes the audio and visual characteristics of these types of alarms and provides guidance on how to respond.

Table 9-1. Alarm indicators

Alarm type	Message bar	Alarm lamp / Alarm status indicator	Audio	Action required
High priority	Red, with alarm message	Red, flashing	A sequence of 5 beeps, repeated until the alarm is reset. If the audible alarm is not silenced during the first minute, the continuous-tone buzzer also sounds.	The patient's safety is compromised. The problem needs immediate attention.
Medium priority	Yellow, with alarm message	Yellow, flashing	A sequence of 3 beeps, repeated periodically.	The patient needs prompt attention.
Low priority	Yellow, with alarm message	Yellow, solid	Two sequences of beeps. This is not repeated.	Operator awareness is required.
Technical fault	Red, with the text, *Safety ventilation* or *Technical fault: xxxxxx*	Red, flashing	Same as for high-priority alarm, if technically possible. At a minimum, a continuous buzzer tone. The buzzer cannot be silenced.	The ventilator enters Safety ventilation, or, if it cannot safely ventilate, the Ambient state. • Provide alternative respiratory support. • Turn off the ventilator. • Have the ventilator serviced.

Alarm type	Message bar	Alarm lamp / Alarm status indicator	Audio	Action required
Technical event	Depends on severity of the event. Can be low, medium, or high.	Same as the associated alarm level	Same as the associated alarm level.	A technical alarm cannot typically be corrected by the operator. Ventilation continues. If needed, have the ventilator serviced.
Technical note	Provides technical information about a hardware or software issue, displayed only in the Event log.	--	--	No action is required.

Figure 9-1. Visual alarm indications



1	Alarm lamp	4	Audio pause key
2	Message bar	5	Audio pause indicator and countdown
3	MMP and colored bar associated with alarm		

9.1.1 Alarm limit indicators

Alarm limits are shown in the Alarms > Limits windows.

When an alarm limit is disabled, that is, no limit applies, the device shows the following Alarm Off[1] icon.

For details about setting alarm limits, see Section 5.7.

9.1.2 Configurable alarm delay

For the Vt low/high alarms, you can configure a short delay before the triggering condition generates an alarm in Configuration (Section 13.6). The setting applies to all patient groups.

Table 9-2. Alarm delay settings in Configuration

Alarm delay	Description
OFF	The alarm is generated when the triggering condition persists over two (2) patient breaths.
ON	The alarm is generated when the triggering condition persists over three (3) patient breaths.

[1] Not available in all markets.

9.1.3 Responding to an alarm

⚠ WARNING

When an Audio pause is active, the following critical alarms still generate an audible alarm:

- Apnea
- External power loss
- Oxygen supply failed
- Technical events: 231003, 243001, 243002, 283007, 284003, and 285003
- All technical faults

⚠ CAUTION

Carefully set alarm limits according to the patient's condition. Setting limits too high or too low defeats the purpose of the alarm system.

NOTICE

The factory default alarm limit settings are set in line with the selected patient group, allowing for unattended monitoring. These settings, however, can *never* replace individual review of the patient and adjustment of alarm limits based on their condition.

Before proceeding, review the safety information in Section 1.8.

Alarms may result from either a clinical condition or an equipment issue. In addition, a single alarm condition can generate multiple alarms.

Your search for the causes of the alarm condition should be assisted by, but not limited to, the alarm messages displayed.

To respond to an alarm

1. Approach the patient immediately.
2. Secure sufficient and effective ventilation for the patient.

   You can pause the audible alarm, if appropriate and available. See Section 9.1.4.
3. Correct the alarm condition from the alarm messages. See Section 9.4.
4. For a technical fault, remove the ventilator from use, note the fault code, and have the ventilator serviced.
5. If appropriate, readjust the alarm limit.

9.1.4 Temporarily silencing an alarm

One component of an alarm is the audible alarm sound. With most alarms, you can pause (silence) the alarm sound for two (2) minutes at a time.

To temporarily silence an alarm

- Press (2 MIN.) (Audio pause) on the front of the ventilator (Figure 10-2).

The audible ventilator alarm is muted for two (2) minutes. Pressing the key a second time cancels the Audio pause.

The indicator light next to the Audio pause key turns red while an Audio pause is active.

The display also indicates an Audio pause is engaged as follows (Figure 9-1):

- The Audio pause indicator is displayed.
- A countdown timer on the main display shows the remaining time for the Audio pause.

When the time expires and the issue has not yet been resolved, an audible alarm sounds again.

9.2 About the alarm buffer

The alarm buffer shows up to five (5) active alarm messages or up to six (6) inactive alarm messages:

- The alarm buffer shows active alarms as they are generated (Figure 9-2). The alarm messages also alternate in the message bar. Active alarms are shown in wide color-coded boxes.
- If no alarms are active, the alarm buffer shows the most recent inactive alarms (Figure 9-3). Inactive alarms are shown in narrow color-coded boxes. In addition, the i-icon is visible on the display.
- Touch an alarm entry to view troubleshooting help directly on the display.

To view alarms

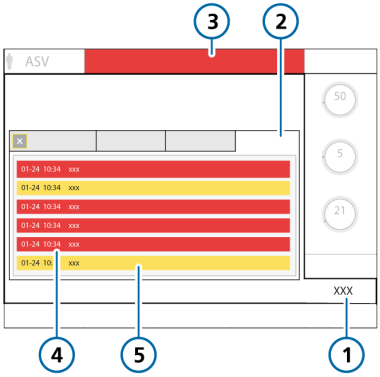
- Open the Alarms > Buffer window by doing one of the following:
  – Touch an active alarm in the message bar at the top of the display (Figure 9-2).
  – Touch the inactive alarm indicator (the i-icon) (Figure 9-3).
  – Touch the Audio pause indicator at the bottom right of the display (Figure 9-1).
  – Touch **Alarms** > **Buffer**.

The most recent alarm is at the top of the list.

To clear the list of inactive alarms

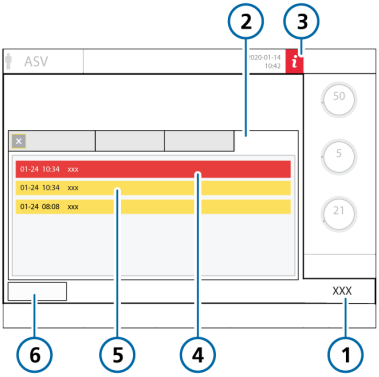
- Touch the **Reset** button (Figure 9-3).
  Closing the alarm buffer does not erase its contents.

Figure 9-2. Alarm buffer with active alarms



1	Alarms	4	High-priority alarm (red)
2	Buffer	5	Low- or medium-priority alarm (yellow)
3	Alarm text in message bar		

Figure 9-3. Alarm buffer with inactive alarms



1	Alarms	4	Inactive high-priority alarm (red)
2	Buffer	5	Inactive low- or medium-priority alarm (yellow)
3	i-icon	6	Reset

9.2.1 Accessing on-screen troubleshooting help

Troubleshooting help is available for alarms.

To view the help for an alarm

1. Touch the alarm message in the buffer.

   A Help window opens in the buffer, providing troubleshooting information for the selected alarm.

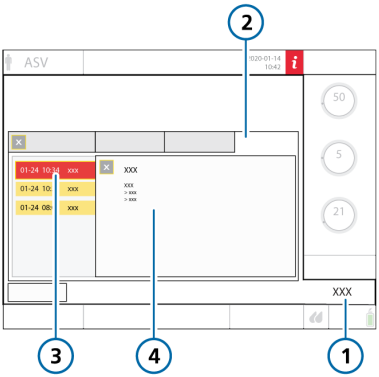
2. To view help for another alarm, touch the next alarm message.

   The contents of the Help window refresh with the new information.

   The alarm is displayed as long as the window is open even if the alarm is no longer active.

3. Touch **X** to close the Help window.

Figure 9-4. On-screen help window



1	Alarms	3	Selected alarm
2	Buffer	4	Alarm text and troubleshooting information

9.3 Adjusting alarm loudness (volume)

⚠ WARNING

Be sure to set the auditory alarm loudness above the ambient sound level. Failure to do so can prevent you from hearing and recognizing alarm conditions.

You can set the loudness of the audible alarm. By default, the loudness is set to 5.

If you set the loudness below the default value during a patient session, the value is reset to the default upon:

- Setting up a new patient
- Turning the ventilator off and on again

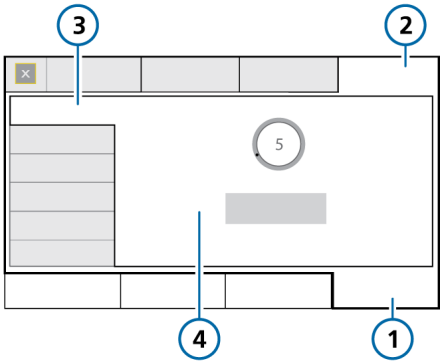
You cannot set the loudness below the minimum level configured for the device (Chapter 13).

To adjust the alarm loudness

1. Touch **System** > **Settings**.
2. Touch the **Loudness** button if the Loudness window is not already displayed.
3. Activate and adjust the **Loudness** control, as needed.
4. Touch **Test** to check the loudness level.

   Ensure the loudness level is above the ambient sound level.
5. Repeat the process as required, and close the window.

Figure 9-5. Alarm loudness control



1	System	3	Loudness
2	Settings	4	Loudness control and Test button

9.4 Troubleshooting alarms

Table 9-3 is an alphabetical list of the alarm messages displayed by the ventilator, along with their definitions and suggested corrective actions.

These corrective actions are sequenced to correct the most probable issue or to present the most efficient corrective action first. The proposed actions, however, may not always correct the particular problem.

If your issue is not resolved after performing the recommended tasks, contact your Hamilton Medical authorized service personnel.

For additional information, see the appropriate documentation as follows:

- For SpO2-related alarms, see the *Pulse Oximetry Instructions for Use, HAMILTON-C1/T1* (PN 624992).
- For HAMILTON-H900-related alarms, see Section 11.1.6 and the *HAMILTON-H900 Instructions for Use* (PN 624431).

Table 9-3. Alarms and other messages

Alarm	Definition	Action needed
Ambient state	The inspiratory and expiratory channels are opened, letting the patient breathe room air unassisted. See Section 7.8.	Provide alternative respiratory support immediately.
Apnea ventilation ended	*Low priority*. Backup mode was reset, and ventilator is again ventilating in its original support (pre-apnea) mode.	No action required.
Apnea ventilation	*Low priority*. Apnea backup ventilation has started. No breath delivered for the operator-set apnea time. Apnea backup ventilation is on.	• Check patient condition. • Check trigger sensitivity. • Check the control settings for the backup mode. • Consider changing the mode.
Apnea	*High priority*. No patient trigger within the operator-set apnea time in APVsimv, VS, SPONT, DuoPAP, APRV, or NIV mode. Apnea backup is off.	• Check patient condition. • Check trigger sensitivity. • Consider changing the mode.

Alarm	Definition	Action needed
ASV: Cannot meet the target[1]	*Low priority*. The operator-set %MinVol cannot be delivered, possibly due to setting conflicts or lung-protective rules.	• Check patient condition. • Check the Plimit setting and adjust if appropriate. • Consider a mode change. However, be aware that other modes may not enforce lung-protective rules.
Battery 1: Calibration required	*Low priority*. The battery requires calibration. You may continue to use the battery.	Have the ventilator serviced to calibrate the battery.
Battery 1: Defective	*High priority*. Battery is defective. Ventilation continues if an alternative power source is connected.	• Replace battery. • Prepare alternative respiratory support. • If the problem still persists, have the ventilator serviced.
Battery 1: Replacement required	*Low priority*. Battery capacity is insufficient for reliable operation and must be replaced immediately.	Have the ventilator serviced to replace the battery.
Battery 1: Temperature high	*High priority*. The battery temperature is higher than expected.	• Remove the ventilator from the sun or other heat source. • Provide alternative respiratory support. • Have the ventilator serviced to replace the battery.
Battery 1: Wrong battery	*Low priority*. The battery in use is not the correct battery for this ventilator.	Have the ventilator serviced to replace the battery.
Battery communication error	*High priority*. Battery data is not available. Ventilation continues.	Have the ventilator serviced to replace the battery.

[1] Not applicable when the HAMILTON-C1 neo option is enabled and the ventilator is dedicated to neonatal ventilation.

Alarm	Definition	Action needed
Battery low	The **Battery low** alarm has different levels of priority depending on battery age and condition. The alarm priority levels are defined as follows: **High priority**. The ventilator is running on battery power, and the battery charge is critically low. You have a minimum of 5 minutes operating time left. If the high-priority **Battery low** alarm occurs when starting up the ventilator, you may have less than 5 minutes of operating time remaining. **Medium priority**. The ventilator is running on battery power and the battery charge is low. **Low priority**. The ventilator is running on primary power and the battery charge is low.	• Connect the ventilator to a primary power source. • Install charged battery. • If necessary, be prepared to provide alternative respiratory support.
Battery power loss	*High priority*. No battery is present.	Have the ventilator serviced to install the battery.
Battery totally discharged	*High priority*. The battery charge level is below 5%. The ventilator switches to the Ambient state.	• Connect the ventilator to primary power (AC). Connecting to primary power also charges the battery. • Immediately provide alternative respiratory support until the issue is resolved. • If the problem still persists, have the ventilator serviced.
Blower fault	*High priority*. A blower malfunction was detected. A technical alarm cannot typically be corrected by the operator. The ventilator switches to the Ambient state.	• Immediately provide alternative respiratory support. • Have the ventilator serviced.
Blower service required	*Low priority*. The blower has reached the end of its lifespan.	Have the ventilator serviced.

Alarm	Definition	Action needed
Buzzer defective	*High priority*. A buzzer malfunction was detected. A technical alarm cannot typically be corrected by the operator.	• Restart device. • Provide alternative respiratory support until the issue is resolved. • If the problem persists, have the ventilator serviced.
Check CO2 airway adapter	*Low priority*. Adapter disconnection, optical block, or adapter type changed.	• Check patient condition. • Check the airway adapter for excess moisture accumulation / contamination by secretions. • Replace / perform zero calibration on airway adapter.
Check CO2 sampling line	*Low priority*. The CO2 sidestream sensor sampling line is occluded by water.	• Check patient condition. • Replace sampling line.
Check flow sensor for water[1]	*Neonatal only*. Water is detected inside the flow sensor, which is affecting measurements. *Medium priority*. You must reset the alarm within 90 seconds by pressing the Audio pause key. This gives you time to remove any accumulated water from the flow sensor and tubing. If the alarm is not reset within 90 seconds, the alarm becomes *high priority*. The alarm is active until flow sensor measurements are again within the expected range. You can specify alarm sensitivity or disable the alarm in Configuration. See Section 13.3.5.	• Remove all water from the flow sensor and flow sensor tubing. • You *must* position the flow sensor at a ≥ 45° angle to avoid water accumulation. • Adjust the FS alarm sensitivity control.

[1] Not available in all markets.

Alarm	Definition	Action needed
Check flow sensor	*High priority*. Flow sensor measurements are out of the expected range. If the alarm continues for 3 consecutive breath cycles, the External flow sensor failed alarm is generated and the ventilator switches to Sensor Failure mode (Section 7.8).	• Make sure the flow sensor is the correct type for the patient (Adult/Ped or Neonatal). • Check the flow sensor connection to the ventilator. • Connect and calibrate a new flow sensor.
Check flow sensor tubing	*High priority*. The flow sensor tubes are disconnected or occluded. If the alarm continues for 3 consecutive breath cycles, the External flow sensor failed alarm is generated and the ventilator switches to Sensor Failure mode (Section 7.8).	• Check the flow sensor connection to the ventilator. • Connect and calibrate a new flow sensor.
Check for blockage	*Medium priority*. Internal pressure is above 45 cmH2O in HiFlowO2. If the pressure increases further and exceeds 50 cmH2O, the alarm becomes *high priority*, flow stops, and the pressure is released.	• Observe the patient • Check patient interface for blockage. If no blockage is observed, consider reducing the flow to decrease pressure. • Check breathing circuit limbs and tubing for kinks.
Check patient interface	*High priority*. Generated when using a speaking valve and the Vt low or Low pressure alarm is active. For additional alarm details when using a speaking valve, see Table 10-1.	Check for: • Disconnection • Whether tracheostomy cuff is fully deflated • Upper airway occlusion • Proper operation of the speaking valve
Check Plimit	*Low priority*. Inspiratory pressure, including PEEP/CPAP, is above the pressure limit (Plimit). Does not apply in APVcmv, APVsimv, or ASV modes.	• Check the patient for adequate ventilation. • Adjust Plimit and/or the pressure control settings, as appropriate.

Alarm	Definition	Action needed
Check settings	*Low priority*. A change to a control or alarm setting was not saved.	Check and confirm settings, including alarms.
Circuit calibration needed	*Medium priority, Low after Audio pause is activated*. The ventilator does not have correct calibration data. Only active in nCPAP and nCPAP-PC modes.	Calibrate the neonatal breathing circuit (Section 6.2.2).
CO2 calibration needed	*Low priority*. A previous sensor zero calibration failed.	Perform the following checks, repeating the calibration after each one, until calibration is successful: • Clean or replace airway adapter. • Perform a zero calibration of the sensor, making sure there is no source of CO2 near the airway adapter. • Replace the airway adapter. • Replace the CO2 sensor. • If the problem persists, have the ventilator serviced.
CO2 sensor disconnected	*Low priority*. The CO2 module is installed, but there is no signal from the CO2 sensor. CO2 monitoring is enabled.	• Make sure a CO2 sensor is connected. • Check CO2 sensor connections (CO2 sensor cable to module, CO2 module to ventilator). • If the problem persists, have the ventilator serviced.
CO2 sensor faulty	*Low priority*. The CO2 sensor signal indicates a hardware error or a third-party sensor is installed.	• Disconnect the sensor from the CO2 module. Wait a few seconds, and reconnect. • Perform a zero calibration of the sensor. Ensure the sensor is attached to the airway adapter during zero calibration. • Replace the CO2 sensor. Make sure the sensor is a genuine Hamilton Medical part.

Alarm	Definition	Action needed
CO2 sensor over temperature	*Low priority*. The temperature at the CO2 sensor is too high.	⚠ **CAUTION!** *Do not place the CO2 sensor directly on the patient's skin. It can burn the skin as the sensor may reach a temperature of 46°C (115°F).* • Check whether the sensor is affected by an external heating source. • Remove the sensor from the airway, and disconnect the sensor from the CO2 module. Reconnect. • Verify that system is running within the specified environmental conditions. Check for excessive airway temperature, which could be caused by defective humidifier, heater wire, or probe.
CO2 sensor warmup	*Low priority*. The CO2 operating temperature has not yet been reached or is unstable.	Wait for the sensor to warm up (approx. 2 minutes).
CO2: Poor signal	*Low priority*. The CO2 sensor signal quality is poor.	• Check patient condition. • Check CO2 sensor and adapter connections. • Ensure that airway adapters are not in a horizontal position relative to the floor to reduce accumulation of patient secretions. If accumulation occurs, remove the adapter, rinse with sterile water, and reconnect.
CPR ON	*Low priority*. CPR ventilation is on. The alarm limits for ExpMinVol, fTotal, and Vt are set to their minimum and maximum values.	• Check and confirm settings, including alarms. • To stop CPR ventilation, press the Power/Standby key or change the ventilation mode.

Alarm	Definition	Action needed
Device temperature high	*High priority*. The internal temperature of the ventilator is higher than expected.	• Remove the ventilator from the sun or other heat source. • Check the cooling fan filter and fan. • Prepare alternative respiratory support. • Have the ventilator serviced.
Disconnection on patient side	*High priority*. VTE is less than one-eighth of the delivered VTI, and delivered VTI exceeds 50 ml. Applicable in invasive modes. For APRV and DuoPAP modes, only applicable during the P high phase. For alarm details when using a speaking valve, see Table 10-1.	• Check patient condition. • Check if ventilator is in synchrony with the patient. • Check the breathing circuit for a disconnection between the patient and the flow sensor, or for other large leaks (for example, ET tube).
Disconnection on ventilator side	*High priority*. One of the following has occurred: • Excessive leakage from the breathing circuit for 2 consecutive breaths. • The inspiratory volume measured at the ventilator outlet is 2 x VTI, measured at the proximal flow sensor for 2 breaths, while the measured Ppeak < (PEEP + ΔPinsp) − 5 cmH2O Applicable in invasive modes. For alarm details when using a speaking valve, see Table 10-1.	• Check the expiratory valve: – Check the condition of the expiratory valve set. If anything is defective, replace. – Check if ventilator is in synchrony with the patient. – Check whether the expiratory valve is affected by any nebulizing agent. – Make sure that the expiratory valve is properly installed. – Check whether there is a disconnection at the expiratory valve. • Replace the expiratory valve. • Check the flow sensor. If needed, replace the flow sensor.

Alarm	Definition	Action needed
Exhalation obstructed	*High priority*. Either the end-expiratory pressure is too high or the end-expiratory flow is too low. The inspiratory valve opens so that the patient can exhale through the inspiratory limb. Note that you must use an inspiratory filter to prevent contamination. The ventilator may be contaminated if no inspiratory filter is used. Not active during HiFlowO2.	• Check patient condition. • Check the expiratory limb for occlusion. • Check the expiratory valve set. Replace if needed. • Check the flow sensor tubes for occlusion. • Adjust breath timing controls to increase the expiratory time. • Provide alternative respiratory support until the issue is resolved. • Have the ventilator serviced.
External connections disabled	*Medium priority, Low after Audio pause is activated*. The Connectivity Module is turned off. Repeated connection attempts have failed. Ventilation can continue, but connection with other devices is not possible.	• If no patient is connected, restart the ventilator. • If the problem persists, have the ventilator serviced.
External flow sensor failed	*High priority*. The external flow sensor does not work properly. The alarm is generated when either the Check flow sensor or Check flow sensor tubing alarm is active for 3 consecutive breath cycles. The ventilator switches to Sensor Failure mode (Section 7.8).	• Check flow sensor for excessive secretions and/or water accumulation. • Provide alternative respiratory support and clean the flow sensor with sterile water. • Connect and calibrate a new flow sensor.
Fan failure	*Medium priority*. There is a problem with the cooling fan.	• Provide alternative respiratory support until the issue is resolved. • Disconnect the ventilator from the patient. • Have the ventilator serviced.

Alarm	Definition	Action needed
Flip the flow sensor	*Medium priority*. Either the flow sensor is connected to the breathing circuit facing the wrong direction or the flow sensor connections to the ventilator are reversed. Ventilation continues, but the ventilator corrects for the reversed signal.	• Check the flow sensor. The end marked PATIENT faces the patient. • Reverse the flow sensor tube connections on the ventilator. • The blue tube attaches to the blue connector. The clear tube attaches to the white connector.
Flow sensor calibration needed	*High priority during ventilation, low in Standby*. The ventilator has incorrect calibration data or flow sensor cannot be calibrated. In Standby, may indicate that the patient group has changed. Note that flow, volume, and pressure measurements are less accurate with an uncalibrated flow sensor.	• Ensure the correct flow sensor for the selected patient group is attached to the breathing circuit. • Calibrate the flow sensor as soon as possible.
Function key not operational	*Medium priority*. The function key is defective. Ventilation continues.	• Turn off the ventilator using the Power/Standby button. • Have the ventilator serviced.
High Flow	*Medium priority, Low after Audio pause is activated.*. Flow has reached the set limit. Only active in nCPAP and nCPAP-PC modes.	• Check the patient interface and breathing circuit for disconnection or excessive leakage. • Check ventilator settings and alarm limits.
High frequency	*Medium priority*. The measured fTotal exceeds the set alarm limit.	• Check the patient for adequate ventilation (VTE). • Check alarm limits. • Check the trigger sensitivity. • If the ventilator is in ASV mode, see Section 7.7.
High minute volume	*High priority*. The measured ExpMinVol exceeds the set alarm limit.	• Check patient condition. • Check and confirm settings, including alarms.

Alarm	Definition	Action needed
High oxygen	*High priority*. One of the following has occurred: • If the Oxygen alarm limits are set automatically, the measured oxygen is more than 5% (absolute) above the current Oxygen control setting. • If the Set Oxygen alarm limits manually checkbox is selected, the measured oxygen is above the set upper limit.	• Calibrate the O2 sensor. • Install a new O2 sensor. • Check alarm limits (if set manually).
High PEEP	*Medium priority*. Monitored PEEP exceeds (set PEEP + 5 cmH2O) for two consecutive breaths. *For DuoPAP and APRV only*: Alarm applies to both P high and P low settings. The alarm sounds when the monitored P high exceeds (set P high + 5 cmH2O) or monitored P low exceeds (set P low + 5 cmH2O) for 2 consecutive breaths. If T low is set to < 3 seconds, the High PEEP alarm is disabled for P low settings. This reduces the incidence of false positive alarms.	• Check patient condition. • Check and confirm settings, including alarms. • Check the expiratory valve set for possible obstructions. • Check for obstructions in the expiratory limb. • Check the flow sensor tubes for occlusion.
High pressure during sigh[1]	*High priority*. A sigh cannot be fully delivered because excessive inspiratory pressure would be required. The sigh is partially delivered.	• Check patient condition. • Check the artificial airway of the patient for kinks and occlusions. • Check the breathing circuit limbs and flow sensor tubes for kinks and occlusions. • Consider disabling the Sigh function.

[1] Not applicable when the HAMILTON-C1 neo option is enabled and the ventilator is dedicated to neonatal ventilation.

Alarm	Definition	Action needed
High pressure	*High priority, Low after Audio pause is activated*. The measured inspiratory pressure exceeds the set high Pressure alarm limit. The ventilator immediately stops gas flow to the patient and opens the expiratory valve to reduce pressure to the PEEP/CPAP level. If the pressure reaches 15 cmH2O above the high Pressure alarm limit for longer than 5 seconds, the ventilator opens the release valve. If the pressure reaches 15 cmH2O above the high Pressure alarm limit for longer than 7 seconds, the ventilator enters the Ambient state.	• Check patient condition. • Adjust the Pressure alarm limit. • Check the artificial airway of the patient for kinks and occlusions. • Check the breathing circuit limbs and flow sensor tubes for kinks and occlusions. • Provide alternative respiratory support once the ventilator enters the Ambient state.
Inspiratory volume limitation	*Medium priority*. The delivered Vt is more than 1.5 times the set high Vt alarm limit. Pressure is reduced to PEEP level. The APV controls reduce the pressure for the next breath by 3 cmH2O. Disabled in noninvasive modes. For alarm details when using a speaking valve, see Table 10-1.	• Reduce the ΔPsupport setting. • Adjust the high Vt alarm limit.
Invalid communication board	*Low priority*. The installed communication board is invalid.	• Contact your Hamilton Medical technical representative. • Have the ventilator serviced.
IRV	*Low priority*. The set I:E ratio is above 1:1, leading to inverse ratio ventilation. Does not apply in PSIMV+PSync, SPONT, NIV, or NIV-ST modes, or in HiFlowO2.	Check the timing control settings.
JTAG not working	*Low priority*. A hardware component failed the self-test during startup.	Remove the ventilator from use and have it serviced.

Alarm	Definition	Action needed
Loss of external power	*Low priority*. The ventilator is running on battery power due to loss of a primary power source.	• Silence the alarm. • Check integrity of connection to primary power source. • Check battery status. • Prepare for possible power loss. • Provide alternative respiratory support until the issue is resolved.
Loss of PEEP	*Medium priority*. One of the following conditions is in effect: • Pressure during exhalation is below (set PEEP/CPAP – 3 cmH2O) for more than 10 seconds • Measured end-expiratory pressure is below (set PEEP/CPAP ≥ 4 cmH2O) for 2 consecutive breaths	• Check patient condition. • Check the breathing circuit for leaks. Replace the breathing circuit, if necessary. • Check the condition of the expiratory valve set. If anything is defective, replace.
Loudspeaker defective	*High priority*. A loudspeaker malfunction was detected. A technical alarm cannot typically be corrected by the operator. Ventilation continues.	• Check patient condition. • Provide alternative respiratory support until the issue is resolved. • Have the ventilator serviced.
Low frequency	*Medium priority*. Measured fTotal is below the set alarm limit.	• Check patient condition. • Adjust the low fTotal alarm limit.
Low minute volume	*High priority*. Measured ExpMinVol is below the set alarm limit.	• Check patient condition. • Check the breathing circuit and artificial airway of the patient for leaks and/or disconnection. • Check and confirm settings, including alarms.

Alarm	Definition	Action needed
Low oxygen	*High priority*. One of the following has occurred: • If the Oxygen alarm limits are set automatically, the measured oxygen is more than 5% (absolute) below the current Oxygen control setting. • If the Set Oxygen alarm limits manually checkbox is selected, the measured oxygen is below the set lower limit.	• Check patient condition. • Check the oxygen supply. Provide an alternative source of oxygen, if necessary. • Calibrate the O2 sensor. • Provide alternative respiratory support and install a new O2 sensor.
Low pressure	*High priority*. The set pressure during inspiration was not reached.	• Check patient condition. • Check the breathing circuit for a disconnection between the patient and the flow sensor, or for other large leaks.
Maximum leak compensation	*Low priority*. The set Vt cannot be reached due to a leak. In APVsimv and APVcmv modes only.	• Check patient condition. • Inspect the system for leaks. • Suction the patient, if needed. • Ensure the high Pressure limit is appropriate. • Switch to a different ventilation mode.
O2 sensor calibration needed	*Low priority*. O2 sensor calibration data is not within the expected range, or the sensor is new and requires calibration.	• Calibrate the O2 sensor. • Verify temperature settings are within environmental specifications. • Replace O2 sensor if required. • Have the ventilator serviced.
O2 sensor defective	*Low priority*. The O2 sensor is depleted.	Install a new O2 sensor.
O2 sensor missing	*Low priority*. There is no signal from the O2 sensor.	Install an O2 sensor or use an external monitor, according to ISO 80601-2-55.

Alarm	Definition	Action needed
O2 sensor not system compatible	*Low priority*. The incorrect type of O2 sensor is installed.	Ensure a Hamilton Medical O2 sensor is used and it is properly installed.
Obstruction	*High priority*. End-expiratory pressure > set PEEP/CPAP + 5, or Flow < 1 l/min. Only active in nCPAP and nCPAP-PC modes.	• Check the patient. • Check the expiratory limb for occlusion. • Check the expiratory valve set. • Check the pressure line for occlusion. • Adjust breath timing controls to increase the expiratory time. • Have the ventilator serviced.
Options not found	*High priority*. Options were not found during startup.	• Restart device. • If the problem persists, have the ventilator serviced.
Oxygen supply failed	*High priority*. Oxygen source flow is lower than expected. Ventilation continues with 21% oxygen.	• Check patient condition. • Check the oxygen supply. Provide an alternative source of oxygen, if necessary. • Check the oxygen source/supply for potential leakage. • Provide alternative respiratory support until the issue is resolved.
Performance limited by high altitude	*Medium priority, Low after Audio pause is activated*. The airway pressure cannot be reached at the current altitude. As long as the device remains above the altitude limit, the pressure cannot be reached, and the alarm is active.	• Check patient condition. • If at all possible, consider lowering altitude to reach the target performance. • Provide alternative respiratory support until the issue is resolved.
PetCO2 high	*Medium priority*. PetCO2 exceeds the set alarm limit.	• Check patient condition. • Check and confirm settings, including alarms.

Alarm	Definition	Action needed
PetCO2 low	*Medium priority*. PetCO2 is below the set alarm limit.	• Check patient condition. • Check the breathing circuit and flow sensor/artificial airway of the patient for leaks. • Check and confirm settings, including alarms.
Pressure limit has changed	*Low priority*. The pressure limit setting (Plimit) has changed. Either the Plimit setting or the high Pressure alarm limit setting has been adjusted by the operator. Changing Plimit or the high Pressure alarm limit automatically changes the other: The high Pressure alarm limit is always 10 cmH2O greater than Plimit.	Make sure the pressure limit is high enough so that sufficient pressure can be applied for adequate breath delivery. If sufficient pressure cannot be applied, the Pressure limitation alarm is generated.
Pressure limitation	*Medium priority, Low after Audio pause is activated*. Inspiratory pressure, including PEEP/CPAP, is above the pressure limit (Plimit). The ventilator limits applied pressure, so the target pressure or volume may not be achieved.	• Check the patient for adequate ventilation. • Check and confirm settings, including alarms.
Pressure not released	*High priority*. Airway pressure has exceeded the Pressure limit, and the pressure was not released via the expiratory valve after 5 seconds. The ventilator enters the Ambient state.	• Check expiratory valve and breathing circuit for kinks and occlusions. • Provide alternative respiratory support until the issue is resolved. • Have the ventilator serviced.
Preventive maintenance required	*Low priority*. The device was last serviced more than 1 year ago. The ventilator requires preventive maintenance.	Have the ventilator serviced as soon as possible.
Real-time clock failure	*Medium priority*. The date and time are not set.	Set the date and time (System > Settings window).

Alarm	Definition	Action needed
Release valve defective	*Low priority*. During the routine check of the ambient valve during the Leak test, the valve was found to be defective. The alarm is reset when a Leak test is successfully passed. Ventilation is not necessarily affected.	If the problem still persists, have the ventilator serviced as soon as possible.
Replace HEPA filter	*Low priority*. The air inlet HEPA filter shows increased resistance.	Replace the HEPA filter as soon as possible.
Replace O2 sensor	*High priority*. Communication error, O2 sensor is defective. Ventilation is not necessarily affected. Oxygen concentration should not be affected by this issue. Ventilation can continue.	• Replace O2 sensor. • If you cannot replace the O2 sensor, consider disabling it.
Safety mode	*Technical fault*. A hardware or software issue was detected. The ventilator switches to Safety mode.	• Provide alternative respiratory support until the issue is resolved. • Have the ventilator serviced.
Safety ventilation	*Technical fault*. A hardware or software issue was detected. The ventilator switches to Safety ventilation.	• Provide alternative respiratory support until the issue is resolved. • Have the ventilator serviced.
Self test failed	*High priority*. The self test failed during startup. The **Start ventilation** button is unavailable. Note that if this error occurs when the device is restarting from a complete power loss, the device enters the Ambient state.	• Restart device. • If the problem persists, have the ventilator serviced. • If the device enters the Ambient state, provide alternative respiratory support and have the ventilator serviced.
SpeakValve OFF	*Low priority*. SpeakValve compatibility is deactivated.	Press the Audio pause key to confirm and reset the alarm.

Alarm	Definition	Action needed
SpeakValve ON	*Low priority*. SpeakValve compatibility is activated.	• If a speaking valve is in use, no action required. • If a speaking valve is *not* in use, turn off compatibility in the Controls > SpeakValve window.
Suctioning maneuver	*Low priority*. Ventilation suppression is active, and ventilator settings are being maintained, although the ventilator is not delivering breaths.	Resume ventilation when desired by first reconnecting the patient.
Technical event: xxxxxx	*Low, medium, or high priority*. A hardware or software issue was detected. A technical alarm cannot typically be corrected by the operator. Ventilation continues.	Have the ventilator serviced.
Technical fault: xxxxxx	*Technical fault*. A hardware or software issue was detected. The ventilator switches to the Ambient state or to Safety ventilation.	• Provide alternative respiratory support until the issue is resolved. • Have the ventilator serviced.
Technical state failed	*Technical fault*. There is a problem with the hardware configuration. Ventilation is not possible.	Have the ventilator serviced.
Touch not functional	*Low priority*. The touch screen is defective.	• Turn the ventilator off and on again. • If the problem persists, have the ventilator serviced.
Unknown part number	*Technical fault*. A hardware or software issue was detected. The ventilator switches to the Ambient state.	• Provide alternative respiratory support until the issue is resolved. • Have the ventilator serviced.

Alarm	Definition	Action needed
Vent outlet temperature high	*High priority*. Inspiratory temperature is too high. Ventilation continues, but if temperature stays high, the ventilator may enter the Ambient state.	• Check whether the room temperature exceeds the ventilator's operating temperature limit. • Check that the air intake on the device is not obstructed. • Provide alternative respiratory support until the issue is resolved. • Have the ventilator serviced if temperature cannot be reduced.
Ventilation canceled	*Technical fault*. A hardware or software issue was detected. The ventilator switches to the Ambient state.	• Provide alternative respiratory support until the issue is resolved. • Contact your Hamilton Medical representative. • Have the ventilator serviced.
Vt high	*Medium priority*. Measured VTE exceeds the set limit for 2 or 3 consecutive breaths.[1] In invasive modes, if the delivered tidal volume exceeds 150% of set high Vt alarm limit (Vt > 1.5 * high Vt alarm limit), the Inspiratory volume limitation alarm is generated.	• Reduce the pressure and volume settings. • Check and confirm settings, including alarms.
Vt low	*Medium priority*. Measured VTE is below the set limit for 2 or 3 consecutive breaths.[1] *High priority.* When speaking valve compatibility is activated. This alarm can indicate the cuff is still inflated. See Table 10-1.	• If a speaking valve is in use, ensure the cuff is deflated. • Check patient condition. • Check and confirm settings, including alarms. • Check the breathing circuit and artificial airway of the patient for leaks, kinked limbs or tubing, or disconnection.

[1] Depending on the Alarm delay setting in Configuration.

Alarm	Definition	Action needed
Wrong expiratory valve[1]	*Medium priority, Low after Audio pause is activated.* The type of expiratory valve installed does not match the selected patient group, or no expiratory valve is installed. In addition to the alarm message, after attempting to start ventilation, the device displays a dialog box describing the risks of proceeding with the wrong valve. The alarm is recorded in the Events log and remains in the alarm buffer.	Install the appropriate expiratory valve. To start ventilating the patient, you must confirm that you are aware of the issue by selecting either **Accept** or **Decline** in the dialog box. • By selecting **Accept**, you accept the risks associated with using the wrong valve for selected patient. Ventilation starts after touching **Accept**. This option is only to be used in emergency cases, where the appropriate expiratory valve for the patient group is not available and mechanical ventilation must be delivered. • By selecting **Decline**, the dialog box closes and you remain in standby. The selection you make (Accept or Decline) is recorded with the alarm in the Events log.

[1] Applies only to devices with serial number > 6000.

10
Ventilator settings and functions

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10.1 Overview

Before proceeding, review the safety information in Chapter 1.

This chapter describes changing ventilation settings during active ventilation, as well as how to perform special functions on the ventilator.

10.2 Accessing settings during ventilation

You can change patient data and ventilation control settings during ventilation, as needed.

10.2.1 Accessing patient data during ventilation

NOTICE

Changing the patient height (Adult/Ped.) or weight (Neonatal) automatically adjusts the following settings based on the recalculated IBW or updated Weight:

- Apnea backup setting (when set to Automatic)
- Safety ventilation/Safety mode startup values

Other settings and alarm limits are not adjusted.

During ventilation, the Controls > Patient window displays the basic patient profile, including sex, height, and ventilation time (Section 5.2).

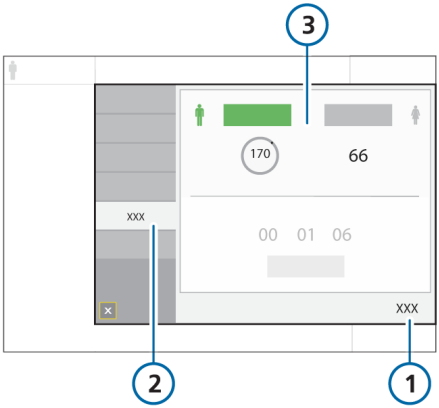
When the ventilator is in Standby, the patient controls are accessible in the Standby window.

Note that if you are ventilating using the Last patient setup, patient settings are grayed out and unavailable.

To change patient data during ventilation

- Open the Controls > Patient window by doing either of the following (see Figure 10-1):
  - Touch the Patient icon at the top left of the display, next to the mode name.
  - Touch **Controls**, then touch the **Patient** button, and adjust settings as needed.

Figure 10-1. Controls > Patient window (Adult/Ped shown)



1 Controls

2 Patient

3 **Adult/Ped:** Sex and height, calculated IBW
Neonatal: Weight

10.2.2 Accessing settings during ventilation

At any time during ventilation, you can adjust settings, as needed. Changes for the Controls and Modes are applied at the latest at the end of the current breath cycle.

- Touch any MMP, the SpO2 parameter under the MMPs, or **Alarms** to access the alarm limit controls.
- Touch **Controls** to access the mode controls. Some controls are also available on the right side of the main display.
- Touch the mode name at the top left of the display (Figure 5-1) or the **Modes** button to change the selected ventilation mode.

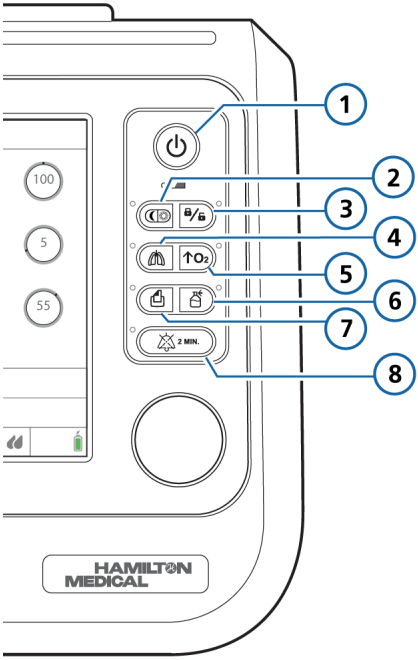
  Note that you can only select the nCPAP and nCPAP-PC modes when in Standby.
- You can only select HiFlowO2 therapy when in Standby.
- Touch the **Patient** icon or touch **Controls** > **Patient** to access patient settings.
- Touch the **Humidifier** icon to access the Humidifier window.
- Touch the **Connectivity** icon to access the Connectivity window.

The ventilator also provides access to key functions.

Keys on the front of the ventilator provide access to important functions, including entering Standby and pausing the audible alarm.

When a selected function is active, the indicator light next to the key is lit.

Figure 10-2. Function keys



1	Power/Standby	5	O2 enrichment
2	Day/Night[1]	6	Nebulizer
3	Screen lock/ unlock	7	Print screen
4	Manual breath	8	Audio pause

[1] Applies only to devices with serial number > 6000.

10.3 Entering/exiting Standby

WARNING

When in Standby, the ventilator does *not* automatically resume ventilation when the patient is reconnected. You must manually restart ventilation.

NOTICE

- Patient alarms are suppressed in Standby.
- Acoustic patient alarms are suppressed for 30 seconds after starting ventilation from Standby.

Standby is a waiting state that lets you maintain ventilator settings while the ventilator is not performing any ventilatory functions.

To stop ventilation and place the ventilator in Standby

1. Press and quickly release ⏻ (Power/Standby) while the ventilator is turned on (Figure 10-2).

   The Activate Standby window opens (Figure 10-3).

2. Touch **Activate standby**.

   The Standby window opens (Figure 10-4).

A timer shows the elapsed time the ventilator has been in Standby.

Note that, if another window is open on the display, the elapsed time appears in a small yellow box on the left side of the Standby window.

Figure 10-3. Activate Standby window

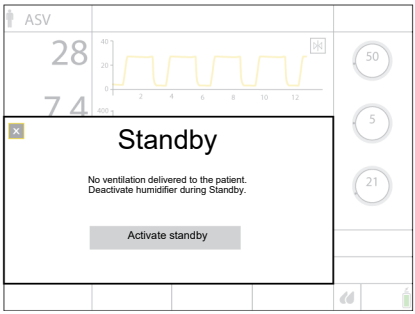
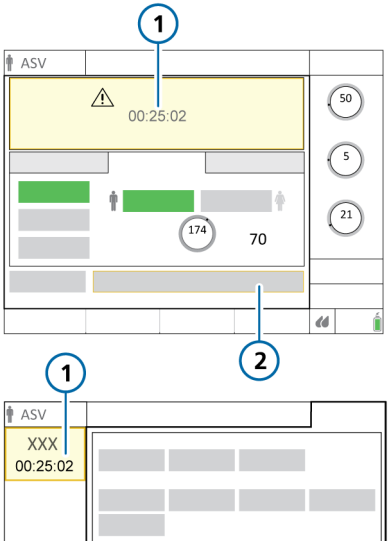


Figure 10-4. Standby window



1	Elapsed time in Standby	2	Start ventilation[1]

To end Standby and start ventilation

- Do either of the following:
  - Touch **Start ventilation**[1].
  - Press and quickly release ⏻.

Ventilation resumes with the previous settings.

[1] When HiFlowO2 is selected: Start therapy; when CPR ventilation is active: Start CPR.

10.4 Oxygen (O2) enrichment

NOTICE

- Oxygen alarms are suppressed while O2 enrichment is active.
- O2 enrichment is not available when using low-pressure oxygen.
- The Disconnection on patient side alarm is suppressed while O2 enrichment is active.

Oxygen enrichment is useful before or after tracheal/endotracheal suctioning or for other clinical applications.

The device delivers the following oxygen concentration for 2 minutes depending on the selected patient group:

– **Adult/Ped.** 100% oxygen
– **Neonatal.** 125% of the current Oxygen setting

To start O2 enrichment

- Press ↑O₂ (O2 enrichment) (Figure 10-2).

  After a short time, the ventilator starts delivering increased oxygen (see above).

When active, the indicator light next to the key is green. The Oxygen control turns green and displays the currently applied concentration, with a count-down timer.

To stop O2 enrichment manually

- Do either of the following:

  – Press ↑O₂.

  – Change the O2 concentration using the Oxygen control.

Ventilation resumes at the set oxygen concentration.

10.4.1 Performing an open-suctioning maneuver

⚠ CAUTION

Air leaks may compromise the ventilator's ability to detect a reconnection of the patient after the open-suctioning maneuver, resulting in no ventilation being delivered for the remaining suctioning period (up to 60 seconds). In such cases, stop the maneuver manually, as described in the following procedure.

NOTICE

- The Suctioning tool is *only* available if the option is enabled on your device.
- Suctioning may affect measured values.

The Suctioning tool is intended to protect the operator from possible contamination, as well as ensure the patient's safety during an open-suctioning maneuver. The Suctioning tool stops gas flow when a patient disconnection is detected by the ventilator.

Suctioning is disabled when using:

- HiFlowO2
- NIV or NIV-ST modes
- LPO
- During neonatal ventilation

To perform an open suctioning maneuver

1. Press ↑O₂ (O2 enrichment) for pre-oxygenation.
2. Disconnect the patient.

   The text Suctioning maneuver is displayed in the message bar.

   Disconnecting the patient pauses ventilation.

   All alarms are suppressed for one minute.
3. Use a suctioning catheter (not included) to suction all secretions out of the patient's airway.
4. Reconnect the patient to the ventilator.

Ventilation resumes, post-oxygenation starts, and all acoustic alarms are again suppressed for one minute. Alarm messages and the alarm lamp are still active.

To stop the maneuver manually

- Press ↑O₂ again.

10.4.2 About closed-suctioning maneuvers

NOTICE

- When performing a closed-suctioning maneuver, follow your institution's protocols.
- Ensure O2 enrichment is *not* active when performing the closed-suctioning maneuver.

Verify alarm limit settings and consider whether O2 enrichment should be used prior to performing a closed-suctioning maneuver. Be sure to stop O2 enrichment before performing a closed-suctioning maneuver.

When performing a closed-suctioning maneuver, ventilation continues and the current settings do *not* need to be adjusted.

You can perform a closed-suctioning maneuver with the following pressure-controlled ventilation modes: APVcmv, APVsimv, PCV+, PSIMV+, DuoPAP, APRV, SPONT, or ASV.

10.5 High flow oxygen therapy

High flow oxygen (HiFlowO2[1]) is indicated for adult, pediatric, and neonatal patients who are able to inhale and exhale spontaneously.

HiFlowO2 is an optional therapy in which a continuous flow of heated and humidified respiratory gases are delivered to the patient. Active humidification is mandatory

The set flow can vary from 2 to 60 l/min for adult and pediatric patients, and 2 to 15 l/min for neonatal patients.[2] In Configuration, you can specify the maximum Flow that can be set in HiFlowO2 for neonatal patients. For details, see Section 13.3.6.

The operator sets the oxygen and flow rate. If a flow sensor is connected, the airway pressure (Pprox) is monitored.

Depending on the circuit and interface resistance, higher pressures may be required to deliver the set flow. Pressure is measured inside the ventilator.

If pressure exceeds the high pressure limit of 45 cmH2O, the medium-priority Check for blockage alarm is generated. For details about the alarm and alarm troubleshooting, see Table 9-3.

If the pressure increases further and exceeds 50 cmH2O, the Check for blockage alarm becomes high priority. In this case, the gas flow stops immediately and the pressure is released. Flow resumes after 8 seconds (Adult/Ped) or 4 seconds (Neonatal) at the set flow rate.

This respiratory support is usually delivered through a nasal cannula, with the flow exceeding the patient's peak inspiratory flow to provide inspired oxygen of up to 100%.

The oxygen consumption during HiFlowO2 therapy can be calculated as

Oxygen Consumption = Set Flow * (Set Oxygen – 20.9%)/79.1%

High flow oxygen therapy can be delivered using single or double limb breathing circuits, using a high-flow nasal cannula or a tracheal adapter/tracheal mask to enable the patient to exhale.

Note that during high flow oxygen therapy, disconnection and apnea alarms are inactive.

10.5.1 Delivering high flow oxygen therapy

Note that you must be in Standby to change the mode.

To deliver high flow oxygen therapy

1. Set up the patient with an appropriate breathing circuit.

   Figures 2-8 and 2-10 show a noninvasive circuit set.

2. Place the ventilator in Standby, and touch **Modes**.

[1] Not available in all markets.
[2] In some markets, the maximum possible Flow setting may be different.

3. Touch **HiFlowO2**, then touch **Confirm**.

   The Controls > Basic window opens.

   Be sure to carefully read the safety information displayed in the window:

   Use only interfaces intended for high flow O2.
   The use of unsuitable interfaces poses a risk to the patient.
   Active humidification is mandatory.

4. Set the desired values for Oxygen and Flow, then touch **Confirm**.

   You can change these settings at any time.

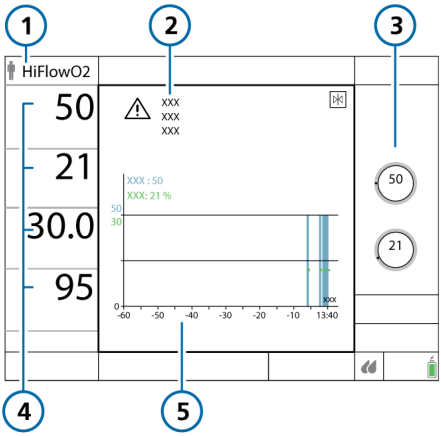
   The Standby window is displayed, showing the **Start therapy** button.

5. Perform the preoperational checks, especially the Leak test. See Section 5.4.

The main display changes to show the following safety information about oxygen therapy in addition to graphics and parameter values related to the therapy.

Hi Flow O2 therapy
No apnea detection!
No disconnection detection!

Figure 10-5. High flow oxygen therapy display, Flow/Oxygen Trend view



1	HiFlowO2 mode	4	MMPs: Flow, Oxygen, T humidifier[1], SpO2[2]
2	Safety information	5	Selectable graph (Flow/Oxygen trend shown)
3	Flow and Oxygen controls		

10.5.2 Changing the high flow oxygen therapy display

Any of the following graphs can be displayed when delivering high flow oxygen therapy:

- Flow/Oxygen trend, the default (Figure 10-5)
- SpO2/Oxygen trend
- SpO2/FiO2 trend
- Plethysmogram (Figure 10-6)

[1] When remote access to a HAMILTON-H900 humidifier is enabled.
[2] When SpO2 sensor enabled.

To change the display in HiFlowO2 mode

1. Touch the graph.

   The graphics selection window appears.
2. For the Trends graph (Figure 10-5):

   – Touch the **Trends** tab.

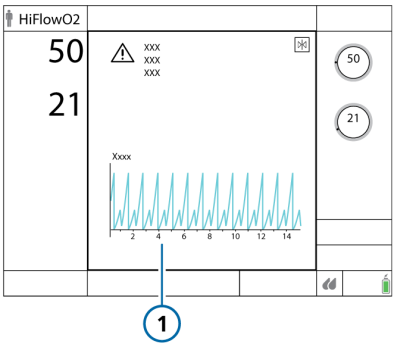
   – Select the desired trend option and touch **Confirm**.
3. For the plethysmogram (Figure 10-6):

   – Touch the **Waveforms** tab.

   – Touch the **Plethysmogram** button.

The window closes and the selected graph is displayed.

Figure 10-6. High flow oxygen therapy display, Plethysmogram view (1)



You can also disable graphs altogether. Other elements of the display are not adjustable.

To disable graphs

1. In the graphics selection window, touch the **Waveforms** tab.
2. Touch **Off**.

The window closes; the graph area is empty.

10.5.3 Parameters monitored in HiFlowO2 mode

When high flow oxygen therapy is in progress, the following parameters are monitored:

- Oxygen
- Flow (in trend and as an MMP)
- T humidifier[1]
- SpO2/FiO2, SpO2, if enabled
- If a flow sensor is connected, Pprox is monitored[2]

The Alarms > Limits 1 window is not available during high flow oxygen therapy.

[1] When remote access to a HAMILTON-H900 humidifier is enabled.
[2] Pprox is displayed in the Monitoring window.

10.6 NIV-only option

Before proceeding, review the safety information in Chapter 1.

The HAMILTON-C1 ventilator can be configured to provide only noninvasive ventilation for adult and pediatric patients (Adult/Ped patient group) with the NIV-only option.

The available modes are NIV and NIV-ST. If installed, HiFlowO2 therapy is also available. For details about these modes, see Sections 7.5 and 7.6.

When the NIV-only option is installed and enabled, all invasive modes are disabled. Ventilator operation remains the same.

10.6.1 Enabling the NIV-only option

Enabling the NIV-only option requires access to the ventilator Configuration mode, as described in Section 13.2.

Enabling the NIV-only option comprises the following steps:

1. Obtain a license key for the NIV-only option. Contact your Hamilton Medical representative.
2. Remove all currently installed features and options. See Section 13.12.4.
3. Install and activate the NIV-only option. See Section 13.12.2.
4. Install any other desired options.

   For a list of options that can be installed when the NIV-only option is active, see Section 10.6.1.1.

Once enabled, the Modes window displays only noninvasive modes.

10.6.1.1 Compatible with NIV-only option

When the NIV-only option is active, the following options are available:

- Adult/Ped patient group
- IntelliSync+
- Trends/Loops
- HiFlowO2
- Masimo Rainbow
- Hamilton Connect Module

No other options are available when the NIV-only option is active.

10.6.2 Working with the NIV-only option

Ventilator operation with the NIV-only option is the same as with full mode availability.

When the NIV-only option is active:

- The Modes window only shows the noninvasive modes[1], NIV and NIV-ST, as well as HiFlowO2 therapy[1].
- The Apnea backup mode for NIV changes to NIV-ST. For details, see Section 5.6.3).
- Should a Sensor Failure mode become active, ventilation continues in NIV-ST. For details, see Section 7.8.1.

[1] If option is installed.

For detailed information about:

- The noninvasive modes, see Section 7.5.
- Working with noninvasive modes, see Section 7.6.
- Working with HiFlowO2, see Section 10.5.
- Specifying patient information, selecting the mode, and configuring ventilation parameters for your patient, see Sections 5.3 and 5.5.

10.7 Manual breath

You can prolong inspiration as well as deliver a manually triggered breath.

When active, the indicator light next to the Manual breath key is green.

Note that manual breath is disabled when HiFlowO2 is selected.

To deliver a manual breath

- Press and release (Manual breath) during exhalation (Figure 10-2).

The manual breath uses the mandatory breath settings (standard or operator set).

If you try to initiate a manual breath during the early stage of inspiration or the early stage of exhalation, the breath will not be delivered.

To deliver a prolonged inspiration

- Press and hold (Manual breath) during any breath phase.

If the ventilator is in exhalation, the device applies a minimum exhalation phase and then switches to inspiration. The device maintains the inspiration pressure until you release the key, or for a maximum of 15 seconds.

10.8 Working with a nebulizer

The ventilator supports the use of Aerogen and pneumatic nebulizers for adult and pediatric patients.[1]

For neonatal patients, use an Aerogen nebulizer system.[2]

For connection, positioning, and use details, see the *Nebulizer Positioning Guidelines* (ELO2020-124-TW) available in the Hamilton Medical Resource Center, as well as the manufacturer's *Instructions for use*.

[1] See the Hamilton Medical e-catalog for compatible devices.
[2] Aerogen nebulization is not supported for patients younger than 28 days old in the USA.

10.8.1 Working with a pneumatic nebulizer

Before proceeding, review the safety information in Chapter 1.

Nebulization with a pneumatic nebulizer is available in most ventilation modes. It is *not* available during neonatal ventilation, or when using HiFlowO2.

You can use a standard inline nebulizer for delivery of prescribed medications in the ventilator circuit. The ventilator provides a stable pressure source to power a pneumatic nebulizer connected to the Nebulizer port, optimally specified for a flow of approximately 8 l/min.

The ventilator automatically compensates the additional volume provided by the pneumatic nebulizer to deliver the set tidal volume.

For effective nebulization, use a pneumatic nebulizer jar.

For additional information about nebulizer use, including adding medication, refer to the manufacturer's *Instructions for use*. For connection and setup details, see Section 4.6.

To start and stop nebulization

1. Press (Nebulizer) (Figure 10-2).

   When active, the indicator light next to the key is green.

   The fixed nebulizer flow, using 100% O2, is synchronized with the inspiratory phase of each breath for 30 minutes.

2. To stop nebulization at any time, press again.

10.9 Working with a speaking valve

⚠ CAUTION

- *Do not leave the patient unattended when SpeakValve is turned ON and a speaking valve is connected to the patient.*
- *When SpeakValve is turned on:*

  – Apnea backup ventilation is disabled. When SpeakValve compatibility is turned off, Apnea backup ventilation returns to its previous settings.

  – Some alarm limits are changed and some alarms are disabled. For details, see Section 10.9.4.

  – Some changes apply to monitoring parameters. For details, see Section 10.9.3.

With the Speaking valve option, the ventilator offers speaking valve compatibility for Adult/Ped. invasive ventilation when using any of the following modes: PCV+, PSIMV+, and SPONT.

In the Controls window, the **SpeakValve** tab provides access to the On and Off buttons, together with important safety information.

For details about connecting a speaking valve, as well as activating the use of a speaking valve with the ventilator, see Section 4.7.

10.9.1 Mode changes that automatically turn off compatibility

The following actions automatically deactivate speaking valve compatibility:

- Entering Standby.

  You must manually reactivate compatibility when restarting ventilation, if desired.
- Selecting a mode that does not support use of a speaking valve.
- Entering CPR mode, Safety ventilation or Ambient mode.

Note that upon automatic deactivation, the message SpeakValve OFF appears in the ventilator message bar.[1] See Table 10-1.

10.9.2 SpeakValve-related control settings

In PSIMV+ and SPONT modes, the control setting TI max is available in the Controls > More window when speaking valve compatibility is activated (ON).

When speaking valve compatibility is deactivated (OFF), TI max is unavailable in these modes unless configured otherwise (Section 13.4.4).

When a speaking valve is connected to a patient, remove the speaking valve before activating CPR ventilation.

Speaking valve compatibility is *not* accessible during CPR.

10.9.3 Parameters monitored when compatibility is activated

When SpeakValve compatibility is *activated*, the following parameter changes are in effect:

- The following monitoring parameters are invalid and show dashes (---): AutoPEEP, Cstat, Exp Flow, ExpMinVol, MVLeak, P0.1, Pmean, Pplateau, PTP, RCexp, Rinsp, VLeak, VTE, VTESpont, Vt/IBW
- If VTE is set as a main monitoring parameter (MMP), VTI is displayed instead.

  If *both* VTI and VTE are selected as MMPs, upon activation, the VTE value shows dashes (---).
- Apnea backup ventilation is disabled.

Once Speakvalve compatibility is deactivated, Apnea backup ventilation returns to its previous setting, and the parameters listed above, including VTE, are again actively monitored.

10.9.4 SpeakValve-related alarms

The alarms listed in the following table are related to speaking valve compatibility. For help resolving alarm situations, see Table 9-3.

[1] Except in Safety ventilation/Safety mode or Ambient mode.

Table 10-1. SpeakValve-related alarm conditions

Alarm	Status
SpeakValve ON	
SpeakValve ON *Low priority*	Always displayed as long as compatibility is activated.
Vt low *High priority when speaking valve compatibility (SpeakValve) is activated*	When SpeakValve is ON, this alarm is based on delivered volume instead of exhaled volume. VTI was below the limit for two (2) consecutive breaths. This alarm can indicate that the tracheostomy cuff is still inflated! Be sure to also carefully check the alarm and ventilator settings.
Check patient interface *High priority*	Generated when the Vt low or Low pressure alarm is active. Check for: • Disconnection • Whether tracheostomy cuff is fully deflated • Upper airway occlusion • SpeakValve is operating properly
ExpMinVol low ExpMinVol high	Automatically set to OFF.
Disconnection on patient side Disconnection on ventilator side	Suppressed. If the lower Pressure limit is appropriately set, when a disconnection occurs, a Low pressure alarm is generated.
Inspiratory volume limitation	Suppressed.
SpeakValve OFF (after being enabled)	
Volume related, including low and high ExpMinVol limits	Upon deactivation, all volume-related alarm limits are reset based on the patient's IBW.
SpeakValve OFF *Low priority*	Displayed when SpeakValve compatibility has been automatically deactivated. Confirm the change in status by pressing the Audio pause key.

10.10 Cardiopulmonary resuscitation (CPR) ventilation

The HAMILTON-C1 uses CPR ventilation to continue respiration during the administration of cardiopulmonary resuscitation. When activated, CPR ventilation adjusts the ventilator to:

- Use either APVcmv or PCV+ ventilation mode
- Display relevant MMPs, waveforms, and a CPR duration timer
- Modify the alarm limits while CPR ventilation is in use (see Table 10-4)

CPR ventilation is available for adult, pediatric, and neonatal patients.

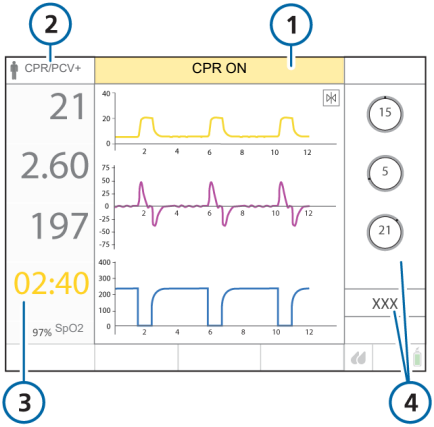
CPR ventilation is available during all ventilation modes *except* for nCPAP, nCPAP-PC, and when using HiFlowO2 therapy. CPR ventilation is not available when the NIV-only option is enabled.

Table 10-2 provides an overview of working with CPR.

Table 10-2. CPR ventilation overview

For details about ...	See ...
Configuring a default mode	Section 13.9
CPR-related control settings	Section 10.10.1
Starting and stopping CPR ventilation	Section 10.10.2
Working with CPR ventilation	Section 10.10.2
Monitoring and display when CPR ventilation is on	Section 10.10.3
CPR-related alarms	Section 10.10.4

Figure 10-7. CPR ventilation on



1	CPR ON alarm	3	CPR timer
2	Active ventilation mode	4	Controls for the active ventilation mode

10.10.1 About the CPR modes and settings

The ventilator uses one of two modes during CPR ventilation:

- APVcmv (default mode)
- PCV+

You can change the default ventilation mode to use. For details, see Section 13.9.

The mode control settings are described in Table 10-3.

Table 10-3. CPR ventilation controls and default settings

Parameter	Default
Rate (b/min)	10
I:E	1:5
PEEP/CPAP (cmH2O)	5
Plimit (cmH2O)	45
Oxygen (%)	100
Vt/IBW (ml/kg) (only in APVcmv)	6
ΔPcontrol (cmH2O) (only in PCV+)	15
Apnea time (s)	10

10.10.2 Working with CPR ventilation

⚠ WARNING

When activating CPR ventilation for a patient using a speaking valve, you must first remove the speaking valve, then inflate the tracheostomy tube cuff.

When you start CPR ventilation, the ventilator switches to the configured mode and settings. You can start CPR at any time, from Standby or during active ventilation.

Note the following when CPR ventilation is on:

- Flow trigger is unavailable and set to OFF.
- P-ramp is unavailable and set to 50 ms.
- In APVcmv mode, the Vt/kg setting is defined in Configuration; this defines the initial startup setting for tidal volume (Vt). For details, see Section 13.9).
- For neonatal patients, Apnea time is set to 10 seconds.
- The upper alarm limit is set to its maximum value and the lower alarm limit is set to its minimum value for each of the following alarms: ExpMinVol, fTotal, Vt, and PetCO2
- The SpO2 and Pulse alarm limits are set to OFF, if applicable.
- SpeakValve compatibility is deactivated.
- The low-priority CPR ON alarm is active.
- HAMILTON-H900 humidification switches to Invasive mode.

To start CPR ventilation

1. Touch **Modes**.
2. In the Modes window, touch **CPR**.

   The Controls > Basic window opens.
3. Review and, if needed, adjust the control settings, then touch **Confirm** to start CPR ventilation.

The mode changes to the default CPR mode set on the ventilator, and the CPR ON alarm is generated. Ventilation starts or continues.

To stop CPR ventilation and enter Standby

1. Press the Power/Standby button.
2. In the confirmation window, touch **Activate standby**.

CPR ventilation stops and the device enters Standby.

To restart CPR ventilation, touch **Start CPR**.

To stop CPR ventilation and continue ventilating the patient

1. Touch **Modes**.
2. Select and confirm a ventilation mode.

The ventilator starts ventilation in the selected mode using the previously defined settings.

CPR ventilation events and elapsed CPR ventilation time are recorded in the Event log.

10.10.3 Monitoring and display during CPR

When CPR ventilation is on, the following MMPs are displayed: Ppeak, VTE, fTotal, and the CPR Timer.

In addition to the MMPs, the Paw, PCO2[1], and Flow waveforms are displayed. See Figure 10-7.

10.10.4 CPR-related alarms

The following alarms are related to CPR ventilation. For help resolving alarm situations, see Table 9-3.

Stopping CPR ventilation or changing the ventilation mode resets the alarms to the previous settings.

Table 10-4. CPR ventilation-related alarm conditions

Alarm	Status
CPR ON	Always displayed as long as CPR ventilation is on.
Pressure high	As already configured (Plimit + 10 cmH2O).
Low/high alarms for the following: ExpMinVol, fTotal, Vt, PetCO2,[2] Pulse,[2] SpO2[2]	The low alarm limits are automatically set to the minimum value, and the high alarm limits are automatically set to the maximum value.

[1] Only available if the CO2 communication board is installed and the CO2 sensor is enabled.
[2] If the option is installed and activated.

10.11 Locking and unlocking the touch screen

You can lock the touch screen to prevent inadvertent entries.

When screen lock is active:

- The indicator light next to the key is lit green.
- Touching the screen generates an audible beep and the message, Screen is locked!, is displayed.
- Some device controls remain available, while others are disabled, as follows:

  – **Active controls.** Audio pause, Manual breath, O2 enrichment, Nebulizer, Day/Night[1]

  – **Inactive controls.** Touch screen, Power/Standby, Print screen, P&T knob

To lock or unlock the screen

▸ Press (Screen lock/unlock) (Figure 10-2).

10.12 Capturing a screenshot

Before using a USB drive with the ventilator, review the safety information in Section 1.5.4.

The (Print screen) key saves a JPG file of the current ventilator display. You can save the screenshot to a USB drive or to internal ventilator memory.

To capture a screenshot of the display

1. Insert a USB drive into the USB port. If the potential equalization USB cable is in use, remove it from the USB port.
2. Press (Figure 10-2) when the desired display is shown.

   The device saves the image to the screenshots folder on the USB drive. The indicator light next to the key is lit green while the ventilator saves the image.
3. Reinsert the potential equalization USB cable into the USB port, if needed. CO2 sensor readings resume within 20 seconds.

The file name uses the following format:

screenshot_C1-sn_yyyy-mm-dd_hh-mm-ss.jpg

where:

C1 is the device name
sn is the device serial number
yyyy is the year
mm is the month
dd is the date
hh is the hour (in 24-hour format)
mm is the minute
ss is the second

[1] Applies only to devices with serial number > 6000.

10.13 Setting display options

You can set the day and night display brightness, as well as the device date and time.

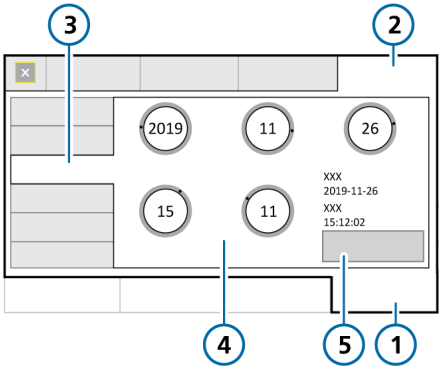
10.13.1 Setting date and time

You set the date and time for the ventilator in the System > Settings window. Ensure the date and time are set correctly so that event log entries have accurate time and date stamps.

To set the date and time

1. Do either of the following:
   – Touch the Date/Time indicator at the top of the display (Table 2-3).
   – Touch **System** > **Settings** > **Date & Time** (Figure 10-8).
2. Adjust the date and time, then touch **Apply** to save the changes.

Figure 10-8. Date & Time settings



1	System	4	Date and time settings
2	Settings	5	Apply
3	Date & Time		

10.13.2 Day and night display brightness

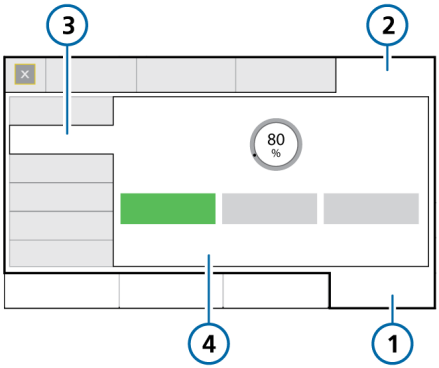
Use these settings to set the brightness of the display for use during the day and night.

To set the display brightness

1. Touch **System** > **Settings** (Figure 10-9).
2. Touch **Day & Night**.
3. To select Day mode with a bright display, touch the **Day** button.
   To select Night mode with a dimmer display, touch the **Night** button.
4. Adjust the brightness of the display in each mode using the Brightness control. The setting you choose becomes the new default for that mode.
5. To have the device control the brightness based on ambient light, touch the **Automatic** button.

   The device continuously senses the available light and dynamically adjusts the display brightness settings.

Figure 10-9. Brightness window



1	System	3	Day, Night, Automatic, Brightness setting
2	Brightness		

Table 10-5. Day and Night settings

Setting	Brightness range	Default
Day	10% to 100%	80%
Night	10% to 100%	40%

The (Day/Night) key[1] allows you to quickly switch the display between defined Day and Night settings. When the Night setting is active, the green indicator light next to the key is lit.

To change the display brightness to the defined Day or Night setting

- Press (Figure 10-2).

10.14 About the Event log

Once the ventilator is turned on, event logs collect data about clinically relevant ventilator activities, including ventilator start and shutdown times, alarms, technical notes, setting changes, calibrations, maneuvers, and special functions.

The date, time, and a unique identification reference (ID) for event classification is included.

Alarms are shown in color, depending on priority level (yellow for low or medium, red for high).

A more extensive log including technical and configuration details is available to service engineers.

When setting up a new patient:

- Data is appended to the existing event log when you select the Last patient tab.
- The event log is cleared and starts again when you select a different patient group tab (Adult/Ped or Neonatal).

Event log data persists after shutting off the ventilator or in the event of a power loss. A maximum of 10,000 events is stored. When a log buffer is full, new events overwrite the oldest log entries.

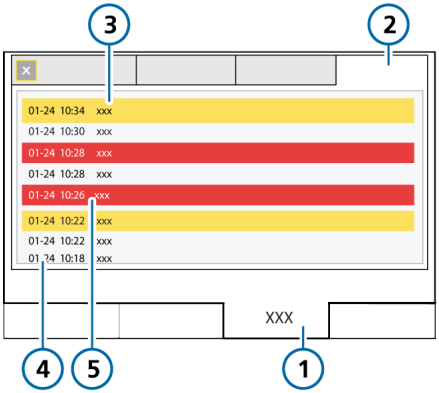
You can copy event log data. See Section 10.14.1.

[1] Applies only to devices with serial number > 6000.

To display the Event log

- Touch **Events**.

Figure 10-10. Events window



1	Events	4	Informational message
2	All	5	High-priority alarm (red)
3	Low-/medium-priority alarm (yellow)		

10.14.1 Exporting event log data

Before using a USB drive with the ventilator, review the safety information in Section 1.5.4.

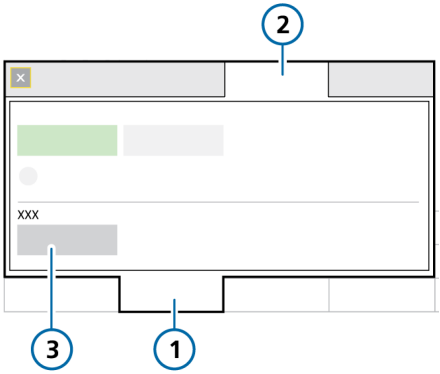
The USB drive must have a FAT or FAT32 format and it must *not* have an operating system or a security system installed.

To copy the log files

1. Place the ventilator into Standby and insert a USB drive into the USB port (Figure 2-5).
2. Touch **Tools** > **Utilities** (Figure 10-11).
3. Touch **Export Logs**.
4. Remove the USB drive when the text Export successful is displayed.

The log files are saved to the folder named C1-sn<serial number> on the USB drive.

Figure 10-11. Data transfer window



1	Tools	3	Export Logs
2	Utilities		

10.15 Viewing device-specific information

The System > Info windows display device-specific information including serial number, model, operating hours, hours since startup, battery capacity, oxygen consumption, software version, and installed options.

The System > Info > About window provides information about third-party open source libraries that were used to develop the ventilator software.

To view device-specific information

1. Touch **System**.
2. If needed, touch the **Info** tab.

11
Working with external devices

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11.1 Working with the HAMILTON-H900 humidifier

Before proceeding, review the safety information in Chapter 1.

Using the HAMILTON-H900 humidifier with the ventilator offers remote access to humidifier controls and status directly from the ventilator display. In addition, functions between the devices are synchronized.

You can control some humidifier functions from the ventilator or on the humidifier itself.

This section describes using the ventilator to manage and monitor humidifier settings.

For detailed information about the settings, specifications, patient set up, humidifier operation, humidifier configuration, and important safety information, see the *HAMILTON-H900 Instructions for use*.

Table 11-1. Operation overview

For details about ...	See ...
Accessing humidifier controls on the ventilator	Section 11.1.1
Humidification modes	Section 11.1.2
Changing humidity using temperature controls	Section 11.1.3
Entering Standby	Section 11.1.4
Turning the humidifier on/off	Section 11.1.5
Humidifier-related alarms	Section 11.1.6
Humidifier-related parameters	Section 11.1.7

11.1.1 Accessing humidifier controls on the ventilator

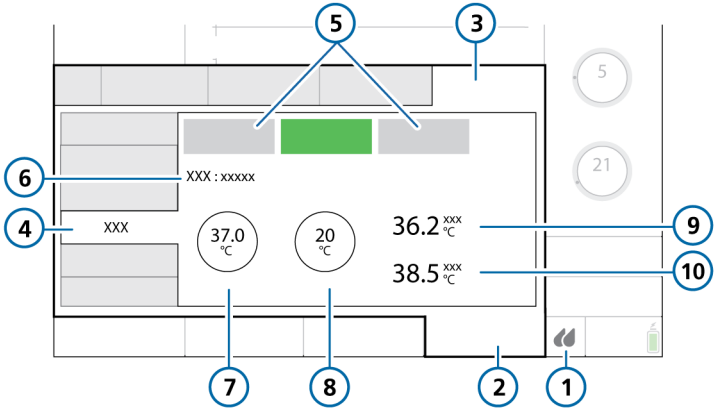
The Humidifier window shows the humidification chamber exit temperature (T humidifier) and the humidifier Y-piece temperature (T Y-piece). It also provides access to the operations listed in Table 11-1.

To open the Humidifier window

- Do either of the following (Figure 11-1):
  - Touch (Humidifier).
  - Touch **System** > **Settings** > **Humidifier**.

If communication between the humidifier and the ventilator is lost, the window is disabled.

Figure 11-1. System > Settings > Humidifier window



1	Humidifier icon	6	Currently active humidification mode (Invasive, NIV, HiFlow)
2	System	7	Set temp control
3	Settings	8	T gradient control
4	Humidifier	9	T humidifier
5	Off, Auto, Manual	10	T Y-piece

11.1.1.1 About the Humidifier button

The (**Humidifier** button) at the bottom right of the display provides quick access to the Humidifier window and indicates the state of the humidifier, including whether any alarms are active.

Table 11-2. Humidifier button icon states

Icon state	Description
	Grayed out. Humidifier is not connected. If no icon is displayed, this option is not available in your country.
	Outline only. Humidifier is connected but turned off.
	Full, white. Humidifier is connected and turned on.
	Yellow. Humidifier is connected and a low- or medium-priority humidifier alarm is active.
	Red. Humidifier is connected and a high-priority humidifier alarm is active.

11.1.1.2 Verifying connection status

When communication is established between the humidifier and the ventilator, the active connection status is displayed on both devices: the Humidifier icon on the ventilator display (Table 11-2), and the (Connection to ventilator) symbol on the humidifier become active.

Note that the connection status icon on the humidifier is not displayed when in Standby.

11.1.2 About the humidification modes

The humidifier offers three humidification modes: Invasive, NIV, and HiFlow.[1]

The set mode determines the initial temperature settings at the humidification chamber exit and at the Y-piece, as well as the allowed temperature ranges for these settings. The control settings are described in Table 11-3.

The Invasive mode allows for a higher temperature range than the NIV mode. For details about the humidifier settings and ranges, see the *HAMILTON-H900 Instructions for use*.

The currently set humidification mode is shown in the System > Settings > Humidifier window.

Figure 11-2 shows the Invasive mode selected; Figure 11-3 shows the NIV mode selected.

[1] On the ventilator display, the text HiFlowO2 is shown; on the HAMILTON-H900 humidifier, HiFlow is shown.

When connected to the ventilator, the humidifier *automatically* matches the humidification mode to the type of ventilation mode selected on the ventilator. For example, when the mode on the ventilator is invasive, such as ASV, the humidifier is automatically set to Invasive mode.[1]

Depending on the selected humidification mode, you can set controls automatically or manually:

- The humidifier supports invasive and noninvasive ventilation modes, as well as high flow oxygen therapy, for which you can use either automatic (Auto) or manual settings.
- Any time the humidifier changes from one mode to another, it also automatically switches to Auto settings and loads the configured default settings for the newly selected humidification mode.

For details about Auto and Manual control settings, see Section 11.1.2.1.

Further, the humidifier matches the operating status of the ventilator. If ventilation is active, the humidifier is running. If the ventilator is in Standby, the humidifier automatically enters Standby.

Note that if the humidifier is turned off and the ventilator is still on, starting ventilation will *not automatically* start the humidifier. The humidifier must be turned on manually. See Section 11.1.5.

11.1.2.1 Auto and Manual control settings

The humidification chamber exit temperature and temperature gradient are set using either of the following methods:

- Loaded from the configured default settings on the humidifier (Auto mode)
- Set manually by the operator (Manual mode)

When set to Auto, the temperature controls in the System > Settings > Humidifier window are disabled. You must first enable Manual mode to change any settings.

In both cases, the humidifier automatically controls the temperatures to reach the specified settings.

[1] Supported for HAMILTON-H900 version 1.10x and later. If using an older version of humidifier, when treating the patient using HiFlowO2 therapy, the humidifier uses the same temperature and humidity specifications as the humidifier's Invasive mode.

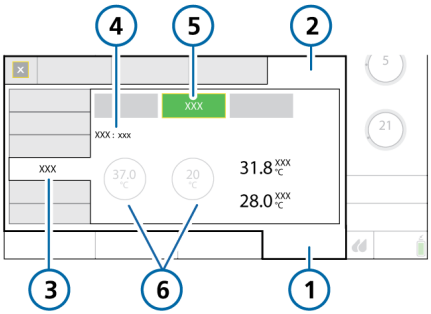
Automatic settings (Auto)

When set to Auto, the humidifier loads the associated default settings specified for the selected humidifier mode in its configuration and uses them to control the gas temperature.

In Auto mode, the temperature controls in the ventilator System > Settings > Humidifier window are grayed out (disabled), but they display the configured Auto settings (Figure 11-2).

For details about these settings, see the *HAMILTON-H900 Instructions for use*.

Figure 11-2. Auto mode



1	System	4	Invasive
2	Settings	5	Auto
3	Humidifier	6	Disabled controls showing the configured Auto temperature settings

Manual settings

When set to Manual, you set controls as follows:

- Invasive, NIV: Set temp, T gradient
- HiFlow: Set temp

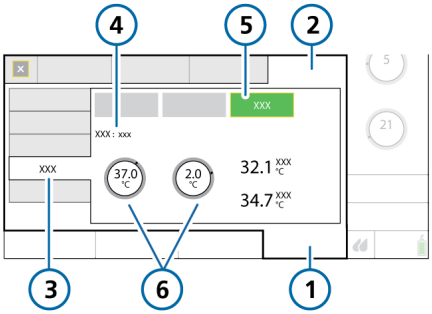
Table 11-3 describes these controls.

The temperature controls in the ventilator System > Settings > Humidifier window are enabled (Figure 11-3).

You can change settings both in the Humidifier window as well as directly on the humidifier.

When you change values on the humidifier, the values are also reflected on the controls on the ventilator.

Figure 11-3. Manual mode



1	System	4	Noninvasive
2	Settings	5	Manual
3	Humidifier	6	Available temperature controls

11.1.3 Changing humidity using temperature controls

You can adjust the following controls on either device.

Table 11-3. Adjustable humidifier controls

Control	Description
Set temp	Temperature at the humidification chamber exit. The possible range of values for this control depends on the selected humidifier operating mode: Invasive, noninvasive (NIV), or HiFlow. Higher values result in higher absolute humidity.
T gradient	The difference between the temperature at the humidification chamber exit and at the Y-piece. A higher value decreases condensation. Can only be changed in Invasive and NIV modes.

In a way, the Set temp and T gradient parameters are linked. The maximum allowed temperature at the patient (Y-piece) is 42°C. The combination of the values set for these two parameters cannot exceed this limit.

For example, if T gradient is set to 2°C, the highest possible setting for Set temp in the Invasive mode is 40°C.

Note, however, that the T gradient setting takes precedence over the Set temp value. For example, if Set temp is set to 40°C, you can set T gradient to 3°C even though the combination exceeds 42°C. Once the T gradient setting is accepted, the Set temp value automatically resets to 39°C.

To manually specify humidifier settings

- Do either of the following:
  - In the System > Settings > Humidifier window on the ventilator, touch the **Manual** button, then select the desired Set temp and T gradient values.
  - Change the chamber exit temperature or temperature gradient directly on the humidifier.

The changes are applied immediately.

For details about working directly on the humidifier, see the *HAMILTON-H900 Instructions for use* (PN 624431).

11.1.4 Entering Standby

The humidifier automatically enters Standby mode when the ventilator enters Standby.

11.1.5 Turning the humidifier on/off

You can turn the humidifier on or off both from the ventilator and from the device itself.

When you connect the humidifier to the ventilator, the humidifier assumes the same state as the ventilator.

That is, if the ventilator is in Standby, the humidifier is as well. If the ventilator is in active ventilation, the humidifier starts operation immediately.

To turn off the humidifier from the ventilator

- In the System > Settings > Humidifier window, touch the **Off** button (Figure 11-1).

The **Off** button turns green and all of the controls in the window are disabled.

The **Auto** and **Manual** buttons remain available.

To turn the humidifier back on from the ventilator

1. In the System > Settings > Humidifier window, touch the **Manual** or **Auto** button to turn on the humidifier (Figure 11-1).
2. Check the settings and adjust, if needed.

When you start ventilation, the humidifier starts automatically.

If the humidifier is turned off and you start ventilation, it will *not* automatically turn on.

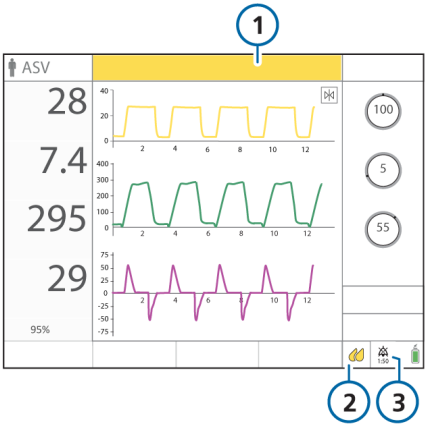
11.1.6 About humidifier-related alarms

Alarms on the HAMILTON-H900 are displayed on the ventilator immediately. Humidifier-related alarm messages are indicated in the following locations:

- On the humidifier, graphically
- Alarm message on the ventilator main display
- The **Humidifier** icon changes color (Table 11-2)

The alarms listed here may not be comprehensive. Be sure to review the *HAMILTON-H900 Instructions for use* (PN 624431) for details and troubleshooting information.

Figure 11-4. Humidifier-related alarm indicators on ventilator



1	Alarm message bar	3	Audio pause indicator
2	Humidifier icon		

To pause the audible humidifier alarm

- Touch (Audio pause) on either the ventilator or the humidifier.

  Note that touching the Audio pause key on the ventilator also temporarily silences the alarm on the humidifier.

Table 11-4 lists the humidifier-related alarms shown on the ventilator and the associated icon on the humidifier.

Table 11-4. HAMILTON-H900 alarms

Alarm	Alarm icon	Description	Action needed
High priority			
Humidifier tilt		Humidifier is dangerously inclined. The humidifier is at a 10° angle or higher relative to the floor.	• Check the mounting of the humidifier. • Check the ventilator trolley. • Operate the humidifier at an angle less than 10° relative to the floor.
Humidifier chamber temp high Humidifier Y-piece temp high		The gas temperature at the water chamber exit or at the Y-piece is above the set value.	• Check whether the breathing circuit is covered by the patient's bed covers. • Check whether the breathing circuit or the humidifier chamber is directly exposed to sunlight. • Replace the breathing circuit.
Humidifier water high		The water level in the water chamber is above the maximum level mark.	• Empty humidifier chamber to reduce the water level. • Replace the water chamber. • Operate the humidifier at an angle less than 10° relative to the floor.

Alarm	Alarm icon	Description	Action needed
Humidifier error	n/a	There is a problem with the humidifier.	• Check humidifier operation and all connections. • Replace the humidifier and have it serviced. • If a technical fault number is displayed, make a note of it and provide it when the humidifier is serviced.
Check humidifier *High, medium, and low priority. Displayed on the ventilator only.*	n/a	When the alarm is related to something other than the humidifier alarms listed in this table, the ventilator displays this text.	Check humidifier operation and all connections.
Medium priority			
Humidifier chamber temp low Humidifier Y-piece temp low		The gas temperature at the water chamber exit or at the Y-piece is below the set value.	• Wait until the system heats up completely (approx. 30 minutes). • Check whether all settings are correct. • Avoid direct air flow from air conditioning and the like to the humidifier and breathing circuit.
Humidifier water low		The water level in the water chamber is below the low level mark.	• Check water bottle and refill tubing. • If the water bottle is empty, connect a new water bottle. • Refill or exchange empty water chamber. • Operate the humidifier at an angle less than 10° relative to the floor.
Humidifier check chamber		No chamber or incompatible water chamber is inserted.	Insert a new water chamber and connect the breathing circuit.

Alarm	Alarm icon	Description	Action needed
Humidifier check left tube Humidifier check right tube		The display and connection indicators show which limb is faulty. • No limb or defective limb connected. • No air flow. • A limb is not properly connected. • The WHITE humidifier expiratory limb is connected to the ventilator *To patient* inspiratory port.	• Insert or reseat the breathing circuit correctly. • Replace the breathing circuit. • Connect the BLUE humidifier inspiratory limb to the ventilator *To patient* inspiratory port. When the connection indicator is: *Green*: The limb is inserted correctly. *Orange*: The humidifier is testing the connection. *Red*: The connection is either faulty or nonexistent.
Low priority			
Check humidifier communication *Displayed on the ventilator only.*	The Connection to ventilator symbol ( ) is absent.	There is a problem with the connection between the humidifier and the ventilator. The humidifier information in the ventilator System > Info > Info 2 window is absent, and the Humidifier button is grayed out.	• Ensure that the humidifier communication cable is securely connected to the humidifier and to the HAMILTON-H900 / COM1 port on the ventilator communication board. • Open the alarm buffer by touching the message bar or the i-icon, if displayed, to reset the alarm.

11.1.7 About humidifier-related parameters

Humidifier data is displayed in the following locations:

- System > Settings > Humidifier window
- As an MMP (if configured)
- System > Info > Info 2 window

The following parameters are related to humidifier operation.

Table 11-5. HAMILTON-H900-related parameters

Parameter	Description
HAMILTON-H900	Indicates the humidifier is connected, and shows the current software version. Displayed in the System > Info > Info 2 window.
Set temp	Control parameter. See Table 11-3.
T humidifier	Monitored parameter. Measured temperature at the water chamber exit. Displayed in System > Settings > Humidifier window. In Configuration, this parameter can be set as an MMP. Displayed as an MMP during HiFlowO2 therapy.
T gradient	Control parameter. See Table 11-3.
T Y-piece	Monitored parameter. Measured temperature at the Y-piece. Displayed in System > Settings > Humidifier window. In Configuration, this parameter can be set as an MMP.

11.2 Working with clinical networks

The HAMILTON-C1 can connect to external devices over Bluetooth.

Preparing the ventilator for connectivity comprises the following steps:

- Configuring ventilator connectivity for use in your institution, performed by technical personnel (see Table 11-6)
- For medical caregivers, enabling the connection type (see Section 11.2.1)

Table 11-6. Connectivity tasks for technical personnel

To ...	See ...
These configuration tasks are performed by technical personnel.	
Configure network and connectivity	See the *Hamilton Connect Configuration Tool User Guide* (PN 10110032), *Hamilton Connect Communication Guide* (PN 10102528).
Copy Connectivity configuration settings to the ventilator	Section 13.10

Table 11-7. Connectivity tasks for medical caregivers

To ...	See ...
The following tasks are performed by medical personnel caring for patients.	
Enable the Bluetooth connection type	Section 11.2.1
Connect using Bluetooth	Section 11.2.2

11.2.1 Enabling/disabling a connection type

Depending on your institution's network policy, you can enable a Bluetooth connection on the ventilator.

Connection type	Symbol
Bluetooth	ᛒ

To enable/disable a connection type

1. Do either of the following:
   – Touch the Bluetooth icon in the lower right of the display.
   – Touch **System** > **Settings** > **Connectivity**.
   The Connectivity window opens, displaying the Status tab. See Figure 11-5.
2. Touch **Bluetooth** to enable/disable the connection.

When Bluetooth is enabled:

– A checkmark is displayed (item 5 in Figure 11-5).

– The Bluetooth tab is enabled in the Connectivity window (item 6 in Figure 11-5).

– The Bluetooth icon in the bottom right of the main display turns white (item 8 in Figure 11-5).

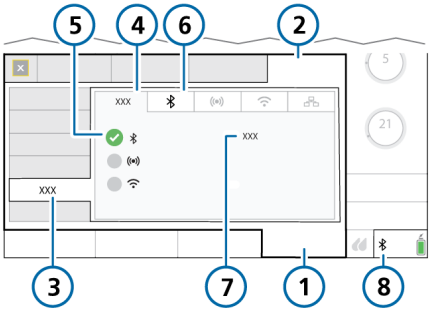
When Bluetooth is disabled:

– A gray radio button is displayed.

– The Bluetooth tab is disabled.

– The Bluetooth icon in the bottom right of the display is grayed out.

Figure 11-5. System > Settings > Connectivity > Status window



1	System	5	Connection types and status (Bluetooth enabled)
2	Settings	6	Bluetooth tab
3	Connectivity	7	Connection status
4	Status	8	Bluetooth icon (shortcut to Connectivity window)

11.2.2 Setting up a Bluetooth connection

The Bluetooth wireless technology connection type allows you to connect a supported device to the ventilator using Bluetooth. You do *not* need to be on your institution's network.

To connect using Bluetooth

1. Enable Bluetooth on the ventilator, if needed (Section 11.2.1).
2. In the System > Settings > Connectivity window, touch the tab.

   The Bluetooth window opens, displaying the configured name of the Bluetooth connection, PIN, and a QR code. See Figure 11-6.

   You can now select the ventilator on the device to pair.
3. After the device is connected:

   – On the Bluetooth tab, the name of the connected device is displayed and the **Disconnect** button is enabled.

   – The Status tab displays Connected.

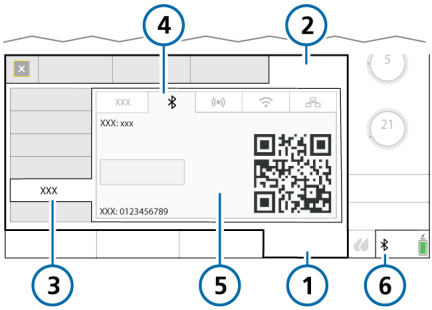
   – The connection icon in the bottom right of the main display turns green.

To disconnect a paired device

1. In the System > Settings > Connectivity window, touch the ✱ tab.
2. Touch **Disconnect**.

The device is disconnected from the ventilator.

Figure 11-6. Bluetooth window



1	System	4	Bluetooth
2	Settings	5	Device name, PIN, QR code
3	Connectivity	6	Connectivity icon (shortcut to Connectivity window)

12
Maintenance

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12.1 Overview

NOTICE

(*USA only*) Only use EPA-registered and approved surface cleaning/disinfection agents.

Before proceeding, review the safety information in Chapter 1.

This chapter provides information about ventilator maintenance procedures and schedule, as well as cleaning and disinfection instructions.

All of the procedures in this chapter are to be performed by the operator.

For additional maintenance requirements, contact your Hamilton Medical service representative. Any documents referenced in this chapter are available in the Hamilton Medical Resource Center (https://www.hamilton-medical.com/Resource-center).

12.2 Cleaning, disinfection, and sterilization

Ventilator components must be regularly cleaned and disinfected, using the cleaning methods and solutions specific to the individual components.

It is important that you use the appropriate method and materials when cleaning and disinfecting the ventilator and its components, not only to avoid damaging the equipment, but also to avoid cross-contamination.

Cleaning and disinfection information is presented as follows:

- Table 12-1 lists the applicable ventilator-related components, and indicates which cleaning and disinfection methods can be used for each one, the frequency with which the component must be cleaned/disinfected, and any other relevant information.
- Table 12-2 provides cleaning and disinfection information for ventilator-compatible external devices and sensors.
- Table 12-3 lists the supported cleaning and disinfection agents, as well as the concentration to be used for the ventilator.
- Table 12-4 lists the supported cleaning and disinfection agents for the CO2 sensors.

When working with the ventilator components, cleaning methods, and cleaning agents, keep the following in mind:

- Do *not* attempt decontamination procedures unless specified by Hamilton Medical or the original manufacturer.
- While we provide guidelines for agents and concentrations to use, if you have specific questions about the use of a particular cleaning or disinfection agent, contact the manufacturer of the agent.
- After cleaning and decontaminating parts, be sure to perform any required tests and calibrations described in Chapter 5.

Table 12-1. Ventilator cleaning and disinfection methods

Part	Frequency	Cleaning/disinfection method	Remarks
For supported cleaning and disinfection agents, see Table 12-3.			
Ventilator exterior including: • Housing • Power cables • Gas supply hoses • Mounting systems	After each patient use or as needed.	Wipe with a damp cloth using a registered and approved cleaning/disinfection solution.	Do not clean the ventilator interior to avoid damaging internal components.
Touch screen	After each patient use or as needed.	Wipe with a damp cloth using a registered and approved cleaning/disinfection solution or a nonabrasive glass cleaner.	• Lock the touch screen before cleaning. See Section 10.11. • Do not use any vinegar based solutions. • Avoid using a gritty cloth.
Trolley-related accessories including: • Trolley • Basket • O2 cylinder holding system	After each patient use or as needed.	Wipe with a damp cloth using a registered and approved cleaning/disinfection solution.	
Autoclavable expiratory valve	After each patient use or as needed.	Clean and sterilize according to the instructions in the *Expiratory Valve Reprocessing Guide* (PN 624591).	For details about assembly, installation, and disassembly of the expiratory valve, see Section 3.4.3.
CO2 sensors	After each patient use or as needed.	Wipe with a damp cloth using a registered and approved cleaning/disinfection solution (Table 12-4). Dry before use.	• Ensure that the sensor/module is disconnected and cooled to room temperature before cleaning. • Do not immerse the sensor/module in liquid.

Table 12-2. Cleaning and disinfection methods for external devices

Device	Frequency	Remarks
HAMILTON-H900 humidifier	After each patient use or as needed.	Refer to the *HAMILTON-H900 Instructions for use*.
Third-party humidifiers	After each patient use or as needed.	Refer to the humidifier *Instructions for use*.
SpO2 sensors	After each patient use or as needed.	Refer to the *Pulse Oximetry Instructions for use* and the sensor manufacturer's *Instructions for use*.

Table 12-3. Cleaning/disinfection agents for the ventilator

Cleaning/disinfection agent	Concentration
EPA-registered cleaning/disinfection agents	
Sani-Cloth 70 wipes	n/a
Approved cleaning/disinfection agents	
Mikrobac Tissues wipes	n/a
mikrozid sensitive wipes	n/a
mikrozid AF liquid	Ready for use
Bacillol 30 Sensitive Foam	Ready for use
Ethanol	--
Incidin Foam	Ready for use
Incidin Pro	0.25% to 4%
Incidin Rapid	0.25% to 2%
Isopropyl alcohol	--
Mikrobac forte	0.25% to 4%
perform	3%
terralin protect	2%

Table 12-4. Cleaning/disinfection agents for CO2 sensors

Cleaning/disinfection agent	LoFlo (sidestream)	CAPNOSTAT 5 (mainstream)
EPA-registered cleaning/disinfection agents		
Steris Coverage Spray	X	X
PDI Sani Cloth Bleach		X
PDI Sani Cloth AF		X
Approved cleaning/disinfection agents		
Ammonia	X	
2% glutaraldehyde solution	X	
Isopropyl alcohol 70%	X	X
A 10% aqueous solution of chlorine bleach	X	X
Clinell Wipes		X
Speedy Clean		X
Tuffie		X
Tuffie 5		X
WIP Anios		X

12.3 Preventive maintenance

WARNING

Use only Hamilton Medical-approved parts, spare parts, and accessories, including ventilator mounting solutions, that are specified in this guide and in the product e-catalog, or that are specified as being compatible with this ventilator. Doing so safeguards the patient, ensures proper ventilation operation, avoids degraded performance, and keeps your warranty in force.

Perform preventive maintenance on your ventilator according to the schedule shown in Table 12-5.

The System > Info window shows the number of hours the ventilator has been in operation.

Table 12-5. Preventive maintenance schedule

Interval	Part/accessory	Procedure
Between patients and according to hospital policy	Breathing circuit (including mask, inspiratory or expiratory filter, flow sensor, nebulizer jar, expiratory valve set)	Replace with sterilized or new single-patient use parts and run the preoperational checks (Section 5.4).
	Entire ventilator	Run the preoperational checks (Section 5.4).
Every month (or more often if required)	Fan filters (rear panel), air intake filters (white filters on outside of HEPA inlet filter)	Check for dust and lint. If needed, replace. See Section 12.4.1.
Every 6 months	Battery	Recharge battery by plugging the ventilator into a primary power source for at least 4 hours.
Yearly or as necessary	Battery	Have the battery serviced.[1]
	Galvanic O2 sensor	Replace if depleted. See Section 12.4.2.
	HEPA inlet filter	Replace. See Section 12.4.1.
	Ventilator	Perform service-related preventive maintenance.[1]
For information related to the HAMILTON-H900 humidifier, see the *HAMILTON-H900 Service Manual*.		

[1] Must be performed by Hamilton Medical authorized service personnel according to instructions in the *Service Manual*.

12.4 Performing maintenance tasks

The following sections describe how to clean and replace filters and a galvanic O2 sensor.

12.4.1 Maintaining the filters

The following sections show how to replace the air, fan, and HEPA inlet filters.

Replacing air and HEPA inlet filters

Figure 12-1. *Step 1.* Remove and replace air filter.

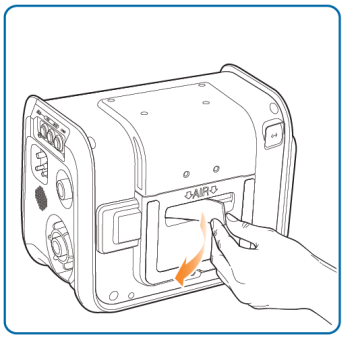


Figure 12-2. *Step 2.* Remove and replace fan filter.

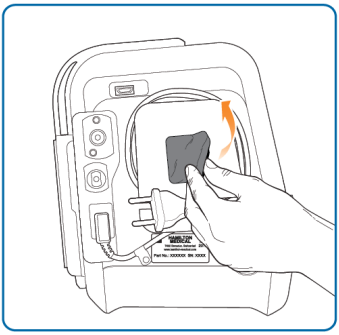


Figure 12-3. *Step 3.* Remove back panel

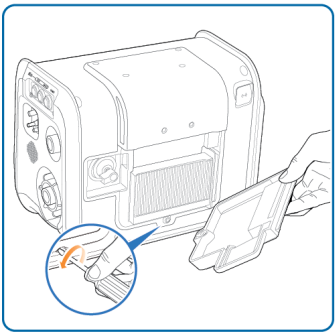
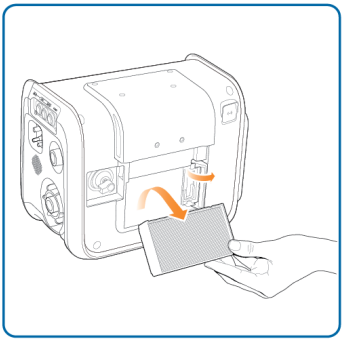


Figure 12-4. *Step 4.* Remove and replace HEPA inlet filter. Replace back cover when finished.



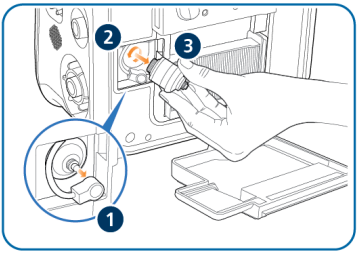
12.4.2 Replacing the galvanic O2 sensor

Before proceeding, review the safety information in Chapter 1.

Remove the back cover first (Section 12.4.1, step 3).

To replace the sensor, reverse the steps.

Figure 12-5. Remove connection cable (1). Unscrew the sensor counter-clockwise (2) and remove (3).



12.5 Charging and storing batteries

To maintain the battery charge and to prolong the life of the battery, keep the ventilator connected to its primary power source.

Have the battery recharged every six (6) months, depending on storage conditions. For details, see Section 15.4.

12.6 Repacking and shipping

⚠ CAUTION

Inform Hamilton Medical if you are shipping a contaminated (nonsterilized and nondisinfected) device for service.

If you must ship the ventilator, use the original packing materials. If these materials are not available, contact your Hamilton Medical representative for replacement materials.

13
Configuration

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13.1 Overview

During configuration, you set up the ventilator with a default language, main monitoring parameter display, startup settings for a new patient, and units of measure, among other settings.

13.2 Accessing Configuration mode

You can access all Configuration mode settings when the ventilator is in Standby. Access requires a configuration code; contact your administrator.

To access Configuration mode

1. Touch **Tools** > **Configuration**.
2. Using the keys on the onscreen keypad, type the configuration code; then touch **Enter**.

   The **Configuration** button is enabled.
3. Touch **Configuration**.

The Configuration window appears, displaying the Language window.

You can now define settings and add options.

13.3 Configuring general settings

You can configure some general default settings for the ventilator, including language, units of measure, communication interface to use, and minimum loudness for alarms.

13.3.1 Selecting the default language

To select the user interface language

- Touch **General** > **Language** and select the desired language.

13.3.2 Selecting the units of measure

To select the units of measure

- Touch **General** > **Units** and select the unit of measure for pressure, CO2, and length.

13.3.3 Enabling the communication interface

You can connect external devices to the ventilator using the communication interface. For a list of the communication protocols, see Table 2-2.

To select the communication protocol

1. Touch **Connectivity** > **More**.
2. Select the desired protocol for use from the RS232 Protocol dropdown list.
3. Restart the ventilator.

The ventilator must be restarted to establish communication using the selected protocol.

For setup and configuration details, see the *Communication Interface User Guide*, available in the Hamilton Medical Resource Center.

13.3.4 Setting the minimum alarm loudness (volume)

You can specify a minimum alarm loudness (volume) setting for the ventilator. Once set, the ventilator operator cannot set the alarm volume below the value set here in Configuration.

To set the minimum alarm loudness

1. Touch **General** > **More**.
2. Touch the **Min. loudness** button and choose the minimum alarm volume to allow on the device.

The setting is applied to the ventilator. Note that if the new minimum is greater than the currently set alarm volume, the alarm volume is reset to the new minimum level.

To verify the setting, check the **Loudness** value in the System > Settings > Loudness window.

13.3.5 Setting sensitivity for Check flow sensor for water alarm

Applicable for Neonatal patients only.

Under certain conditions, water may accumulate in the flow sensor, which can result in overstated volume measurements.

You can set how sensitive the alarm trigger for water in the flow sensor is. *Sensitivity* refers to the deviation from the dry value that the flow sensor tolerates before the ventilator generates the Check flow sensor for water alarm. By default, sensitivity is set to 12%. You can also turn off the alarm.

To set the flow sensor sensitivity

1. In Configuration, touch **General** > **More**.
2. Activate the FS alarm sensitivity control and set it to the desired value.

   Increasing the value lowers sensitivity; decreasing the value increases sensitivity.

13.3.6 Setting the maximum available Flow in HiFlowO2 for neonates

You can specify the maximum Flow that can be set in HiFlowO2 for neonatal patients. Once set, the ventilator operator cannot set Flow above the value set here in Configuration.

To specify the maximum Flow setting in HiFlowO2 for neonates

1. Touch **General** > **More**.
2. Touch the **HiFlowO2 limitation** control and choose the maximum setting to allow on the device.

13.4 Selecting mode options

You can set the following:

- Mandatory breath timing philosophy to use for PCV+ and APVcmv modes
- Naming convention for volume-controlled, pressure-adaptive modes
- ASV version
- Enable the TI max control for certain invasive modes

13.4.1 Setting breath timing options

The ventilator controls mandatory breath timing using a combination of inspiratory time (TI) and Rate.

For the modes PCV+ and APVcmv, you can set the ventilator to use either of the following to control breath timing: I:E or TI.

To change the breath timing selection

- In the Modes > General > Philosophy window, touch the desired breath timing option.

13.4.2 Choosing the mode naming convention

You can select the naming convention used for adaptive modes: *APVcmv / APVsimv* or *(S)CMV+ / SIMV+*.

By default, (S)CMV+ / SIMV+ are used.

To select the mode naming convention

- In the Modes > General > Philosophy window, select the desired option.

13.4.3 Choosing the ASV version

By default, the device uses ASV version 1.1.[1] For details about the different ASV versions, see Section 7.4.1.1.

To select the ASV version

- In the Modes > General > Philosophy window, select the desired version.

13.4.4 Enabling TI max for invasive modes

In Configuration, you can enable or disable the TI max control setting, as desired, for adult/pediatric patients in the following modes: APVsimv, VS, PSIMV+, DuoPAP, and SPONT

To enable/disable TI max

1. Open the Modes > General > Philosophy window.
2. Touch the Available in invasive modes checkbox to enable/disable the setting.

   A checkmark indicates TI max is enabled.

13.5 Configuring MMPs

You can specify which MMPs are displayed on the ventilator.

The list of entries in the Configuration window is shown in the same order as the MMPs appear on the main display.

To select the MMPs to display

1. In Configuration, touch **Graphics**, then the **MMP** tab.
2. In each dropdown list, select the desired parameter to show in that position in the MMP list on the main display.

[1] Not applicable when the HAMILTON-C1 neo option is enabled and the ventilator is dedicated to neonatal ventilation.

13.6 Configuring alarm delay

⚠ WARNING

To prevent possible patient injury, make sure the alarm limits are appropriately set before you place the patient on the ventilator.

For the Vt low/high alarms, you can configure a short delay before the triggering condition generates an alarm. The setting applies for all patient groups.

Table 13-1. Alarm delay settings in Configuration

Alarm delay	Description
OFF	The alarm is generated when the triggering condition persists over two (2) patient breaths.
ON	The alarm is generated when the triggering condition persists over three (3) patient breaths.

To set the system alarm delay

1. In Configuration, touch **Setups** > **Alarms**.
2. Touch **On** or **Off** as appropriate.

13.7 Defining Quick setups

A Quick setup refers to a group of settings you define, including patient characteristics, mode selection and control settings, alarm limit settings, and weaning zone limits.

The settings saved with a Quick setup are automatically applied when the setup is selected in the Standby window.

For each patient group, you can configure up to three Quick setups, and can specify a setup to be selected by default when the ventilator is turned on.

13.7.1 Configuring individual setup settings

To configure a Quick setup

1. In Standby, configure the ventilator with the parameters you will save as a Quick setup.

   Select:

   – Patient group and sex/height (Adult/Ped) or Weight (Neonatal)

   – Ventilation mode

   – Mode control settings

   – Alarm limits

   – Humidifier settings

   – CPR ventilation settings
2. Touch **Start ventilation** and select the desired graphic layout and graphics to display. See Section 8.3.
3. Return to Standby.
4. Access Configuration mode.

5. In the Configuration window, touch **Setups**, and then touch the button (1, 2, or 3, or your custom-defined labels) for the setup to configure.

   The General setup configuration window is displayed. Note that the buttons in the left panel now change to provide access to the setup options.

6. Touch **Rename setup** to give the setup a meaningful name.

   You must define a name as it is used as the Quick setup button label in Standby, as well as in this Configuration window.

7. Select the configuration settings to apply to this setup by touching the appropriate button:

   – To apply the ventilator settings you selected in step 1, touch **Use current settings**.

   – To apply factory settings, touch **Use factory settings**.

8. Touch **Mode Ctrls** > **Controls** to review patient parameter settings.

   Some parameters are not displayed, as they are based on weight:

   – The following parameters are set based on ideal body weight (IBW) (Adult/Ped): Vt, Rate, T low, T high, and TI.

   – The following parameters are set based on body weight (Neonatal): Vt, Rate, T low, T high, TI, and TI max.

9. Touch **Vt/IBW** (Adult/Ped) or **Vt/Weight** (Neonatal) to set the tidal volume per IBW or weight, respectively.

   The ventilator uses the Vt/IBW or Vt/Weight setting in calculations for the following:

   – To set the initial delivered Vt in volume-controlled modes

   – To set the initial high and low alarm limits for Vt and ExpMinVol

10. Review the alarm settings in the Alarms window.

11. In Vent Status, set patient parameters manually.

    The Vent Status window allows you to configure the weaning zone ranges shown in the Vent Status panel according to your institution's protocol.

12. Touch the **Back** button to return to the Default setup window.

Configuration of the Quick setup is complete.

13.7.2 Selecting a default Quick setup

A Default setup comprises a group of settings that are automatically loaded when turning on the ventilator.

After you have configured one or more Quick setups, select the default to use.

To set a Quick setup as the default

- In Configuration, touch **Setups** and select the one to use as the default.

13.8 Activating SpO2 and CO2 measurement

To enable SpO2 and/or CO2 measurement on the ventilator, you must activate the associated hardware option in Configuration. See Section 13.12.3.

You must also enable each sensor in the System window. See Section 4.5.

13.9 Configuring CPR ventilation

You can specify the default ventilation mode and control settings to be used during CPR ventilation.

To change the default mode and control settings for CPR ventilation

1. In Configuration, touch **Setups**, then **CPR**.
2. Select the desired mode and adjust the control settings, as appropriate.

   Not all control settings are available when configuring the default mode for CPR ventilation. See Table 15-14.

Note that changes apply only to the selected patient group.

13.10 Configuring connectivity settings

When the Hamilton Connect Module[1] is enabled, your ventilator supports communication using Bluetooth.

On the ventilator, you can update the Hamilton Connect Module firmware, import and export configuration settings, as well as delete data and settings that are saved to the module.

The Hamilton Connect Configuration Tool is a separate application that allows IT personnel to define the connectivity configuration settings for the ventilator. For details, see the *Hamilton Connect Configuration Tool User Guide* (PN 10110032).

13.10.1 Updating Hamilton Connect Module firmware

NOTICE

Turning off the device while the firmware is being installed may corrupt the Hamilton Connect Module.

Module firmware updates are provided to you by your Hamilton Medical technical representative.

An update can take up to 10 minutes to complete. Note that you cannot install a firmware version that is older than the version currently installed on the Hamilton Connect Module.

To update the Hamilton Connect Module firmware

1. Insert the provided USB drive containing the update into the USB port on the ventilator (Figure 2-5).
2. In Configuration, touch **Connectivity** > **Firmware**.

   Information about the currently installed version is displayed, as well as important safety information.
3. Select the desired version to install from the New version dropdown list.

[1] Available for HAMILTON-C1 PN 1610010.
Available for the HAMILTON-C1 PN 161001 with SN > 6000 with the Hamilton Connect Module (HCM) Upgrade kit.

4. Touch **Start**.

   Do not turn off the device during the update.

When the new firmware is installed, the text, Update successfully completed is displayed. Ensure that the new firmware version is displayed.

The ventilator is ready to use. You do *not* need to restart the ventilator.

13.10.2 Copying Connectivity configuration settings

To enable communication using the Hamilton Connect Module, you must first import the Connectivity configuration file created for your ventilator.

This file defines the connection types to enable on your ventilator, as well as the ventilator name and various settings associated with your institution's network.

Connectivity configuration settings are created using the Hamilton Connect Configuration Tool. For details, see the *Hamilton Connect Communication Guide* (PN 10102528) and the *Hamilton Connect Configuration Tool User Guide* (PN 10110032).

If changes need to be made to the contents of this configuration file, you can export the file (Section 13.10.2.2) and modify it as required.

13.10.2.1 Importing Connectivity configuration settings

Once the Connectivity configuration file has been created or updated, you can import the file to the ventilator using a USB drive.

To import the Connectivity configuration file

1. Insert the USB drive into the USB port on the ventilator (Figure 2-5).
2. In Configuration, touch **Connectivity** > **Configuration**.
3. Select the desired file from the Import configuration dropdown list.
4. Touch **Import**.

The features defined in the file are now enabled in the System > Settings > Connectivity window.

13.10.2.2 Exporting Connectivity configuration settings

You can export the Connectivity configuration file from the ventilator to a USB drive.

To export the configuration file from the ventilator

1. Insert a USB drive into the USB port on the ventilator (Figure 2-5).
2. In Configuration, touch **Connectivity** > **Configuration**.
3. Touch **Export**.

The configuration file is saved onto the USB drive.

13.10.3 Setting the Hamilton Connect Module to the factory default settings

NOTICE

When ventilator connectivity is reset to the factory defaults, all connection types are disabled.

You can reset the Hamilton Connect Module to the factory default settings, which removes the Connectivity configuration file and deletes all saved data.

To delete only the saved data while retaining the Connectivity configuration, see Section 13.10.4.

Note that the currently installed Hamilton Connect Module firmware version remains unchanged.

To reset the Hamilton Connect Module to the factory default settings

1. In Configuration, touch **Connectivity** > **Configuration**.
2. Touch **Use factory settings**.

   A confirmation window is displayed. Touch **Yes** to continue or **No** to cancel.
3. When complete, Reset successful is displayed.

The Hamilton Connect Module factory defaults are restored.

13.10.4 Deleting data from the Hamilton Connect Module

You can delete data (such as ventilation-related data) that has been saved to the Hamilton Connect Module.

To remove saved data

1. In Configuration, touch **Connectivity** > **More**.
2. Touch **Delete recorded data**.

   A confirmation window is displayed. Touch **Yes** to continue or **No** to cancel.
3. When complete, Recorded data deleted successfully is displayed.

All recorded data is deleted from the Hamilton Connect Module. This does *not* remove information about paired devices or have any effect on the connectivity configuration.

13.11 Copying configuration settings

Before proceeding, review the safety information in Chapter 1.

You can copy and transfer configuration settings to other HAMILTON-C1 devices. For details about configuration settings, ranges, and defaults, see Table 15.9.

You copy configuration settings to/from the ventilator using a USB drive.

You must be in Standby to copy configuration settings.

To copy configuration settings using a USB drive

1. Insert a USB drive into the ventilator USB port. See Figure 2-5.
2. In Configuration, touch **Transfer**.
3. In the Transfer window, touch **Import** or **Export**.

   – The device begins transferring the files. A message is displayed after the files are successfully transferred.

   – Exported files are stored in the import-export config folder on the USB drive.

   – Imported configuration files are immediately applied to the ventilator.

If you remove the USB drive before the files are successfully transferred, you must start over and repeat the process.

13.12 Configuring device options

Before use, you must enable any installed hardware options (for example, CO2 and SpO2), and add and enable software options.

13.12.1 Reviewing installed options

To view installed options

1. In Configuration, touch **Options**.
2. Touch **SW options** for software or **HW options** for hardware.
3. Scroll through the options to review, as needed.

13.12.2 Adding software options

Software options are added using license keys.

Trial versions of software options may be available. Trial options expire and are automatically deactivated after 30 days.

Have all required keys available before proceeding.

To add a software option

1. In Configuration, touch **Options**.
2. In the Options window, touch **SW options**.
3. Touch **Add options**.
4. Type the activation code exactly as provided into the field and touch **Enter**.

   If the message Option code invalid! appears, re-enter the code.

   The message Option valid indicates the code is correct and the option has been added.
5. Repeat until all desired software options are added.
6. Touch the **X** to close the window.
7. Restart the ventilator to enable the options.

Upon turning on the ventilator, the added options are available for use.

13.12.3 Activating hardware options

Communication board-related functions (CO2, SpO2) are activated at two levels:

- The hardware itself must be activated in configuration to make the functionality available to the user, described in this section.
- Sensors that plug into the hardware are individually enabled by the user, as needed, in the System window. See Chapter 4.

To activate hardware options in Configuration

1. Touch **Options**.
2. In the Options window, touch the **HW options** tab.

   The window lists hardware that requires activation.
3. Select the checkbox for options to activate.

   A checkmark indicates the option is activated.

Upon exiting Configuration, the activated hardware is available for use.

SpO2 and CO2 sensors require an additional step: they must also be enabled in the System > Sensors window. See Section 4.5.

13.12.4 Removing options

Note the following:

- Trial options are automatically removed at the end of the trial period.
- Selecting **Clear options** removes *all* non-trial options.
- The patient groups on the ventilator, Adult/Ped. and Neonatal, are treated as options. Clearing options removes them and the associated ventilation modes. You must re-add them before using the ventilator on a patient.
- Installing the NIV-only option requires removal of all currently installed features and options. For more information, see Section 10.6.1.

To remove software options

You can remove all non-trial software options from the ventilator.

1. In the SW options window, touch **Clear options**.

   You are prompted to confirm deletion of all non-trial options. See the previous notes.
2. Touch **Clear options** to remove the options.

   Touch **Cancel** to leave the options installed.
3. Restart the ventilator.

   Once you restart the ventilator, all options (including patient groups) listed in the window are cleared.
4. To re-add the patient groups and any other desired options, re-enter Configuration mode.
5. Add software options (including the patient groups), as appropriate.

13.12.4.1 Deactivating hardware options

To deactivate hardware options

- In the HW options window, clear the checkboxes to deactivate the hardware.

14
Parts and accessories

14.1 Overview 306

14.1 Overview

This chapter lists parts available for the HAMILTON-C1 ventilator. Note that not all parts are available in all markets.

For ordering information, refer to the e-catalog on the Hamilton Medical website or contact your Hamilton Medical representative.

Figure 14-1. Ventilator parts and accessories

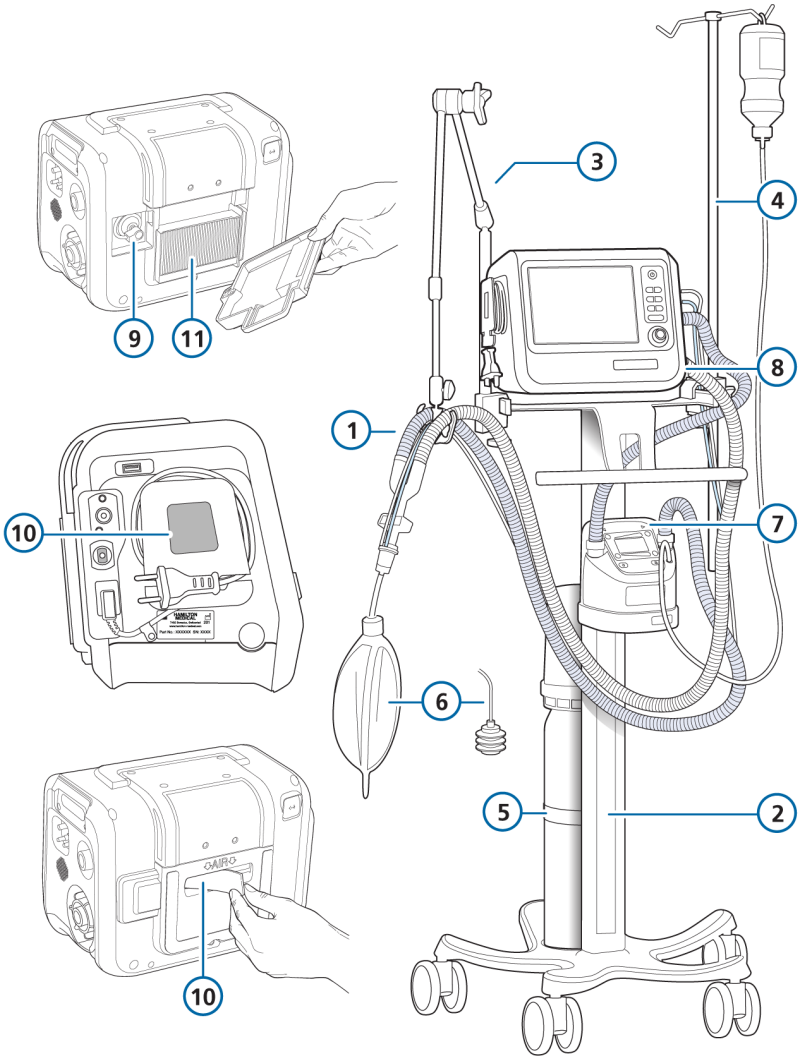

Table 14-1. Ventilator parts and accessories

Item no. (ref to Fig 14-1)	Description	Part number (PN)
1	**HAMILTON-H900 breathing circuit set, adult/pediatric**	
	Breathing circuit set BC8022, dual limb, single use, preassembled, box of 15	260161
	Breathing circuit set BC4022, single limb, single use, preassembled, box of 15	260186
	HAMILTON-H900 breathing circuit set, neonatal	
	Breathing circuit set BC8010, dual limb, single use, preassembled, box of 15	260185
	Breathing circuit set BC8010-A, dual limb, autoclavable, preassembled, box of 1	260189
	Breathing circuit set BC4010, single limb, single use, preassembled, box of 15	260187
1	**Breathing circuit set, coaxial, single use, adult/pediatric**	
	Breathing circuit set, coaxial, single use, adult/pediatric, length 1.80 m, box of 20	260206
	Preassembled with flow sensor, length 180 cm, box of 20	260207
	Breathing circuit set, coaxial, single use, adult/pediatric, length 240 cm, box of 10	260239
	Preassembled, with flow sensor, length 240 cm, box of 10	260240
	Preassembled, with expiratory valve set, flow sensor, and elbow adapter, length 240 cm, box of 10	260127
	Preassembled, with expiratory valve set, flow sensor, and elbow adapter, length 180 cm, box of 20	260128
	Preassembled, with expiratory valve set, flow sensor, and elbow adapter, length 300 cm, box of 10	260167
	Preassembled, with expiratory valve set, flow sensor, and elbow adapter, length 480 cm, box of 8	260168
	Preassembled, with flow sensor and elbow adapter, length 180 cm, box of 20	260087
	Preassembled, with flow sensor and elbow adapter, length 240 cm, box of 10	260094

Item no. (ref to Fig 14-1)	Description	Part number (PN)
1	Preassembled, with flow sensor and elbow adapter, length 300 cm, box of 10	260145
	Preassembled, with flow sensor and elbow adapter, length 480 cm, box of 8	260144
1	**Breathing circuit sets, dual limb, single use, neonatal**	
	With Y-piece, flow sensor, flow sensor calibration adapter, and pressure line with T-piece connectors, length 150 cm, box of 20	260180
	With Y-piece, flow sensor, flow sensor calibration adapter, and pressure line with T-piece connectors, length 300 cm, box of 10	260182
	With expiratory valve set, Y-piece, flow sensor, flow sensor calibration adapter, and pressure line with T-piece connectors, length 150 cm, box of 20	260170
	With expiratory valve set, Y-piece, flow sensor, flow sensor calibration adapter, and pressure line with T-piece connectors, length 300 cm, box of 10	260169
1	**Breathing circuit sets, dual limb, single use, pediatric/neonatal**	
	With Y-piece, length 150 cm, box of 20	260241
	With Y-piece, length 300 cm, box of 20	260244
1	**Breathing circuit sets, autoclavable** *See the Hamilton Medical e-catalog.*	
1	**Flow sensors, adult/pediatric**	
	Flow sensor, single use, adult/pediatric, 188 cm, box of 10	281637
	Flow sensor, single use, adult/pediatric, 260 cm, box of 10	282049
	Flow sensor, autoclavable, adult/pediatric, 188 cm, box of 1	950185
	Flow sensor calibration adapter, single use, adult/pediatric, box of 10	279937
	Flow sensor calibration adapter, autoclavable, adult/pediatric, box of 10	282323

Item no. (ref to Fig 14-1)	Description	Part number (PN)
1	**Flow sensors, neonatal**	
	Flow sensor, single use, neonatal, 160 cm, box of 10	260177
	Flow sensor, single use, neonatal, 188 cm, box of 10	155500
	Flow sensor, single use, neonatal, 310 cm, box of 10	260179
	Flow sensor calibration adapter, single use, neonatal, box of 10	279964
8	**Expiratory valve**	
	Expiratory valve set, autoclavable, adult/pediatric, box of 1	161175
	Membrane, expiratory valve, autoclavable, adult/pediatric/ neonatal, box of 5	161390
	Expiratory valve set, single use, adult/pediatric, box of 10	161186
	Expiratory valve set, autoclavable, neonatal (incl. membrane, expiratory valve)	161188
	Expiratory valve set, single use, neonatal, box of 10	161189
not shown	**Pressure-monitoring line (for nCPAP, nCPAP-PC modes)**	
	Pressure line, single use, neonatal/pediatric, 160 cm, box of 10	260174
	Pressure line, single use, neonatal/pediatric, 310 cm, box of 10	260176
	Luerlock adapter kit for nCPAP/nCPAP-PC with breathing set, single use, neonatal, box of 50	279971
not shown	**Nasal cannulas (adult/pediatric/neonatal)** *See the Hamilton Medical e-catalog.*	
not shown	**Masks and accessories, adult/pediatric** *See the Hamilton Medical e-catalog.*	
not shown	**Masks and accessories, neonatal**	
	nCPAP Starter kit, large (10 sets, incl. mask, prongs, and bonnets)	281975
	nCPAP Starter kit, small (1 set, incl. mask, prongs, and bonnets)	282330

Item no. (ref to Fig 14-1)	Description	Part number (PN)
not shown	**CO2 mainstream measurement**	
	HAMILTON CAPNOSTAT-5 CO2 sensor (90° angled)	282157
	CO2 mainstream airway adapter, single use, adult/pediatric, box of 10	281719
	CO2 mainstream airway adapter, single use, neonatal, box of 10	281720
	CO2 mainstream airway adapter, reusable, adult/pediatric, box of 1	281721
	CO2 mainstream airway adapter, reusable, neonatal, box of 1	281722
	OD15/ID15 adapter, single use, neonatal, box of 25	281803
not shown	**CO2 sidestream measurement**	
	HAMILTON LoFlo sidestream CO2 sensor	281928
	CO2 sidestream adapter, single use, adult/pediatric, box of 10	281929
	CO2 sidestream adapter, single use, adult/pediatric, box of 10	281931
	CO2 sidestream adapter, single use, neonatal/pediatric, box of 10	281930
	CO2 sidestream adapter, single use, neonatal, box of 10	281932
7	**Humidifier**	
	HAMILTON-H900 humidifier *See the Hamilton Medical e-catalog.*	
2	**Trolley**	
	Trolley (incl. humidifier support)	161150
3	Support arm, quick positioning, basic	281671
not shown	Tubing holder, dual	282722
4	Water bottle holder with quick lock (max. 1 kg per side)	160162
5	Cylinder holder	161152

Item no. (ref to Fig 14-1)	Description	Part number (PN)
not shown	Small basket (max. 3 kg capacity)	10101016
not shown	Large basket (max. 5 kg capacity)	10101017
6	**Demonstration lung**	
	IntelliLung, maximum 1 liter	281869
	Demonstration lung assembly with endotracheal tube, adult, 2 liter, with OD15 connector	151815
	Demonstration lung assembly with endotracheal tube, pediatric, 0.5 liter, with OD15/OD22 connector	151816
	Demonstration lung, neonatal, OD15 *A passive lung simulator with two independent compartments for simulating neonatal patients.*	R53353
10	**Filter**	
	Filter set *Air intake dust filter and fan filter, set of 5*	161275
11	HEPA inlet filter	161236
not shown	**Patient filter**	
	HME filter (HMEF), single use, adult/pediatric	279963
	HME filter (HMEF), single use, adult/pediatric	279974
	Inspiratory bacteria filter	279211
not shown	**Power cord**[1]	
	Power cord with US plug, 2-pin, 3.0 m	355198
	Power cord with British angled plug, 3.0 m	355199
	Power cord with continental European plug, 2-pin, 3.0 m	355200
	Power cord with Chinese plug, 3.0 m	355308

[1] Only use power supply cords that are compliant with IEC 60601-1 requirements. Additional national standards and requirements may apply.

Item no. (ref to Fig 14-1)	Description	Part number (PN)
9	**Oxygen sensor**	
	Galvanic O2 sensor	396200
	Galvanic O2 sensor, lead free	10110473
not shown	**Communication**	
	Extended communication board CO2, Nurse call, COM1	161520
	Extended communication board CO2, SpO2, COM1	161636
	Extended communication board CO2, SpO2, /COM1 (for communication with the HAMILTON-H900 humidifier)	10076964
	Cable to COM1, 26 cm	161545
	Cable to COM1, 50 cm	161650
	Communication Y-cable to HAMILTON-H900 and RS-232	10077038
	Cable to HAMILTON-H900	950473
	Cable, Nurse Call	160166
not shown	**Battery**	
	Li-Ion battery	369108
not shown	**High-pressure oxygen connector**	
	DISS – diameter index safety standard	160470
	NIST – no interchangeable screw thread	160471
not shown	**Gas supply hoses and parts**	
	Coupling insert for low pressure O2 inlet, 4.8 mm ID	279913
not shown	**SpO2 sensors and accessories (Masimo)** *See the Hamilton Medical e-catalog.*	
	SpO2 sensors and accessories (Nihon Kohden) *See the Hamilton Medical e-catalog.*	
not shown	**Nebulizer and accessories** *See the Hamilton Medical e-catalog.*	

Item no. (ref to Fig 14-1)	Description	Part number (PN)
not shown	**Tools and test equipment** *See the Hamilton Medical e-catalog.*	
not shown	**Ventilator hardware and mounting options**	
	Shelf mount plate	161439
	Universal bed mount	161148
	Language kit	
	English	10102106
	English-US	10102187
	German	10102107
	Spanish	10102108
	French	10102109
	Italian	10102113
	Russian	10102110
	Chinese	10102111
	Portuguese	10102112
	Neonatal Language kit	
	English	10102114
	English-US	10102188
	German	10102115
	Spanish	10102116
	French	10102117
	Italian	10102121
	Russian	10102118
	Chinese	10102119
	Portuguese	10102120

Item no. (ref to Fig 14-1)	Description	Part number (PN)
	Extended warranty	
	Extended warranty of 1 year	700503
	Extended warranty of 2 years	700504
	Extended warranty of 3 years	700505
	Extended warranty of 4 years	700511

15
Specifications

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15.1 Physical characteristics

Table 15-1. Physical characteristics[1]

Dimen-sion	Specifications
Device/trolley	
Weight	4.9 kg (10.8 lb) (device) 16.9 kg (37.3 lb) with trolley The trolley can accommodate a maximum safe working load of 44 kg (97 lb).[2]
Dimen-sions	See the following figures.
Gas cylinder	
Diameter	100 to 140 mm (3.9 to 5.5 inches)
Height	≤ 820 mm (32 inches)
Weight	≤ 8 kg (17.6 lb)

Figure 15-1. HAMILTON-C1 dimensions

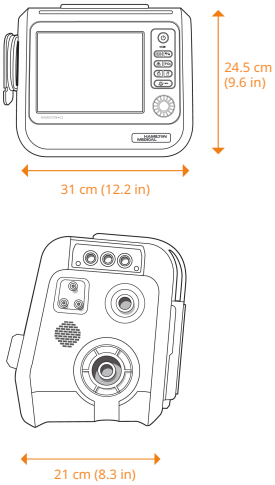
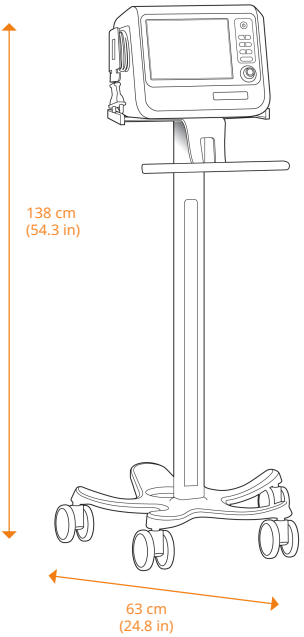


Figure 15-2. HAMILTON-C1 trolley dimensions



[1] For accessories, see Chapter 14.
[2] The maximum safe working load applies to a stationary, properly load-balanced trolley.

15.2 Environmental requirements

Table 15-2. Environmental requirements

Environment		Specifications
Temperature	Operation:[1]	5°C to 40°C (41°F to 104°F)
	Shipment/ storage:	-20°C to 60°C (-4°F to 140°F), in original packaging
Altitude		-650 to 4000 m (-2,132 to 13,123 ft) Note that at higher altitudes the ventilator performance may be limited. The Performance limited by high altitude alarm is generated and a message is shown on the display. See Table 9-3.
Atmospheric pressure	Operation,[1] shipment, and storage:	620 to 1100 hPa
Relative humidity	Operation,[1] shipment, and storage:	10% to 95%, noncondensing
Ingress protection[2]		HAMILTON-C1, PN 161001: IP21 HAMILTON-C1, PN 1610010: IP22
For specifications related to any external devices and sensors, refer to the manufacturer's *Instructions for use*.		
For specifications related to the mainstream and sidestream CO2 sensor, see Section 15.12.		

[1] The stated operating conditions apply to operation of the ventilator within the limitations specified in the Intended use.
[2] Software version 3.0.x can be installed on the ventilator regardless of the IP rating indicated on the device

15.3 Pneumatic specifications

Table 15-3. Pneumatic specifications

Component	Specifications	
High-pressure oxygen inlet[1]	Pressure:	2.8 to 6 bar / 41 to 87 psi
	Flow:	Maximum of 200 l/min
	Connector:	DISS (CGA 1240) or NIST
Low-pressure oxygen inlet[1]	Peak pressure:	Maximum 6 bar / 87 psi
	Flow:	≤ 15 l/min
	Connector:	Quick-coupling system, compatible with Colder Products Company (CPC) PMC series
Air supply	Integrated blower	
Gas mixing system	Delivered flow (HAMILTON-C1):	• > 260 l/min ±10% against ambient pressure (at sea level) • > 200 l/min with 100% oxygen
	Delivered flow (HAMILTON-C1 neo):	> 40 l/min ±10% against ambient pressure (at sea level)
	Delivered pressure:	*Adult/Ped.:* 0 to 60 cmH2O
		Neo: 0 to 45 cmH2O
	Flow accuracy:	±10% or ±300 ml/min (whichever is greater)
Inspiratory outlet (*To patient* port)	Connector:	ISO ID15/OD22 conical
Expiratory outlet (*From patient* port)	Connector (on expiratory valve):	ISO ID15/OD22 conical

[1] Measurement expressed in STPD (standard temperature and pressure, dry).

15.4 Electrical specifications

Table 15-4. Electrical specifications

Element	Specifications	
Input power	100 to 240 VAC, 50/60 Hz	
Power consumption	50 VA typical, 150 VA maximum	
Battery	Hamilton Medical provides a high-capacity[1] battery.	
	Electrical specifications:	10.8 V DC, 6.7 Ah, 72 Wh
	Type:	Lithium-ion, supplied by Hamilton Medical only
	Recharge time:	While ventilator is connected to primary power, approximately 3.25 h to fully recharge one battery.
	Storage:	-20°C to 60°C, ≤ 85% relative humidity. The storage location should be free from vibration, dust, direct sunlight, moisture, and corrosive gases, and with a recommended temperature range < 21°C. Extended exposure to temperatures above 45°C can degrade battery performance and life.
Battery	Normal operating time:	Operating times are measured with one fully charged battery, the blower in use, without communication board, and with the following settings: Mode = PCV+, Rate = 10 b/min, ΔPcontrol = 10 cmH2O, I:E = 1:4, PEEP = 5 cmH2O, Flow trigger = 5 l/min, FiO2 = 40%. Approximate operating times under these conditions are as follows: • One battery, display brightness = 80%: 4 h • One battery, display brightness = 20%: 4.5 h This operating time applies to new, fully charged Li-ion batteries not exposed to extreme temperatures. The actual operating time depends on battery age and on how the battery is used and recharged.

[1] PN 369108, revision 4 and later.

15.5 Ventilation-related terminology

Table 15-5. Ventilation mode terminology comparison, Hamilton Medical ventilators and EN ISO 19223:2019

Hamilton Medical mode name	EN ISO 19223 mode terminology	Description
(S)CMV+/APVcmv	A/C-vtPC	Synchronized controlled mandatory ventilation with volume-targeted pressure control
SIMV+/APVsimv	SIMV-vtPC\PS	Synchronized intermittent mandatory ventilation with volume-targeted pressure control and pressure support
VS	CSV-vtPS	Continuous spontaneous ventilation with volume-targeted pressure support
PCV+	A/C-PC	Synchronized pressure-controlled ventilation
PSIMV+	SIMV-PC\PS	Synchronized intermittent mandatory pressure controlled ventilation with pressure support
DuoPAP	SIMV-PC\PS	Synchronized intermittent mandatory ventilation with synchronized termination pressure control, pressure support and ACAP[1]
APRV	IMV-PC\PS	Intermittent mandatory pressure controlled ventilation with pressure support
SPONT	CSV-PS	Continuous spontaneous ventilation with pressure support
ASV	n/a	Synchronized intermittent mandatory ventilation with volume-targeted pressure control and pressure support
NIV	CSV-PS	Continuous spontaneous ventilation with pressure support
NIV-ST	SIMV-PC	Synchronized intermittent mandatory ventilation with pressure control
nCPAP	CPAP	Continuous positive airway pressure with ACAP[1]
nCPAP-PC	CSV-PC	Continuous spontaneous ventilation with pressure control

[1] ACAP is defined as *assured constant airway pressure*.

Table 15-6. Control-related terminology comparison, Hamilton Medical ventilators and EN ISO 19223:2019

Hamilton Medical terminology	EN ISO 19223 terminology
ΔPsupport	Δp (support pressure)
ΔPcontrol	Δp (delta inspiratory pressure)
ΔPinsp	Δp
P high	BAP_H (baseline pressure high)
P low	BAP (baseline pressure)
PEEP/CPAP	BAP (baseline pressure)
P-ramp	Rise time
Plimit	APL (adjustable pressure limit)
Vt	V_T (tidal volume)
%MinVol	$\%V_M$ (minute volume in relation to ideal body weight)
Flow (in high flow oxygen therapy)	Continuous flow
Rate	Rate
TI	ti (inspiratory time)
I:E	I:E ratio
T high	t_H
T low	t_L, BAP phase
Flow trigger	Flow trigger
ETS	Term'n Flow % (inspiratory termination flow or termination flow)
Base flow	Bias flow

Table 15-7. Monitoring-related terminology comparison, Hamilton Medical ventilators and EN ISO 19223:2019

Hamilton Medical terminology	EN ISO 19223 terminology
PEEP	PEEP
Paw	paw
Ppeak	Peak inspiratory pressure or peak pressure
Pplateau	Plateau inspiratory pressure or plateau pressure
AutoPEEP	AP (auto-PEEP)
Insp Flow	Peak inspiratory flow
Exp Flow	expiratory flow
ExpMinVol MinVol NIV	V_M (minute volume)
MVSpont MVSpont NIV	V_{MAddn} (additional minute volume)
VTI	V_I
VTE	V_{TE}
VLeak	V_{TLeak} (airway leak)
MV Leak	V_{MLeak} (leakage minute volume)
fTotal	RRtot (total rate)
fSpont	RRspont (spontaneous rate)
fControl	Rate
I:E	I:E
TI	ti or t_H (inspiratory time)
TE	t_{BAP} or t_L (expiratory time)
Cstat[1]	Cdyn

[1] Calculated using the least squares fitting method.

15.6 Control settings

Table 15-8. Control settings, ranges, and accuracy

Parameter or setting (unit)	Range: Adult/Ped	Range: Neonatal	Default settings: Adult/Ped	Default settings: Neonatal	Accuracy[1]
%MinVol[2] (%)	25–350	--	100	--	--
Apnea backup	On, Off	On, Off	On	On	--
ETS[3, 4] (%)	5–80	5–80	25	25	--
Flow[5] (l/min)	2–60	2–15	15	2	±10% or ±1 l/min, whichever is greater
I:E[6]	1:9–4:1	1:9–4:1	1:4	1:3	--
IBW[7] (kg)	3–139	--	70	--	--
Oxygen (%)	21–100	21–100	50	40	± (volume fraction of 2.5% + 2.5% gas level)
P high (in APRV) (cmH2O)	0–60	0–45	20 startup setting = PEEP + 15	20 startup setting = PEEP + 15	±5% or ±1 cmH2O, whichever is greater
P high (in DuoPAP) (cmH2O)	0–60	3–45	20	20	±5% or ±1 cmH2O, whichever is greater

[1] The stated accuracy includes the tolerance interval for each measurement.
[2] Only in ASV mode.
[3] Expiratory trigger sensitivity, in % of inspiratory peak flow.
[4] When changing ventilation modes, the device uses the ETS value set in the previous mode, if available. If the previous mode did not use ETS, the device sets ETS to default values.
[5] Only when using HiFlowO2.
[6] In PCV+ and APVcmv / (S)CMV+ modes, mandatory breath timing can be controlled by using a combination of inspiratory time (TI) and Rate, or by the I:E ratio; set the method in Configuration. All other modes are controlled by using a combination of inspiratory time (TI) and Rate.
[7] IBW is calculated using height and sex, and is used for adult and pediatric patients. Actual body weight is used for neonates.

Parameter or setting (unit)	Range: Adult/Ped	Range: Neonatal	Default settings: Adult/Ped	Default settings: Neonatal	Accuracy[1]
P low (in APRV) (cmH2O)	0–35	0–25	5	5	±5% or ±1 cmH2O, whichever is greater
Pat. height (cm) (in)	30–250 12–98	-- --	174 69	-- --	-- --
PEEP/CPAP (cmH2O)	0–35	3–25	5	5	±5% or ±1 cmH2O, whichever is greater
Plimit (cmH2O)	5–60	5–45	30	30	±5% or ±1 cmH2O, whichever is greater
P-ramp[2] (ms)	0–2000 ASV, NIV, NIV-ST, SPONT, VS: max = 200	0–600 NIV, NIV-ST, SPONT, nCPAP-PC, VS: max = 200	70	50	±10
Rate[3] (b/min)	1–80 APVcmv, PCV+: 4–80 PSIMV+, NIV-ST: 5–80	1–80 PSIMV+: 5–80 nCPAP-PC, APVcmv, PCV+, PSIMV+PSync, NIV-ST, APVsimv + Apnea Backup: 10–80	35 (3.0–5.9 IBW) 30 (6.0–8.9 IBW) 25 (9.0–19.9 IBW) 20 (20–30 IBW) 17 (31–39 IBW) 15 (40–59 IBW) 12 (60–139 IBW)	60 (0.2–1.25 kg) 45 (1.26–2.99 kg) 35 (3.0–5.9 kg) 30 (6.0–8.9 kg) 25 (9.0–19.9 kg) 20 (20–30 kg)	±1

[1] The stated accuracy includes the tolerance interval for each measurement.
[2] P-ramp is limited to one-third (1/3) of TI time. Adjustment of TI time can override the P-ramp setting. Limitation in ASV, SPONT, NIV, NIV-ST, nCPAP-PC: max 200 ms.
[3] Startup setting derived from IBW (adult/pediatric), body Weight setting (neonatal). Does not apply in ASV mode.

Parameter or setting (unit)	Range: Adult/Ped	Range: Neonatal	Default settings: Adult/Ped	Default settings: Neonatal	Accuracy[1]
Set temp[2] (°C)	INV: 35–41 NIV: 30–35 HiFlowO2: 33–37	INV: 35–41 NIV: 30–35 HiFlowO2: 33–37	INV: 37 NIV: 31 HiFlowO2: 35	INV: 37 NIV: 31 HiFlowO2: 35	--
Sex	Male, Female	--	Male	--	--
Sigh[3]	On, Off	--	Off	--	--
SpeakValve compati-bility	On, Off	--	Off	--	--
T gradient[4] (°C)	-2–3	-2–3	2	3	--
T high (in APRV)[5] (s)	0.1–40	0.1–40	Based on rate (IBW)	Based on rate (Weight)	±0.01
T high (in DuoPAP)[5] (s)	0.1–40	0.1–40	Based on rate (IBW)	Based on rate (Weight)	±0.01
T low (in APRV) (s)	0.2–40	0.2–40	Based on rate (IBW)	Based on rate (Weight)	±0.01
TI max (s)	0.5–3	0.25–3	1.5	1.0 (≤ 10 kg) 1.5 (> 10 kg)	±0.1
TI[5,6,7] (s)	0.1–12	0.1–12	Based on rate (IBW)	Based on rate (Weight)	±0.01

[1] The stated accuracy includes the tolerance interval for each measurement.
[2] When the humidifier is operating in HiFlow, the Set temp control *cannot* be set to a value higher than 39°C. If the control on the ventilator is set above 39°C, the setting is automatically rounded down to 39°C.
[3] Sigh is disabled in DuoPAP and APRV modes, when using HiFlowO2, when using CPR ventilation, and for neonates.
[4] T gradient is always set to 2°C when the humidifier is set to HiFlow.
[5] Startup setting derived from IBW (adult/pediatric), body Weight setting (neonatal). Does not apply in ASV mode.
[6] In PCV+ and APVcmv / (S)CMV+ modes, mandatory breath timing can be controlled by using a combination of inspiratory time (TI) and Rate, or by the I:E ratio; set the method in Configuration. All other modes are controlled by using a combination of inspiratory time (TI) and Rate.
[7] Inspiratory time; used with Rate to set the breath cycle time.

Parameter or setting (unit)	Range: Adult/Ped	Range: Neonatal	Default settings: Adult/Ped	Default settings: Neonatal	Accuracy[1]
Trigger, expiratory	ETS, IntelliSync+[2]	ETS	ETS	ETS	--
Trigger, flow[3] (l/min)	0.5–20 APVcmv, PCV+: 0.5–20 / Off	0.1–5 APVcmv, PCV+: 0.1–5.0 / Off	5	0.5	±10%
Trigger, inspiratory	Flow trigger, IntelliSync+[2]	Flow trigger	Flow trigger	Flow trigger	--
Vt/IBW Vt/Weight (ml/kg)[4]	5–12	5–12	8	5	--
Vt[5] (ml)	20–2000	2–300	Based on IBW	Based on Weight	*Adult/Ped.:* ±10% or ±10 ml, whichever is greater *Neo:* ±10% or ±2 ml, whichever is greater
Weight (kg)	--	0.2–30	--	2.0	--
ΔPcontrol[6] (cmH2O)	5–60	3–45 nCPAP-PC: 0–45	15	15	±5% or ±1 cmH2O, whichever is greater

[1] The stated accuracy includes the tolerance interval for each measurement.
[2] Not available in all markets.
[3] Flow trigger is leak compensated.
[4] Set in Configuration. IBW is calculated using height and sex, and is used for adult and pediatric patients. Actual body weight is used for neonates.
[5] Startup setting derived from IBW (adult/pediatric), body Weight setting (neonatal). Does not apply in ASV mode.
[6] Control pressure, added to PEEP/CPAP.

Parameter or setting (unit)	Range: Adult/Ped	Range: Neonatal	Default settings: Adult/Ped	Default settings: Neonatal	Accuracy[1]
ΔPinsp[2] (cmH2O)	3–60	3–45	15	15	±5% or ±1 cmH2O, whichever is greater
ΔPsupport[3] (cmH2O)	0–60	0–45	15	15	±5% or ±1 cmH2O, whichever is greater

[1] The stated accuracy includes the tolerance interval for each measurement.
[2] Inspiratory pressure, added to PEEP/CPAP.
[3] Pressure support, added to PEEP/CPAP.

15.7 Monitored parameters

Table 15-9 provides monitored parameter details.

Tables 15-10 and 15-11 list the ranges of the real-time curves and loops.

Pressure, flow, and volume measurements are based on readings from the flow sensor, and are expressed in BTPS (body temperature and pressure saturated).

The monitored parameters displayed on the ventilator are rounded to the nearest whole number, when required.

Waveforms displayed on the ventilator are not filtered and represent the actual monitored values.

Table 15-9. Monitored parameters, ranges, and accuracy

Parameter (units)	Range: Adult/Ped	Range: Neonatal	Accuracy[1]
Pressure			
AutoPEEP[2] (cmH2O)	0–80	0–80	±2 cmH2O + 4% of the actual reading
Driving pressure, ΔP (cmH2O)	0–100	0–100	±2 cmH2O + 4% of the actual reading
PEEP/CPAP (cmH2O)	0–80	0–80	±2 cmH2O + 4% of the actual reading
ΔPinsp[3] (cmH2O)	0–50	0–50	±2 cmH2O + 4% of the actual reading
Pmean (cmH2O)	0–80	0–80	±2 cmH2O + 4% of the actual reading
Ppeak (cmH2O)	0–80	0–80	±2 cmH2O + 4% of the actual reading
Pplateau (cmH2O)	0–80	0–80	±2 cmH2O + 4% of the actual reading
Pprox[4] (cmH2O)	0–80	0–80	±2 cmH2O + 4% of the actual reading

[1] The stated accuracy includes the tolerance interval for each measurement, except for measurements displayed from external sensors (CO2). See Section 15.12.1 for details.
[2] Not available in nCPAP, nCPAP-PC modes.
[3] Inspiratory pressure displayed in the Vent Status panel.
[4] Only in HiFlowO2.

Parameter (units)	Range: Adult/Ped	Range: Neonatal	Accuracy[1]
Flow			
Insp Flow (peak) (l/min)	0–260	0–260	*Adult/Ped.:* ±10% or ±20 ml/s, whichever is greater *Neo:* ±10% or ±2 ml/s, whichever is greater
Exp Flow (peak)[2] (l/min)	0–260	0–260	*Adult/Ped.:* ±10% or ±20 ml/s, whichever is greater *Neo:* ±10% or ±2 ml/s, whichever is greater
Flow (in HiFlowO2) (l/min)	2–60	2–15	--
Flow (in nCPAP/nCPAP-PC) (l/min)	--	0–30	±10% or ±20 ml/s, whichever is greater
Volume			
ExpMinVol[3, 4] MinVol NIV[5, 4] (l/min)	0–99.9	0–99.9	±10% or ±0.3 l/min, whichever is greater
MVSpont[3, 4] MVSpont NIV[5, 4] (l/min)	0–99.9	0–99.9	±10% or ±0.3 l/min, whichever is greater
VTE[3, 4] VTE NIV[5, 4] (ml)	0–9000	0–9000	*Adult/Ped.:* ±10% or ±10 ml, whichever is greater *Neo:* ±10% or ±2 ml, whichever is greater

[1] The stated accuracy includes the tolerance interval for each measurement, except for measurements displayed from external sensors (CO2). See Section 15.12.1 for details.
[2] Not available in HiFlowO2 or if SpeakValve is active.
[3] Only for invasive modes.
[4] Not available in nCPAP, nCPAP-PC modes.
[5] Only for use with noninvasive modes.

Parameter (units)	Range: Adult/Ped	Range: Neonatal	Accuracy[1]
VTESpont[2] (ml)	0–9000	0–9000	±10% or ±10 ml, whichever is greater
VTI[2] (ml)	0–9000	0–9000	*Adult/Ped.:* ±10% or ±10 ml, whichever is greater *Neo:* ±10% or ±2 ml, whichever is greater
Vt/IBW (ml/kg)	2–20	--	--
Vt/Weight (ml/kg)	--	2–20	--
VLeak[2] (%)	0–100	0–100	±10% (100 ml < VLeak < 2000 ml)
MVLeak[2] (l/min)	0–99.9	0–99.9	±10% or ±0.3 l/min, whichever is greater
Time			
I:E	9.9:1–1:99	9.9:1–1:99	--
fControl (b/min)	0–999	0–999	±1 b/min
fSpont[2] (b/min)	0–999	0–999	±1 b/min
fTotal (b/min)	0–999	0–999	±1 b/min
TI (s)	0–60	0–60	±100 ms
TE (s)	0–60	0–60	±100 ms

[1] The stated accuracy includes the tolerance interval for each measurement, except for measurements displayed from external sensors (CO2). See Section 15.12.1 for details.
[2] Not available in nCPAP, nCPAP-PC modes.

Parameter (units)	Range: Adult/Ped	Range: Neonatal	Accuracy[1]
Other calculated and displayed parameters			
CPR timer (mm:ss)	00:00–99:59	00:00–99:59	--
Cstat[2] (ml/cmH2O)	0–300	0–300	--
Oxygen (%)	18–105	18–105	± (volume fraction of 2.5% + 2.5% gas level)
O2 consumption[3] (l/min)	0–300	0–300	±10% or ±0.3 l/min, whichever is greater
P0.1[2] (cmH2O)	-99–0	-99–0	--
PTP[2] (cmH2O*s)	0–99	0–99	--
RCexp[4, 2] (s)	0–99.9	0–99.9	--
Rinsp[2] (cmH2O / (l/s))	0–999	0–999	--
RSB (1 / (l*min))	0–400	0–400	--
Ventilation counter (days/hours/minutes)	0–999	0–999	--

[1] The stated accuracy includes the tolerance interval for each measurement, except for measurements displayed from external sensors (CO2). See Section 15.12.1 for details.
[2] Not available in nCPAP, nCPAP-PC modes.
[3] If option is installed.
[4] Least square fit method.
[5] Only available if the CO2 communication board is installed and the CO2 sensor is enabled.

Parameter (units)	Range: Adult/Ped	Range: Neonatal	Accuracy[1]
CO2 related[2]			
FetCO2 (%)	0–20	0–20	CO2 (BTPS): 0–40 mmHg: ±2 mmHg 41–70 mmHg: ±5% of reading 71–100 mmHg: ±8% of reading 101–150 mmHg: ±10% of reading For sidestream CO2 sensor above 80 b/min: ±12% of reading
PetCO2 (mmHg)	0–150	0–150	
slopeCO2[3] (%CO2/l)	0–99.9	0–99.9	--
Vtalv[3] (ml)	0–9999	0–9999	--
V'alv[3] (l/min)	0–20	0–20	--
V'CO2[3] (ml/min)	50–9999	50–9999	--
VDaw[3] (ml)	0–999	0–999	--
VDaw/VTE[3] (%)	0–100	0–100	--
VeCO2[3] (ml)	0–999	0–999	--
ViCO2[3] (ml)	0–999	0–999	--

[1] The stated accuracy includes the tolerance interval for each measurement, except for measurements displayed from external sensors (CO2). See Section 15.12.1 for details.
[2] Only available if the CO2 communication board is installed and the CO2 sensor is enabled.
[3] Only for mainstream CO2.

Parameter (units)	Range: Adult/Ped	Range: Neonatal	Accuracy[1]
Humidifier related			
T humidifier (°C)	0–99.9	0–99.9	--
T Y-piece (°C)	0–99.9	0–99.9	--

Table 15-10. Real-time waveforms

Parameter	Range	Y-axis scale
All waveforms show time, in seconds, on the x-axis. *Adult/Ped waveforms: 6, 12, 18, 24, 30; Neonatal waveforms: 3, 6, 12, 18, 24*		
Volume[2, 3] (V) (ml) / time (s)	0–3200	0–5, 0–10, 0–25, 0–50 (*Neonatal default*), 0–100, 0–200, 0–400, 0–800 (*Adult/Ped default*), 0–1600, 0–3200
Flow[2, 3] (l/min) / time (s)	-300–300	±2.5, ±5, ±10 (*Neonatal default*), ±15, ±25, ±45, ±75 (*Adult/Ped default*), ±150, ±300
Airway pressure (Paw) (cmH2O) / time (s)	-10–120	-5–20, -5–40 (*default*), -5–80, -5–120
FCO2[4] (%) / time (s)	0–20	0–6 (*default*), 0–10
PCO2[4] (mmHg) / time (s)	0–150	0–60 (*default*), 0–100

[1] The stated accuracy includes the tolerance interval for each measurement, except for measurements displayed from external sensors (CO2). See Section 15.12.1 for details.
[2] Scaled automatically. Not leak compensated.
[3] Not applicable in nCPAP and nCPAP-PC modes.
[4] Available with the CO2 option.

Table 15-11. Real-time graphics and loops

Parameter	X-axis scale	Y-axis scale
ASV graphs[1,2]		
ASV target graphics: Vt/Rate x-axis: b/min y-axis: ml	0–60	0–5, 0–10, 0–25, 0–50, 0–100, 0–200, 0–400, 0–800 (*default*), 0–1600, 0–3200
Loops		
Pressure/Volume x-axis: cmH2O y-axis: ml	-10–80	0–3200
Volume/Flow x-axis: ml y-axis: l/min	0–3200	-300–300
Pressure/Flow x-axis: cmH2O y-axis: l/min	-10–80	-300–300
Volume/PCO2[3] x-axis: ml y-axis: mmHg	0–3200	0–100
Volume/FCO2[3] x-axis: ml y-axis: %	0–3200	0–10

[1] Not applicable when the HAMILTON-C1 neo option is enabled and the ventilator is dedicated to neonatal ventilation.
[2] Not applicable when the NIV-only option is enabled and the ventilator is dedicated to noninvasive ventilation.
[3] Available with the CO2 option.

15.8 Alarms

Table 15-12. Adjustable alarm priority, range, defaults, and resolution

Alarm (units)	Priority	Range: Adult/Ped	Range: Neo	Default: Adult/Ped	Default: Neo	Resolution
Apnea time[1] (s)	High	15–60	5–60	20	5	*Adult/Ped:* 5 *Neo:* 1 (< 15) 5 (≥ 15)
ExpMinVol (high)[2,1] (l/min)	High	0.1–50 NIV, NIV-ST: 0.1–50 / Off	0.03–10 / Off	Based on Rate and Vt 1.5 * Rate * Vt	Based on Rate and Vt 1.5 * Rate * Vt	*Adult/Ped.:* 0.1 (< 2) 0.5 (≥ 2) 1 (≥ 10) *Neo:* 0.01 (< 1) 0.1 (≥ 1)
ExpMinVol (low)[2,1] (l/min)	High	0.1–50 NIV, NIV-ST: Off / 0.1–50	Off / 0.01–10	Based on Rate and Vt 0.6 * Rate * Vt	Based on Rate and Vt 0.6 * Rate * Vt	*Adult/Ped.:* 0.1 (< 1) 0.5 (≥ 1) 1 (≥ 10) *Neo:* 0.01 (< 1) 0.1 (≥ 1)
Flow (high)[3] (l/min)	Medium	--	8–30	--	15	1
fTotal (high) (b/min)	Medium	0–99	2–210	40	70	1
fTotal (low) (b/min)	Medium	0–99	0–200	0	0	1

[1] Not applicable in nCPAP and nCPAP-PC modes.
[2] Startup setting derived from IBW (adult/pediatric), body Weight setting (neonatal). Does not apply in ASV mode.
[3] Only active in nCPAP and nCPAP-PC modes.

Alarm (units)	Priority	Range: Adult/Ped	Range: Neo	Default: Adult/Ped	Default: Neo	Resolution
Oxygen (high)[1,2] (%)	High	18–105	18–105	55 or +5 % of the current setting	55 or +5 % of the current setting	1
Oxygen (low)[1,2] (%)	High	18–97	18–97	45 or -5% of the current setting	45 or -5% of the current setting	1
PetCO2 (high)[3] (mmHg)	Medium	11–100/ Off	11–100/ Off	60	60	1
PetCO2 (low)[3] (mmHg)	Medium	Off / 10–99	Off /10–99	30	30	1
Pressure (high) (cmH2O)	High	15–70	18–55 nCPAP, nCPAP-PC: 10–55 APRV: 15–55	40	40 nCPAP, nCPAP-PC: 15	1
Pressure (low) (cmH2O)	High	4–60	4–55 nCPAP, nCPAP-PC: 2–55	PEEP	PEEP nCPAP: 3, nCPAP-PC: 5	1
Pressure limitation[4] (cmH2O)	Medium, Low after silence	5–60	8–45	Pmax - 10cmH2O	Pmax - 10cmH2O	1

[1] Active only when O2 monitoring is enabled.
[2] The high and low Oxygen alarm limits are automatically set in relation to the current Oxygen setting: Oxygen setting + 5 (high Oxygen limit) and Oxygen setting - 5 (low Oxygen limit). For example, if the Oxygen setting is 70%, the high Oxygen limit is set to 75 and the low limit is set to 65.
[3] CO2 option required.
[4] Can also be adjusted using Plimit. Pressure limitation is always 10 cmH2O below the pressure high limit.

Alarm (units)	Priority	Range: Adult/Ped	Range: Neo	Default: Adult/Ped	Default: Neo	Resolution
Vt (high)[1] (ml)	Medium	10–3000 / Off	0.1–300 / Off	Vt is based on IBW 1.5 * Vt	Vt is based on Weight 1.5 * Vt	*Adult/Ped.:* 5 (< 100), 10 (< 500), 50 (≥ 500), *Neo:* 0.1 (< 10), 1 (≥ 10 AND < 100), 5 (≥ 100)
Vt (low)[1] (ml)	Medium	Off / 10–3000	Off / 0.1–300	Vt is based on IBW 0.5 * Vt	Vt is based on Weight 0.5 * Vt	*Adult/Ped.:* 5 (< 100), 10 (< 500), 50 (≥ 500), *Neo:* Off, 0.1 (< 10), 1 (≥ 10 AND < 100), 5 (≥ 100)

[1] In ASV mode, this alarm only applies for spontaneous breaths.

15.9 Configuration

Table 15-13. Configuration specifications

Parameter	Configuration range	Default setting
General		
Language	English, US English, Chinese, Croatian, Czech, Danish, Dutch, Finnish, French, German, Greek, Hungarian, Indonesian, Italian, Japanese, Korean, Norwegian, Polish, Portuguese, Romanian, Russian, Serbian, Slovak, Spanish, Swedish, Turkish, Ukrainian	English
Units	Pressure: hPa, mbar, cmH2O	cmH2O
	CO2: mmHg, Torr, kPa	mmHg
	Length: cm, in	cm
More	Min. loudness	1
	FS alarm sensitivity: 5 to 15%, Off	12%
	HiFlowO2 limitation[1]: 2 to 15 l/min	15 l/min
Modes		
Philosophy	Inspiratory time philosophy: I:E, TI	I:E
	Mode label: (S)CMV+/SIMV+ or APVcmv/APVsimv	(S)CMV+/SIMV+
	ASV: ASV, ASV 1.1	ASV 1.1
	TI max available in invasive modes	Disabled
Graphics		
Main monitoring parameters (MMP)[2]	MMP 1 to 4: Pmean, PEEP/CPAP, Ppeak, ΔP (Driving pressure), ExpMinVol, VTI, VTE, VLeak, fTotal, fSpont, Oxygen, Cstat, Rinsp, I:E, TI, TE, MVSpont, AutoPEEP, P0.1, PTP, RCexp, Pplateau, VTESpont, MVLeak, Insp Flow, Exp Flow, Vt/IBW, Vt/Weight, T humidifier and T Y-piece (HAMILTON-H900)	Ppeak[3], ExpMinVol, VTE, fTotal

[1] Only applies to the Neonatal patient group.
[2] Additional parameters available when the CO2 option is installed.
[3] The default setting is configurable.

Parameter	Configuration range	Default setting
Settings	For all mode, control, and alarm settings, see the appropriate tables in this chapter.	
Setups	This information applies to the default adult/pediatric Quick setup configurations. You can also specify default neonatal settings. For information about CPR configuration settings, see Table 15-14.	
Mode Ctrls	Vt/IBW (*Adult/Ped.*): 5 to 12 ml/kg Vt/Weight (*Neo*): 5 to 12 ml/kg	*Adult/Ped.:* 8 ml/kg *Neo:* 5 ml/kg
Vent Status		
Oxygen[1] (%)	22 to 80	40
PEEP[2] (cmH2O)	1 to 20	8
ΔPinsp (cmH2O)	1 to 50	10
%MinVol high (%)	100 to 250	150
%MinVol low (%)	25 to 99	50
RSB high (1 / (l*min))	50 to 150	100
RSB low (1 / (l*min))	0 to 49	10
%fSpont[3] (%)	0 to 99	75
Connectivity		
More	Communication protocol: Hamilton, GALILEO compatible, Hamilton P2, Philips VueLink Open, DrägerTestProtocol, Hamilton Block Protocol	GALILEO

[1] The low Oxygen setting is always 21%.
[2] The low PEEP setting is always 0 cmH2O.
[3] The high %fSpont setting is always 100%.

Table 15-14. CPR default settings

Parameter	APVcmv	PCV+
For ranges, see Section 15.6.		
Apnea time (s)	10	10
Oxygen (%)	100	100
ΔPcontrol (cmH2O)	--	15
PEEP/CPAP (cmH2O)	5	5
Plimit (cmH2O)	45	45
Rate (b/min)	10	10
TI (s)	1	1
Vt/IBW (ml/kg)	6	--

15.10 ASV technical data

Table 15-15. ASV technical data

ASV-related data	Specifications
ASV-related operator settings	
%MinVol	25% to 350%
Patient height	*Adult:* 130 to 250 cm / 50 to 100 in *Pediatric:* 30 to 150 cm / 12 to 60 in
Internal calculations	
IBW	In kg, calculated based on patient height and sex (see Section 5.3)
MinVol (target)	In l/min, target minute volume is calculated as: IBW (in kg) x NormMinVent (in l/kg/min) x %MinVol/100 where NormMinVent is the normal minute ventilation from Figure 7-20.
fTotal	In b/min
VDaw	2.2 ml/kg IBW
Vt (target)	MinVol / f(target)
ASV graph	
Status of patient (numerical)	fControl, fSpont, ΔPinsp
Graphics display (curve)	fTotal versus Vt, target value, current value, safety window
Alarms	
All alarms are functional except apnea alarms	See Chapter 9
Special	ASV: Cannot meet target alarm

ASV-related data	Specifications
Performance specifications	
Response time (90% of steady state)	< 1 min (typical)
Overshoot/undershoot	< 25%
Maximum pressure change per breath	3 cmH2O
Settling time	< 120 seconds
Steady state deviation	< 10%
Lung-protective rules	
Minimum Vt	4.4 ml/kg x IBW
Maximum Vt depends on	The maximum tidal volume in ASV is the smallest value of the following conditions: • V / Pmedian x (Plimit − PEEP) • 15 ml/kg x IBW • 1.5 x high Vt alarm limit
Maximum machine rate	The maximum rate in ASV is the smallest value of the following conditions: • 1 / (minimum inspiratory time + minimum expiratory time) • MinVol (target) / Minimum Vt • 60 b/min
Minimum target rate	7.5 to 15 b/min (depending on IBW)
Minimum ΔPinsp	5 cmH2O above PEEP/CPAP
Maximum ΔPinsp	High Pressure alarm limit − 10 cmH2O − PEEP
Minimum inspiratory time (TI)	0.5 seconds or RCexp, whichever is longer
Maximum inspiratory time (TI)	IBW = 30 kg: 2 seconds IBW < 30 kg: 1.5 seconds
Minimum expiratory time (Te)	0.5 seconds or 2 x RCexp, whichever is longer
Maximum expiratory time (Te)	12 seconds
I:E range	1:4 to 1:1

15.11 Ventilator breathing system specifications

Table 15-16. Ventilator breathing system specifications

Parameter	Specification	
Resistance[1]	Adult/Ped circuit (ID15 to ID22, flow of 30 l/min)	≤ 0.06 cmH2O/l/min
	Adult/Ped circuit (ID12 to ID15, flow of 15 l/min)	≤ 0.12 cmH2O/l/min
	Neonatal circuit (ID09 to ID12, flow of 15 l/min)	≤ 0.12 cmH2O/l/min
Compliance[1]	Adult/Ped circuit (ID15 to ID22)	≤ 4.0 ml/cmH2O at 60 cmH2O ± 3 cmH2O
	Adult/Ped circuit (ID12 to ID15)	≤ 4.0 ml/cmH2O at 60 cmH2O ± 3 cmH2O
	Neonatal circuit (ID09 to ID12)	≤ 1.5 ml/cmH2O at 60 cmH2O ± 3 cmH2O
Volume[1]	Adult circuit (ID19)	2.4 l
	Neonatal circuit (ID10)	~ 0.9 l
Bacteria filter	Particle size	Captures particles of 0.3 microns with > 99.99% efficiency
	Resistance	< 2.0 cmH2O at 60 l/min
Flow sensor dead space	Adult/pediatric	< 9 ml (single use)
		< 11 ml (reusable)
	Neonatal	< 1.3 ml

[1] As tested, the inspiratory limb includes ambient valve, flow sensor, inspiratory filter, inspiratory tubes, and humidifier. It does not include the heating wire. The expiratory limb includes expiratory tubes, water trap, expiratory valve, and flow sensor.

15.12 Technical performance data

Table 15-17. Technical performance data

Description	Specification
Patient predicted body weight (IBW, determined from Pat. height setting (used for adult/pediatric patients)	3 to 139 kg (6.6 to 306 lb)[1]
Weight (used for neonatal patients)	0.2 to 30 kg (0.44 to 66 lb)
Inspiratory pressure	0 to 60 cmH2O
Maximum limited pressure	60 cmH2O
Maximum working pressure	*Adult/Ped:* 60 cmH2O (total inspiratory pressure). Ensured through pressure limiting *Neo:* 45 cmH2O (limitation depending on frequency)
Maximum inspiratory flow	260 l/min (120 l/min with 100% O2)
Tidal volume/target tidal volume	*Adult/Ped:* 20 to 2000 ml *Neo:* 2 to 300 ml
Minute volume capability	Up to 60 l/min
Inspiratory time (spontaneous breaths)	0.2 to 3 seconds
Minimum expiratory time	20% of cycle time; 0.2 to 0.8 seconds
Automatic expiratory base flow	*Adult/Ped:* Fixed at 3 l/min *Neo:* Fixed at 4 l/min
Means of inspiratory triggering	Flow trigger control
Oxygen mixer accuracy	± (volume fraction of 2.5% + 2.5% of actual reading)

[1] Actual patient weight can be much greater (e.g., 300 kg or 661 lb).

Description	Specification	
Measuring devices		
Continuous oxygen measurement	The delivered oxygen concentration is continuously measured when an O2 sensor is enabled.	
	Type of sensor: Galvanic lead-free O2 sensor	
	Sensing position:	Inspiratory pneumatics
	Measurement, delivered oxygen concentration, range:	18% to 105%
	Response time:	< 45 seconds to reach 90% of final oxygen concentration
	Initialization time (time from turning on device to operating performance):	< 40 seconds
	Drift:	< 0.1%/month of sensor output signal at dry ambient air
	Storage temperature:	-20°C to 40°C (-4°F and 104°F) -20°C to 50°C (-4°F and 122°F), for a maximum of 1 week To maximize the shelf life of unused lead-free galvanic O2 sensors, store them between 15°C and 25°C (59°F and 77°F). Storage at higher temperatures will shorten the life of the lead-free O2 sensor.
	Replacement	Every 2 years or when depleted, whichever comes first

Description	Specification	
Continuous oxygen measurement	*Type of sensor: Galvanic O2 sensor*	
	Sensing position:	Inspiratory pneumatics
	Measurement, delivered oxygen concentration, range:	18% to 105%
	Response time:	≤ 45 seconds to reach 90% of final oxygen concentration
	Initialization time (time from turning on device to operating performance):	< 40 seconds
	Drift:	≤ 1.0% vol. oxygen per month
	Storage temperature:	-20°C to 50°C (-4°F to 122°F) To maximize the shelf life of unused galvanic O2 sensors, store them between 5°C and 15°C (41°F and 59°F).
	Replacement	Every year or when depleted, whichever comes first
Pressure and volume measurements	Type:	Differential pressure transducer, variable orifice
	Sensing position:	Patient Y-piece
	Measurements:	See Table 15-9

Description	Specification	
CO2 measurement	Two types of CO2 sensors are supported: CAPNOSTAT-5 (mainstream) and LoFlo (sidestream)	
	Type: CAPNOSTAT 5	
	Sensing position:	Mainstream
	Principle of operation:	Nondispersive infrared (NDIR) technology
	Measurements:	See Table 15-9
	Rise time:	< 60 ms
	Initialization time:	Capnogram displayed in < 15 seconds at an ambient temperature of 25°C, full specifications within 2 minutes
	Sampling frequency:	100 Hz
	CO2 calculation method:	BTPS
	CO2 stability[1]:	Short-term drift: ≤ 0.8 mmHg over 4 hours Long-term drift: Accuracy specification maintained over 120 hours
	CO2 noise (rms):	≤ 0.25 mmHg at 7.5% CO2
	Operating conditions:	Temperature: 0°C to 45°C (32°F to 113°F) Humidity: 10% to 90% relative humidity, noncondensing Pressure (barometric + airway pressure): 400 mmHg to 850 mmHg
	Storage conditions:	Temperature: -40°C to 70°C (-40°F to 158°F) Humidity: < 90% relative humidity, noncondensing Pressure (atmospheric): 375 mmHg to 795 mmHg

[1] Neither humidity (noncondensing) nor cyclical pressures have any effect on the stated accuracy of the device.

Description	Specification	
CO2 measurement	*Type: LoFlo*	
	Sensing position:	Sidestream
	Principle of operation:	Nondispersive infrared (NDIR) technology
	Measurements:	See Table 15-9
	Rise time:	200 ms for on-airway adapter kits Additional 30 ms for sidestream sampling cannulas. Additional 80 ms for extension line and dehumidification tubing.
	Initialization time:	Capnogram displayed in < 20 seconds at an ambient temperature of 25°C, full specifications within 2 minutes
	Sampling frequency:	100 Hz
	Gas sampling rate:	50 ml/min ±10 ml/min
	CO2 calculation method:	Actual, corrected for temperature and pressure in the sample cell
	CO2 stability[1]:	Short-term drift: ≤ 0.8 mmHg over 4 hours Long-term drift: Accuracy specification maintained over 120 hours
	CO2 noise (rms):	≤ 0.25 mmHg at 5% CO2
	Sensing position:	Inside ventilator
	Measurements:	See Table 15-9
	Operating conditions:	Temperature: 0°C to 40°C (32°F to 104°F) Humidity: 10% to 90% relative humidity, noncondensing Pressure (barometric + airway pressure): 400 mmHg to 800 mmHg

[1] Neither humidity (noncondensing) nor cyclical pressures have any effect on the stated accuracy of the device.

Description	Specification	
CO2 measurement	Storage conditions:	Temperature: -40°C to 70°C (-40°F to 158°F) Humidity: 10% to 90% relative humidity, noncondensing Pressure (atmospheric): 400 mmHg to 800 mmHg
Tests and special functions	Leak test, flow sensor/circuit/O2 sensor/CO2 sensor zero calibration, O2 enrichment, manual breath, nebulization, leak compensation, communication interface, compensation of breathing circuit resistance and compliance	
Display device	Display of settings, alarms, and monitored data *Type:* Color TFT *Size:* 640 x 480 pixels, 8.4 in (214 mm) diagonal	
Brightness setting for display	The range is 10% to 100% brightness. By default, Day = 80%; Night = 40%.	
Classification of applied parts (IEC 60601-1)	Type BF Heated breathing tubes, SpO2 sensor, CO2 sensor, Nebulizer (integrated or standalone (supply through USB))	
Alarm volume (Loudness[1])	The range is 1 to 10. The default is 5.	
Sound power level[2]	51 dB(A) ±3 dB(A)	
Sound pressure level[2]	43 dB(A) ±3 dB(A)	

[1] Volume at 1 meter distance from ventilator. A setting of 1 = 62 dB(A), 5 = 76 dB(A), and 10 = 85 dB(A), with accuracy of ±3 dB(A).
[2] Per ISO 80601-2-12.

15.12.1 Accuracy testing

The ventilator's parameter and measurement accuracy is tested using an IMT FlowAnalyzer. The tolerance intervals for the data generated by the FlowAnalyzer are as specified below.

Table 15-18. Tolerance intervals for accuracy testing

Parameter type	Tolerance interval of measurement
Volume	≤ 50 ml: ±1% > 50 ml: ±1.75%
Pressure	±0.75% or ±0.1 cmH2O, whichever is greater
Flow	±1.75% or ±0.5 l/min, whichever is greater
O2	±1%

15.12.2 Essential performance

Table 15-19. Essential performance

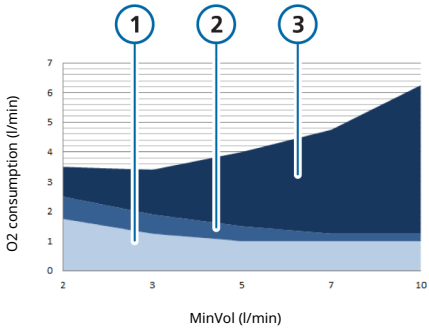
Component	Requirement
Gas supply failure	Gas supply failure must be detected and the operator informed.
Oxygen level alarm condition	If O2 is higher or lower than the set alarm limits or the O2 sensor fails, this must be detected and the operator informed through an alarm.
CO2 level alarm condition[1]	If CO2 is higher or lower than the set alarm limits or the CO2 sensor fails, this must be detected and the operator informed through an alarm.
SpO2 level alarm condition[1]	If SpO2 is higher or lower than the set alarm limits or the SpO2 sensor fails, this must be detected and the operator informed through an alarm.
Pressure	The airway pressure must be monitored. If it is higher or lower than the set alarm limits, this must be detected and the operator informed through an alarm.
Volume	The applied and expired volumes must be monitored. If they are higher or lower than the set alarm limits, this must be detected and the operator informed through an alarm.
Electrical supply failure	An electrical supply failure must be detected and the operator informed.
Internal electrical power source nears depletion	The remaining battery capacity must be monitored and qualitatively indicated. At least 5 minutes prior to depletion, an alarm must be issued.

[1] If option is installed.

15.12.3 Estimated oxygen consumption relative to minute volume

The following graphs show oxygen consumption as a function of minute volume.

Figure 15-3. Oxygen consumption as a function of minute volume, oxygen set to 60%



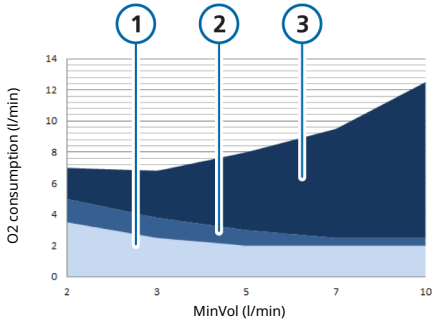
1 Oxygen consumption of the device. This accounts for base flow.

2 Compressible volume in the breathing circuit.

The compressible volume is a significant factor that must be taken into account for smaller patients due to smaller tidal volumes. See Section 5.8.1.2.1.

3 Oxygen volume delivered to patient.

Figure 15-4. Oxygen consumption as a function of minute volume, oxygen set to 100%



1 Oxygen consumption of the device. This accounts for base flow.

2 Compressible volume in the breathing circuit.

The compressible volume is a significant factor that must be taken into account for smaller patients due to smaller tidal volumes. See Section 5.8.1.2.1.

3 Oxygen volume delivered to patient.

15.13 Functional description of ventilator system

The HAMILTON-C1 is an electronically-controlled pneumatic ventilation system with an integrated air compressing system. It runs on AC power with battery backup to protect against power failure or unstable power and to facilitate intra-hospital transport.

The user provides inputs to the HAMILTON-C1 microprocessor system through a touch screen, keys, and a press-and-turn knob. These inputs become instructions for the HAMILTON-C1's pneumatics to deliver a precisely controlled gas mixture to the patient. The ventilator receives inputs from the proximal flow sensor and other sensors within the ventilator. Based on this monitored data, the ventilator adjusts gas delivery to the patient. Monitored data is also displayed by the graphical user interface.

The ventilator's microprocessor system controls gas delivery and monitors the patient. The gas delivery and monitoring functions are cross-checked by an alarm controller. This cross-checking helps minimize the possible hazards of software failure.

A comprehensive system of visual and audible alarms helps ensure the patient's safety. Clinical alarms can indicate an abnormal physiological condition. Technical alarms, triggered by the ventilator's self-tests including ongoing background checks, can indicate a hardware or software failure. In the case of some technical alarms, a special safety ventilation ensures basic minute ventilation while giving the operator time for corrective actions.

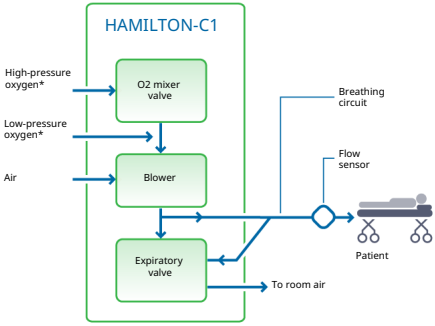
When a condition is critical enough to possibly compromise safe ventilation, the HAMILTON-C1 is placed into the Ambient state. The inspiratory channel and expiratory valves are opened, letting the patient inspire room air through the inspiratory channel and exhale through the expiratory valve.

The HAMILTON-C1 has several means to ensure that safe patient or respiratory pressures are maintained. The maximum working pressure is ensured by the high pressure alarm limit. If the set high pressure limit is reached, the ventilator cycles into exhalation. The ventilator pressure cannot exceed 60 cmH2O.

15.13.1 Gas supply and delivery

The HAMILTON-C1 uses room air and high- or low-pressure oxygen (Figure 15-5). The use of medical oxygen is mandatory. Air enters through a fresh gas intake port and is compressed together with the oxygen by the blower. Oxygen enters through a high[1]- or low[2]-pressure inlet.

Figure 15-5. Gas delivery in the HAMILTON-C1



** only one oxygen source required*

Within the ventilator, the gas enters the ventilator's pneumatic system. If high-pressure oxygen is supplied, a mixer valve provides for the operator-set concentration. If low-pressure oxygen is supplied, the delivered oxygen concentration is determined by the flow of the oxygen source.

Gas is supplied to the patient through the blower. The microprocessor controls the speed of the blower and the length of time it runs to meet the user settings.

The ventilator delivers gas to the patient through the inspiratory limb breathing circuit parts, which may include one or more of the following: inspiratory filter, flex tubes, humidification system, water traps, Y-piece, and flow sensor. An internal pneumatic nebulizer supplies the nebulizer flow.

Gas exhaled by the patient passes through the expiratory limb breathing circuit parts, which includes one or more of the following: flex tubes, flow sensor, Y-piece, and expiratory valve set. Gas is vented through the expiratory valve housing such that no exhaled gas comes into contact with any internal components of the ventilator. The expiratory valve is heated to reduce the possibility of rainout in the expiratory limb.

Measurements taken at the flow sensor are used in the pressure, flow, and volume measurements.

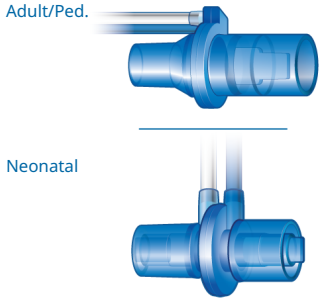
The ventilator monitors the oxygen concentration of the gas to be delivered to the patient using a galvanic O2 sensor. The galvanic O2 sensor generates a voltage proportional to the partial pressure of oxygen in the delivered gas.

The operations of the blower and expiratory valve are coordinated to maintain system pressure levels.

[1] High-pressure oxygen: Maximum allowed pressure is 6 bar (600 kPa).
[2] Low-pressure oxygen: Maximum allowed pressure is 600 kPa, maximum allowed flow 60 l/min.

15.13.2 Gas monitoring with the flow sensor

Figure 15-6. Flow sensor, illustrated



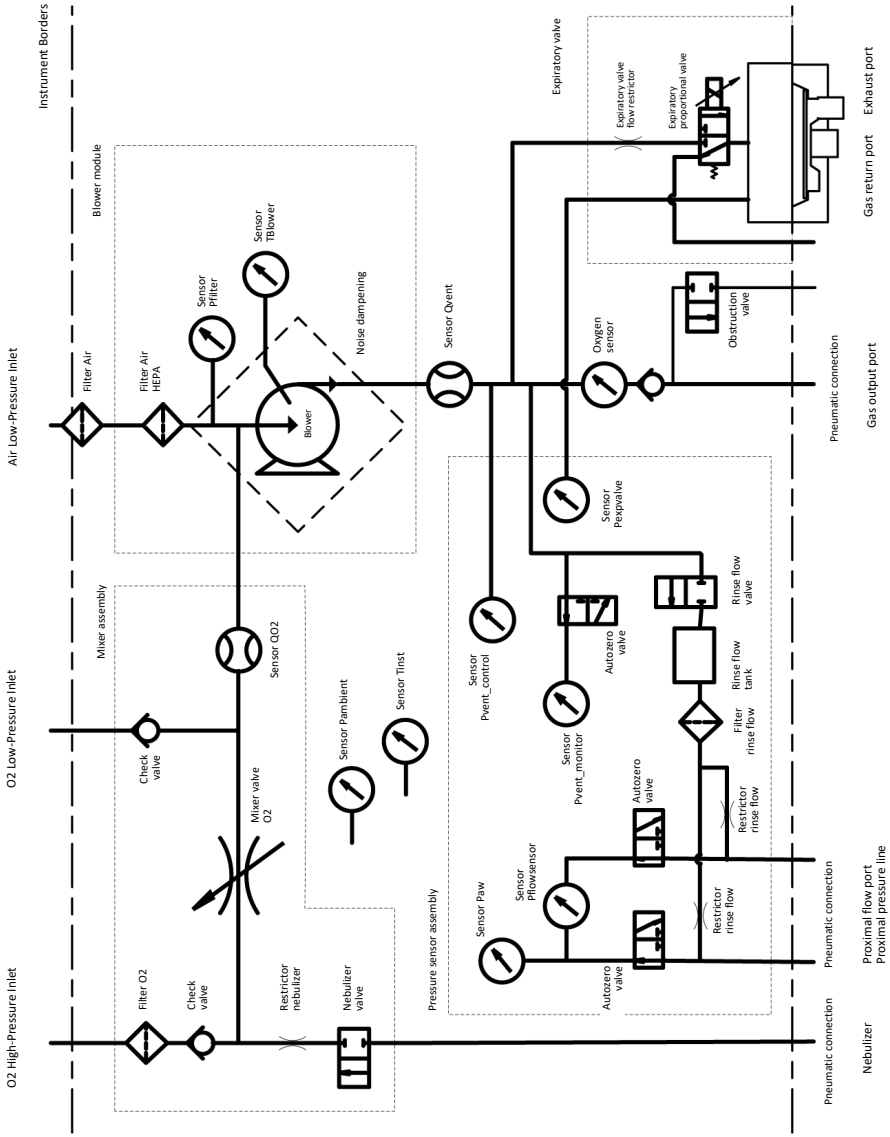
The HAMILTON-C1 accurately measures flow, volume, and pressure in the patient's airway with the Hamilton Medical flow sensor. This proximal flow sensor lets the ventilator sense even weak patient breathing efforts. Between its highly sensitive flow trigger and fast response time, the ventilator helps minimize the patient's work of breathing.

The flow sensor contains a thin membrane within the outer housing and has a pressure port on either side. The membrane allows bidirectional flow through its variable orifice.

The area of the orifice changes depending on the flow rate. It opens progressively as the flow increases, creating a pressure drop across the orifice. The pressure difference is measured by a high-precision differential pressure sensor inside the ventilator. The pressure difference varies with flow (relationship determined during flow sensor calibration), so the patient's flow is determined from the pressure drop. The ventilator calculates volume from the flow measurements.

The flow sensor is highly accurate even in the presence of secretions, moisture, and nebulized medications. The ventilator flushes the sensing tubes with mixed gases (rinse flow) to prevent blockage and contamination of the device.

15.13.3 Pneumatic diagram



15.14 Symbols used on device labels and packaging

Table 15-20. Symbols used on device, device labels, and packaging

Symbol	Definition
	Power/Standby key
	Day/Night key
	Screen lock/unlock
	Manual breath key
	O2 enrichment
	Print screen key
	Nebulizer key
2 MIN.	Audio pause key
NFC	Near field communication
	IntelliSync+
/COM1	HAMILTON-H900/COM1 port
	To patient inspiratory port
	From patient expiratory port
	Flow sensor connection ports
	Pneumatic nebulizer port
EXHAUST	Expiratory valve exhaust
	External equipment precaution
	USB port and warning for electrical connection
MR	The HAMILTON-C1 poses unacceptable risks to the patient, medical staff, or other persons within the MRI environment.
	Indicates the degree of protection against electric shock according to IEC 60601-1. Class II devices have double or reinforced insulation, as they have no provision for protective grounding.
DO NOT OBSTRUCT	Safety valve exhaust / Air intake filter cover
CO_2	CO2 sensor
SpO_2	SpO2 sensor
Neo / Ped / Adult	All patient groups

Symbol	Definition
Ped / Adult	Adult/Pediatric patient groups
INV NIV	Invasive and noninvasive modes
NIV	NIV-only option
	Refer to the operator's manual for complete information.
	Type B applied part (classification of medical electrical equipment, type B, as specified by IEC 60601-1)
	Type BF applied part (classification of medical electrical equipment, type BF, as specified by IEC 60601-1)
IP22	Protected against dripping water when the device is tilted to a maximum of 15 degrees, and from solid particles larger than 12.5 mm.
	Dispose according to Council Directive 2012/19/EU or WEEE (Waste Electrical and Electronic Equipment)
	Mass
SN	Serial number

Symbol	Definition
REF	Part number
	Manufacturer
	Date of manufacture
	Weight (10 kg)
	Female patient
	Male patient
	Neonatal patient
	Alarm Off
	Symbol for "Caution". Applied parts not protected against defibrillation.
	Applicable to neonatal patient group
	Applicable to pediatric patient group
	Applicable to adult patient group
	Applicable to neonatal/pediatric patient groups

Symbol	Definition
	Applicable to pediatric/adult patient groups
	Applicable to all patient groups
	This way up at transport and storage
	Fragile, handle with care at transport and storage
	Keep dry at transport and storage
	Single use
AC	Autoclavable. Autoclavable parts can be used inside an autoclave (for example, a steam autoclave) without damage. These parts withstand temperatures up to approximately 134°C. The correct way to reprocess autoclavable parts is described in the *Reprocessing Guide* provided by the manufacturer. Parts that Hamilton Medical terms as *autoclavable* can undergo autoclaving with steam sterilization without damage.
	Temperature limitations at transport and storage
	Humidity limitations at transport and storage

Symbol	Definition
	Atmospheric pressure limitations at transport and storage
	Stacking limitations at transport and storage
	Recyclable material
EU REP EC REP	Authorized representative in the European Community/ European Union
MD	Medical device
UDI	Unique device identifier
TÜV SÜD C US	The TÜV NRTL mark with the indicators "C" and "US" means that the product complies with Canadian requirements and the requirements of US authorities for safety.
CE 0197	CE Marking of Conformity, seal of approval guaranteeing that the device is in conformance with the Medical Device Regulation (EU) 2017/745 concerning medical devices
FC	Federal Communications Commission (FCC) Licensing

Symbol	Definition
	The RCM (Regulatory Compliance Mark) indicates a device's compliance with applicable ACMA (Australian Communications and Media Authority) technical standards for telecommunications, radio communications, or broadcasting equipment.
	Chinese RoHS
R 202-LSF056 T D 17-0014 202	*Japan only*. Ministry of Internal Affairs and Communications Approval Label

15.14.1 Symbols used on the trolley

Figure 15-7. Trolley warning stickers

1	Make sure the wheel brakes are unlocked when moving the trolley	3	Do not park the trolley on an incline greater than 5 degrees
2	Do not lean on the trolley	4	Weight The maximum safe working load applies to a stationary, properly load-balanced trolley.

15.15 Standards and approvals

The HAMILTON-C1 was developed in accordance with pertinent international standards and FDA guidelines.

The ventilator is manufactured under a QMS system as required by EN ISO 13485, ISO 9001 and article 10(9) of Regulation EU 2017/745.

The ventilator meets the general safety and performance requirements according to Regulation (EU) 2017/745, Annex I.

Where standards are mentioned, the HAMILTON-C1 complies with the versions listed in Table 15-22.

The ventilator meets relevant parts of the following standards, listed in Table 15-21.

Table 15-21. Standards

IEC 60601-1	Medical electrical equipment, Part 1: General requirements for basic safety and essential performance. The device classification is: Class II, Type B applied part (ventilator breathing system, VBS), type BF applied part (CO2 sensor including CO2 module connector, and SpO2 sensor including SpO2 adapter), continuous operation

IEC 60601-1-2	Medical electrical equipment - Part 1-2: General requirements for basic safety and essential performance. • Collateral standard: Electromagnetic disturbances • Requirements and tests
IEC 60601-1-10	Medical electrical equipment - Part 1-10: General requirements for basic safety and essential performance. Collateral Standard: Requirements for the development of physiologic closed-loop controllers
ISO 80601-2-12	Medical electrical equipment - Part 2-12: Particular requirements for the basic safety and essential performance of critical care ventilators
EN ISO 5356-1	Anaesthetic and respiratory equipment - conical connectors - Part 1: Cones and sockets
EN ISO 80601-2-55	Medical electrical equipment - Part 2-55: Particular requirements for the basic safety and essential performance of respiratory gas monitors

Table 15-22. Standards and approvals, valid versions

IEC 60601-1:2005/A1:2012
IEC 60601-1-2:2014
ISO 80601-2-12:2011 + Cor.:2011
ISO 80601-2-55:2018
IEC 61000-3-2:2005
IEC 61000-3-3:2008
IEC 61000-4-2:2008
IEC 61000-4-3:2006 + A1:2007+A2:2010
IEC 61000-4-4:2004
IEC 61000-4-5:2005
IEC 61000-4-6:2003+A1:2004+A2:2006
IEC 61000-4-8:2009
IEC 61000-4-11:2004
EN ISO 5359:2008 + A1: 2011
IEC 60950-1:2013
ISO 15883-1:2006+A1:2014
ISO 15883-2:2006
ISO 15883-3: 2006
ISO 15883-4:2008
ISO 11607-1: 2006 + AMD1:2014
EN ISO 5356-1:2015
ISO 4135:2001

15.16 Disposal and year of manufacture

Disposal

The device must be disposed of according to your institution's protocols and Directive 2012/19/EU.

All parts removed from the device must be considered contaminated, and pose infection risk.

Dispose of all parts removed from the device according to your institution's protocol. Follow all local, state, and federal regulations with respect to environmental protection, especially when disposing of the electronic device or parts of it (for example, O2 sensor, batteries).

Year of manufacture

The year of manufacture is shown on the serial number label on the HAMILTON-C1 ventilation unit.

15.17 Warranty

LIMITED WARRANTY

THE WARRANTY DESCRIBED IN THIS AGREEMENT IS IN LIEU OF ANY AND ALL OTHER WARRANTIES, EXPRESS OR IMPLIED, INCLUDING IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE. HOWEVER, IMPLIED WARRANTIES ARE NOT DISCLAIMED DURING THE PERIOD OF THIS LIMITED WARRANTY.

Hamilton Medical guarantees its products to be shipped free from defects in material and workmanship.

The warranty does not include disposable items. Disposable items and consumable products are considered to be of single use or of limited use only and must be replaced regularly as required for proper operation of the product following the operator's manual.

Hamilton Medical shall have no obligations nor liabilities in connection with the product other than what is specified herein, including without limitation, obligations and/ or liabilities for alleged negligence, or for strict liability.

In no event shall the company be liable for incidental or consequential damages, either direct or contingent.

This Limited Warranty shall be void and not apply:

1. If the product has not been installed and connected by an authorized local representative of Hamilton Medical in accordance with the instructions furnished by Hamilton Medical and by a Hamilton Medical representative.
2. If replacements and/or repairs have not been performed by authorized or properly trained personnel.
3. If no evidence is present that the occurrence of damage/ repair happened within the certified warranty period.
4. If the serial number has been altered, effaced or removed and there is no bill of sale or evidence to verify the product's purchase date.

5. If the defects arise from misuse, negligence, or accidents or from repair, adjustment, modification or replacement made outside Hamilton Medical's factories or other than an authorized service center or authorized service representative.
6. If the product has been modified, or in any nature altered without prior written authorization from Hamilton Medical.
7. If yearly preventative maintenance is not performed.
8. If the product is or has been used in any way that is not specified under "Intended Use" (see "General cautions and notes").
9. If the product has been used by anyone but properly trained personnel under the supervision of a physician. Replacements and/or repairs furnished under this Limited Warranty do not carry a new warranty, but carry only the unexpired portion of the original Limited Warranty. The warranty of repaired and/or replaced components does not exceed the Limited Warranty of the device.

To obtain service under this Limited Warranty, claimant must promptly notify the country's sales partner of Hamilton Medical regarding the nature of the problem, serial number and the date of purchase of the Product.

Except as stated above, Hamilton Medical shall not be liable for any damages, claims or liabilities including, but not limited to, personal bodily injury, or incidental, consequential, or special damages. Nor will Hamilton Medical be liable for any damages, claims or liabilities including, but not limited to, personal bodily injury, or incidental, consequential, or special damages resulting from misuse of the device or failure to comply with any of the provisions made in this manual.

The general terms and conditions of Hamilton Medical shall be applicable. This agreement shall be governed by and construed in accordance with the laws of Switzerland and may be enforced by either party under the jurisdiction of the court of Chur, Switzerland.

(S)CMV+
See APVcmv

alarm lamp
Lamp on top of the ventilator that lights in the color corresponding to the active alarm

Alarm Off symbol
Displayed when the associated alarm limit is disabled (set to Off)

apnea
Cessation of breathing

APRV
Airway pressure release ventilation, a ventilation mode

APVcmv
Adaptive pressure ventilation with controlled mandatory ventilation, a ventilation mode; can also be shown as (S)CMV+ (configurable)

APVsimv
Adaptive pressure ventilation with synchronized intermittent mandatory ventilation, a ventilation mode; can also be shown as SIMV+ (configurable)

ASV
Adaptive support ventilation mode. ASV adjusts pressure and rate on a breath-by-breath basis, taking into account changing patient conditions and applying lung-protective strategies to meet the targets

ASV Graph
An Intelligent panel that shows ASV target and patient data graphically, available in ASV mode

AutoPEEP
Unintended positive end-expiratory pressure, a monitored parameter

b/min
Breaths per minute

backup
Apnea backup ventilation

backup buzzer
A buzzer that sounds for at least 2 minutes in certain conditions; also functions as a backup for the ventilator loudspeaker

base flow
A continuous and constant gas flow from the inspiratory outlet to the expiratory outlet

breathing circuit set
Breathing limbs and components used to deliver respiratory gases to the patient

BTPS
Body temperature, barometric pressure at sea level, saturated with water vapor

CE
A seal of approval guaranteeing that the device is in conformance with the Medical Device Regulation (EU) 2017/745 concerning medical devices

control
A virtual dial, slider or other input icon on the display that allows you to specify the value of a setting

control setting, control parameter
Any setting that the ventilator uses as an input for the delivered ventilation therapy. For example, PEEP/CPAP, IBW, or Weight, Vt, and so on. Note that some control settings, such as IBW, are not directly specified by the user.

CPR timer
Displayed as an MMP during CPR ventilation, shows how long CPR ventilation has been on

CPR ventilation
CPR ventilation allows you to continue respiration during the administration of cardiopulmonary resuscitation.

Cstat
Static compliance, a monitored parameter

Driving pressure (ΔP)
A calculated value showing the ratio of tidal volume to static compliance, which reflects the difference between Pplateau and PEEP total; can provide information to help optimize ventilation for ARDS patients

DuoPAP
Duo positive airway pressure, a ventilation mode

Dynamic Lung
Intelligent panel that graphically represents tidal volume, lung compliance, resistance, and patient triggering in real time

EMC
Electromagnetic compatibility

EMI
Electromagnetic interference

EN
European norm, a European standard

ET tube
Endotracheal tube. Tube inserted into the patient airway, used in invasive ventilation, to deliver breathing gas from the ventilator.

ETS
Expiratory trigger sensitivity is the percent of peak inspiratory flow at which the ventilator cycles from inspiration to exhalation.
Increasing the ETS setting results in a shorter inspiratory time. The ETS setting lets you match the inspiratory time of pressure-supported breaths to the patient´s neural timing.

event log
A record of clinically relevant ventilator occurrences, including alarms, settings changes, calibrations, maneuvers, and special function uses that have occurred since the ventilator was turned on

Exp Flow
Peak expiratory flow, a monitored parameter

ExpMinVol
Expiratory minute volume, a monitored parameter and alarm setting; in the Vent Status panel, ExpMinVol is the percentage of normal minute ventilation based on IBW

f
Respiratory rate

fControl
Mandatory breath frequency, a monitored parameter

FDA
United States Food and Drug Administration

FetCO2
Fractional end-tidal CO2 concentration, a monitored parameter

Flow (in nCPAP/nCPAP-PC)
In the neonatal nCPAP and nCPAP-PC modes, monitored parameter that measures and displays the current flow; the upper (high) limit is controlled by the Flow alarm

fSpont
Patient-initiated breath frequency, a monitored parameter

fTotal
Total breathing frequency, a monitored parameter and alarm setting

HEPA
High efficiency particle air filter

HME, HMEF
Heat and moisture exchanger (artificial nose), heat and moisture exchanging filter

HPO
High-pressure oxygen

I:E
Ratio of inspiratory time to expiratory time, a setting, timing parameter, and monitored parameter

IBW
Ideal body weight, a calculated value for adult and pediatric patients based on the patient's sex and height; used as the basis for initial settings of various parameters

ID
Inner diameter

IEC
International Electrotechnical Commission

Insp Flow
Peak inspiratory flow, a monitored parameter

inspiratory pressure
The total inspiratory pressure to be applied during ventilation. In some modes, this is the sum of the pressure control + PEEP/CPAP

Intelligent panel
A type of graphic display on the ventilator

IntelliTrig
Intelligent trigger, a feature that ensures that the set trigger sensitivity can trigger a breath independent from leakage and breath pattern

IRV
Inverse ratio ventilation: the set expiratory time is less than the inspiratory time

ISO
International Organization for Standardization

loudness
Sets the volume for the audible ventilator alarms

LPO
Low-pressure oxygen

LSF
Least squares fitting method; a mathematical procedure for finding the best fitting curve for a given set of points by minimizing the sum of the squares of the offsets of the points from the curve

mandatory breath
The start of inspiration (triggering) is determined by the ventilator or the patient. The end of inspiration (cycling) is determined by the ventilator.

manual breath
A user-triggered mandatory breath started by pressing the Manual breath key

MinVol (%)
Minute volume, a calculated and monitored parameter used in ASV mode; based on the operator-set %MinVol, the ventilator calculates the target MinVol in l/min, then measures and displays this value in the ASV Graph

MVLeak
Total minute volume leakage; MVLeak shows VLeak * frequency (respiratory rate)

MVSpont
Spontaneous expiratory minute volume, a monitored parameter

nCPAP
Neonatal-only ventilation mode that applies CPAP over a nasal interface (mask or prongs)

nCPAP-PC
Neonatal-only ventilation mode that delivers, in addition to the set CPAP, intermittent, time-cycled, and pressure-controlled breaths

NIST
Noninterchangeable screw thread, a standard for high-pressure gas inlet fittings

NIV
Noninvasive ventilation, a ventilation mode

NIV-ST
Spontaneous/timed noninvasive ventilation, a ventilation mode

NPPV
Noninvasive positive pressure ventilation

OD
Outer diameter

Oxygen
Oxygen concentration of the delivered gas, a control setting and a monitored parameter

P high
High pressure in APRV and DuoPAP modes

P low
Low pressure setting in APRV mode

P&T knob
Press-and-turn knob; used to navigate the display, select list items, activate controls, and set values

P0.1
Airway occlusion pressure, a monitored parameter

Pat. height
Patient height; a control setting used to compute the patient's ideal body weight (IBW) in calculations for ASV and startup settings

patient group
A control setting used to define initial startup settings for the patient; options are Adult/Ped. (adult and pediatric patients) and Neonatal

PCV+
Pressure controlled ventilation, a ventilation mode

PEEP/CPAP
PEEP (positive end-expiratory pressure) and CPAP (continuous positive airway pressure), a control setting and monitored parameter; PEEP and CPAP are constant pressures applied during both the inspiratory and expiratory phases

PetCO2
Partial pressure of end-tidal CO2, the measure of CO2 present in the exhaled air

Plimit
Maximum pressure to apply during ventilation, a control setting

Pmean
Mean airway pressure, a monitored parameter

Ppeak
Peak airway pressure, a monitored parameter

Pplateau
Plateau or end-inspiratory pressure, a monitored parameter

P-ramp
Pressure ramp, a control setting

pressure control
Maintenance of a consistent transrespiratory pressure waveform despite changing respiratory system mechanics

PSIMV+
Pressure-controlled synchronized intermittent mandatory ventilation, a ventilation mode

PTP
Inspiratory pressure time product, a monitored parameter

Rate
Breath frequency or number of breaths per minute, a control setting

RCexp
Expiratory time constant, a monitored parameter

Rinsp
Inspiratory flow resistance, a monitored parameter

RSB
Rapid shallow breathing index, a monitored parameter

Sex
Sex of patient, a control setting

sigh
Breaths delivered to deliberately increase tidal volume at a regular interval. If enabled, a sigh breath with an additional 10 cmH2O is delivered every 50 breaths. Note

that in volume-controlled modes, a sigh breath delivering 150% of the set tidal volume is delivered every 50 breaths.

SIMV+
See APVsimv

slopeCO2
Slope of the alveolar plateau on the FCO2 / Volume curve, a monitored parameter

speaking valve (SpeakValve)
A speaking valve allows certain tracheostomized adult and pediatric patients to communicate verbally, in addition to other clinical benefits. This ventilator supports the use of a speaking valve with the Speaking valve option. In the Controls window, the SpeakValve button provides access to the On and Off controls, together with important safety information.

SPONT
Spontaneous (pressure support) mode of ventilation, a ventilation mode

spontaneous breath
A breath for which both the inspiratory and expiratory triggers are controlled by the patient; the patient both triggers and cycles the breath

Standby
The ventilator is in a waiting state; there is no breath delivery

STPD
Standard temperature and pressure, dry; defined as dry gas at 0°C (32°F) at 758 mmHg (101 kPa) pressure at sea level

T high
Set time interval for the high pressure level in the APRV and DuoPAP modes

T humidifier
HAMILTON-H900 humidifier only. Measured temperature at the humidification chamber exit, a monitored parameter

T low
Set time interval for the low pressure level in APRV mode

T Y-piece
HAMILTON-H900 humidifier only. Measured temperature at the humidifier Y-piece, a monitored parameter

TE
Expiratory time, a monitored parameter

technical fault
A type of alarm generated when the ventilator's ability to safely ventilate the patient may be at risk

TI
Inspiratory time, a control setting and monitored parameter

TI max
Maximum inspiratory time, a control setting

touch screen
The glass portion of the monitor that you touch to interact with the display elements

trends
Trend data for a selected parameter or group of parameters includes all of that parameter's data values since the ventilator was turned on for the past selectable period of time

trigger
The patient's inspiratory effort that causes the ventilator to deliver a breath, a control setting; controlled by flow, pressure, or IntelliSync+

V'alv
Alveolar minute ventilation, a monitored parameter

V'CO2
Net exhaled volume of CO2, a monitored parameter

VDaw
Airway dead space

VDaw/VTE
Airway dead space fraction at the airway opening, a monitored parameter

VeCO2
Expiratory CO2 volume, a monitored parameter

Vent Status panel
An Intelligent Panel that illustrates six parameters related to the patient's ventilator dependence, including oxygenation and patient activity

ventilator breathing system (VBS)
A breathing system bounded by the low-pressure gas input port(s), the gas intake port(s), and the patient connection port, together with the fresh-gas inlet and exhaust port(s), if fresh-gas inlet or exhaust ports are provided, as described in ISO 4135

ViCO2
Inspiratory CO2 volume, a monitored parameter

VLeak
Leakage percent, a monitored parameter

Volume Support (VS)
A ventilation mode; breaths in VS are volume-targeted and spontaneous. Pressure is adjusted between breaths to achieve the target tidal volume

Vt
Tidal volume; a control setting, alarm setting, and monitored parameter

Vt/IBW
Tidal volume calculated according to ideal body weight, used for adult/pediatric patients; a monitored parameter

Vt/Weight
Tidal volume calculated according to actual body weight, used for neonatal patients; a monitored parameter

Vtalv
Alveolar tidal ventilation, a monitored parameter

VTE
Expiratory tidal volume, a monitored parameter; it is the integral of all negative flow measurements during exhalation

VTESpont
Spontaneous expiratory tidal volume, a monitored parameter

VTI
Inspiratory tidal volume, a monitored parameter

ΔPcontrol
Pressure control, a control setting valid during mandatory breaths; pressure (additional to PEEP/CPAP) to be applied during the inspiratory phase

ΔPinsp
Inspiratory pressure, the target pressure (additional to PEEP/CPAP) to be applied during the inspiratory phase. Set by the operator in the PSIMV+PSync and NIV-ST modes; displayed in the Vent Status panel and the ASV Graph.

ΔPsupport
Pressure support, a control setting valid during spontaneous breaths. ΔPsupport is pressure (additional to PEEP/CPAP) to be applied during the inspiratory phase.

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