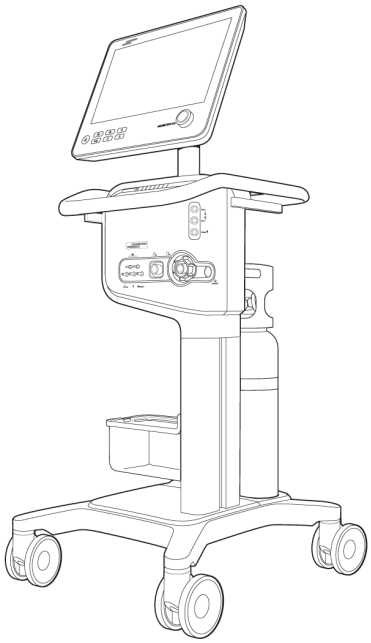




HAMILTON-C6

Operator's Manual

REF 160021

Software version 1.x.x

624945/02 | 2021-02-15

CE 0197

HAMILTON MEDICAL

Intelligent Ventilation since 1983

Operator's Manual

HAMILTON-C6

2021-02-15

624945/02

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HAMILTON-C6 documentation

This guide is part of a documentation suite that includes, among others, the following documents:

Table 1. HAMILTON-C6 documentation suite

Document title	Description
Operator's Manual (this guide)	Provides detailed information about the setup and use of the HAMILTON-C6 ventilator.
INTELLiVENT-ASV Operator's Manual	Provides setup and use information for the INTELLiVENT-ASV ventilation mode.
Pulse Oximetry Instructions for Use	Provides setup and use information for using SpO2 and related sensors with the ventilator.
Volumetric Capnography User Guide	Provides reference information for CO2 capnography.
HAMILTON-H900 Instructions for Use	Provides specifications, and setup and use information for the HAMILTON-H900 humidifier
IntelliCuff Instructions for Use	Provides specifications, and setup and use information for the IntelliCuff cuff pressure controller.
Aerogen Solo/Aerogen Pro Instructions for Use	Provides specifications, and setup and use information for the Aerogen Solo and Aerogen Pro nebulizers.
Communication Interface User Guide	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.
Service Manual	Provides information about installing and setting up the medical equipment, as well as additional technical and servicing information for the ventilator.
EMC Declarations Guide	Provides emissions and EMC-related safety and use information.
HAMILTON-C6 Installation Guide	Provides installation and setup information for the ventilator and the trolley.

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

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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 *Open the System > Settings window* means touch the **System** button, then touch the **Settings** tab.
- The graphics shown in this manual may not exactly match what you see in your environment.
- The graphics shown in this manual may display either of the product logos: HAMILTON-C6 or HAMILTON-C6S. The HAMILTON-C6S is not available in all markets.
- *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.
- *Software version:* The software version for the ventilator is displayed in the System > Info 1 window and should match the version on the title page of this manual.

Safety messages are displayed as follows:

⚠ WARNING

A WARNING alerts the user to the possibility of injury, death, or other serious adverse reactions associated with the use or misuse of the device.

⚠ CAUTION

A CAUTION alerts the user to the possibility of a problem with the device associated with its use or misuse, such as device malfunction, device failure, damage to the device, or damage to other property.

NOTICE

A NOTICE emphasizes information of particular importance.

In tables, safety messages are indicated as follows:

⚠ WARNING!

⚠ CAUTION!

NOTICE!

Intended use

The HAMILTON-C6 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 health care facilities

The HAMILTON-C6 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.

⚠ WARNING

(USA only) INTELLiVENT-ASV is not available in the USA.

⚠ CAUTION

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

1 Safety information

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1.10 Service and testing 35

1.1 Overview

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

Be sure to review this Operator's Manual before using the ventilator and any accessories.

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 Electromagnetic susceptibility

⚠ WARNING

- **MR UNSAFE.** Keep away from magnetic resonance imaging (MRI) equipment. The HAMILTON-C6 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 or provided by the manufacturer of this equipment can result in increased electromagnetic emissions or decreased electromagnetic immunity of this equipment, and may result in improper operation.
- 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 HAMILTON-C6 ventilator, including any cables specified by the manufacturer. Otherwise, degradation of the performance of this equipment can occur.
- 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.
- Ensure a minimum of 5 cm distance between the monitor (interaction panel) and any 125 kHz RFID equipment.

The HAMILTON-C6 complies with the IEC 60601-1-2 EMC (Electromagnetic Compatibility) Collateral Standard.

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 624982).

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

1.3 Fire and other hazards

⚠ WARNING

- It is *not* permitted to use any of the equipment with flammable gases or anesthetic agents, or in insufficiently ventilated areas. Danger of fire!
- It is *not* permitted to use the ventilator with helium or mixtures of helium.
- 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 could 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* use if primary power source cables are damaged.
- The HAMILTON-C6 can be used in an oxygen-enriched environment. To reduce the risk of fire, use only breathing circuits intended for use in oxygen-enriched environments. Do *not* use antistatic or electrically conductive tubing.

1.4 General operation and setup

This section provides the following safety information:

- General operation and setup
- Electrical: power and batteries
- Oxygen supply
- USB ports

1.4.1 General operation and setup

⚠ WARNING

- Modifications to the device and any accessories are *not* permitted.
- In case of ventilator failure, the lack of immediate access to appropriate alternative means of ventilation can result in patient death.
- 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 a Hamilton Medical authorized service engineer.
- To ensure proper ventilation operation, avoid degraded performance, and keep your warranty in force, use only parts and accessories specified in Chapter 15 and in the product e-catalog, or that are specified as being compatible with this ventilator.
- The use of this equipment is restricted to one patient at a time.

- Only use the ventilator and its components and accessories according to the intended use and as described in the associated *Instructions for Use*.
- Do *not* connect any component or device to the exhaust port of the expiratory valve unless authorized by Hamilton Medical.
- The ventilator must *not* be used in a hyperbaric chamber.
- 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 (for example, the USB port) or conductive parts of the ventilator enclosure and the patient.
- 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 that the system complies with the requirements for medical electrical systems. Local laws take priority over the above-specified requirements.

⚠ CAUTION

To prevent possible patient injury, do NOT block the holes at the back and bottom of the ventilator. These holes are vents for the fresh air intake and the cooling fan.

NOTICE

- 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.

1.4.2 Electrical: power and batteries

⚠ WARNING

- *(USA only)* To ensure grounding reliability, use a special hospital-grade receptacle.
- Ventilation stops if the internal battery or batteries are discharged and no external power supply is connected.
- To minimize the risk of electrical shock, plug the ventilator power cord into an appropriate grounded power receptacle. It is the hospital's responsibility to ensure that the receptacle is properly grounded (earth).
- The HAMILTON-C6 requires protective earth grounding, because it is a class I device, as classified according to IEC 60601-1.
- Power sockets that can lead to a failure of ventilation *must* have a locking device.
- It is the responsibility of the operator to ensure that the power system of any device connected to the ventilator power outlet complies with the requirements for medical electrical systems as well as local regulations.
- Periodically check or replace the battery.

- Check the battery charge level before ventilating a patient and before unplugging the ventilator for transport or other purposes.
- The batteries will *not* charge if the ambient temperature is above 43°C.

⚠ CAUTION

To electrically isolate the ventilator electrical circuits from all poles of the primary power supply simultaneously, disconnect the power plug.

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 life 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.
- After power has been interrupted, the device stores the last settings, including any specified alarm limits. Upon reconnection with the power supply, the device resumes ventilation with these stored settings.

1.4.3 Gas supply

⚠ CAUTION

Always check the status of the oxygen cylinders or other supply before using the ventilator during transport.

NOTICE

To prevent damage to the ventilator, connect only clean, dry medical grade oxygen.

1.4.4 USB ports

⚠ WARNING

- During transfer of a ventilated patient, to prevent water intake, the ventilator USB port 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.
- The USB connector is intended for passive memory devices only.
- The memory device must be USB 1.1 compatible.

1.5 Setting up for ventilation

This section provides the following safety information:

- Patient breathing circuits, components, and accessories
- Performing preoperational checks and testing
- Humidifier
- IntelliCuff
- CO2 monitoring setup and operation
- Nebulization
- SpO2 monitoring setup and operation

  See the *Pulse Oximetry Instructions for use*.

1.5.1 Patient breathing circuits, components, and accessories

In addition to the information provided in this section, carefully review the information in Sections 1.3 and 1.4.

⚠ WARNING

- **To prevent patient or ventilator contamination, always use a bacteria filter or HMEF between the patient and the inspiratory port. If no inspiratory filter is used, the exhaled gas can contaminate the ventilator.**
- Ensure that all of the components of the breathing circuit set, including but *not* limited to flow sensor, humidifier, and other accessories, match the associated intended use for the target patient group.
- Adding attachments or other components/assemblies to a breathing system can change the pressure gradient across the ventilator, which can adversely affect ventilator performance.
- Make sure a HEPA filter is installed by the air intake. See Figure 2-4.
- For each new patient, always use a new or reprocessed breathing circuit to avoid cross contamination.
- During ventilation, regularly check the breathing circuit filter for increased resistance and blockage.

NOTICE

- Any bacteria filter, HMEF, or additional accessories in the expiratory limb may substantially increase flow resistance and impair ventilation.
- When adding components to the Hamilton Medical breathing circuit configurations, do *not* exceed the inspiratory and expiratory resistance values of the ventilator breathing system as specified in Section 16.10, as required by ISO 80601-2-12.
- Pressure and volume measurement accuracy may be affected by using a breathing circuit with high resistance. Accuracy was tested with Hamilton Medical devices using the breathing circuits PN 260039 for adults, PN 260189 for pediatrics, and PN 151969 for neonates.

1.5.2 Preoperational check and tests

⚠ CAUTION

- *To prevent possible patient injury, disconnect the patient from the ventilator before running these 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 tests have passed.*

NOTICE

- To ensure that all breathing circuit connections are leak-tight, perform the tightness 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.
- If you close the System > Tests & calib window when CO2 sensor zero calibration has failed, the ventilator starts

or continues ventilating, but continues to display the message **CO2 calibration needed**. This may result in inaccurate monitoring.

- When the **Set Oxygen alarm limits manually** checkbox is selected (in Configuration), you can only calibrate the O2 sensor while in Standby, using 21% oxygen.

1.5.3 Humidifier

⚠ WARNING

- Before using the humidifier, review the *HAMILTON-H900 Humidifier Instructions for Use* as well as the *Instructions for Use* provided with its accessories.
- 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.
- Regularly check the water traps and the breathing circuit limbs for water accumulation. Empty as required.

1.5.4 IntelliCuff

⚠ WARNING

- Never connect the tubing to any other device or connector other than to the IntelliCuff port on the ventilator and to the inflating tube on the tracheal tube or tracheostomy tube.
- Disconnect the IntelliCuff tubing from the tracheal or tracheostomy tube when IntelliCuff is turned off.

⚠ CAUTION

- *Use only Hamilton Medical disposable tubing with a filter and safety valve. Use of any other tubing will result in the immediate loss of cuff pressure if disconnected at the ventilator. Use of any other tubing without a filter may result in the device being contaminated.*
- *Check tubing regularly. Bent or kinked tubes can provide incorrect monitoring information.*

1.5.5 CO2 sensor setup and operation

⚠ WARNING

- 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 CO2 airway adapter and replace if needed.

- Elevated baseline can be caused by sensor problems or an issue with the patient.
- Do *not* use any CO2 sensor/adapter if they appear to be damaged or if they fail to operate properly. Refer servicing to Hamilton Medical authorized personnel.
- Do *not* use the CO2 components when they are wet or have exterior condensation.
- In NIV and neonatal ventilation with uncuffed tubes, leaks may influence the volumetric capnogram and the measured values.
- Always connect all components securely and check for leaks according to standard clinical procedures. Displacement of the nasal or combined nasal-oral cannulas can cause lower-than-actual CO2 readings.
- Positioning of tubes 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 CO2 sensor 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).
- 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 the *Approved cleaning agents for CO2 components*, available on MyHamilton.
- Periodically check the sensor and tubing for excessive moisture or secretion build-up, and replace if needed. Excessive moisture can affect measurements.
- **LoFlo sidestream CO2 sensor.**
  Do *not* use with patients that 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.

⚠ CAUTION

- *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 adapter. In adult patients, smaller geometrics increase airway resistance and induce low tidal volumes and intrinsic PEEP. In neonatal patients, large geometrics impede effective CO2 removal.*
- *Do NOT place the CO2 sensor on the patient. It can burn the skin as the sensor may reach a temperature of 46°C (115°F).*

- *Use during nebulization may influence the CO2 measurements. In addition, the medication can contaminate the sensor 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 water, and reconnect.
- Do *not* combine the neonatal CO2 airway adapter and the adult flow sensor. Doing so can increase resistance, create artifact, or lead to hypoventilation, intrinsic PEEP, or overinflation.
- Do *not* place the CO2 sensor/adapter between the ET tube and the elbow, 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.

1.5.6 Nebulization

For additional safety information related to Aerogen[§] nebulizers, see the *Aerogen Solo/Aerogen Pro Instructions for Use*.

⚠ WARNING

- Nebulization of drugs can cause an occlusion and increased resistance of a connected expiratory filter. Check the filter frequently for increased resistance or blockage.
- Connect the nebulizer in the inspiratory limb per 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.
- 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 the expiratory filter.

NOTICE

Pneumatic nebulization is disabled during neonatal ventilation and during high flow oxygen therapy. If needed, use an Aerogen nebulizer.[1]

[1] Not available in all markets. Aerogen nebulization is not supported for neonatal patients in the USA.

1.6 Ventilating the patient

This section provides the following safety information:

- Specifying patient settings
- Neonatal ventilation
- Apnea backup
- TRC settings
- P/V Tool Pro
- Noninvasive ventilation
- Using high flow oxygen therapy

1.6.1 Specifying patient settings

⚠ 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 to prevent hyper- or hypo-ventilation.

1.6.2 Neonatal ventilation

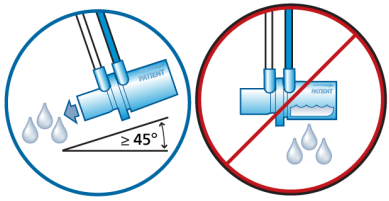
In addition to the information provided in this section, carefully review the information in Sections 1.5 and 1.6.

⚠ WARNING

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

⚠ CAUTION

- *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 (Y-piece, flow sensor, ET tube, CO2 airway adapter) may 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.*



NOTICE

- When switching between the **Adult/Ped** to the **Neonatal** patient groups, you must calibrate the flow sensor and perform the tightness test.
- Because neonatal ET tubes often do *not* have a cuff, leakage can be significant, that is, the measured inspiratory tidal volume (**VTI**) can be much greater than the measured expiratory tidal volume (VTE).
- Check the **VLeak** parameter in the Monitoring window from time to time; the leak may *not* be predictable.

1.6.3 Apnea backup

⚠ CAUTION

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

1.6.4 TRC settings

⚠ WARNING

To ensure patient safety, check that the **Pressure** alarm limit is set appropriately when using TRC, as real pressure may be higher than the set pressure.

⚠ CAUTION

To prevent patient injury, be especially careful when defining TRC settings, as using the incorrect tube type or size setting can endanger the patient.

1.6.5 P/V Tool Pro

⚠ WARNING

Do *not* attempt to use the P/V Tool on an active patient as it can cause patient discomfort and erroneous readings.

NOTICE

- During a maneuver and for 30 seconds following the end of the maneuver, all patient alarms are silenced.
- Apnea time begins after the end of the maneuver.
- Use of the P/V Tool provides information that, in conjunction with hemodynamic data and other clinical information, may be used to optimize PEEP and other ventilator settings.
- During the maneuver, the high **Pressure** alarm is automatically set to **Ptop** + 5 cmH2O.
  When the maneuver is finished, the high **Pressure** alarm limit returns to the previous setting.
  If IntelliCuff is connected, **Pcuff** may also be affected. For details, see Section 12.2.4.1.
- A calibrated flow sensor and a tight circuit produce the best results.

1.6.6 Noninvasive ventilation

NOTICE

- As a precaution, you must be prepared to intubate the patient and start invasive ventilation at any time while noninvasive ventilation is in use.

- The use of a mask can increase dead space. Always comply with the mask manufacturer's instructions when using noninvasive ventilation.
- The **Inspiratory volume limitation** alarm is inactive in noninvasive modes.

1.6.7 Using high flow oxygen therapy

⚠ WARNING

- Use only interfaces intended for high flow oxygen therapy that allow the patient to exhale, such as a nonoccclusive 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.
- The ventilator is a high-flow device that can operate with flows above 80 l/min and with a high oxygen concentration.
- 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.
- Always use active humidification during high flow oxygen therapy.

⚠ CAUTION

To reach a high oxygen concentration in a short period of time, flows higher than 4 l/min are required at the beginning of the therapy.

1.7 Monitoring and alarms

⚠ CAUTION

- *To prevent possible patient injury, make sure the alarm limits are appropriately set before you place the patient on the ventilator.*
- *The HAMILTON-C6 oxygen monitoring function can be disabled. Ensure that an alternative means of oxygen monitoring is always available and enabled.*
- *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.*

NOTICE

- The HAMILTON-C6 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.
- To prevent leakage within the ventilator, make sure an O2 sensor is installed at all times, even if you use an external O2 monitor or disable oxygen monitoring.
- 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.

- It is recommended that additional independent monitoring devices be used during mechanical ventilation. The operator of the ventilator must still maintain full responsibility for proper ventilation and patient safety in all situations.
- Do *not* pause the audible alarm when leaving the patient unattended.
- The Auto function is not available during neonatal ventilation.

1.8 Using the trolley

⚠ 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.

1.9 Maintenance

This section provides the following safety information:

- Maintenance, cleaning, and disinfection
- Preventive maintenance

1.9.1 General maintenance, cleaning, and disinfection

⚠ 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 prevent patient exposure to sterilizing agents and to prevent premature deterioration of parts, sterilize parts using only the techniques recommended in Chapter 13 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 bacteria filters to minimize the risk of bacterial contamination or physical damage. 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 registered/approved cleaning and disinfection solutions, as approved by your institution's protocol, after each patient use, according to the cleaning agent manufacturer's recommendations.*
- *(USA only) 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 recommendations.*
- *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 component to ensure removal of residual cleaning/disinfection agents.*
- *Cleaning and disinfection agent residues can cause blemishes or fine cracks, especially on parts exposed to elevated temperatures during sterilization.*

NOTICE

- Because sanitation practices vary among institutions, Hamilton Medical cannot specify specific practices that will meet all needs or be responsible for the effectiveness of these practices.
- This *Operator's Manual* only provides general guidelines for cleaning, disinfecting, and sterilizing. It is the operator's responsibility to ensure the validity and effectiveness of the actual methods used.
- 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.

1.9.2 Preventive maintenance

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 (for example, O2 sensor).
- 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 inspiration filter is used, the device must be considered contaminated and must be serviced.

1.9.3 O2 sensor

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 oxygen sensor is installed at all times, even if you use an external monitor or disable oxygen monitoring.
- The paramagnetic O2 sensor must only be replaced if it fails. In this case, have the ventilator serviced.

1.10 Service and testing

- To ensure proper servicing and to prevent possible physical injury, only Hamilton Medical authorized service personnel may service the ventilator using information provided in the Service Manual.
  In addition, all accessories and devices must only be serviced by Hamilton Medical authorized service personnel.
- The manufacturer can only be responsible for the safety, reliability, and performance of the ventilator if all of the following requirements are met:
  - Appropriately trained personnel 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 operator's manual.
  - Do *not* attempt service procedures other than those specified in the service manual.
- 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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2.2 Physical descriptions 41
2.3 Navigating the windows and controls 54

2.1 Overview

The HAMILTON-C6 ventilator system comprises the following main components:

- Detachable monitor with integrated alarm lamp and touch screen display
- Ventilation unit for gas mixing and control, and patient breathing circuit for gas delivery and exchange
- Oxygen monitoring using a galvanic or optional paramagnetic sensor
- Optional connections to a humidifier, nebulizer, IntelliCuff cuff pressure controller, 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
- Monitoring and control of the HAMILTON-H900 humidifier from the ventilator
- Monitoring and control of the IntelliCuff cuff pressure controller from the ventilator
- Transpulmonary pressure measurement
- Support for pneumatic or Aerogen nebulization

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 the standard software configuration and options. Table 2-2 lists the standard equipment (hardware) and options.

Table 2-1. Standard software configuration and options

Function	Patient group	
	Adult/Ped	Neonatal
Standard: X Option: O Not applicable: --		
Patient groups	X	O
Modes		
Intelligent ventilation modes		
ASV	X	--
INTELLiVENT-ASV ⚠ **WARNING!** Not available in the USA.	O	--
Volume-targeted, pressure-controlled modes		
APVcmv / (S)CMV+	X	X
APVsimv / SIMV+	X	X
Volume-controlled, flow-controlled modes		
(S)CMV	X	--
SIMV	X	--
Pressure-controlled modes		
DuoPAP, APRV	X	X
PCV+	X	X
PSIMV+	X	X
SPONT	X	X
Noninvasive modes		
HiFlowO2: high flow oxygen therapy	O	O
NIV, NIV-ST	X	X
nCPAP-PS	--	O
Other functions		
P/V Tool	O	O
Transpulmonary pressure monitoring	X	X
IntelliSync+	O	--

Function	Patient group	
	Adult/Ped	Neonatal
Flow and pressure triggers	X	X
TRC	X	X
Suctioning tool	X	X
Trends/Loops	X	X
On-screen help	X	X

Table 2-2. Standard equipment (hardware) configuration and options

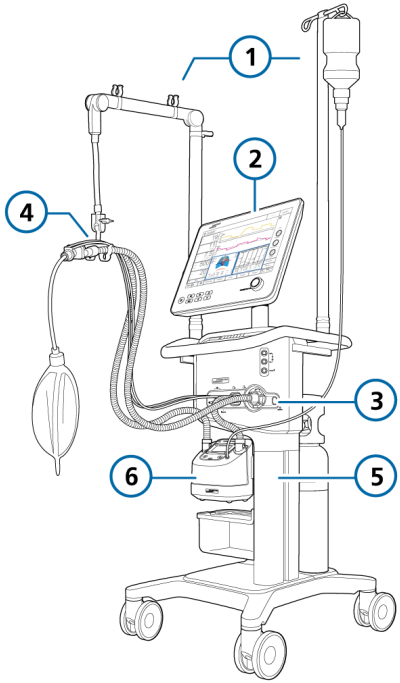
Functions	HAMILTON-C6
Standard: X Option: O Not applicable: --	
Trolley or shelf mount solution (selected when ordering)	X
Trolley accessories: Basket for suctioning catheter, O2 bottle holding system, HAMILTON-H900 mounting system	O
Second battery	O
Communication board: CO2/SpO2 or CO2/SpO2/Aerogen nebulizer	O
Extended communication ports: Three COM ports, two USB ports, DVI, Nurse call	X
Communication protocols: GALILEO compatible, Hamilton P2, Hamilton Block, Philips VueLink Open, DrägerTestProtocol, HAMILTON-H900	X
Paramagnetic O2 sensor	O
HAMILTON-H900 humidifier integration[2]	X
IntelliCuff cuff pressure controller integration[3]	X

[2] Activated upon connection of a HAMILTON-H900 humidifier.
[3] Activated upon connection of an IntelliCuff cuff pressure controller.

2.2 Physical descriptions

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

Figure 2-1. HAMILTON-C6 with accessories

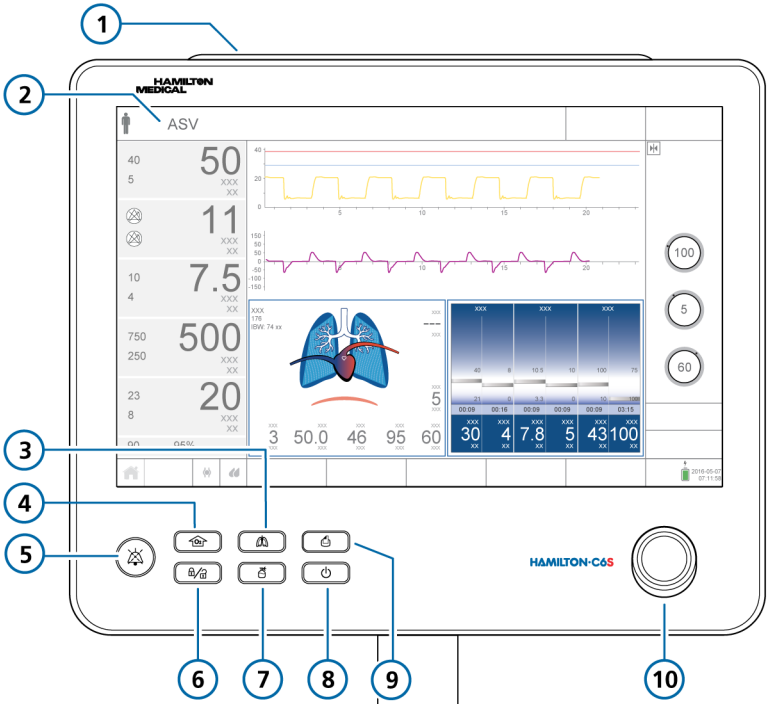


1	Support arm and infusion arm	4	Breathing circuit
2	Monitor and controls	5	Trolley
3	Breathing circuit connections	6	Humidifier

2.2.1 About the ventilator

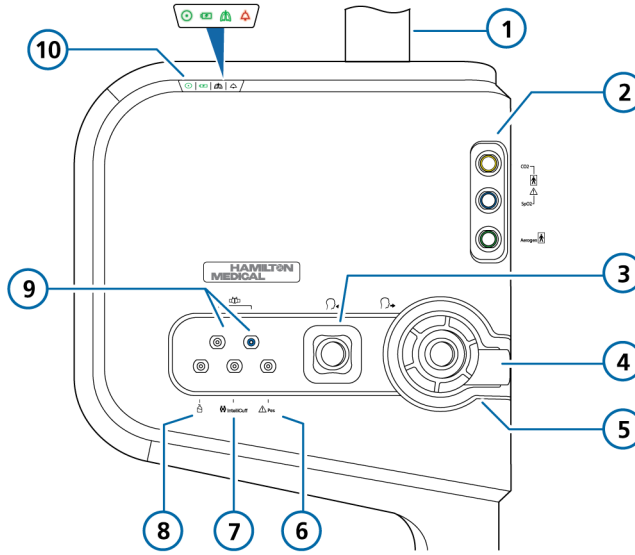
Figures 2-2 through 2-5 provide an overview of the device.

Figure 2-2. Front view, ventilator monitor



1	Alarm lamp	6	Screen lock/unlock
2	Touch screen display (Figure 2-6)	7	Nebulizer key
3	Manual breath key	8	Power/Standby key
4	O2 enrichment key	9	Print screen key
5	Audio Pause key	10	Press-and-Turn (P&T) knob

Figure 2-3. Front view, ventilator body

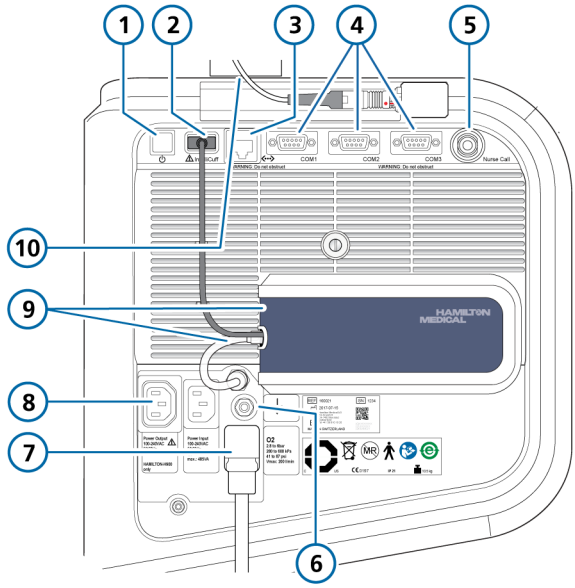


1		Monitor post	6	Pes	Pes port
2	CO2 SpO2 Aerogen	Communication board* with CO2, SpO2, Aerogen ports (optional)**	7	IntelliCuff	IntelliCuff port
3		To patient port	8		Pneumatic nebulizer port
4		From patient port	9		Flow sensor ports
5		Expiratory valve set	10		Status indicator panel (Section 2.2.1.1)

** When the board is not installed, this area is covered by a plate.*

***Note that the SpO2, CO2, and Aerogen labels on the ventilator body are always present, regardless of whether the communication board is installed or a given connection port on the board is active.*

Figure 2-4. Rear view, ventilator body

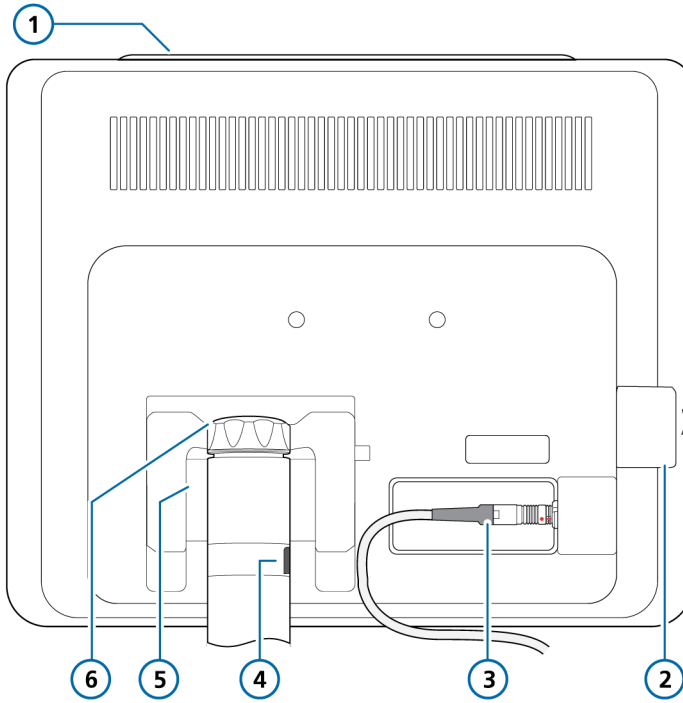


1	Power/Standby button	6	Potential equalization conductor
2	IntelliCuff USB port*	7	High-pressure oxygen DISS or NIST inlet fitting
3	LAN port (internal use only)	8	Power sockets: one for HAMILTON-H900 humidifier *only* (left), AC power (right)
4	RS-232 COM1, COM2, COM3** ports	9	IntelliCuff housing and connection cables (shown connected)
5	Nurse call port	10	Monitor cable

** Used for both built-in and standalone IntelliCuff connection (shown with built-in IntelliCuff connected)*

*** Only for HAMILTON-H900 connection*

Figure 2-5. Rear view, ventilator monitor



1	Alarm lamp	4	Mounting post with lock/release button
2	USB port	5	Tilt and swivel mount
3	Monitor connection port and cable to ventilator	6	Tilt and swivel mount locking cap

2.2.1.1 About the status indicators on the ventilator

Indicator lights on the front of the ventilator unit show important ventilation status information.

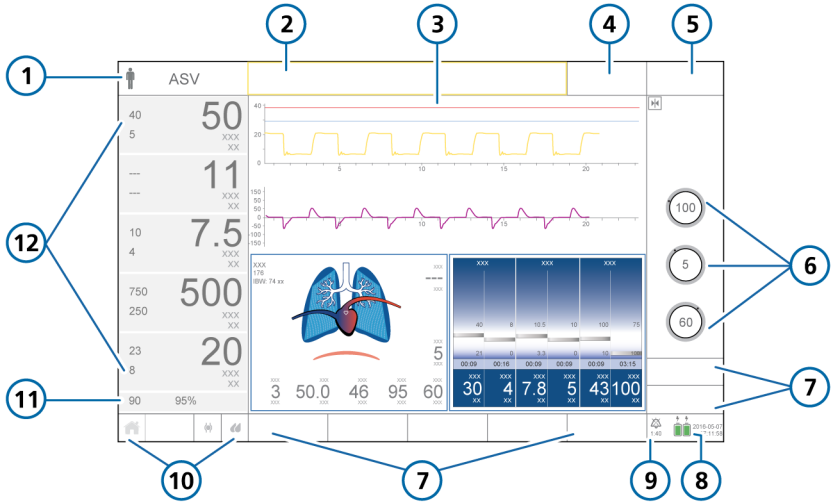
Table 2-3. Status indicators

Symbol	Description
	**Power indicator.** Solid green when the ventilator is turned on.
	**Battery status indicator.** *Solid green*: Lit to show that the battery is fully charged and connected to primary power, even when the ventilator is turned off. *Flashing green*: Flashes to show that the battery is charging, even when the ventilator is turned off. *Not lit*: Dark to show the battery is not charging (the battery is overheated or a primary power source is missing).
	**Active ventilation indicator.** Light pulses green with each inspiratory breath. For details, see Section 7.7.
	**Alarm indicator.** Flashes red when an alarm is generated. For alarm related information, see Chapter 9.

2.2.2 About the main display

Directly access all the windows for mode, controls, alarms, and monitoring from the main display during normal ventilation.

Figure 2-6. Main display



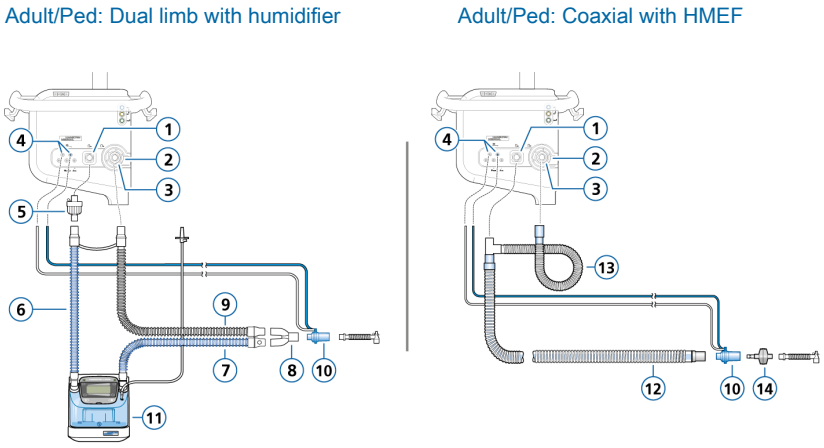
1	Patient group symbol and active mode	7	Window buttons: Alarms, Controls, Monitoring, Graphics, Tools, Events, System
2	Message bar (color coded)	8	Power source and date/time
3	Configurable graphic display (full-length waveforms shown)	9	Audio Pause indicator and countdown timer
4	Target button, available in INTELLiVENT-ASV	10	Quick access buttons
5	Modes button	11	SpO2 low alarm limit and current value*
6	Main controls for the active mode	12	Main monitoring parameters (MMP)

** When SpO2 monitoring is enabled.*

2.2.3 About the patient breathing circuits

For details about connecting and setting up the breathing circuit, see Section 3.4.

Figure 2-7. Adult/pediatric breathing circuits: dual limb with humidifier (left), coaxial with HMEF (right)

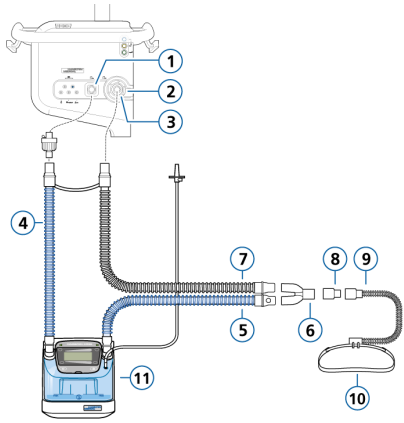


1	To patient inspiratory port	8	Y-piece
2	From patient expiratory port	9	Heated expiratory limb
3	Expiratory valve set	10	Flow sensor
4	Flow sensor ports	11	Humidifier
5	Bacteria filter	12	Coaxial inspiratory/expiratory limb
6	Inspiratory limb to humidifier	13	Expiratory limb extension
7	Heated inspiratory limb with temperature sensor, to patient	14	HMEF

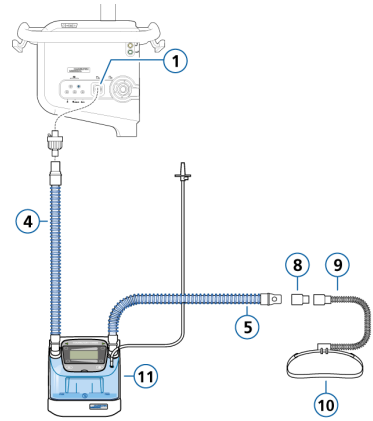
To prevent patient or ventilator contamination, always use a bacteria filter or HMEF between the patient and the inspiratory port.

Figure 2-8. Adult/pediatric breathing circuits: high flow oxygen therapy, dual limb (left) and single limb (right)

Adult/Ped: Dual limb, high flow oxygen therapy



Adult/Ped: Single limb, high flow oxygen therapy



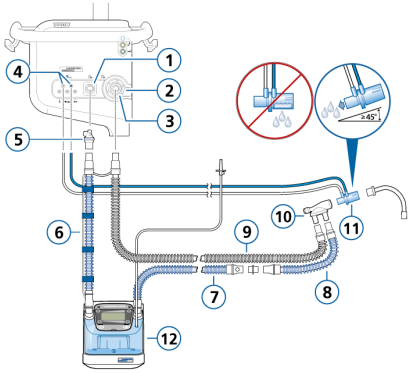
1	To patient inspiratory port	7	Heated expiratory limb
2	From patient expiratory port	8	Adapter
3	Expiratory valve set	9	Nasal cannula
4	Inspiratory limb to humidifier	10	Attachment strap
5	Heated inspiratory limb with temperature sensor, to patient	11	Humidifier
6	Y-piece		

To prevent patient or ventilator contamination, always use a bacteria filter or HMEF between the patient and the inspiratory port.

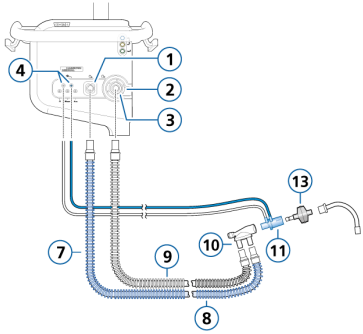
To provide the required humidification during high flow oxygen therapy, we recommend using the HAMILTON-H900 humidifier.

Figure 2-9. Neonatal breathing circuits: dual limb with humidifier (left), dual limb with HMEF (right)

Neonatal/pediatric: Dual limb with humidifier



Neonatal/pediatric: Dual limb with HMEF

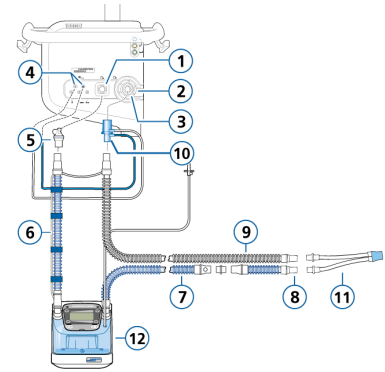


1	To patient inspiratory port	8	Unheated inspiratory limb extension, for use in incubator
2	From patient expiratory port	9	Heated expiratory limb
3	Expiratory valve set	10	Y-piece
4	Flow sensor ports	11	Flow sensor
5	Bacteria filter	12	Humidifier
6	Inspiratory limb to humidifier	13	HMEF
7	Heated inspiratory limb with temperature sensor, to patient		

To prevent patient or ventilator contamination, always use a bacteria filter or HMEF between the patient and the inspiratory port.

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.

Figure 2-10. Neonatal breathing circuit: nCPAP-PS

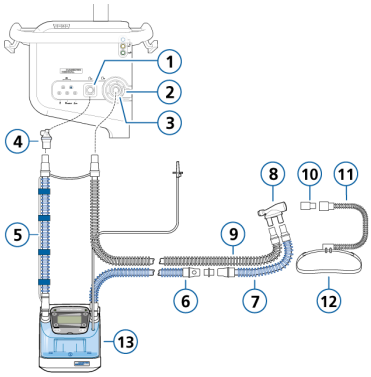


1	To patient inspiratory port	7	Heated inspiratory limb with temperature sensor, to patient
2	From patient expiratory port	8	Unheated inspiratory limb extension, for use in incubator
3	Expiratory valve set	9	Heated expiratory limb
4	Flow sensor ports	10	Flow sensor (connected to expiratory port)
5	Bacteria filter	11	Patient interface
6	Inspiratory limb to humidifier	12	Humidifier

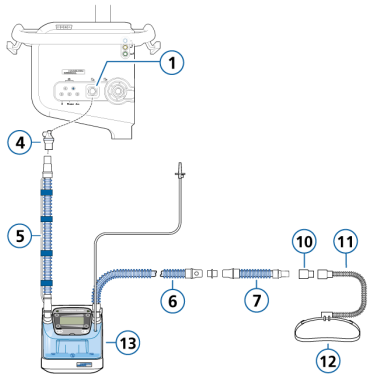
To prevent patient or ventilator contamination, always use a bacteria filter or HMEF between the patient and the inspiratory port.

Figure 2-11. Neonatal breathing circuits: high flow oxygen therapy, dual limb (left) and single limb (right)

Neonatal/pediatric: Dual limb, high flow oxygen therapy



Neonatal/pediatric: Single limb, high flow oxygen therapy



1	To patient inspiratory port	8	Y-piece
2	From patient expiratory port	9	Heated expiratory limb
3	Expiratory valve set	10	Adapter
4	Bacteria filter	11	Nasal cannula
5	Inspiratory limb to humidifier	12	Attachment strap
6	Heated inspiratory limb with temperature sensor, to patient	13	Humidifier
7	Unheated inspiratory limb extension, for use in incubator		

To prevent patient or ventilator contamination, always use a bacteria filter or HMEF between the patient and the inspiratory port.

To provide the required humidification during high flow oxygen therapy, we recommend using the HAMILTON-H900 humidifier.

2.2.4 About the trolley and mounting variations

The HAMILTON-C6 can optionally be ordered with a trolley or a shelf mount solution. The trolley has space for oxygen cylinders.

2.2.4.1 Preparing the trolley for intrahospital transport

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, such as a patient support arm, can result in the trolley tipping over.

If using a HAMILTON-C6 trolley, the ventilator and its components, as well as the trolley, **must be** configured and positioned as follows during transport within the hospital:

- The oxygen cylinders must be securely attached to the trolley.
- *Only* the following components are allowed to be connected during transport:
  - Breathing circuit
  - Flow sensor
  - CO2 sensor (mainstream or sidestream)
  - O2 cylinder
  - SpO2 sensor, including Masimo adapter board
  - Aerogen nebulizer
  - IntelliCuff
  - Humidifier
  - Water bottle
  - Water bottle holder

2.2.5 Adjusting the monitor

You can adjust the monitor's position and set it to the desired orientation and angle by turning and tilting it, as needed.

An adjustment cap allows you to adjust the force required to turn the monitor from side to side. Two screws allow you to adjust the force required to change the tilt angle of the monitor.

Figure 2-12. Turning the monitor side to side

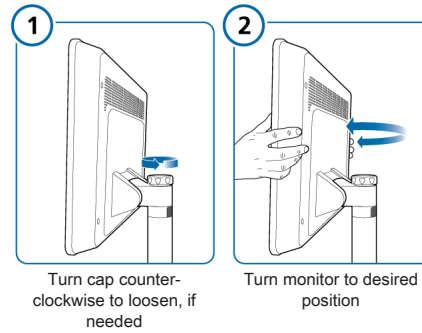
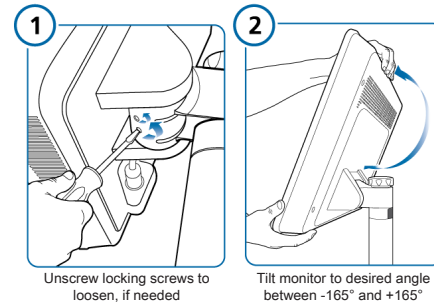


Figure 2-13. Tilting the monitor up and down



2.3 Navigating the windows 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-C6 user interface as follows:

- Touch elements on the display to open windows and make selections, as well as specify settings by using the control slider, when available.
- Use the P&T knob to select, specify, and confirm selections. A selected item is highlighted in yellow.
- If using INTELLiVENT-ASV, you can:
  - Swipe left/right on the panels that are displayed during active ventilation (horizons, maps, plethysmogram/capnogram, SBT history) to cycle through the panel options.
    - ► Swipe within the SBT history panel to cycle through previous SBT data.
    - ► Swipe within the Oxygenation map panel to switch between the PEEP/SpO2 and FiO2/PEEP maps.
  - In the INTELLiVENT-ASV Settings window, swipe left/right on the left-hand map panel to switch between the Oxygenation and the Ventilation maps.

This section describes how to navigate the interface.

2.3.1 Accessing windows

To open a window

▸ Do any 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.

2.3.2 Adjusting controls

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

The HAMILTON-C6 offers multiple ways to adjust control settings:

- Activate the control and use the P&T knob to set and confirm the value.
- Activate the control and use the control slider (when available) to set the value.

To adjust a control setting

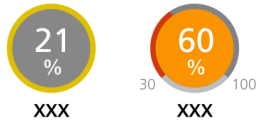
1. **Activate** the control by doing any of the following:

   – Touch the control to select and activate it.

   – Turn the P&T knob to move the cursor to the control, then press the P&T knob to activate it.

   The activated control is orange.

Figure 2-14. Selected control (yellow outline), activated control (orange)



2. **Adjust** the value by doing any of the following:

   – If displayed, touch the slider (Figure 2-15) and drag it to the desired value. The value is also shown on the associated control.

   – Tap the **+** or **–** buttons in the slider area to incrementally increase/decrease the value.

   – Turn the P&T knob to increase or decrease the value.

3. **Confirm** the setting by doing any of the following:

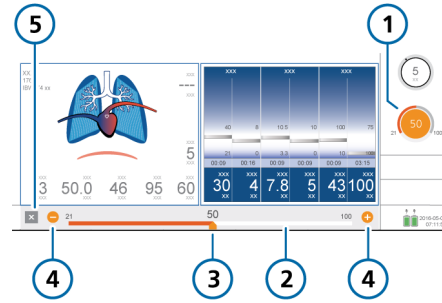
   – Touch the control again.

   – Press the P&T knob.

The new setting is immediately applied and the slider bar (if open) is automatically closed.

You can manually close the slider bar at any time by touching the **X** button. Any changes you made are discarded.

Figure 2-15. Control slider



1	Activated control and value	4	+/- : incrementally increase/decrease the value
2	Control slider bar	5	X (close) button
3	Slider showing current value		

2.3.3 Selecting list items

Some selections are presented in a scrollable list; for example, selecting a parameter for a Trend graph.

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.

2.3.4 Using shortcuts

The ventilator provides shortcuts for some key functions.

Table 2-4. Shortcuts

Touch Quick access icon/ shortcut on main display ...	To display the ...
	Controls > Patient window[4]
Mode name	Mode window
Any MMP	Alarms > Limits 1 window
SpO2 value[5] (under MMPs)	Alarms > Limits 2 window
Any graphic (waveform, Intelligent panel, loop, trend)	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

Touch Quick access icon/ shortcut on main display ...	To display the ...
	Default layout specified for the selected Quick setup
	System > IntelliCuff window[6]
	System > Humidifier window[6]

[4] When the Patient window is available, during active ventilation. If the Patient window is not available, displays the Controls > Basic window.
[5] When SpO2 sensor enabled.
[6] If connected.

3
Preparing the ventilator

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3.2 Connecting to a power source 58
3.3 Connecting the oxygen supply 59
3.4 Setting up the patient breathing circuit 59
3.5 Setting up esophageal/transpulmonary pressure monitoring 63
3.6 Turning the ventilator on and off 64

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 3.6
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.

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 batteries are charging.

To connect the ventilator to a primary power supply

1. 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.

2. Connect one end of a grounding cable to the equipotential grounding post on the ventilator (Figure 2-4) and the other to a properly grounded outlet.

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 2 minutes.

Batteries are charged whenever the ventilator is connected to the primary power supply, whether or not it is turned on. The battery status indicator on the front of the ventilator body (Section 2.2.1.1) shows the charge status of the battery.

During active ventilation when the ventilator is running on battery power, the time remaining on the current battery charge is displayed in the System > Info 1 window in the **Battery rem. time** field. If the display shows dashes (--), the remaining time is being recalculated.

An optional second battery is available. It is shown on the display when installed.

Figure 3-1. Power source indicators on display



Table 3-1. Battery/power state

Power icon on display	Battery/power state
	Device is plugged into primary power and the battery is charging.
	Device is running on battery power.
	Battery is fully charged.
	Battery is partially charged.
	Battery has less than 10% charge left.
	The primary battery is either defective or not installed.
Battery status indicator	See Section 2.2.1.1.

If a battery is not fully charged, recharge it by connecting the ventilator to the primary power source. For details, see Section 16.4.

Chapter 13 describes how to replace the battery.

3.3 Connecting the oxygen supply

Before proceeding, review the safety information in Chapter 1.

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 oxygen cylinders to the trolley. If you use gases from cylinders, secure the cylinders to the trolley with the accompanying straps.

To connect the oxygen supply to the ventilator

- Connect the oxygen hose to the ventilator's oxygen inlet fitting (Figure 2-4).

3.4 Setting up the patient breathing circuit

Before proceeding, review the safety information in Chapter 1.

Connecting the breathing circuit comprises the following steps.

For neonatal ventilation, see Chapter 6.

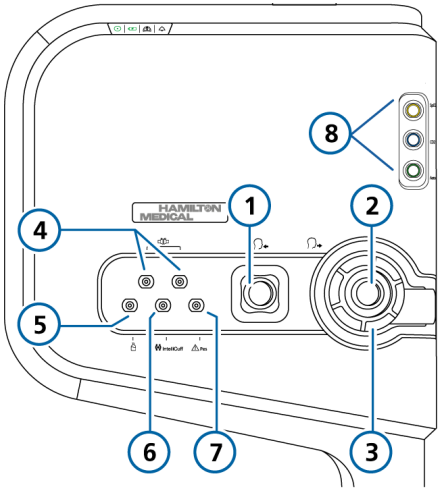
To ...	See ...
Install the expiratory valve.	Section 3.4.2
Select the appropriate breathing circuit and components.	Section 3.4.3
Assemble the breathing circuit.	Section 3.4.4
Adjust the position of the breathing circuit.	Section 3.4.5
Connect external devices and sensors.	Section 4
Perform any required tests, calibrations, and the preoperational check.	Chapter 5

3.4.1 Breathing circuit connections on the ventilator

Figure 3-2 illustrates the key ports on the ventilator for connecting the breathing circuit set.

For breathing circuit diagrams, see Section 2.2.3.

Figure 3-2. Key connection ports, front of ventilator



1	To patient inspiratory port	5	Nebulizer port
2	From patient expiratory port	6	IntelliCuff tubing port
3	Expiratory valve set	7	Pes port
4	Flow sensor connectors	8	Communication board with CO2, SpO2, Aerogen ports, if installed

3.4.2 Working with the expiratory valve set

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

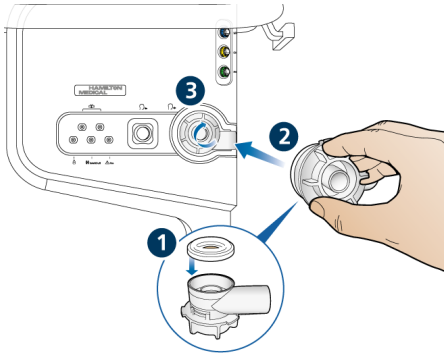
To assemble/install the expiratory valve set

1. Holding the expiratory valve housing (Figure 3-3), seat the silicone membrane onto the housing (**1**).

   The metal plate must face up and be visible.

2. Position the housing in the expiratory port (**2**) and twist clockwise until it locks into place (**3**).

Figure 3-3. Installing the expiratory valve set



To disassemble the expiratory valve set

- Holding the expiratory valve housing, remove the silicone membrane (**1** in Figure 3-3) by lifting it up.

3.4.3 Selecting the breathing circuit components

Select the correct breathing circuit parts for your patient.

For neonatal ventilation, see Chapter 6.

Table 3-2. Breathing circuit component specifications

Patient data/ Component	Adult	Pediatric
Patient height (cm)	> 130	30 to 150
IBW (kg)	> 30	3 to 42
Tracheal tube ID (mm)	≥ 5	3 to 7
Breathing circuit limb ID (mm)[7]	15 to 22	10 to 22
Flow sensor	Adult/Ped	Adult/Ped
CO2 airway adapter	Adult/Ped[8]	Adult/Ped[8]

3.4.3.1 Using a filter in the breathing circuit

Before proceeding, review the safety information in Chapter 1.

Inspiratory bacteria filter

To prevent patient or ventilator contamination, be sure to connect a bacteria (inspiratory) filter or HMEF between the patient and the inspiratory port.

For neonatal patients, use a neonatal-pediatric bacteria (inspiratory) filter or HMEF.

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

If no inspiratory filter is used, the exhaled gas can contaminate the ventilator. If you are not using an inspiratory filter, and an exhalation obstructed alarm is generated, the ventilator may be contaminated. Have the ventilator serviced.

Expiratory bacteria filter

An expiratory filter is not required on the HAMILTON-C6, but you may use one according to your institution's protocol. It is not required because the expiratory valve design prevents internal ventilator components from coming into contact with the patient's exhaled gas.

If you use an expiratory filter, place it on the patient side of the expiratory valve cover. Monitor closely for increased expiratory circuit resistance.

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, remove the expiratory filter or replace the filter to eliminate it as a potential cause.

Heat and moisture exchanging filter (HMEF)

The HMEF is a passive humidification component used together with a bacteria filter. Use an HMEF when ventilating with a coaxial breathing system.

3.4.4 Assembling the patient breathing circuit

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

For neonatal ventilation, see Chapter 6.

3.4.4.1 Connecting the flow sensor

NOTICE

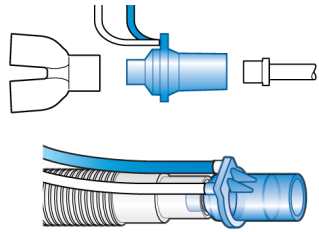
To prevent inaccurate flow sensor readings, make sure the flow sensor is correctly connected.

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.

   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 3-2).

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

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

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

NOTICE

Only use a neonatal/pediatric breathing circuit with an adult/pediatric flow sensor when the patient IBW is 20 kg or below.

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 tightness 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

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.

3.5 Setting up esophageal/transpulmonary pressure monitoring

The Pes port allows you to use pressure readings other than airway pressure (Paw), for example, from an esophageal balloon catheter, for monitoring purposes. Transpulmonary pressure is also calculated using a combination of the Paw and Pes pressures.

To display Pes-related parameters

- Connect an esophageal catheter to the Pes port on the front of the ventilator (Figure 2-3).

The associated pressure-related parameters are available in the Monitoring > Pes window. For details, see Section 8.5.

3.6 Turning the ventilator on and off

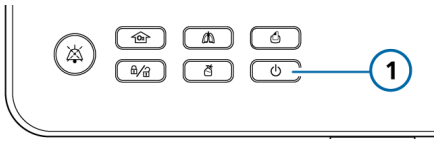
To turn on the ventilator

- Press the ventilator **Power/Standby** key on the front of the monitor.

  The ventilator runs a self-test. After a short time, the Standby window is displayed.

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

Figure 3-4. Power/Standby key



To turn off the ventilator

Note that while using IntelliCuff, you must first deflate the cuff and turn off IntelliCuff before turning off the ventilator.

1. From active ventilation, press the **Power/Standby** key on the front of the monitor to open the Activate Standby window.
2. Touch the **Activate standby** button to confirm.
3. Press and hold the **Power/Standby** key for about 3 seconds to turn off the ventilator.

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

- Press and hold the **Power/Standby** key for about 10 seconds to turn off the ventilator.

4

Setting up external devices and sensors

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4.4 Setting up CO2 monitoring 68
4.5 Setting up SpO2 monitoring 71
4.6 Enabling sensors 71
4.7 Setting up nebulization 72

4.1 Overview

The HAMILTON-C6 supports a variety of external devices and sensors for ventilation, including:

- Humidifier
- IntelliCuff cuff pressure controller
- CO2 monitoring sensors
- Pulse oximetry (SpO2 monitoring) sensors
- Nebulizers

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 integration of humidifier operation and data monitoring directly from the ventilator display[9,10]. Other humidifiers are supported, without the integration.

To connect a non-Hamilton Medial 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.
2. Connect the HAMILTON-H900 humidifier power cable to the dedicated power socket on the ventilator (Figure 2-4).
3. Connect a potential equalization cable to the humidifier and to a grounding socket at your facility.
4. Connect the communication cable to the humidifier and to the configured COM port on the ventilator (Figure 2-4).

   COM3 is configured for the HAMILTON-H900.

If data export is configured, humidifier data is also transmitted from the ventilator to an external monitoring system.

For additional details about:

- Working with the humidifier, see the *HAMILTON-H900 Instructions for use*.
- Controlling the humidifier from the ventilator, see Chapter 12.

4.3 Setting up the IntelliCuff cuff pressure controller

The ventilator supports the use of an optional IntelliCuff cuff pressure controller[11], and offers integrated operation and monitoring of the device.

For details on using IntelliCuff during ventilation, see Section 12.2.

The following options are available: Built-in and standalone

Built-in IntelliCuff

IntelliCuff is installed into a compartment in the rear of the ventilator, and all controls and operations are managed from the ventilator display.

[9] Not available in all markets.
[10] Supported for HAMILTON-H900 version 0.1.0.5b and later.
[11] Supported for IntelliCuff version 1.0.2.2 and later.

The USB communication/power cable and cuff tubing set are integrated with the ventilator, and are already connected to the appropriate ports. You connect the cuff tubing from the patient to the dedicated IntelliCuff port on the front of the ventilator.

For setup details, see Section 4.3.2.

Standalone IntelliCuff

IntelliCuff is connected as a standalone device, and all controls and operations are available on the device itself, as well as on the ventilator display.

You connect the USB communication/power cable to the dedicated IntelliCuff USB port on the back of the ventilator. You connect the cuff tubing from the patient directly to the IntelliCuff device.

For setup details, see Section 4.3.3.

4.3.1 About the IntelliCuff tubing

The IntelliCuff connector on the front of the ventilator is designed specifically to securely connect the cuff tubing to the ventilator.

The ventilator end of the tubing has a built-in shut-off valve, which prevents loss of cuff pressure in the event of a disconnection from the ventilator. For added protection, the IntelliCuff connector allows connection only from the ventilator end (with the shut-off valve) of the Hamilton Medical tubing.

4.3.2 Setting up a built-in IntelliCuff

If not already installed, contact your technical service representative to configure IntelliCuff default settings and install IntelliCuff into the ventilator compartment.

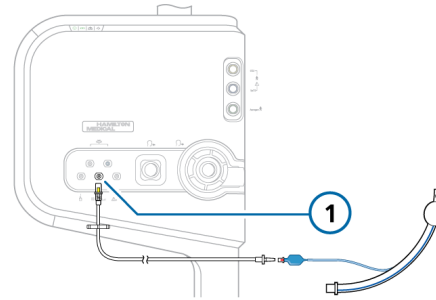
Once installed, the device is always available.

For each patient, you connect the cuff and tubing to the patient tubing and to the ventilator, and specify the desired settings.

To connect the cuff tubing

1. Connect the cuff tubing to the patient tubing as described in the *IntelliCuff Instructions for use*.
2. Connect the other end of the cuff tubing to the IntelliCuff port on the front of the ventilator (Figure 4-1).

Figure 4-1. Connect IntelliCuff tubing to IntelliCuff port on ventilator (1)



For operation details, see Section 12.2 and the *IntelliCuff Instructions for use*.

4.3.3 Setting up a standalone IntelliCuff

You connect the IntelliCuff to the ventilator for data communication and power.

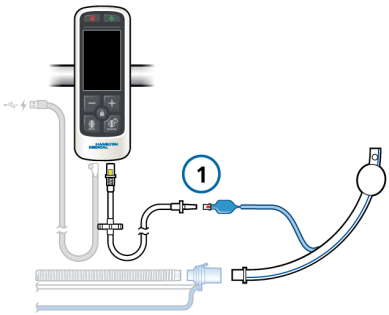
For each patient, you connect the cuff tubing to the patient tubing and to the IntelliCuff device, and specify the desired settings.

To connect the USB communication/power cable

- Connect the IntelliCuff USB communication/power cable to the IntelliCuff USB port on the back of the ventilator (Figure 2-4).

To connect the cuff tubing

1. Connect the cuff tubing to the patient tubing (**1**) as described in the *IntelliCuff Instructions for use*.
2. Connect the other end of the cuff tubing to the tubing connection port on the bottom of the IntelliCuff device.



For operation details, see Section 12.2 and the *IntelliCuff Instructions for use*.

4.4 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.

Both options require the communication board with the CO2 connection port activated.

Note that the display of a volumetric capnogram is only available when using a mainstream CO2 sensor.

4.4.1 Mainstream CO2 measurement

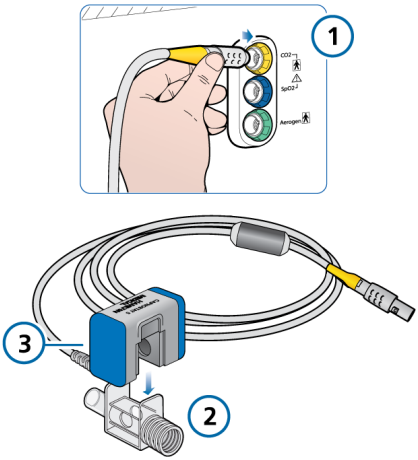
The CO2 monitoring option comprises the following components (shown in Figure 4-2): communication board, airway adapter, and CO2 sensor.

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 4-2. Mainstream CO2 monitoring components and assembly



1 Communications board with CO2 connection port

2 Airway adapter

3 CO2 sensor

4.4.1.1 Connecting the mainstream CO2 sensor

⚠ CAUTION

When using active humidification, prevent water accumulation in the CO2 adapter/sensor by ensuring that they are 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 sensor to a neonatal flow sensor.

Before proceeding, review the safety information in Chapter 1.

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

To set up mainstream CO2 monitoring

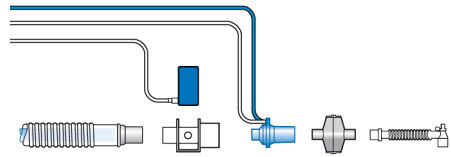
1. Connect the sensor cable to the CO2 connection port (**1**) on the ventilator (see Figure 4-2).
2. Attach the CO2 sensor (**3**) to the airway adapter (**2**), aligning the arrows on both components.

   Press the components together until they click.
3. When connecting a CO2 sensor for the first time, perform the zero calibration of the sensor/adapter, if needed, as described in Section 5.4.5.
4. Connect the sensor/adapter to the breathing circuit proximal to the patient, in a vertical position. See Figure 4-3.

   Do *not* place the airway adapter between the ET tube and the elbow, as this may allow patient secretions to accumulate in the adapter.[12]

   The sensor cable should face away from the patient.
5. Secure the sampling line safely out of the way.

Figure 4-3. Connecting CO2 sensor/adapter to breathing circuit (Adult/Ped shown)



[12] You can connect the CO2 sensor in front of or behind the flow sensor according to your institution's protocol.

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).

To remove the sensor cable

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

4.4.2 Sidestream CO2 measurement

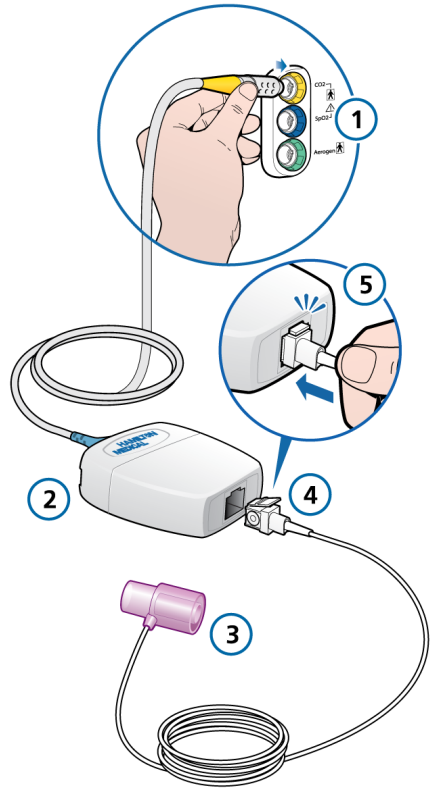
The LoFlo CO2 module is a sidestream CO2 monitoring system comprising the following components: communication board, airway sampling adapter, and CO2 module. See Figure 4-4.

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 by these gases.

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

Figure 4-4. Sidestream CO2 monitoring components and assembly



1	Communications board with CO2 connection port	4	Sampling cell
2	CO2 module	5	Connecting sampling cell to module
3	Airway adapter		

4.4.2.1 Connecting the sidestream CO2 sensor

Before proceeding, review the safety information in Chapter 1.

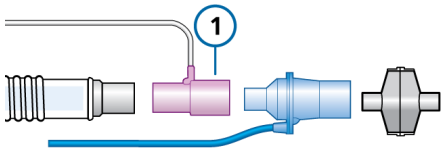
To set up CO2 sidestream monitoring

1. Connect the CO2 module cable to the CO2 connection port (**1**) on the ventilator (see Figure 4-4).
2. Insert the sample cell (**4**) into the CO2 module (**2**) as shown in Figure 4-4. It clicks into place.

   Inserting the sample cell into the module automatically starts the sampling pump. Removing the cell turns the pump off.
3. Perform the zero calibration of the adapter, if necessary, as described in Section 5.4.5 before connecting it to the breathing circuit.
4. Connect the adapter between the inspiratory limb and the flow sensor (or between the inspiratory limb and HMEF, if used). See Figure 4-5.

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

Figure 4-5. Attaching CO2 adapter (1) to the breathing circuit



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.

4.5 Setting up SpO2 monitoring

The HAMILTON-C6 supports input of SpO2 and related pulse oximetry data, and provides integrated monitoring and data display.

For details, see the *Pulse Oximetry Instructions for use*.

4.6 Enabling sensors

Before proceeding, review the safety information in Chapter 1.

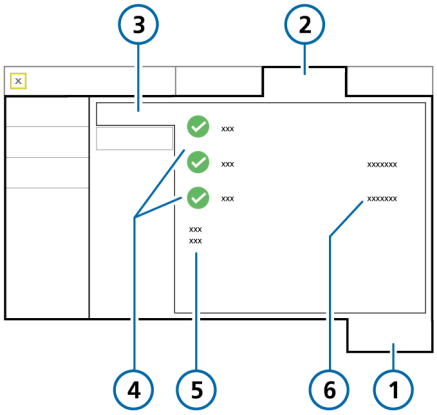
O2, CO2, and SpO2 monitoring must be enabled for data to be available.

To enable sensor monitoring

1. Open the System > Sensors > On/off window.
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 4-6. System > Sensors > On/Off window



1	System	4	O2 sensor, CO2 sensor[13], SpO2 sensor[13]
2	Sensors	5	SpO2 sensor status[13]
3	On/Off	6	SpO2 sensor type[13]

4.7 Setting up nebulization

The HAMILTON-C6 supports the following nebulizers types:

- Pneumatic (Section 4.7.2)
- Aerogen[§] (Section 4.7.3)

4.7.1 Selecting the nebulization type

By default, **Pneumatic** is selected for adult and pediatric patients.

To select the nebulizer type

1. Open the System > Nebulizer window.
2. Touch the appropriate button: **Pneumatic** or **Aerogen**

   If the **Aerogen** button is unavailable:

   – The communication board does not have the Aerogen option.

   – The Aerogen option is not activated in Configuration (Section 14.10.2).

   – The option is not available in your area.

The selected nebulizer is enabled for use.

Note that the nebulizer selection is saved with each Quick Setup (Section 5.2.1).

4.7.2 Setting up a pneumatic nebulizer

Before proceeding, review the safety information in Chapter 1.

Setting up pneumatic nebulization[14] comprises the following steps:

To ...	See ...
Select the pneumatic nebulizer (System > Nebulizer window).	Section 4.7.1
Connect the nebulizer to the breathing circuit.	Section 4.7.2
Start nebulization.	Section 10.6

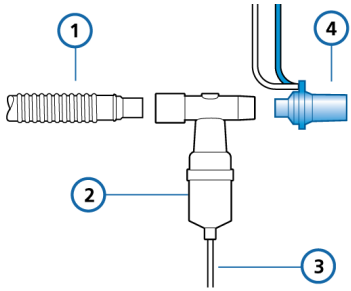
[13] If the option is installed and activated.
[14] Only for adult/pediatric patients.

To connect the nebulizer to the breathing circuit set

- Connect the nebulizer and accessories as shown in Figure 4-7.

  Compatible nebulizers are listed in the Hamilton Medical e-catalog.

Figure 4-7. Connecting a pneumatic nebulizer



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

For operation details, see Section 10.6.

4.7.3 Setting up an Aerogen nebulizer

Before proceeding, review the safety information in Chapter 1 and the Aerogen Solo/Aerogen Pro Instructions for Use.

Support for the Aerogen nebulizer system[15, 16] is available as an option.

The system comprises a communication board component and port (Figure 2-3), and the Aerogen Solo or Aerogen Pro nebulizer.

Detailed information about connecting the nebulizer is provided in the *Aerogen Solo/Aerogen Pro Instructions for Use*.

Setting up nebulization with Aerogen comprises the following steps:

To ...	See ...
Enable the Aerogen option in Configuration.	Section 14.7 (Configuration)
Select the Aerogen nebulizer (System > Nebulizer window).	Section 4.7.1
Connect Aerogen to the breathing circuit.	Section 4.7.3
Start nebulization.	Section 10.6

For operation details, see Section 10.6 and the *Aerogen Solo/Aerogen Pro Instructions for Use*.

[15] If the option is installed and activated.
[16] Not available in all markets. Aerogen nebulization is not supported for neonatal patients in the USA.

5 Specifying ventilation settings

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5.1 Process overview

This section explains how to set up the HAMILTON-C6 for ventilation on an individual patient.

Setting up ventilation generally comprises the following steps, each of which is described in this chapter:

- Selecting the patient group
- Selecting the desired preconfigured settings (Quick setup)
- Specifying patient data
- Performing the preoperational check, including
  – Calibrating the flow sensor, O2 sensor, and zero calibration of the CO2 sensor
  – Performing a breathing circuit tightness test
- Testing alarms
- Selecting the ventilation mode
- Reviewing and adjusting control settings
- Reviewing and adjusting alarm limits

5.2 Selecting the patient group

Before proceeding, review the safety information in Chapter 1.

The HAMILTON-C6 supports the following patient groups: **Adult/Ped** (adult and pediatric patients) and **Neonatal**.

Table 5-1. Patient groups

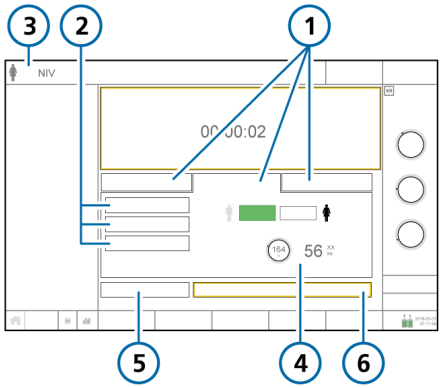
Adult/Ped	Neonatal
Sex: M, F	Weight: 0.2 to 30 kg
Height: 30 to 250 cm	Minimum delivered tidal volume: ≥ 2 ml
IBW: 3 to 139 kg	
Minimum delivered tidal volume: ≥ 20 ml	

To select the patient group and initial settings

1. In the Standby window (Figure 5-1), touch the desired patient group tab:
   – **Adult/Ped**
   – **Neonatal**
   – **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**).

Figure 5-1. Patient group options in Standby window



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 (when HiFlowO2 is selected: Start therapy)

5.2.1 About Quick setups: precon-figured settings

For each of the patient groups, three different default configurations, referred to as *Quick setups*, can be defined.

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

Each Quick setup defines a ventilation mode, mode control settings, graphic display selection, alarm limit settings, Vent Status panel settings, **Vt/IBW** (Adult/Ped) or **Vt/kg** (Neonatal), specified humidifier settings (if connected), and nebulization selection.

The Quick setups are defined in Configuration (Chapter 14).

5.3 Entering patient data

⚠ CAUTION

Entering the correct patient data ensures safe ventilation settings for start up, apnea backup, and safety ventilation.

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 high**, **T low**, 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:
  - **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 tests and calibrations described in this section help verify the safety and reliability of the ventilator.

If a test fails, troubleshoot the ventilator as indicated or have the ventilator serviced. Make sure the tests pass before you return the ventilator to clinical use.

The 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.

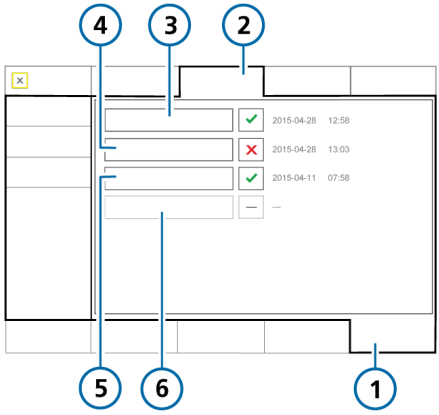
Table 5-2. When to perform tests and calibrations

Test or calibration	When to perform
Preoperational check	Before connecting a new patient to the ventilator.
Flow sensor calibration and tightness test	After connecting a new breathing circuit or component (including a flow sensor).
O2 sensor calibration, if needed	After installing a new O2 sensor or when a related alarm occurs. Not required with a paramagnetic O2 sensor.
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

- Open the System > Tests & calib window, and select the desired operation.

Figure 5-2. System > Tests & calib window



1	System	4	Flow sensor
2	Tests & calib	5	O2 sensor (shown uncalibrated)
3	Tightness	6	CO2 sensor (shown disabled)

A checkmark indicates the component is calibrated and ready. A red **X** indicates the calibration was unsuccessful. A box with no marks indicates the test/calibration has not been performed. A grayed-out box indicates the CO2 sensor is not enabled.

5.4.1 Performing the preoperational check

Before proceeding, review the safety information in Chapter 1.

When to perform

Before connecting a new patient to the ventilator.

To perform the preoperational check

- Use a setup as described in Table 5-3, and perform all of the steps in Table 5-4.

To ensure that the ventilator functions according to specifications on your patient, we recommend that your test circuit be equivalent to the circuit used for ventilation.

Table 5-3. Test breathing circuit setup

Component	Specification
Breathing circuit	Adult/pediatric, 10 to 22 mm ID
Flow sensor	Adult/pediatric, with calibration adapter
Test lung	Demonstration lung, 2 l, with adult ET tube between flow sensor and lung

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.	Breathing circuit is assembled correctly.
3	Turn on the ventilator.	During the self test, the alarm lamp flashes red and yellow in sequence and the buzzer sounds briefly. When complete, the alarm lamp flashes red again.
4	With the ventilator in Standby, touch **Preop check** in the Standby window.	The System > Tests & calib window opens.
5	Calibrate the flow sensor.	The calibration is successful. See Section 5.4.2.
6	Perform the tightness test.	The test passes. 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.

Do or observe…		Verify …
9	Generate an alarm (for example, by disconnecting primary power).	Corresponding alarm message is displayed in message bar (for example, Loss of external power). Note that patient alarms are suppressed in Standby.
10	Resolve the alarm situation (for example, reconnect primary power).	Alarm is reset.

Corrective action

A checkmark indicates the component is calibrated and ready. A red **X** indicates the calibration was unsuccessful.

If the ventilator does not pass the preoperational check, have it serviced.

5.4.2 Calibrating the adult/pediatric flow sensor

This calibration checks and resets the calibration points specific to the flow sensor in use, and measures circuit resistance compensation.

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.

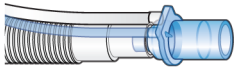
When to perform

After connecting a breathing circuit or component.

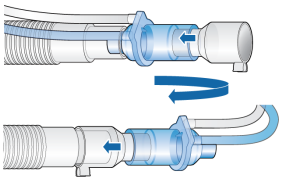
To calibrate an adult/pediatric flow sensor

1. Set up the ventilator for ventilation, complete with breathing circuit and flow sensor.
2. In the System > Tests & calib window, touch **Flow sensor**.

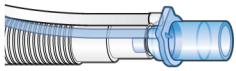
   If you have not already disconnected the patient, the message line displays **Disconnect patient**.
3. Disconnect the patient now.



4. When prompted on the display, attach the adapter and turn the flow sensor around as indicated.



5. When prompted, turn the flow sensor back to its starting position and remove the calibration adapter when indicated.



6. When calibration is complete, verify that there is a checkmark in the **Flow Sensor** checkbox.
7. When successful, continue with other tests or ventilation.

To cancel an ongoing calibration

- Touch **Flow sensor** again.

In case of calibration failure

If the calibration fails, a red **X** 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 flow sensor and expiratory valve set is 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.

If the problem persists, have the ventilator serviced.

5.4.3 Performing the breathing circuit tightness test

Before proceeding, review the safety information in Chapter 1.

This test checks for leakage in the patient breathing circuit.

When to perform

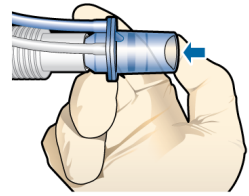
After installing a new or decontaminated breathing circuit or component (including a flow sensor).

To perform the tightness test

1. Set up the ventilator for ventilation, complete with breathing circuit and flow sensor.
2. In the System > Tests & calib window, touch **Tightness**.

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

   The text Tighten patient system is now displayed.
4. Block the opening (wearing a glove is recommended).

   The text Reconnect breathing system is now displayed.
5. Reconnect the breathing system.
6. When the test is complete, verify that there is a checkmark in the Tightness checkbox.

To cancel the test while it is in progress

- Touch **Tightness** again.

In case of test failure

If the test fails, a red **X** is displayed in the Tightness checkbox.

Perform the following checks, repeating the tightness 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 is 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.
- If the calibration still fails, replace the breathing circuit.

If the problem still persists, have the ventilator serviced.

5.4.4 Calibrating the oxygen sensor

NOTICE

When the **Set Oxygen alarm limits manually** checkbox is selected, you can only calibrate the O2 sensor while in Standby, using 21% oxygen.

The device tests the O2 sensor and resets the calibration points specific to the sensor in use.

The galvanic O2 sensor requires approximately 30 minutes warm-up time to reach stable values. O2 monitoring during this time period may be more variable. We recommend performing the calibration after the O2 sensor is warmed up.

The paramagnetic O2 sensor does not require warm-up time, and is only calibrated once, upon installation.

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. In the System > Tests & calib window, touch **O2 sensor**.
3. 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[17]		
Standby	Connected	> 21%
Active ventilation	Connected	> 21%
21% oxygen calibration		
When the oxygen supply is less than 99%, you must disconnect the oxygen supply before calibration.		
Standby	Disconnected	any
Standby	Connected	21%
Active ventilation	Connected	21%

[17] Calibrating at 100% improves the stability of measurements at higher oxygen concentrations during use.

In case of calibration failure

If the calibration fails, a red **X** 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, and you are using a galvanic O2 sensor, replace the sensor.

If the problem persists, have the ventilator serviced.

5.4.5 Performing a zero calibration on the CO2 sensor/adapter

⚠ 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.*

Before proceeding, review the safety information in Chapter 1.

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 below.

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

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.

Wait at least 20 seconds — and for best results, 2 minutes — to perform the zero calibration after removing the adapter from the patient's airway. This time allows any CO2 remaining in the adapter to dissipate.

To perform the zero calibration of the CO2 sensor/adapter (mainstream) and sensor/module (sidestream)

For reference, see Figure 4-2 for the mainstream CO2 assembly and Figure 4-4 for the sidestream assembly.

1. Connect the CO2 sensor (mainstream) or the CO2 module (sidestream) to the ventilator, and ensure CO2 monitoring is enabled.

   Once connected, wait approximately 90 seconds for the device to warm up.

2. Disconnect the CO2 adapter from the breathing circuit.

3. Attach the CO2 adapter to the sensor (mainstream) or plug the sample cell into the CO2 module (sidestream).

   Place these components away from all sources of CO2 (including the patient's and your own exhaled breath) and the exhaust port of the expiratory valve.

4. In the System > Tests & calib window, 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.

In case of zero calibration failure

If the zero calibration fails, a red **X** 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

The HAMILTON-C6 performs a self-check that verifies proper alarm function during startup.

We recommend testing the alarms as part of the preoperational check.

For all of the tests, use a demonstration lung assembly as described in Section 5.4.1.

5.4.6.1 High pressure alarm test

1. Select the PCV+ mode and start ventilation.
2. Set the high Pressure alarm limit to 15 cmH2O above the measured Ppeak.
3. Start ventilation.
4. Squeeze the demonstration lung hard during inspiration.
5. Verify that the high Pressure alarm is generated, the ventilator cycles into exhalation, and pressure falls to the PEEP/CPAP level.

5.4.6.2 Low minute volume alarm test

1. Select a mode, for example, PCV+ and start ventilation.
2. Let the ventilator deliver 10 breaths with no alarms.
3. Adjust the low ExpMinVol alarm limit so it is higher than the measured value.
4. Verify that the Low minute volume alarm is generated.

5.4.6.3 Low oxygen alarm test

1. Select a mode, for example, PCV+ and start ventilation.
2. Set the **Oxygen** control to 50%.
3. Wait for 2 minutes.
4. Disconnect the oxygen supply.
5. Verify the following:
   – The oxygen concentration displayed in the Monitoring window decreases.
   – The **Low oxygen** alarm is generated.
6. Wait 30 seconds or until the oxygen concentration falls below 40%.
7. Reconnect the oxygen supply.
8. Verify that the **Low oxygen** alarm resets.
   The alarm should reset when the measured oxygen exceeds 45%.

5.4.6.4 Disconnection on patient side alarm test

1. Disconnect the demonstration lung during active ventilation.
2. Verify that the **Disconnection on patient side** alarm is generated.
3. Reconnect the demonstration lung.
4. Verify that the alarm resets and that the ventilator automatically resumes ventilation.

5.4.6.5 Loss of external power alarm test

1. With the ventilator connected to primary power, turn it on.
2. Disconnect the power cord.
3. Verify that the **Loss of external power** alarm is generated and that the ventilator is powered by its backup battery.
4. Reconnect the ventilator to primary power.
5. Verify that the alarm resets and that the ventilator is again powered by primary AC power.

5.4.6.6 Exhalation obstructed alarm test

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

5.4.6.7 Apnea alarm test

1. Select the SPONT mode.

   Make sure Apnea backup ventilation is disabled.

2. Wait for the set apnea time.
3. Verify that the **Apnea** alarm is generated.
4. Squeeze the demonstration lung twice.
5. Verify that the **Apnea** alarm resets.

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:

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

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



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

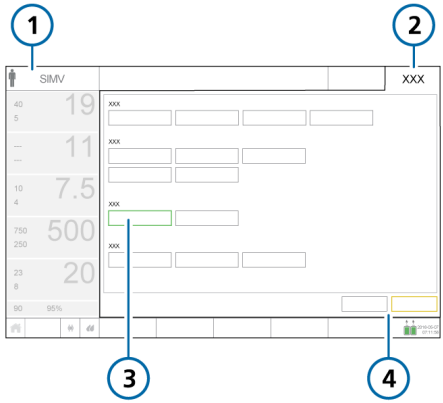
   The **Confirm** button is only displayed after you select a different mode in the window.

   The Controls window opens.

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

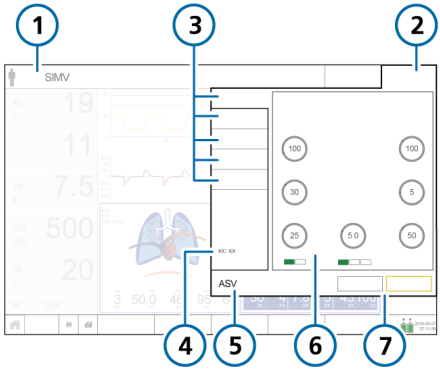
   The newly selected mode is not active *until* you touch **Confirm** in the Controls window. Without confirmation, the window closes after a short time and the currently active mode remains in place.

Figure 5-3. Modes window, changing modes



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

Figure 5-4. Controls window, changing modes



1	Active mode, patient group	5	New mode
2	Modes	6	Controls for new mode
3	Tabs: Basic, More, Apnea, TRC, Patient	7	Cancel/Confirm
4	Values depending on mode (minute volume, timing)		

5.5.1 Reviewing and adjusting ventilation settings

You specify ventilation settings in the Controls window tabs: **Basic**, **More**, **Apnea**, **TRC**. 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 5-5.

   The change takes effect immediately.

   For details about changing the trigger type, see Section 5.5.2.

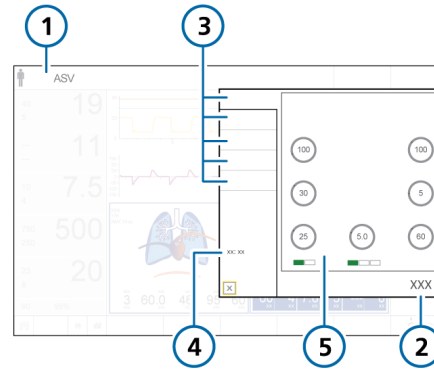
2. Touch **More** to enable/disable **Sigh**, if needed.

3. If applicable, touch **Apnea** and select or deselect **Backup** as needed.

4. If applicable, touch **TRC** and enable/disable/adjust settings as needed. See Section 5.5.4.

5. If you need to change basic patient data, touch **Patient** and adjust settings as needed. See Section 5.3.

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



1	Active mode, patient group	4	Values depending on mode (minute volume, timing)
2	Controls	5	Mode controls
3	Tabs: Basic, More, Apnea, TRC, Patient		

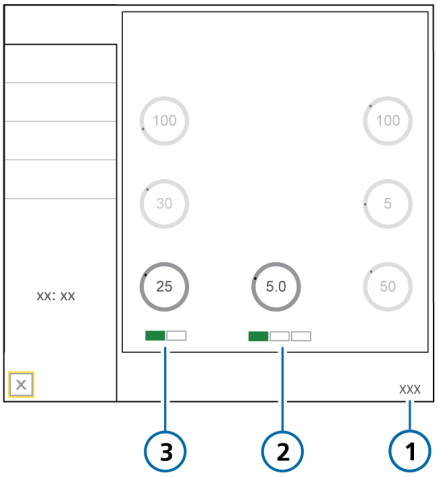
5.5.2 About the trigger types

Before proceeding, review the safety information in Chapter 1.

You can select the conditions that cause the ventilator to trigger a breath based on flow, pressure, or a combination of inputs[18] (Section 5.5.2.1).

In addition, you select the cycling option to use for all breaths based on flow or on a combination of inputs[18] (Section 5.5.2.2).

Figure 5-6. Trigger and cycling controls



1 Controls (Basic)

2 Trigger selection buttons (Flow trigger (F) selected)

3 Cycling selection buttons (ETS (E) selected)

5.5.2.1 Selecting the trigger type

You can select the trigger type to use. Table 5-6 describes the trigger types and behavior.

Table 5-6. Trigger types

Trigger type	Description
Flow trigger (F)	The patient's inspiratory flow that triggers the ventilator to deliver a breath. When selected, the **F** indicator under the control is green.
IntelliSync+ (I)[18]	The ventilator monitors incoming sensor signals from the patient and reacts dynamically to initiate inspiration and expiration in real time. When selected, the **I** indicator under the control is green, and the control itself is blue, displaying the text *IntelliSync+*.
Pressure trigger (P)	The drop in airway pressure when the patient tries to inhale triggers the ventilator to deliver a breath. When selected, the **P** indicator under the control is green.

Changing the setting during the inspiratory phase affects the next breath. Changing it during the expiratory phase affects the breath after 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.

[18] If the IntelliSync+ option is installed.

Note that the ambient valve of the HAMILTON-C6 opens at -3 cmH2O below ambient pressure. Therefore, be sure to set a P trigger setting above this value to ensure accurate trigger sensitivity.

For example, if PEEP is set to 5 cmH2O, P trigger must be set to no more than -7 cmH2O (in total, -3 cmH2O below ambient), to ensure an accurate trigger sensitivity.

To specify the trigger type and setting

1. In the Controls > Basic window, touch the desired Trigger selection button below the control.

   The buttons are labeled **F** (flow trigger), **I** (IntelliSync+), and **P** (pressure trigger). 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.

2. If the flow or pressure trigger is selected, adjust the Trigger setting as needed.

5.5.2.2 Selecting the cycling option

You can select the cycling option to use. Table 5-7 describes the options and behavior.

Table 5-7. Cycling options

Cycling option	Description
Cycle: 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.
Cycle: IntelliSync+ (I)[19]	The ventilator monitors incoming sensor signals from the patient and reacts dynamically to initiate inspiration and expiration 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 cycling option and setting

1. In the Controls > Basic window, touch the desired Cycling selection button below the control.

   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.

2. If ETS is selected, adjust the ETS setting as needed.

[19] If the IntelliSync+ option is installed.

5.5.3 About apnea backup ventilation

Before proceeding, review the safety information in Chapter 1.

The HAMILTON-C6 provides apnea backup ventilation, a mechanism that minimizes possible patient injury due to apnea or cessation of respiration. Apnea backup is available in APVsimv, SIMV, SPONT, DuoPAP, APRV, and NIV modes.

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** 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 7.1.3.

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

To change the Apnea backup control settings

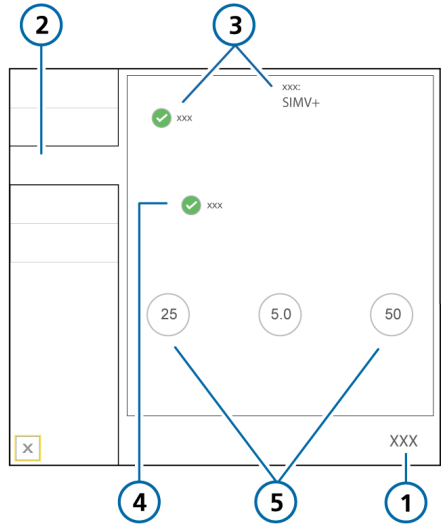
1. In the Controls > Apnea window, clear the **Automatic** checkbox.

   The settings controls are enabled.

2. Change the values as desired.

   The changes take effect immediately.

Figure 5-7. Apnea window, Automatic button



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.

5.5.4 About tube resistance compensation (TRC)

Before proceeding, review the safety information in Chapter 1.

TRC is intended for use with spontaneously breathing patients.

Tube resistance compensation (TRC) is flow-proportional pressure support to compensate the flow resistance of the ventilation tube (endotracheal (**ET**) or tracheostomy (**Trach**)).

100% compensation indicates that resistance due to the tube itself is compensated. Note that internal resistance (for example, from secretions) and external resistance (for example, from tube kinking) are not compensated.

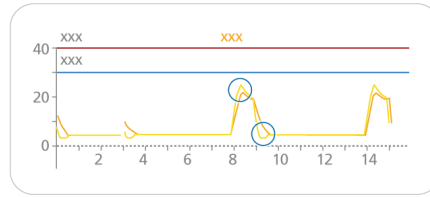
TRC can be enabled or disabled for the expiration phase, as well.

By default, TRC is disabled.

When TRC is enabled:

- The additional work of breathing due to the tube can be partially or completely compensated.
- The tracheal pressure (**Ptrachea**) waveform (orange) is shown together with the Paw waveform (yellow).
- At the beginning of the inspiratory phase, the pressure will be higher than without TRC, and will drop below PEEP at the beginning of the exhalation phase to compensate the flow-dependent resistance. See Figure 5-8 for an example.
- The displayed **Ppeak** may be higher than the set **PEEP/CPAP** plus **Pcontrol/Psupport** due to the additional pressure required to work against the tube resistance.

Figure 5-8. Ptrachea (orange) and Paw (yellow) waveforms, with TRC active



The Ptrachea waveform is calculated as follows:

$$\Delta P_{ETT} = K_{tube} \times \dot{V}$$

where

ΔP_{ETT}	Flow-proportional pressure drop over the tube. This is the difference between the Ptrachea and Paw waveforms.
K_{tube}	Tube coefficient (k-factor). Dependent on inner diameter and length of tube, is equal to flow/resistance at a flow of 1 l/s.
$\dot{V}$	Flow of the breathing gas.

To specify TRC settings

1. Open the Controls > TRC window.
2. To set the ET tube compensation settings, touch the **ET tube** button (Figure 5-9).

   To set the tracheostomy tube compensation settings, touch the **Trach tube** button.

3. Using the **Tube ID** and **Compensate** controls, specify the tube diameter (in mm) and compensation percentage (%) to apply (Figure 5-9).

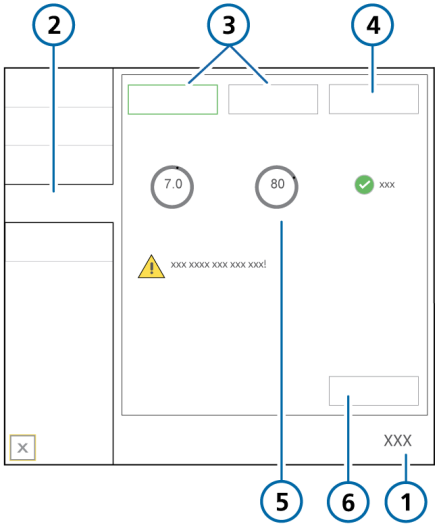
   If the tube is shortened, reduce the compensation percentage.

4. If desired, select the **Expiration** check-box to also activate compensation during exhalation.

5. To disable TRC if it has been enabled, touch **Disable TRC**.

6. Touch **Apply** to confirm the settings.

Figure 5-9. Controls > TRC window



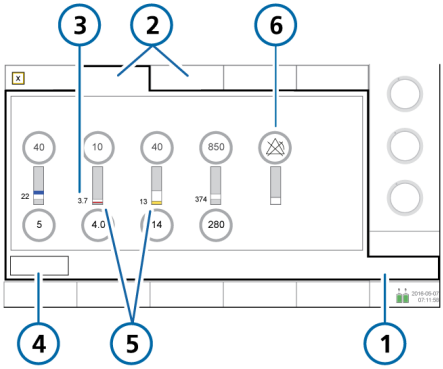
1	Controls	4	Disable TRC
2	TRC	5	Tube ID and Compensate controls, Expiration
3	ET and Trach tube	6	Apply

5.6 Setting alarm limits

Before proceeding, review the safety information in Chapter 1.

You can access the Alarms window and change alarm settings at any time, without affecting ventilation.

Figure 5-10. Alarms > Limits 1 window



1	Alarms	4	Auto[20]
2	Limits 1, 2[21]	5	Red or yellow bar (depending on alarm priority) indicates the monitored value is out of range
3	Current monitored value	6	Alarm Off symbol when an alarm limit is set to OFF

[20] Not available during neonatal ventilation.
[21] If the Masimo rainbow SET pulse oximetry option is activated, related parameters are shown on the Limits 3 tab.

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 5-10).

2. To set an alarm limit individually, touch the alarm control and adjust the value. Repeat for any other alarm.

   Additional alarm settings are available in the Limits 2, and if used, Limits 3 windows.

   Note that when an alarm limit is set to Off, the device displays the Alarm Off symbol.

   For details about the Oxygen alarm limits, including when you can manually set them, see Section 14.3.6.

3. To set alarm limits automatically, touch the **Auto** button[22] 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[23]. 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.

4. Close the window.

The following table briefly describes each of the adjustable ventilator alarms. Additional details are available in Table 16-8.

For SpO2-related alarms, see the *Pulse Oximetry Instructions for use*.

Table 5-8. 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 The Apnea alarm can be turned off in nCPAP-PS mode.
ExpMinVol (low and high)	Low and high expiratory minute volume. If either limit is reached, a high-priority alarm is generated.
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.

[22] Not available during neonatal ventilation.
[23] SpO2-related alarms are also not automatically set.

Alarm	Definition
Oxygen (low and high)	Low and high monitored oxygen concentration (Oxygen). If either limit is reached, a high-priority alarm is generated. You can only adjust the Oxygen alarm limits when the **Set Oxygen alarm limits manually** checkbox is selected in Configuration. See Section 14.3.6.
PetCO2 (low and high)	Low and high monitored **PetCO2**. If either limit is reached, a medium-priority alarm is generated.
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 high Pressure limit minus 10 cmH2O, 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 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 more than 1.5 times the set upper **Vt** alarm limit, the **Inspiratory volume limitation** alarm is generated. In this case, the device aborts the breath and reduces the pressure to **PEEP** level. The APV controls reduce the pressure for the next breath by 3 cmH2O.

5.6.1 About the Oxygen alarm limits

By default, the **Oxygen** high/low alarms are automatically set to the current **Oxygen** setting ± 5%. The **Oxygen** limit controls are disabled in the Alarms > Limits 1 window.

If the **Set Oxygen alarm limits manually** option is selected in Configuration, the **Oxygen** limit controls are enabled in the Alarm > Limits 1 window and can be adjusted as appropriate. For details, see Section 14.3.6.

5.7 Starting ventilation

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

To start ventilation

- Do either of the following:
  - In Standby, touch **Start ventilation**. If the mode selected is HiFlowO2, the button is labeled **Start therapy**.
  - Press the P&T knob.

Ventilation starts.

During active ventilation, the **Power/Standby** key light is white.

5.8 Stopping ventilation

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.

When in Standby, the **Power/Standby** key light is green.

5.9 About the control parameters

Table 5-9 briefly describes each of the ventilator control parameters.

Table 16-5 provides the control parameter ranges and default settings, including accuracy.

Table 5-9. Control parameters, defined

Parameter	Definition
%MinVol	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 patients **IBW**. Applies in APVsimv, SIMV, SPONT, DuoPAP, APRV, and NIV modes. *Be sure to review the safety information in Chapter 1*.
Cycle	The ventilator offers the following cycling options: ETS and IntelliSync +[24], which apply to all breaths. 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, which may be beneficial in patients with obstructive lung disease. The **ETS** setting lets you match the inspiratory time of pressure-supported breaths to the patient's neural timing. With **IntelliSync+**, the ventilator monitors incoming sensor signals from the patient and reacts dynamically to initiate inspiration and expiration in real time. Applies to spontaneous breaths.
Flow	In high flow oxygen therapy, **Flow** is the continuous and constant flow of medical gas to the patient in liters per minute.
Flow pattern	Flow pattern for gas delivery. This is not affected by patient pressure or other limitations as long as the peak inspiratory flow or pressure limit is not exceeded. Applies to volume-controlled mandatory breaths.

[24] If the IntelliSync+ option is installed.

Parameter	Definition
Flow trigger	*See* Trigger.
Sex	Sex of patient. Used to compute ideal body weight (**IBW**) for adults and pediatric patients.
HAMILTON-H900-related parameters	Displayed when a HAMILTON-H900 humidifier is connected. See Table 12-5.
IntelliCuff-related parameters	Displayed when an IntelliCuff cuff pressure controller is connected. See Section 12.2.8.
I:E	Ratio of inspiratory time to expiratory time. Applies to mandatory breaths, and in APVsimv/APVcmv and PCV+.
Oxygen	Oxygen concentration to be delivered. Applies to all breaths.
Pasvlimit	The maximum pressure to apply in ASV mode. For the ASV controller to function correctly, Pasvlimit must be at least 15 cmH2O above PEEP/CPAP. Changing Pasvlimit or the **Pressure** alarm limit automatically changes the other: The **Pressure** alarm limit is always 10 cmH2O greater than Pasvlimit.
Pat. height	Patient height. It determines the ideal body weight (**IBW**), used in calculations for ASV and ventilation settings for adult/pediatric patients.
Pause	Inspiratory pause or plateau, as a percentage of total breath cycle time. After the required gas is delivered (after the operator-set **Vt** is reached), gas remains in the lungs and exhalation is blocked during the **Pause** time. The use of a pause increases the residence time of gas in the patient's lungs. Applies to volume-controlled mandatory breaths, when the device is configured in this manner (Section 14.4.1).
Peak flow	Peak (maximum) inspiratory flow. Applies to volume-controlled mandatory breaths, when the device is configured in this manner (Section 14.4.1).
Pcontrol	The pressure (additional to PEEP/CPAP) to apply during the inspiratory phase in PCV+ and PSIMV+ modes.
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 and with HiFlowO2.

Parameter	Definition
P high	The high pressure setting in APRV and DuoPAP modes. Absolute pressure, including PEEP.
Pinsp	Pressure (additional to PEEP/CPAP) to apply during the inspiratory phase. Applies in PSIMV+ PSync, NIV-ST, and nCPAP-PS.
P low	The low pressure setting in APRV.
P-ramp	Pressure ramp. The rate at which pressure rises to meet the set value. The set **Pressure** is generally reached after approximately 2 x **P-ramp**. 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. To prevent possible pressure overshoot in pediatric applications, we recommend that **P-ramp** be set to at least 75 ms. 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. • Lower **P-ramp** values have been correlated with reduced work of breathing in certain patients. • Setting the **P-ramp** too low, 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.
Pressure trigger	*See* Trigger.
Psupport	Pressure support for spontaneous breaths in SPONT, NIV, APVsimv, SIMV+, 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.
Rate	Respiratory frequency or number of breaths per minute.

Parameter	Definition
Sigh	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 **PControl** or **Pinsp**. • 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, or DuoPAP or APRV modes.
T high	Length of time at the higher pressure level, **P high**, in DuoPAP and APRV modes.
TI	Inspiratory time, the length of time to deliver gas for inspiration at the **Pcontrol** setting. Used with **Rate** to set the breath cycle time. Applies in PCV+, APVcmv, APVsimv, PSIMV+, NIV-ST, and nCPAP-PS. 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**.
T low	Length of time at the lower pressure level, **P low**, in APRV mode.
TI max	Maximum inspiratory time for cycled breaths in NIV, NIV-ST, and SPONT in neonatal modes, as well as the neonatal mode, nCPAP-PS. For all patient groups, the switchover from inspiration to exhalation in spontaneous breaths is normally controlled by the **ETS** (expiratory trigger sensitivity) or IntelliSync+[24]. If gas leakage is significant, however, the set cycle may never be reached. The **TI max** setting provides a back-up so inspiration can be terminated. The ventilator switches over to exhalation when the set **TI max** is reached.
Tip	Inspiratory pause or plateau time. After the required gas is delivered (after the operator-set **Vt** is reached), gas remains in the lungs and exhalation is blocked during the **Tip** time. The use of an inspiratory pause increases the residence time of gas in the patient's lungs. Applies to volume-controlled mandatory breaths, when the device is configured in this manner (Section 14.4.1).
TRC-related settings	Tube resistance compensation. Reduces the patient's work of breathing by offsetting tube resistance. *Review the safety information in Chapter 1.*

Parameter	Definition
TRC: Tube type/ Disable TRC	Options are: ET (endotracheal) tube, Trach (tracheostomy) tube, Disable TRC (TRC off)
TRC: Tube ID	Inner diameter of the tube, in mm.
TRC: Compensate	Compensation percentage (%).
TRC: Expiration	Activate compensation during exhalation.
Trigger	The ventilator offers the following trigger types: Flow, Pressure, and IntelliSync+[24], which apply to all breaths. For details on selecting the trigger to use, see Section 5.5.2. 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.
	Flow The patient's inspiratory flow that triggers the ventilator to deliver a breath.
	Pressure The drop in airway pressure when the patient tries to inhale triggers the ventilator to deliver a breath. Changing the setting during the • Inspiratory phase affects the next breath • Expiratory phase affects the breath after next
	With IntelliSync+, the ventilator monitors incoming sensor signals from the patient and, using a comprehensive set of algorithms, analyzes this data and dynamically adjusts the setting in real-time to address changing patient or system conditions.
Vt	Tidal volume delivered during inspiration in APVcmv and APVsimv modes.
Vt/kg	Tidal volume per weight.
Weight	Actual body weight. Used only with neonates.

6
Specifying neonatal settings

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6.4 Setting the patient weight for ventilation 107
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6.6 O2 enrichment for neonates 107

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 3.4.2
Select and assemble the appropriate breathing circuit and components.	Section 6.1.2
Adjust the position of the breathing circuit.	Section 6.1.2.5
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

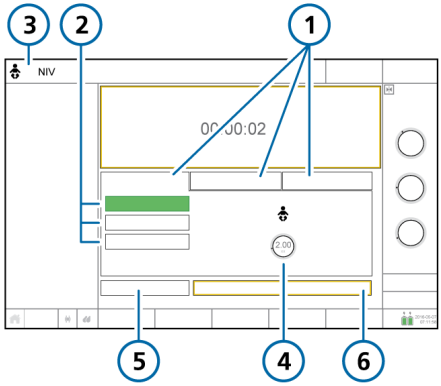
⚠ CAUTION

Entering the correct patient data ensures safe ventilation settings for start up, apnea backup, and safety ventilation.

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)	4	Weight
2	Quick setup buttons	5	Preop check
3	Selected mode and patient group	6	Start ventilation

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

Setting up a neonatal breathing circuit comprises the following steps:

Table 6-1. Assembling the breathing circuit

To ...	See ...
Select the components	Section 6.1.2.3
Connect the breathing circuit	Section 6.1.2.1
Connect the flow sensor	Section 6.1.2.4
Position the circuit	Section 6.1.2.5

6.1.2.1 Connecting the neonatal breathing circuit

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

6.1.2.2 Working with the expiratory valve

The process is the same as for adult and pediatric patients. See Section 3.4.2.

6.1.2.3 Selecting the breathing circuit components

Select the correct breathing circuit parts for your patient from Tables 6-2 and 6-3.

Table 6-2. Neonatal breathing circuit part specifications

Group/component	Specification
Patient group	Neonatal
Weight (kg)	0.2 to 30
Tracheal tube ID (mm)	≤ 4
Breathing circuit tube ID (mm)	10 to 12
Flow sensor	Neonatal
CO2 airway adapter	Neonatal

Table 6-3. Tracheal tubes and CO2

Tracheal tube ID (mm)	CO2 airway adapter
≤ 4	Neonatal

6.1.2.4 Connecting the neonatal flow sensor

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

During calibration, the flow sensor is *always* placed after the Y-piece, regardless of which ventilator mode is selected.

To connect the neonatal flow sensor

1. For all modes except nCPAP-PS and HiFlowO2, connect a flow sensor between the Y-piece of the breathing circuit and the patient connection. See Figure 6-2.

   When using the nCPAP-PS mode, connect the flow sensor between the end of the expiratory limb and the expiratory valve on the ventilator (Figure 6-3).

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

   High flow oxygen therapy does not use 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 silver connection port.

3. Calibrate the flow sensor and perform the tightness test. See Section 6.2.1.

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

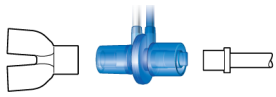
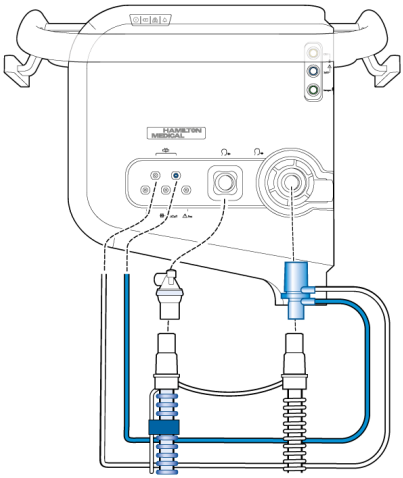


Figure 6-3. Connecting the flow sensor to expiratory valve, nCPAP-PS mode



6.1.2.5 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.

To perform the preoperational check

- Use a setup as described in Table 5-3, and perform all of the steps in Table 5-4.

To ensure that the ventilator functions according to specifications on your patient, we recommend that your test circuit be equivalent to the circuit used for ventilation.

Table 6-4. Test breathing circuit setup

Component	Specification
Breathing circuit	Neonatal, 10 to 12 mm ID
Flow sensor	Neonatal, with calibration adapter
Test lung	Neonatal, with neonatal ET tube between flow sensor and lung model (an IngMar neonatal lung model is recommended)

Table 6-5. Preoperational check, overview

To ...	See ...
Perform the preoperational check.	Section 5.4 in Chapter 5
Calibrate the neonatal flow sensor.	Section 6.2.1
Perform the tightness test.	Section 5.4.3 in Chapter 5
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.

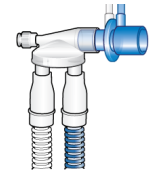
During calibration, the flow sensor is *always* placed after the Y-piece, regardless of which ventilator mode is selected.

A flow sensor is required for all modes except high flow oxygen therapy and nCPAP modes. Before proceeding, ensure you have the calibration adapter available.

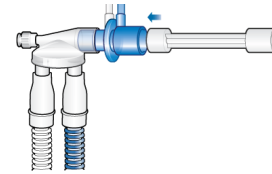
To calibrate a neonatal/pediatric flow sensor

1. Set up the ventilator for ventilation, complete with breathing circuit and neonatal/pediatric flow sensor.
2. In the System > Tests & calib window, touch **Flow sensor**.

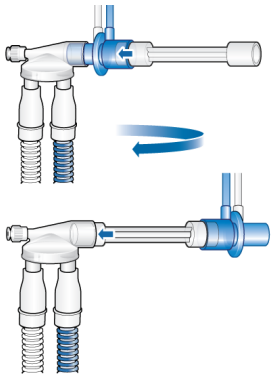
   If you have not already disconnected the patient, the message line displays **Disconnect patient**.
3. Disconnect the patient now.



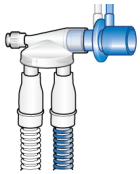
4. When prompted on the display, attach the calibration adapter to the patient end of the flow sensor.



5. When prompted, turn the flow sensor around as indicated and attach the calibration end to the Y-piece.



6. When prompted to turn the flow sensor again, remove the calibration adapter, and turn the flow sensor back to its starting position.



7. When calibration is complete, verify that there is a checkmark in the **Flow Sensor** checkbox.
8. When successful, continue with other tests or ventilation.

To cancel an ongoing calibration

- Touch **Flow sensor** again.

In case of calibration failure

If the calibration fails, a red **X** 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.

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) modes.

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.

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 by 25% of the last oxygen setting.

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

7 Ventilation modes

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7.1 Overview

The HAMILTON-C6 offers a full range of ventilation and therapy 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.

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.

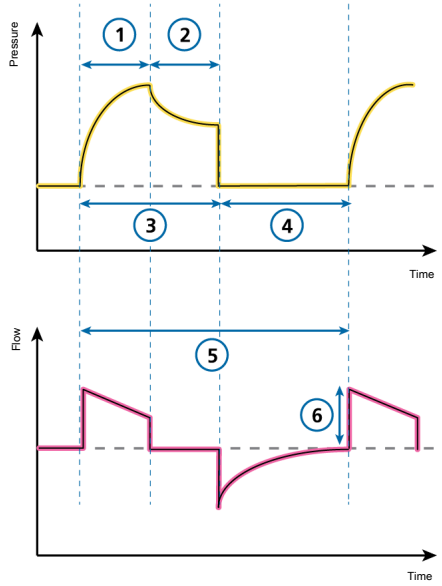
Spontaneous breaths. The start of inspiration (triggering) and end of inspiration (cycling) is determined by the patient. The patient breathes independently or receives support from the ventilator.

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/Pause**, **TI/Pause**, or **Peak flow/Tip**.

To select the breath timing to use, see Section 14.4.1.

Figure 7-1. Breath timing parameters



1	**TI** or **%TI**	4	**I:E** ratio
2	**Pause** or **Tip**	5	**Rate**
3	**I:E** ratio	6	Peak flow

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.

Table 7-1. HAMILTON-C6 ventilation and therapy modes, description and applicable patient group

Mode name	Patient group	Mode
Volume-controlled modes, flow controlled		
(S)CMV	Adult/Ped	Breaths are volume controlled and mandatory, including patient-triggered breaths.
SIMV	Adult/Ped	Volume-controlled mandatory breaths can be alternated with pressure-supported spontaneous breaths.
Volume-targeted modes, adaptive pressure controlled		
APVcmv / (S)CMV+	All	Breaths are volume targeted and mandatory.
APVsimv / SIMV+	All	Volume-targeted mandatory breaths can be alternated with pressure-supported spontaneous breaths.
Pressure-controlled modes		
PCV+	All	All breaths, whether triggered by the patient or the ventilator, are pressure controlled and mandatory.
PSIMV+	All	Mandatory breaths are pressure controlled. Mandatory breaths can be alternated with pressure-supported spontaneous breaths.
DuoPAP	All	Mandatory breaths are pressure controlled. Spontaneous breaths can be triggered at both pressure levels.
APRV	All	Spontaneous breaths can be continuously triggered. The pressure release between the levels contributes to ventilation.
SPONT	All	Every breath is spontaneous, with or without pressure-supported spontaneous breaths.
Intelligent ventilation		
ASV	Adult/Ped	Operator sets %MinVol, PEEP, and Oxygen. Frequency, tidal volume, pressure, and I:E ratio are based on physiological input from the patient.
INTELLiVENT-ASV	Adult/Ped	Fully automated management of ventilation and oxygenation based on physiological input from the patient. The underlying mode is ASV.

Mode name	Patient group	Mode
Noninvasive modes		
NIV	All	Every breath is spontaneous.
NIV-ST	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-PS	Neonatal	Every breath is spontaneous as long as the patient is breathing above the set rate. A backup rate can be set for mandatory breaths.
HiFlowO2	All	High flow oxygen therapy. No supported breaths.

7.1.3 Ventilation controls and settings

The table on the following page provides an overview of all of the modes and their control settings.

Mode type	Intelligent Ventilation		Vol targeted, adaptive press control		Volume controlled		Pressure controlled						Noninvasive			
Mode	**ASV*** **	**INTELLIVENT-ASV*** **	**APVcmv**	**APVsimv**	**(S)CMV *** **	**SIMV *** **	**PCV+**	**PSIMV +PSync**	**PSIMV+**	**DuoPAP**	**APRV**	**SPONT**	**NIV**	**NIV-ST**	**nCPAP-PS****	**HiFlow O2**
Timing	--	--	Rate	Rate	Rate	Rate	Rate	Rate	Rate	Rate	T low	--	--	Rate	Rate	--
	--	--	TI	TI	*	*	TI	TI	TI	T high	T high	--	--	TI	TI	--
Mandatory breaths	--	--	Vt	Vt	Vt	Vt	Pcontrol	Pinsp	Pcontrol	P high	P high	--	--	Pinsp	Pinsp	--
Spontaneous breaths	--	--	--	Psupport	--	Psupport	Pcontrol	Psupport	Pcontrol	Psupport	--	Psupport	Psupport	Pinsp	Pinsp	--
	Cycle	Cycle	--	Cycle	--	Cycle	--	Cycle	Cycle	Cycle	--	Cycle	Cycle	Cycle	Cycle	--
	--	--	--	--	--	--	--	--	--	--	--	TI max	TI max	TI max	TI max	--
Baseline press. PEEP/CPAP	X	AUTO	X	X	X	X	X	X	X	X	P low	X	X	X	X	--
Trigger	X	X	X	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	X	--
Oxygen	X	AUTO	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	X	X	--	X
Pat. height	X	X	X	X	X	X	X	X	X	X	X	X	X	X	--	X
Mode specific	%MinVol	AUTO %MinVol	--	--	Flow pattern	Flow pattern	--	--	--	--	--	--	--	--	--	Flow
	Pasvlimit	Pasvlimit	--	--	Pause	Pause	--									
Sigh* **	X	X	X	X	X	X	X	X	X	--	--	X	X	X	--	--
Apnea backup	--	--	APVsimv	--	APVsimv	(S)CMV	APVsimv	--	--	APVsimv	APVsimv	APVsimv	PCV+	PCV+	PCV+	--

*** I:E/Pause, TI/Pause, or Peak flow/TIP**
-- not applicable

**** Neonatal only**
X applies to this mode

***** Adult/Ped only**

7.2 Volume-controlled modes, flow control

The following modes are volume controlled, with flow control:

- (S)CMV
- SIMV

7.2.1 (S)CMV mode

(S)CMV stands for *synchronized controlled mandatory ventilation*.

Breaths in (S)CMV mode are volume-controlled and mandatory.

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

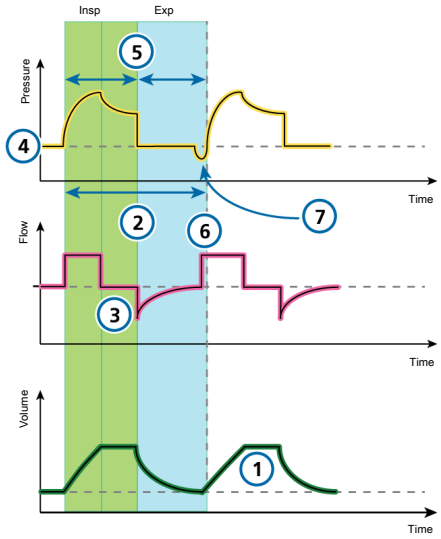
If a breath is not triggered by patient effort within a preset time, the ventilator delivers a set tidal volume with a constant flow or operator-selected flow pattern for a set inspiratory time at a set respiratory rate.

The ventilator always delivers the set tidal volume; pressure in the airway can increase or decrease depending on the resistance and compliance of the patient's lungs.

To protect the patient's lungs it is important to carefully set an upper pressure limit.

- The tidal volume (**Vt**) setting defines the delivered volume.
- The **Rate** and **I:E** define the timing of the breath cycle.
- The **Pause** setting (in %) is always set in relation to the total breath time.

Figure 7-2. (S)CMV mode: Breathing pattern and controls



Ventilator controls

CO2 elimination

1	Vt	3	Pause
2	Rate		Sigh *(not shown)*

Oxygenation

4	PEEP	6	Flow pattern
5	I:E[25]		Oxygen *(not shown)*

Patient synchronization

7	Trigger

[25] Depending on the selected breath timing philosophy.

7.2.2 SIMV mode

SIMV stands for *synchronized intermittent mandatory ventilation*.

The SIMV mode combines attributes of the (S)CMV and SPONT modes, delivering volume-controlled 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 SIMV breath interval.

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

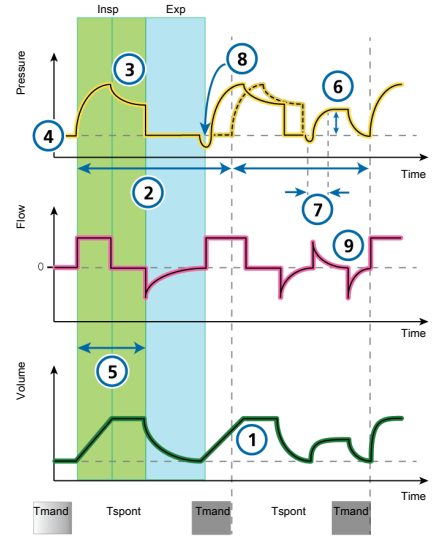
If the patient triggers a breath during **Tmand**, the ventilator immediately delivers a mandatory breath. If the patient triggers a breath during **Tspont**, the ventilator delivers a spontaneous, pressure-supported breath.

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

In SIMV mode, parameters for both the 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.
- **Psupport** defines the pressure support above **PEEP**. For spontaneous breaths, the expiratory trigger sensitivity (**ETS**) setting defines the percentage of peak flow that cycles the ventilator into exhalation.

Figure 7-3. SIMV mode: Breathing pattern and controls



Ventilator controls

CO2 elimination

1	Vt	3	Pause
2	Rate		Sigh *(not shown)*

Oxygenation

4	PEEP	6	Psupport
5	I:E[26]		Oxygen *(not shown)* Flow pattern *(not shown)*

Patient synchronization

7	P-ramp	9	ETS
8	Trigger		

[26] Depending on the selected breath timing philosophy.

7.3 Volume-targeted modes, adaptive pressure control

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

- APVcmv / (S)CMV+
- APVsimv / SIMV+

In this manual, we refer to these modes using the *APVcmv* / *APVsimv* nomenclature. You can select the format to use in Configuration (Section 14.4.2).

NOTICE

- The minimum inspiratory pressure (**Ppeak** – **PEEP**) in 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.
- For adaptive modes, such as APVcmv or APVsimv, be sure the **Pressure** alarm is set appropriately. This alarm 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 is 10 cmH2O below the high **Pressure** limit, indicated by a blue line on the pressure waveform display.
  - If the **Pressure** limit is set too low, there may not be enough margin for the device to adjust its inspiratory pressure to deliver the target tidal volume.

7.3.1 APVcmv / (S)CMV+ mode

APVcmv stands for adaptive pressure ventilation with controlled mandatory ventilation. This mode is also called (S)CMV+, which stands for *synchroniz-ed controlled mandatory ventilation*.

APVcmv is a volume-targeted pressure-controlled ventilation mode. It functions similarly to the conventional volume-controlled mode of ventilation, (S)CMV, 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.

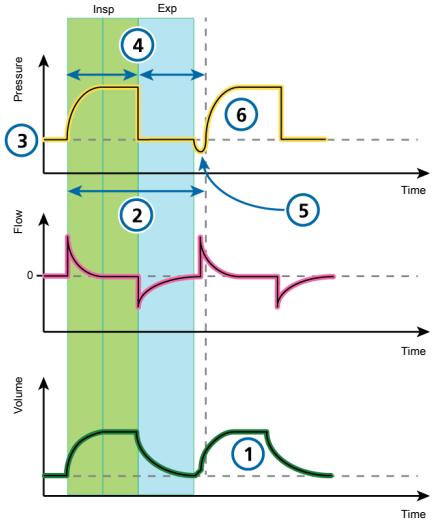
The ventilator uses the high **Pressure** alarm limit minus 10 cmH2O as a safety boundary for its inspiratory pressure adjustment, and does not exceed this value. An exception is sigh breaths, when the ventilator may apply inspiratory pressures 3 cmH2O below the high **Pressure** alarm limit.

Breaths in APVcmv 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.

Figure 7-4. APVcmv / (S)CMV+: Breathing pattern and controls



Ventilator controls

CO2 elimination

1	Vt	2	Rate
	Sigh *(not shown)*		

Oxygenation

3	PEEP	4	I:E[27]
	Oxygen *(not shown)*		

Patient synchronization

5	Trigger	6	P-ramp

[27] Depending on the selected breath timing philosophy.

7.3.2 APVsimv / SIMV+ mode

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

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

APVsimv 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 high **Pressure** limit minus 10 cmH2O as a safety boundary for its inspiratory pressure adjustment, and does not exceed this value. An exception is sigh breaths, when the ventilator may apply inspiratory pressures 3 cmH2O below the high **Pressure** limit.

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

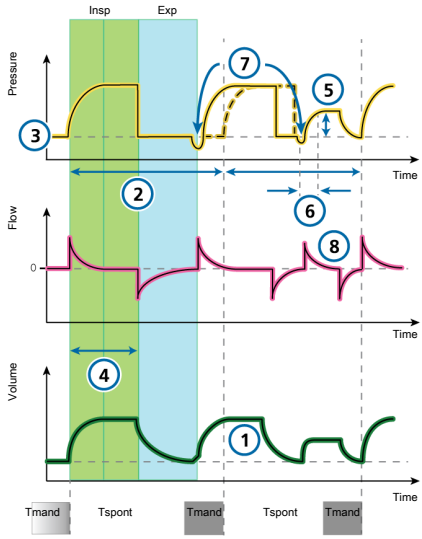
- If the patient triggers a breath during **Tmand**, the ventilator immediately delivers a mandatory breath.
- If the patient triggers a breath during **Tspont**, the ventilator delivers a spontaneous pressure-supported breath.

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, **Psupport** defines the pressure support above PEEP. **ETS** defines the inspiratory timing of the breaths.

Figure 7-5. APVsimv / SIMV+: Breathing pattern and controls



Ventilator controls

CO2 elimination

1 Vt

2 Rate

Sigh *(not shown)*

Oxygenation

3 PEEP

4 I:E[28]

5 Psupport

Oxygen *(not shown)*

Patient synchronization

6 P-ramp

7 Trigger

8 ETS

[28] Depending on the selected breath timing philosophy.

7.4 Pressure-controlled modes

The following modes are pressure controlled:

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

7.4.1 PCV+ mode

PCV+ stands for *pressure-controlled ventilation*.

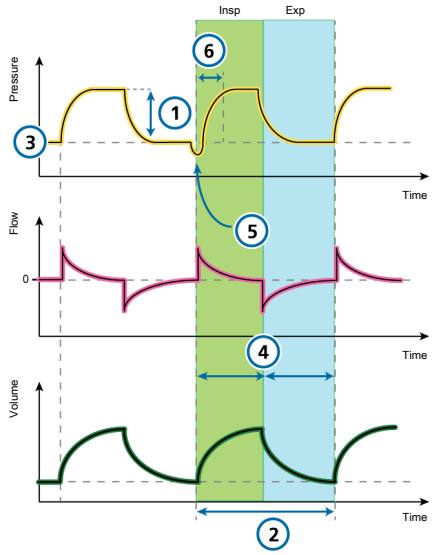
Breaths in PCV+ mode are pressure controlled and mandatory.

The ventilator delivers a constant level of pressure, so the volume will depend 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 (**Pcontrol**) 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.

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



Ventilator controls

CO2 elimination

1	Pcontrol	2	Rate
	Sigh *(not shown)*		

Oxygenation

3	PEEP	4	I:E[29]
	Oxygen *(not shown)*		

Patient synchronization

5	Trigger	6	P-ramp

[29] Depending on the selected breath timing philosophy.

7.4.2 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 7.4.3.

In PSIMV+ mode, the mandatory breaths are PCV+ breaths. These can be alternated with spontaneous 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**.

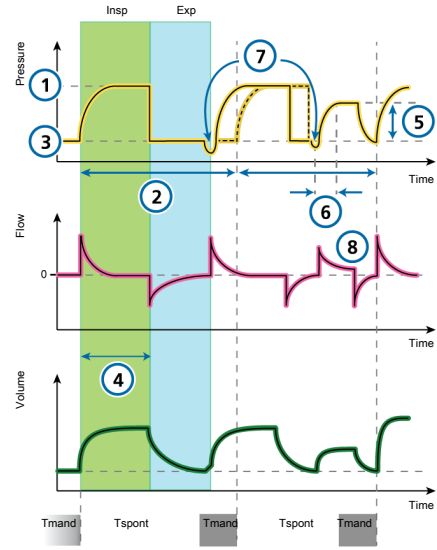
In PSIMV+ mode, parameters for both mandatory and spontaneous breath types are set.

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

  Rate and **I:E** define the timing of the breath cycle.
- For spontaneous breaths, **Psupport** defines the pressure support above PEEP.

  ETS defines the inspiratory timing of the breaths.

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



Ventilator controls

CO2 elimination

1	Pcontrol	2	Rate
	Sigh *(not shown)*		

Oxygenation

3	PEEP	5	Psupport
4	I:E[30]		Oxygen *(not shown)*

Patient synchronization

6	P-ramp	8	ETS
7	Trigger		

[30] Depending on the selected breath timing philosophy.

7.4.3 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 7.4.2.

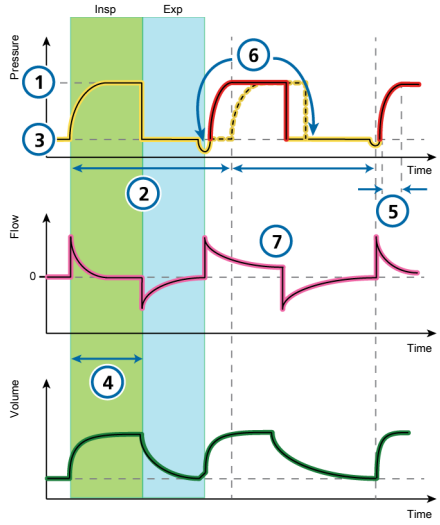
If the patient triggers a breath, the ventilator delivers a breath supported at the **Pinsp** setting.

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

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

- The **Pinsp** setting defines the applied pressure above **PEEP** for mandatory and spontaneous breaths.
- **Rate** and **TI** define the breath timing for mandatory breaths.
- For spontaneous breaths, **ETS** defines the inspiratory timing of the breaths.

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



Ventilator controls

CO2 elimination

1	Pinsp	2	Rate
	Sigh *(not shown)*		

Oxygenation

3	PEEP	4	I:E[30]
	Oxygen *(not shown)*		

Patient synchronization

5	P-ramp	7	ETS
6	Trigger		

7.4.4 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 between the two levels is defined by the pressure settings, **P high** and **PEEP/CPAP**, and the time settings, **T high** and **Rate**.

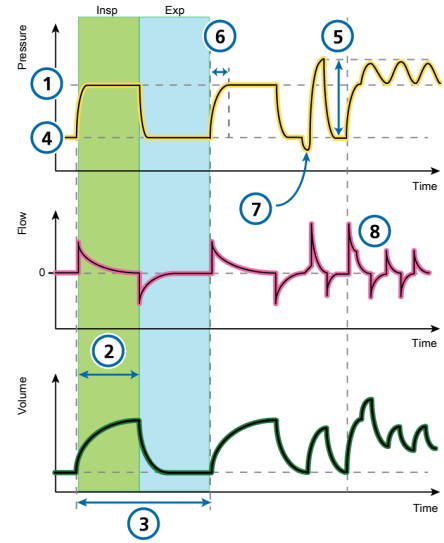
Note the following:

- 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 7.4.5).

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

Psupport 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**.

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



Ventilator controls

CO2 elimination

1 P high
2 T high
3 Rate

Oxygenation

4 PEEP/CPAP
5 Psupport

Oxygen *(not shown)*

Patient synchronization

6 P-ramp[31]
7 Trigger
8 ETS

[31] Pressure rise time to P high and Psupport.

7.4.5 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.

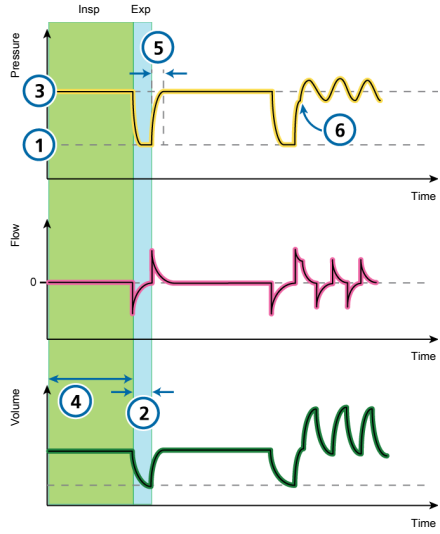
APRV allows spontaneous breathing at any time during the respiratory cycle.

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 timing and pressure settings proposed are based on Table 7-2.

Table 7-2. Default settings for APRV

IBW (kg)	P high / P low (cmH2O)	T high (s)	T low (s)
0.2 to 3	20 / 5	1.4	0.2
3 to 5	20 / 5	1.7	0.3
6 to 8	20 / 5	2.1	0.3
9 to 20	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 to 89	20 / 5	5.4	0.6
90 to 99	23 / 5	5.4	0.6
100	23 / 5	5.4	0.6

Figure 7-10. APRV mode: Breathing pattern and controls



Ventilator controls

CO2 elimination

1	P low	2	T low

Oxygenation

3	P high[32]	4	T high
	Oxygen *(not shown)*		

Patient synchronization

5	P-ramp (to P high)	6	Trigger

[32] With prolonged T high settings and short T low settings, the P high setting in effect becomes the PEEP level.

7.4.6 SPONT mode

SPONT is *spontaneous mode*.

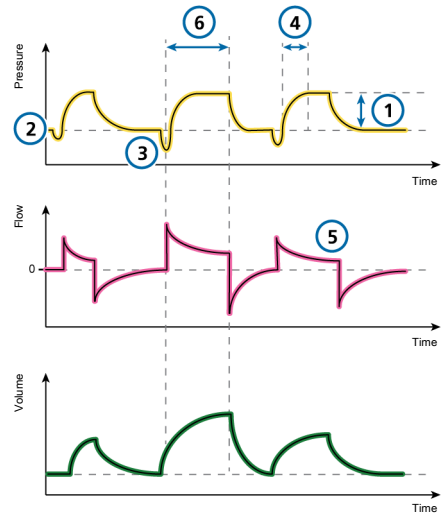
SPONT delivers spontaneous breaths and operator-initiated manual, mandatory breaths.

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

- The pressure support (**Psupport**) setting defines the applied pressure during inspiration.
- **ETS** defines the inspiratory timing of the breaths.

  When the ventilator does not detect an expiratory trigger (for example, due to a leak), inspiratory time is limited by **TI max**.
- The **PEEP** setting defines the PEEP applied during expiration.

Figure 7-11. SPONT mode: Breathing pattern and controls



	Ventilator controls		
	CO2 elimination		
1	Psupport		Sigh *(not shown)*
	Oxygenation		
2	PEEP		Oxygen *(not shown)*
	Patient synchronization		
3	Trigger	5	ETS
4	P-ramp	6	TI max

7.5 Intelligent Ventilation

The following are volume-controlled Intelligent Ventilation modes:

- ASV
- INTELLiVENT-ASV

ASV and INTELLiVENT-ASV are not available for neonatal patients.

7.5.1 ASV mode

ASV stands for *adaptive support ventilation*.

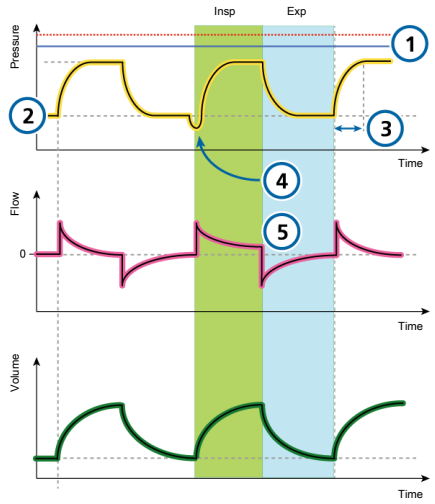
ASV maintains an operator-preset, minimum minute ventilation independent of the patient's breathing activity.

The target breathing pattern (tidal volume and inspiratory rate) is calculated by the ventilator, based on the assumption that the optimal breath pattern results in the least work of breathing, and the minimal force of breathing also results in the least amount of ventilator-applied inspiratory pressure when there is no patient breathing effort. For initial settings, see Table 7-3.

ASV adjusts inspiratory pressure and machine rate on a breath-by-breath basis taking into account the changing patient condition (resistance, compliance, **RCexp**) and applying lung-protective strategies to meet the targets.

A decrease in pressure limitation 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	Pasvlimit		Sigh *(not shown)*
	%MinVol *(not shown)*		
	Oxygenation		
2	PEEP/CPAP		Oxygen *(not shown)*
	Patient synchronization		
3	P-ramp	5	ETS
4	Trigger		

ASV maintains a **preset minimum minute ventilation**:

- Automatically and smoothly 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 Pinsp pressure of **10 cmH2O below the upper pressure limit**

The operator sets the %MinVol, PEEP, and Oxygen.

For details about working with ASV, see Section 7.9.

Table 7-3. Initial breath pattern settings

Patient group	IBW (kg)	Pinsp (cmH2O)	TI (s)	Initial target rate (b/min)	Min. target rate (b/min)
Pediatric	3 to 5	15	0.4	30	15
	6 to 8	15	0.6	25	12
	9 to 11	15	0.6	20	10
	12 to 14	15	0.7	20	10
	15 to 20	15	0.8	20	10
	21 to 23	15	0.9	15	7
	24 to 29	15	1	15	7
	> 30	15	1	15	7
Adult	30 to 39	15	1	14	7
	40 to 59	15	1	12	6
	60 to 89	15	1	10	5
	90 to 99	18	1.5	10	5
	> 100	20	1.5	10	5

7.5.1.1 ASV and ASV 1.1

ASV 1.1 is the default setting for the ASV mode. The 1.0 version of ASV is also available on the device, and can be selected in Configuration.

ASV 1.1 extends the use of ASV with the following additional features and changes:

- Increased target rate and reduced tidal volumes 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 7.9.

7.5.2 INTELLiVENT-ASV mode

INTELLiVENT-ASV[§] is available as an option[33] on the HAMILTON-C6 for adult and pediatric patients.

INTELLiVENT-ASV is an advanced ventilation mode, based on the proven Adaptive Support Ventilation (ASV) mode, to automatically regulate CO2 elimination and oxygenation for both passive and active patients, based on both physiologic data from the patient and clinician-set targets.

With this mode, the clinician sets targets for **PetCO2** and **SpO2** for the patient. INTELLiVENT-ASV then automates management of the controls for CO2 elimination (**%MinVol**), and oxygenation (**PEEP** and **Oxygen**) based on these targets and on the physiologic input from the patient (**PetCO2** and **SpO2**).

INTELLiVENT-ASV continuously monitors patient conditions and automatically and safely adjusts parameters to keep the patient within target ranges, with minimal clinician interaction, from intubation to extubation.

For operation details, see the *INTELLiVENT-ASV Operator's Manual*.

[33] Not available in all markets, including the USA.

7.6 Noninvasive modes

The following modes are noninvasive:

- NIV
- NIV-ST
- nCPAP-PS
- High flow oxygen therapy

The NIV and NIV-ST modes are implementations of noninvasive positive pressure ventilation (NPPV).

nCPAP-PS is a neonatal mode that offers nasal continuous positive airway pressure - and intermittent positive pressure support through a nasal interface (mask or prongs) for infants and neonates.

HiFlowO2 is a therapy in which a continuous flow of heated and humidified air and oxygen is delivered to the patient.

For details about working with noninvasive modes, see Section 7.8.

7.6.1 NIV mode

NIV stands for *noninvasive ventilation*.

NIV mode delivers spontaneous breaths.

NIV is designed for use with a mask or other noninvasive patient interface.

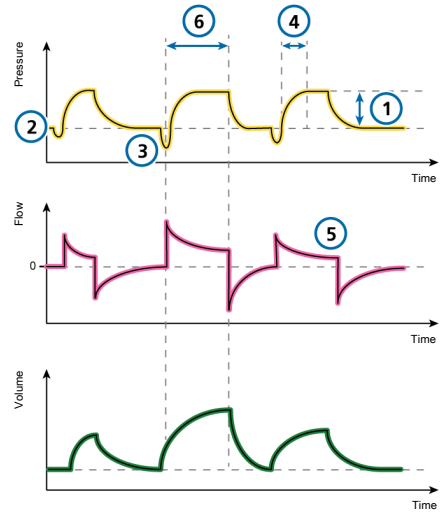
When pressure support is set to zero, the ventilator functions like a conventional CPAP system.

- The pressure support (**Psupport**) setting defines the applied pressure during inspiration.
- **ETS** defines the inspiratory timing of the breaths.

  If the ventilator does not detect an expiratory trigger (for example, due to a leak), inspiratory time is limited by **TI max**.
- The **PEEP** setting defines the PEEP applied during expiration.

For additional details about working with noninvasive modes, see Section 7.8.

Figure 7-13. NIV mode: Breathing pattern and controls



	Ventilator controls		
	CO2 elimination		
1	Psupport		Sigh *(not shown)*
	Oxygenation		
2	PEEP		Oxygen *(not shown)*
	Patient synchronization		
3	Trigger	5	ETS
4	P-ramp	6	TI max

7.6.2 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 **timv**, the ventilator immediately delivers a spontaneous breath. If the patient does not trigger an inspiration during this time, the ventilator initiates a mandatory breath at the end of **timv**.

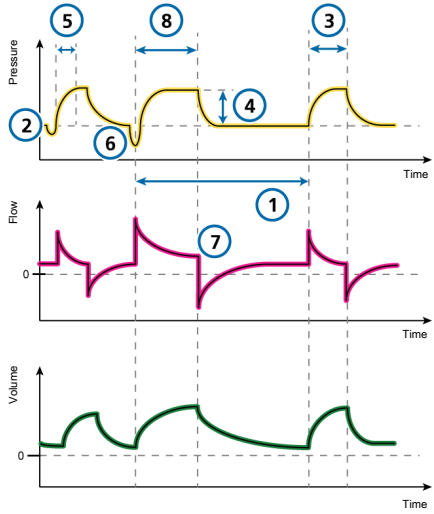
When pressure support is set to zero, the ventilator functions like a conventional CPAP system.

This mode requires that you set the parameters needed for both mandatory and spontaneous breath types.

- The inspiratory pressure setting, **Pinsp**, 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 defines the percentage of peak flow that cycles the device into exhalation.

  If the ventilator does not detect an expiratory trigger (for example, due to a leak), inspiratory time is limited by **TI max**.

Figure 7-14. NIV-ST mode: Breathing pattern and controls



Ventilator controls

CO2 elimination

1	Rate		Sigh *(not shown)*

Oxygenation

2	PEEP	3	TI
	Oxygen *(not shown)*		

Patient synchronization

4	Pinsp	7	ETS
5	P-ramp	8	TI max
6	Trigger		

7.6.3 nCPAP-PS mode

nCPAP-PS stands for *nasal continuous positive airway pressure*.

nCPAP-PS is a neonatal mode that offers nasal continuous positive airway pressure and intermittent positive pressure support through a nasal interface (mask or prongs) for infants and neonates. It is designed to apply CPAP using a nasal interface (mask or prongs).

When **Psupport** is set to zero, the ventilator functions like a conventional nCPAP system. The minimum PEEP setting is 2 cmH2O.

If the patient triggers a breath during the breath interval **timv**, the ventilator immediately delivers a spontaneous breath. If the patient does not trigger an inspiration during this time, the ventilator initiates a mandatory breath at the end of **timv**.

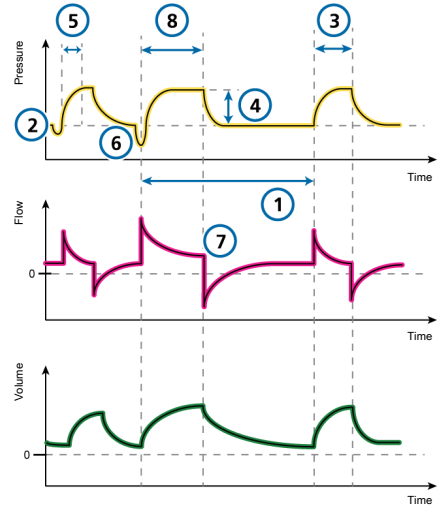
This mode requires that you set the parameters needed for both mandatory and spontaneous breath types.

- The inspiratory pressure setting, **Pinsp**, 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 defines the percentage of peak flow that cycles the device into exhalation.

  If the ventilator does not detect an expiratory trigger (for example, due to a leak), inspiratory time is limited by **TI max**.
- The **TI max** setting provides an alternative: when inspiration lasts longer than **TI max**, the ventilator cycles into exhalation.

Note that volume is not monitored in this mode.

Figure 7-15. nCPAP-PS mode: Breathing pattern and controls



Ventilator controls

CO2 elimination

1 Rate

Oxygenation

2 PEEP

3 TI

Oxygen *(not shown)*

Patient synchronization

4 Pinsp

7 ETS

5 P-ramp

8 TI max

6 Trigger

7.6.4 High flow oxygen therapy

High flow oxygen therapy (HiFlowO2) 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. The set flow can vary from 2 to 80 l/min depending on the patient interface. An operating humidifier is required.

The operator sets the oxygen and flow rate. It is also important to control the temperature and humidity of the gas delivered to the patient.

Pressure is measured at the ventilator's pressure release valve. Flow stops for at least 1 second if pressure exceeds 50 cmH2O. Therapy resumes when the pressure is released.

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%.

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.

7.6.4.1 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 2-11 show a noninvasive circuit set.
2. Place the ventilator in Standby, and open the Modes window.
3. Touch the HiFlowO2 mode button and touch **Confirm**.

   The Controls > Basic window opens.

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

   Use only interfaces intended for HiFlowO2.
   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 anytime.

   The Standby window is displayed, showing the **Start therapy** button.
5. Perform the preoperational checks, especially the tightness test. See Section 5.4.
6. In the Standby window, touch **Start therapy** to begin the oxygen therapy.

   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!

7.6.4.2 Parameters monitored in HiFlowO2 mode

When high flow oxygen therapy is in progress, the following parameters are monitored: **Oxygen**, **SpO2** related (when enabled) and **Control Flow** (in trend and as an MMP).

7.7 Special conditions

If the ventilator encounters certain error conditions, it may switch to safety ventilation or other special state until the situation is resolved.

If these conditions are encountered when delivering high flow oxygen therapy, the ventilator may switch to Safety therapy.

7.7.1 Safety mode/therapy

In the event of certain technical failures, the ventilator switches to Safety mode/therapy. This gives you time to arrange for corrective actions, including organizing a replacement ventilator.

The following conditions apply to ventilation in Safety mode/therapy:

- The ventilator does not monitor patient inputs during Safety mode/therapy.
- During Safety mode, the blower runs constantly to create inspiratory pressure (**Pinsp**) (Table 7-4).

  During Safety therapy, the blower creates a constant pressure of 5 cmH2O at the inspiratory port.
- During Safety mode, the expiratory valve switches system pressure levels between **PEEP** and inspiratory pressure.
- You must turn off ventilator power to exit Safety mode/therapy.

Table 7-4. Safety mode settings

IBW (kg)	Pinsp (cmH2O)	Rate (b/min)	Oxygen
< 3	15	≤ 35	> 21 %
3 to 5	15	30	> 21 %
6 to 8	15	25	> 21 %
9 to 20	15	20	> 21 %
21 to 29	15	15	> 21 %
30 to 39	15	14	> 21 %
40 to 59	15	12	> 21 %
60 to 89	15	10	> 21 %
90 to 99	18	10	> 21 %
≥ 100	20	10	> 21 %

For all patients, PEEP is set to the PEEP of the previous mode and the I:E ratio is 1:4 (Adult/Ped) and 1:3 (Neonatal).

7.7.2 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 ventilation immediately.
- You must turn off ventilator power to exit the Ambient state.

7.7.3 Display and communication error states

When a problem occurs either with the monitor and display or with communication between the monitor and the ventilator unit, the ventilator enters the Display/connection error state.

If this occurs, first check whether the cable connections between the monitor and the ventilator are well seated and secure. If the problem is not resolved, arrange for alternate ventilation and have the ventilator serviced.

The following conditions apply to ventilation in the Display/connection error state:

- There is a noticeable display problem, with either of the following situations:

  – The display is completely dark (not working)

  – The display does not show any data, and one of the following errors is generated: **Panel connection lost** or **Display error**.
- Immediately check the status indicators on the front of the ventilator (Section 2.2.1.1).

  – If the lung icon is green and flashing, ventilation continues.

  – **If the lung icon is dark, ventilation has stopped or has switched to the Ambient state. Provide alternative ventilation immediately.**
- Depending on the nature of the error, the buzzer sounds immediately or after a 30-second delay.

  The buzzer cannot be silenced. You must turn off the ventilator to exit this state.
- Generated alarms are logged in the Event log and Alarm buffer, although you might not be able to review them due to display issues.
- Arrange alternative ventilation.
- Have the ventilator serviced.

7.8 Working with noninvasive modes

This section provides an overview of noninvasive ventilation requirements, contraindications for use, and important information about settings and alarms.

When using NPPV, you can use a mask, mouthpiece, or helmet-type patient interface rather than an invasive conduit such as an endotracheal tube.

7.8.1 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.

7.8.2 Contraindications

⚠ WARNING

Do not place an HMEF between the flow sensor and the patient as doing so limits the ventilator's ability to identify disconnection at the patient, including displacement of a mask or nasal interface.

⚠ 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

7.8.3 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

7.8.4 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**, thus not allowing the ventilator to cycle into exhalation and resulting in endless inspiration. The **TI max** setting provides an alternative 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.
- Adjust **Psupport** or **Pinsp** 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.

7.8.5 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.

Because the noninvasive modes are pressure modes, however, do 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.

7.8.6 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 the 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.

7.8.7 Additional notes about using noninvasive ventilation

Due to some unique characteristics, consider the following points when using noninvasive ventilation.

IntelliTrig (intelligent trigger) 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/CPAP and give rise to autotriggering. If you cannot reach the set PEEP/CPAP, check the mask fit.

The Loss of PEEP alarm alerts you to uncompensated leaks (that is, when the measured PEEP/CPAP is 3 cmH2O lower than the set PEEP/CPAP).

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 > 1 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/CPAP + Pinsp/Psupport). When excessive leaks are present, the ventilator may not be able to reach the set pressure, and generates an alarm.

7.9 Working with ASV

NOTICE

We recommend setting the high Pressure alarm limit at least 25 cmH2O above PEEP/CPAP.

To set up the ventilator using ASV

1. Open the Modes window and touch **ASV**, then touch **Confirm**.
2. 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.
3. Review and adjust alarm limits.

   Set the high Pressure alarm limit to an appropriate value.

   The maximum peak pressure delivered in ASV (Pasvlimit) is 10 cmH2O below the high Pressure alarm limit or equal to the upper Pasvlimit setting.

   The maximum peak pressure for ASV can be also set using the Pasvlimit control in the Controls window.

   Changing the Pasvlimit value also changes the high Pressure limit.
4. Connect the patient to the ventilator and start ventilation.

The ventilator initiates three test breaths.

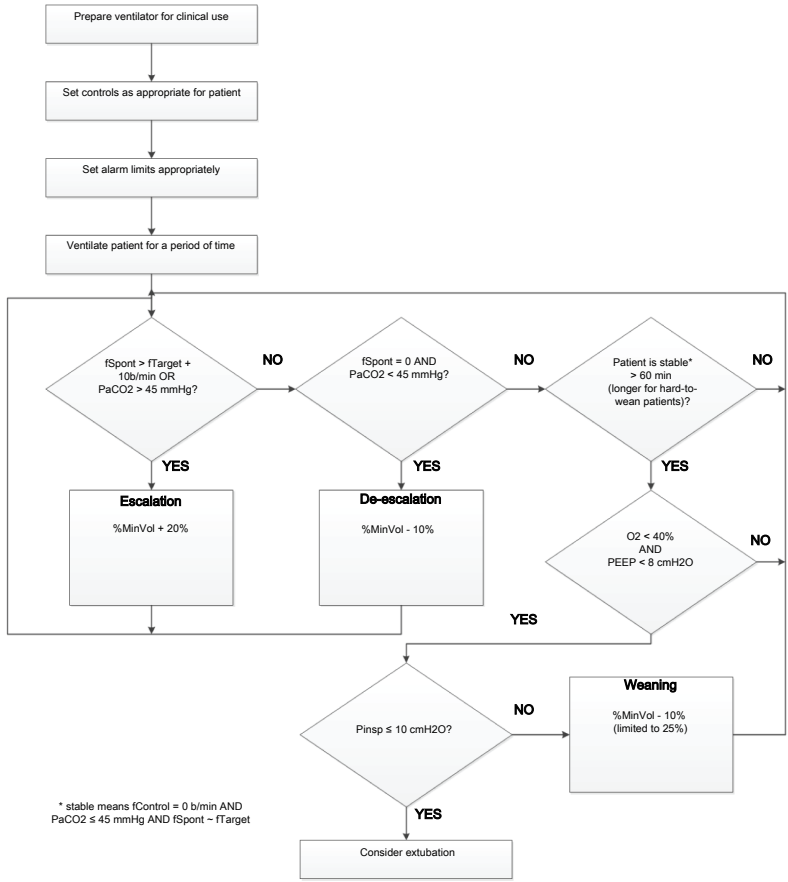
The device automatically selects the values for respiratory rate (fTotal), inspiratory time (TI), and inspiratory pressure (Pinsp) based on the calculated IBW and as specified in Table 7-3.

7.9.1 Clinical workflow with ASV

Figure 7-16 provides an overview of the ASV clinical workflow.

For technical specifications, see Section 16.9.

Figure 7-16. Clinical use of ASV



7.9.2 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 7.9.6.4.

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.

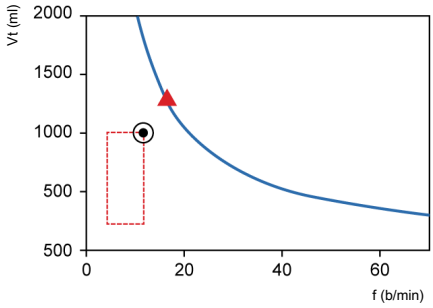
Table 7-5. Blood gas and patient conditions and possible adjustments for ASV

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**

7.9.3 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 7.9.6.4). As a consequence, ASV tries to achieve the maximum possible ventilation and activates the **ASV: Cannot meet target** alarm.

Figure 7-17. Example of high %MinVol setting incompatible with the lung-protective rules strategy



7.9.4 Monitoring ASV

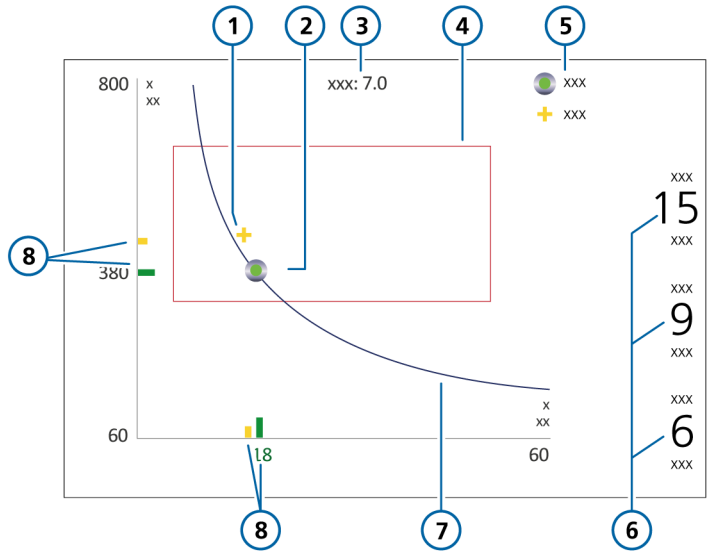
ASV interacts with the patient continuously. Whenever the patient's respiratory mechanics change, ASV adjusts to this change. Whenever the patient's breathing activity changes, ASV adjusts the settings.

The ASV Graph, shown in Figure 7-18, provides a real-time graphical view of the patient status relative to the set target.

To monitor progress over time, it is recommended that you plot trends for **Pinsp**, **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.

For details on displaying the ASV graph, see Section 8.4.

Figure 7-18. ASV Graph panel



1	Current measured point: Intersection of measured tidal volume and rate	5	Legend
2	Target point: Intersection of target tidal volume and target rate	6	**Pinsp**: Inspiratory pressure set by ventilator **fControl**: Machine rate **fSpont**: Spontaneous breath rate
3	Target minute volume	7	Minute volume curve
4	Safety frame	8	Current measured point (in yellow) and target value (in green)

7.9.5 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 with ASV.

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 (**Pinsp**), 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 **Pinsp** needed to achieve the set minute ventilation. Only if **Pinsp** 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

Pinsp	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.

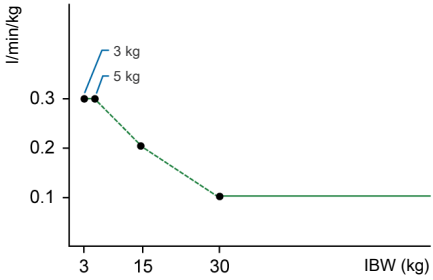
7.9.6 Functional overview

The following sections provide a brief overview of how ASV manages ventilation.

7.9.6.1 Normal minute ventilation

ASV defines normal minute ventilation according to the graph in Figure 7-19.

Figure 7-19. Normal minute ventilation as a function of ideal body weight (IBW)



For patients with an **IBW** ≥ 30 kg, minute ventilation is calculated as 0.1 l/kg * **IBW** (solid line). For patients with an **IBW** < 30 kg, the value is indicated by the dotted line.

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.

7.9.6.2 Compensation for changes in apparatus dead space

Dead space is calculated as 2.2 ml per kg. 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.

7.9.6.3 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 control, determines the total minute ventilation in liters per minute.

A **%MinVol** setting of 100% corresponds to a normal minute ventilation (Section 7.9.6.1). A setting below or above 100% corresponds to a minute ventilation lower or higher than normal.

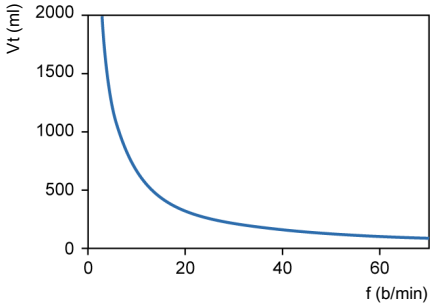
From the **%MinVol**, the target minute ventilation (in l/min) is calculated as:

Ideal body weight (in kg) x NormMinVent (in l/kg/min) x (%MinVol/100)

where **NormMinVent** is the normal minute ventilation. See Figure 7-19.

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 7-20, where all possible combinations of Vt and f lie on the bold line, the target minute volume curve.

Figure 7-20. MinVol = 7 l/min



7.9.6.4 Lung-protective strategy

Not all combinations of Vt and f shown in Figure 7-20 are safe for the patient. The high tidal volumes will overdistend the lungs and the small tidal volumes cannot produce alveolar ventilation at all.

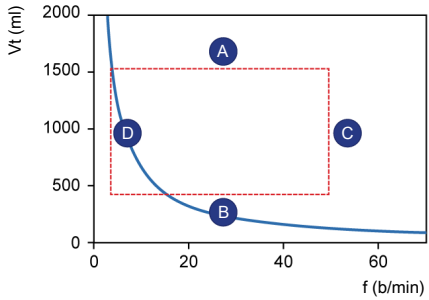
Another risk lies in inadequate respiratory rates. High rates can lead to dynamic hyperinflation or breath stacking, and thus inadvertent PEEP. Low rates can lead to hypoventilation and apnea. Therefore, it is necessary to limit the number of possible combinations of Vt and f.

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 7-21 and explained in the subsequent sections.

Figure 7-21. Lung-protective rules strategy



A: High tidal volume limit

The tidal volume applied by ASV is limited (see A in Figure 7-21) 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 1.5 * 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.

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 (Radford 1954):

VDaw = 2.2 * IBW **(1)**

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

You derive the maximum rate (C in Figure 7-21) from the operator-set %MinVol and the calculated IBW, which is calculated from the operator-set Patient height. The equation used to calculate the maximum rate is:

fmax = target MinVol / minimum Vt **(2)**

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 **(3)**

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 7-21) is predefined according to the IBW. See Table 7-3.

7.9.6.5 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 7-21, 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

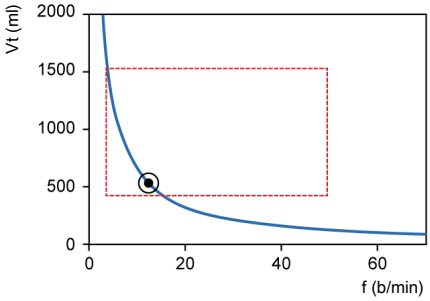
optimal rate based on the operator-set **%MinVol** and the calculated **IBW**, as well as on the measurement of **RCexp** (Section 7.5.1).

Once the optimal rate is determined, the target **Vt** is calculated as follows:

Vt = target MinVol / optimal rate (4)

Figure 7-22 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 7-22. Anatomy of the ASV target graphics window



7.9.6.6 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**. For more information see 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 with a preset pressure and time cycled.

The following controls are operator-set (manual):

- PEEP/CPAP
- Oxygen
- P-ramp
- ETS
- Trigger type and sensitivity

This list of controls is 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

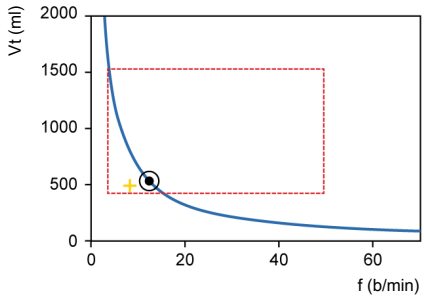
To safely start ASV, you set the **Patient height**, which is then used to calculate the **IBW**.

Upon starting ventilation, three 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.

7.9.6.7 Approaching the target

Figure 7-23 shows a possible scenario after the three 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 7-23. 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 7-23 moves toward the circle. The current Vt is calculated as the average of inspiratory and expiratory volumes of the last 5 breaths. This definition compensates in parts for leaks in the breathing circuit, including the endotracheal tube.

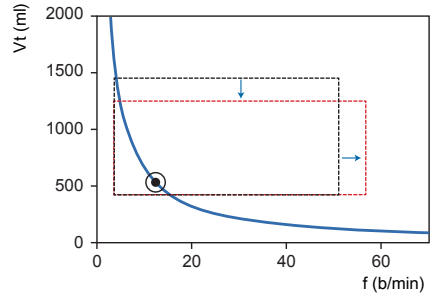
7.9.6.8 Dynamic adjustment of lung protection

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 7.9.6.4. 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 7-24.

Figure 7-24. 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.

7.9.6.9 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.

8 Monitoring ventilation

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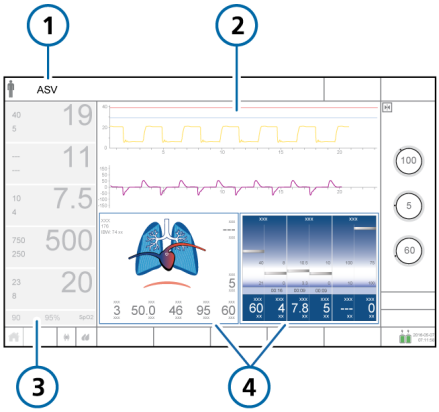
8.1 Overview

During ventilation, you can view patient data on the ventilator display (Figure 8-1). You can configure the layout with different waveforms, loops or trends, or with Intelligent Panel graphics to suit your institution's needs.

Additional monitoring data is available in the Monitoring window, which you can access at any time without affecting breath delivery.

For the list of monitored parameters, see Section 8.6.

Figure 8-1. Main display



1	Current mode	3	Main monitoring parameters (MMP) (Section 8.2.1)
2	Full-screen waveforms	4	Graphic display, configurable (Section 8.3) *Available options depend on the selected layout.*

8.2 Viewing numeric patient data

Numeric patient data is readily available in the following locations:

- The main display prominently shows the configured main monitoring parameters (MMPs). See Section 8.2.1.
- The Monitoring panel, when shown, displays secondary monitoring parameters (SMPs). See Section 8.2.2.
- The Monitoring window provides access to all of the parameter data. See Section 8.2.3.

8.2.1 About the main monitoring parameters (MMP)

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, and the set alarm limits when applicable (Figure 8-2).

The MMPs that are displayed, as well as the order in which they are shown, can be changed in Configuration (Chapter 14).

If **Oxygen** is selected as an MMP, the upper and lower alarm limits shown on the display provide the following information:

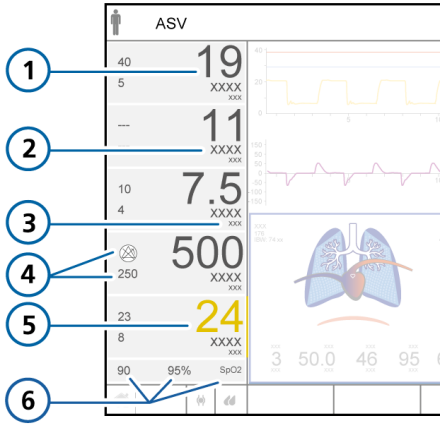
- If the oxygen limits are automatically set, the limits are set to 5% (absolute) above and below the **Oxygen** control setting.
- If the **Set Oxygen alarm limits manually** checkbox is selected in Configuration, the upper and lower limits selected in the Alarms > Limits 2 window are shown.

An MMP is normally displayed in white. It may also be shown in yellow or red if it is directly related to an active alarm. The color of the MMP corresponds 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.

Most of the monitored parameters can be displayed as an MMP. As a result, since the display is configurable, MMPs may differ between individual ventilators. Note that **Ppeak** is always displayed.

Tip. Touch any MMP to display the Alarms window to adjust the limits.

Figure 8-2. MMP components

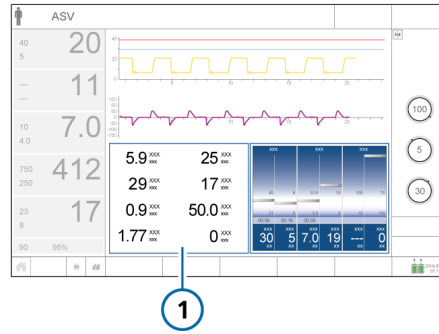


1	MMP value	4	Upper and lower alarm limits Here, the upper limit is disabled (OFF) and shows the Alarm Off symbol.
2	Name of parameter	5	Parameter associated with an active alarm
3	Unit of measure	6	SpO2 lower alarm limit and current SpO2 value (when SpO2 enabled)

8.2.2 About the secondary monitoring parameters (SMPs)

In addition to the MMPs, commonly reviewed data, known as secondary monitoring parameters (SMPs), is displayed in the Monitoring panel.

Figure 8-3. Monitoring panel for SMPs (1)



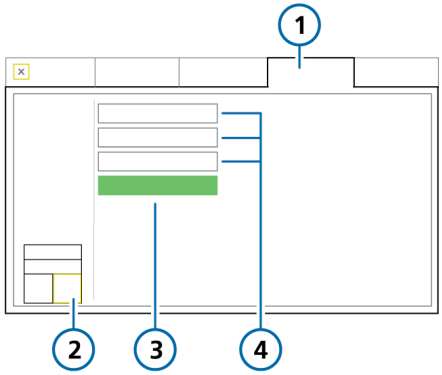
The parameters shown in this panel are configurable; see Section 14.5.

The following parameters are shown as SMPs by default: **Vt/IBW** (Adult/Ped) / **Vt/Weight** (Neonatal), **Pplateau**, **RCexp**, **TI**, **Driving pressure (ΔP)**, **Pmean**, **Cstat**, and **fSpont**.

8.2.2.1 Displaying secondary monitoring parameters (SMPs)

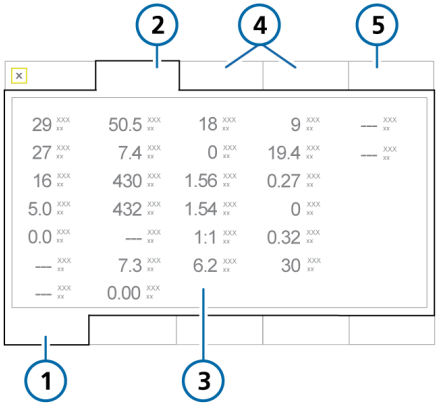
The Monitoring panel showing SMPs can be displayed using graphic layouts 2 and 3 (Table 8-2).

Figure 8-4. Graphics selection > Graphics window



1	Graphics	3	Monitoring
2	Selected panel	4	Dynamic Lung, Vent Status, ASV Graph

Figure 8-5. Monitoring > General window



1	Monitoring	4	CO2 and SpO2 (if enabled)
2	General	5	Pes
3	Parameter values		

To display the Monitoring panel

1. Touch the area of the display where you wish to show the SMPs (Section 8.3.2).
2. In the graphics selection window, touch the **Graphics** tab.
3. Touch the **Monitoring** button.

The Secondary monitoring parameters panel is displayed (Figure 8-3).

8.2.3 Viewing patient data in the Monitoring window

The Monitoring window provides access to all of the parameter data, including CO2 and SpO2 values (when enabled), and values related to esophageal and transpulmonary pressure when an esophageal catheter is connected to the Pes port; see Section 8.5.

To display the Monitoring > General window

1. Touch the **Monitoring** button.
2. If not already displayed, touch the **General** tab.

The Monitoring > General window (Figure 8-5) displays ventilation parameter values.

The **CO2** and **SpO2** tabs, when available, display CO2- and SpO2-related parameter values, respectively. In addition, the PetCO2 and SpO2 values are also shown in the Monitoring > General window for quick reference.

The **Pes** tab displays esophageal and transpulmonary pressure parameters.

8.3 Viewing graphical patient data

In addition to numerical data, the ventilator shows user-selectable graphical views of real-time patient data.

8.3.1 About graphic types and layouts

The HAMILTON-C6 offers a variety of graphic areas on the display that can show full- and half-screen waveforms, as well as graphic and informational panels.

Table 8-1 shows the options for each graphic type.

Table 8-1. Graphical view options

Graphic type	Options	
Waveforms	• Pressure • Flow • Volume • OFF	• PCO2[34] • FCO2[34] • Plethysmogram[35] • Pes[36] • Ptranspulm[36]
Graphics (Intelligent panels)	• Dynamic Lung[37] • Vent Status	• ASV Graph[38] • Monitoring (SMPs)
Trends	1-, 6-, 12-, 24-, or 72-h trend data for a selected parameter or combination of parameters	
Loops	• Pressure/volume • Pressure/flow • Volume/Flow	• Volume/PCO2[34] • Volume/FCO2[34] • Pes/Volume[36] • Ptranspulm/Volume[36]

In addition to the different graphical views of the data, several different display layouts are available (Table 8-2).

You select the layout in the Graphics window (Figure 8-6). The display selections you make for each layout remain configured for the current patient until manually changed. The same settings also apply when using the **Last Patient** setting.

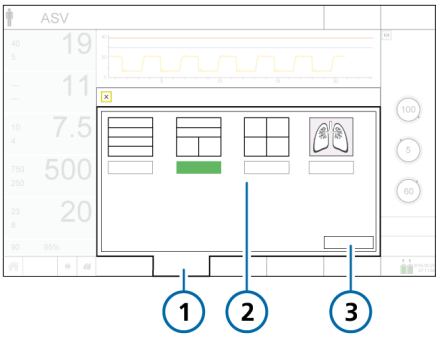
Tip. As a result, for the current patient, you can configure a preferred display configuration for each of the three layouts, and switch between them at any time by selecting the desired layout.

When setting up a new patient, the display selection reverts to the default specified for the selected Quick Setup.

You can define a default layout for each of the available Quick Setups in Configuration. For details, see Section 14.6.2. When setting up a new patient, the default layout is applied.

[34] CO2 option required.
[35] SpO2 option required.
[36] Data is available only when an esophageal catheter is connected to the Pes port on the ventilator.
[37] Only for adult/pediatric patients.
[38] Only in ASV mode.

Figure 8-6. Graphics window, layout options



1	Graphics	3	Defaults
2	Layouts 1, 2, 3, 4		

Table 8-2. Graphic layout options

	*Layout 1.* Four full-screen waveforms
	*Layout 2.* Two full-screen waveforms and any combination of graphic panels and half-screen waveforms
	*Layout 3.* Any combination of half-screen waveforms and graphic panels
	*Layout 4.* Full-display dynamic lung

8.3.2 Selecting display options

You can change the layout and graphics at any time. You can also revert to the default layout.

To change the layout of the display graphics

1. Touch the **Graphics** button at the bottom of the display (Figure 8-6).
2. Touch the desired layout option.

   To revert to the default layout, touch the **Defaults** button in this window.

   Note that at any time during ventilation, you can touch the **Home** button (Table 2-4) at the bottom left of the main display to reset the display to the default layout specified for the selected Quick setup.

The window closes automatically, and the display adjusts to the new selection.

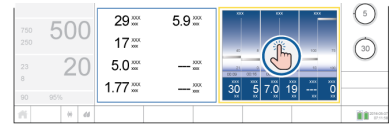
To change the contents of a graphics panel or waveform

1. Touch the area of the display to configure.

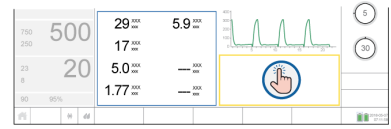
   For example, if using Layout 3 and you wish to select or change the content in the bottom right panel, touch the bottom right part of the display.

   The selected panel is highlighted in yellow.

Change a graphic



Add or change waveform



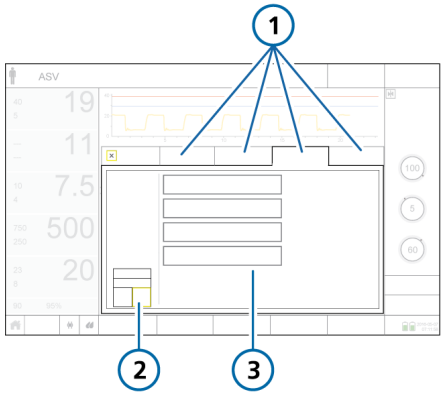
The graphics selection window appears (Figure 8-7), displaying the current selection.

The window also shows a thumbnail of the selected layout, with the area you are changing highlighted in yellow.

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 8-7. Graphics selection window



1	Trends, Loops, Graphics (shown), Waveforms	3	Available options
2	Selected panel		

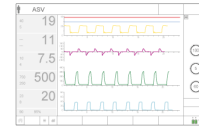
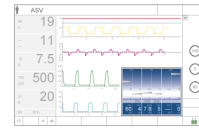
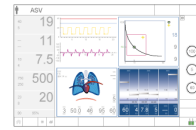
8.3.3 Working with waveforms

The ventilator can plot pressure, volume, and flow against time, in addition to other data as listed in Table 8-1.

8.3.3.1 Waveform views

You can show one or more waveforms on the display, depending on which layout option you select.

Table 8-3. Waveform layout options

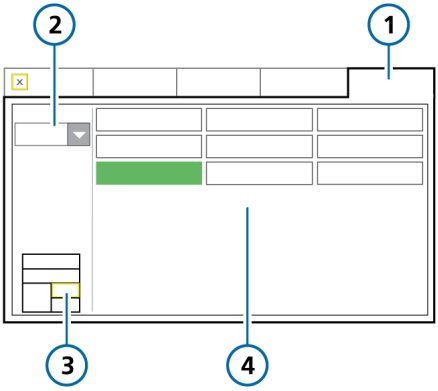
Layout 1. Up to four full-screen waveforms	
Layout 2. Up to two full-screen waveforms and two or more half-screen waveforms	
Layout 3. A combination of two or more half-screen waveforms and graphic panels.	

8.3.3.2 Displaying waveforms

As listed in Table 8-2, you can display half- and full-screen waveforms depending on the selected layout.

You select waveform options in the Waveforms window.

Figure 8-8. Graphics selection > Waveforms window



1	Waveforms	3	Selected panel
2	Time scale	4	Available options

To add or change half-screen waveforms

1. Touch the area of the display where you wish to show a waveform or touch the waveform to change.

   The graphics selection window opens (Figure 8-7).

2. If not already displayed, touch the **Waveforms** tab (Figure 8-8).

   The layout on the left indicates which waveform you are configuring (top or bottom).

3. If needed, change the time scale to apply to all waveforms.

4. Touch the waveform type to display.

   To leave the area blank, select **Off**.[39]

   After making your selection, one of the following occurs:

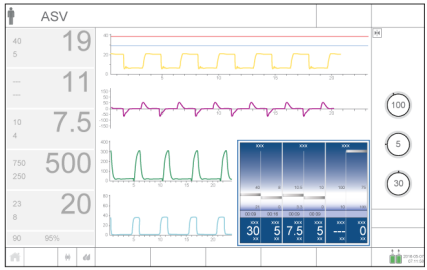
   – If you are adding or changing a single waveform, the window closes and the selected waveform is displayed.

   – If you are replacing a graphic panel with waveforms, the window shows the options for the second waveform.

5. For a second waveform, select the waveform type to display.

Once the selection is made, the window closes and the selected waveform is displayed.

Figure 8-9. Two half-screen waveforms



[39] The Off option is disabled for the topmost full-screen waveform in Layouts 1 and 2.

To add or change full-screen waveforms

1. Touch the area of the display where you wish to show a waveform or touch the waveform to change.

   For example, to show a third full-screen waveform, be sure Layout 1 is selected and touch an empty area of the display.

   The graphics selection window appears, with the **Waveforms** tab selected.

2. If needed, change the time scale to apply to all waveforms.

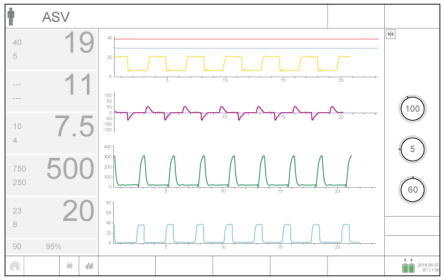
3. Touch the waveform type to display.

   To leave the area blank, touch **Off**.[39]

   Once the selection is made, the window closes and the selected waveform is displayed.

4. Repeat these steps as needed.

Figure 8-10. Four full-screen waveforms

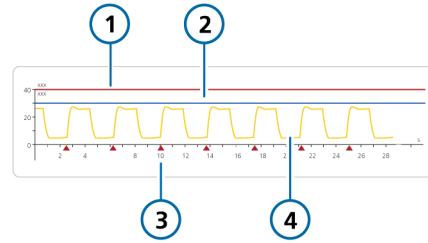


8.3.3.3 About the Pressure/time graph

By default, the Pressure/time graph is shown at the top of the display.

The blue pressure limit line shows the maximum pressure that the ventilator will apply, which is 10 cmH2O below the set high **Pressure** alarm limit. The high **Pressure** limit is shown as a red line.

Figure 8-11. Pressure/time graph



1	High Pressure alarm limit	3	Patient trigger indicator
2	Pressure limitation: High Pressure alarm limit – 10 cmH2O	4	Airway pressure (Paw) waveform

8.3.3.4 Changing the waveform time scale

Scale refers to the displayed values of the **Time** axis (x-axis) of the waveform.

The x-axis represents time, while the y-axis can represent a variety of parameters such as tidal volume, pressure, flow, and so on. You can change the scale 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 22 means that the x-axis displays the waveform from 0 to 22 seconds.

When you switch layouts, the waveforms automatically change to the next higher or lower time scale (if available) depending on the new layout selection. The following table provides some examples.

Table 8-4. Example time scale changes between layouts

Original Layout/ Time scale	New Layout/ Time scale
Layout 1 or 2 / 22 s	Layout 3 / 11 s
Layout 1 or 2 / 11 s	Layout 3 / 5.5 s
Layout 3 / 22 s	Layout 1 or 2 / 33 s

The ventilator offers the following scaling options, in seconds:

- Full-screen waveforms: 11, 22, 33, 66

  The default for the Adult/Ped patient group is 22; for Neonatal, 11.

- Half-screen waveforms: 5.5, 11, 22, 33

To change the time scale

- In the Waveforms window, touch the Time scale arrow (Figure 8-8) and select the scale to use.

Your selection applies to all displayed waveforms.

8.3.3.5 Freezing and reviewing waveforms and trends

You can temporarily freeze the display of waveforms and trends. After 30 seconds of inactivity, they are unfrozen.

When Freeze is enabled, all of the displayed waveforms (and Trend graph, if displayed) are frozen, allowing you to scroll through them for a detailed review. The Freeze function is time-synced across all of the displayed graphics.

The Freeze function is particularly useful when you perform a breath hold maneuver. The display automatically freezes following a successful inspiratory maneuver.

To freeze waveforms

1. Touch the **Freeze** button (**1** in Figure 8-12).

   All of the displayed waveforms (and trend graph, if displayed) are frozen and cursor bars are displayed.

2. To scroll through the graphics for analysis, do either of the following:

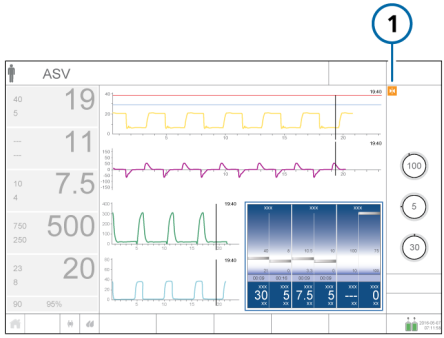
   – Slide your finger along the waveform or trend. The cursor moves to where your finger is.

   – Turn the P&T knob clockwise or counter-clockwise.

   The cursor bars move to the right and to the left as you slide your finger or turn the P&T knob. The bars are shown at the same time point across all of the graphics.

3. To unfreeze the display and return to displaying real-time waveforms and trends, touch the **Freeze** button again or press the P&T knob.

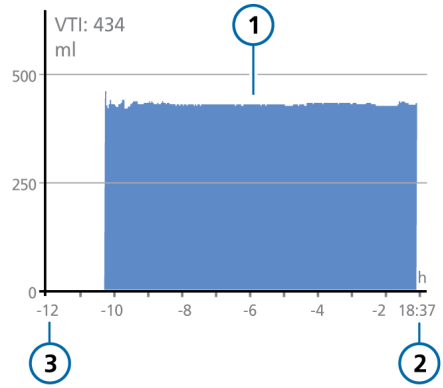
Figure 8-12. Freezing waveforms



8.3.4 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.

Figure 8-13. Trend panel



1	Trend graph	3	Elapsed time relative to present
2	Current time		

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.

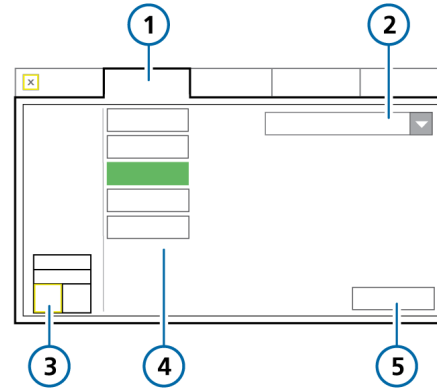
You can also freeze Trend graphs and examine them more closely. When trends are frozen, the Time axis shows elapsed time relative to the present and the corresponding value of the monitored parameter.

Most monitoring parameters can be trended. The following parameters are trended in combination: **Ppeak/PEEP**, **MVSpont/ExpMinVol**, **fTotal/fControl**, and **Vtalv/VTE**.

8.3.4.1 Displaying trends

Trend graphs can be displayed using graphic layouts 2 and 3 (Table 8-2).

Figure 8-14. Graphics selection > Trends window



1	Trends	4	Trend time, in hours
2	Parameter list	5	Confirm
3	Selected panel		

To display trends

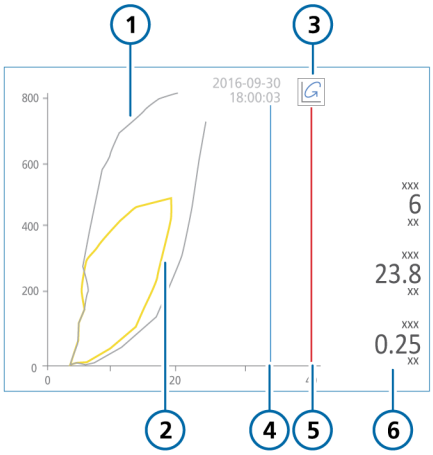
1. Touch the area of the display where you wish to show a trend graph (Section 8.3.2).
2. In the graphics selection window, touch the **Trends** tab (Figure 8-14).
3. Select the parameter(s) to trend.
4. Touch the desired trend time.
5. Touch **Confirm**.

The selected trend information is displayed (Figure 8-13).

8.3.5 Working with loops

The HAMILTON-C6 can display a dynamic loop based on the parameter combinations listed in Table 8-1.

Figure 8-15. Loops panel

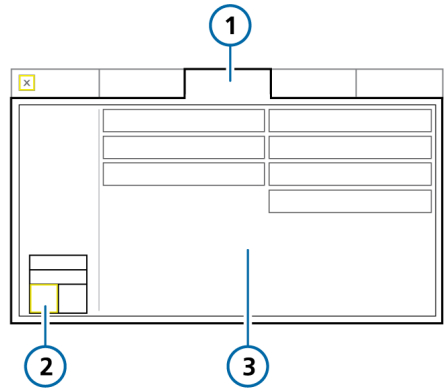


1	Stored reference loop	4	Pressure limitation: High Pressure alarm limit –10 cmH2O
2	Current loop	5	High Pressure alarm limit
3	Loop reference button	6	Key parameters: **Rinsp, Cstat, RCexp**

8.3.5.1 Displaying loops

Loops can be displayed in layouts 2 and 3 (Table 8-2).

Figure 8-16. Graphic selection > Loops window



1	Loops	3	Parameter options
2	Selected panel		

To display loops

1. Touch the area of the display where you wish to show a loop (Section 8.3.2).
2. In the graphics selection window, touch the **Loops** tab.
3. Touch the parameter combination to display.

The selected combination is displayed (Figure 8-15).

8.3.5.2 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 8-15), touch the **Loop reference** button 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

You can set up the ventilator display to show any of the Intelligent panels:

- Dynamic Lung
- Vent Status
- ASV Graph
- Monitoring (SMPs) (Section 8.2.2)

The Intelligent panels are all displayed using the graphics selection window **Graphics** tab.

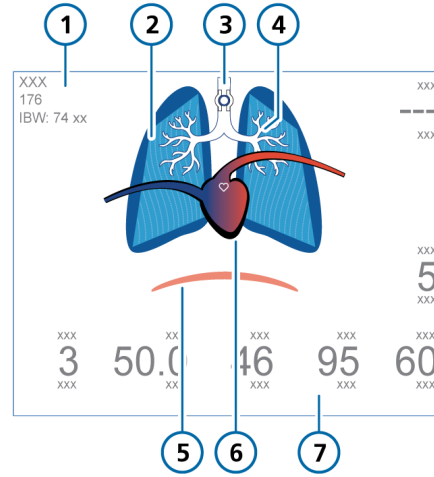
8.4.1 Dynamic Lung panel: real-time breathing status

The Dynamic Lung panel[40] visualizes tidal volume, lung compliance, patient triggering, resistance, and cuff pressure in real-time. The lungs expand and contract in synchrony with the patient's actual breaths.

When the SpO2 option is enabled, the Dynamic Lung panel is expanded to show the circulation of blood through the heart, superimposed on the breathing of the lungs. For details, see the *Pulse Oximetry Instructions for Use*.

The panel shows numeric values for resistance (**Rinsp**) and compliance (**Cstat**), in addition to other key values. The shape of the lungs and the bronchial tree are also related to the compliance and resistance values. If all values are in a normal range, the panel is framed in green.

Figure 8-17. Dynamic Lung panel



1	Sex, height, IBW	5	Patient trigger (diaphragm)
2	Real-time representation of lung compliance	6	Heart and pulse display (when SpO2 sensor enabled and connected)
3	Cuff indicator (when IntelliCuff is connected)	7	Monitored parameter values: **Rinsp**, **Cstat**, **PetCO2**, **SpO2**, **Pulse**, **PVI** (Masimo only), **Pcuff**
4	Real-time representation of airway resistance		

[40] Only for adult/pediatric patients.

8.4.1.1 Displaying the Dynamic Lung

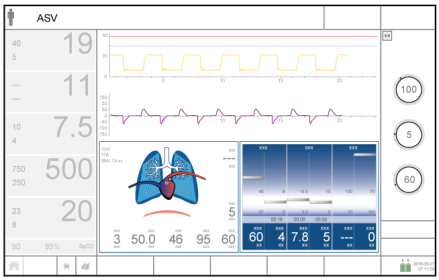
The Dynamic Lung panel can be displayed in layouts 2, and 3, and in full display mode in the Dynamic Lung layout (Table 8-2).

To display the Dynamic Lung

1. Touch the area of the display where you wish to show the Dynamic Lung panel (Section 8.3.2).
2. In the graphics selection window, touch the **Graphics** tab (Figure 8-7).
3. Touch the **Dynamic Lung** button.

The window closes and the Dynamic Lung is displayed.

Figure 8-18. Dynamic Lung in display

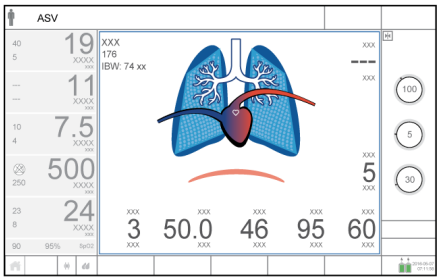


To select the full-display Dynamic Lung

- Touch the **Graphics** button and select **Dyn. Lung** (Figure 8-6).

The window closes and the Dynamic Lung fills the display (Figure 8-19).

Figure 8-19. Dynamic Lung, full display



8.4.1.2 Tidal volume (Vt)

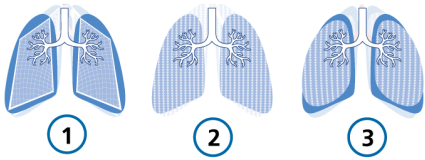
The Dynamic Lung expands and contracts to show tidal volume (**Vt**) in real-time. It moves in synchrony with actual breaths, based on the proximal flow sensor signal. The lung size displayed is relative to the "normal" size for the patient's height.

A **Disconnection** alarm is indicated by a deflated lung. An **Exhalation obstructed** alarm is indicated by an over-inflated lung.

8.4.1.3 Compliance (Cstat)

The Dynamic Lung shows compliance (**Cstat**) breath by breath relative to "normal" values for the patient's height. As Figure 8-20 shows, the shape of the lungs changes with compliance. The numeric value is also displayed.

Figure 8-20. Examples of lung compliance (Cstat) illustrated in Dynamic Lung

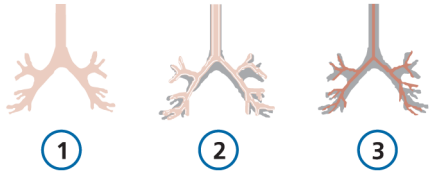


1 Low compliance
2 Normal compliance
3 High compliance

8.4.1.4 Resistance (Rinsp)

The bronchial tree in the Dynamic Lung shows resistance (**Rinsp**) breath by breath relative to "normal" values for the patient's height. The numeric value is also displayed. The gray portion of the image shows the relative degree of resistance.

Figure 8-21. Examples of resistance shown by the bronchial tree of the Dynamic Lung

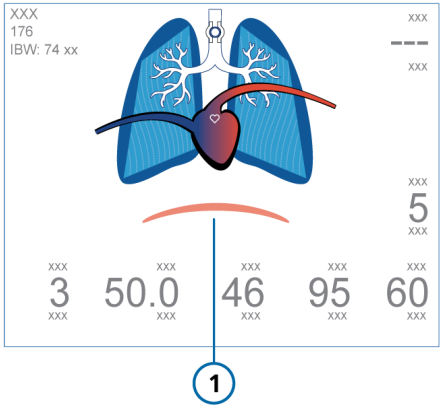


1 Normal resistance
2 Moderately high resistance
3 High resistance

8.4.1.5 Patient triggering

The muscle in the Dynamic Lung shows patient triggering.

Figure 8-22. Patient triggering (1) in Dynamic Lung



8.4.2 Vent Status panel: real-time ventilator dependence status

The Vent Status panel (Figure 8-23) displays six parameters related to the patient's ventilator dependence, in the areas of oxygenation, CO2 elimination, and patient activity.

A floating indicator (floater) moving up and down within the column shows the value for a given parameter.

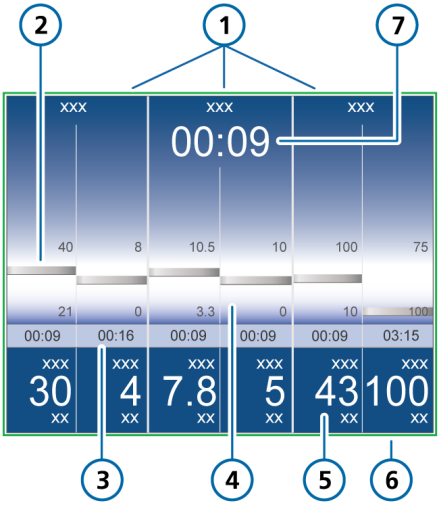
When the indicator is in the light blue (weaning) zone, a timer starts, showing how long that value has been in the weaning zone. When all values are in the weaning zone, the Vent Status panel is framed in green, indicating that weaning should be considered. A timer appears, recording the length of time all values have been in the weaning zone (Figure 8-23).

The panel is updated breath by breath.

Table 8-5 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 14.6.1.

Figure 8-23. 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 8-5. Vent Status parameters

Parameter (unit)	Definition
For additional details, including ranges and accuracy, see Table 16-5.	
Oxygen (%)	Oxygen setting.
PEEP (cmH2O)	PEEP/CPAP setting.
MinVol (l/min)	Normal minute ventilation (see Section 7.9).
Pinsp (cmH2O)	Inspiratory pressure, the target pressure (additional to PEEP/CPAP) applied during the inspiratory phase.
RSB (1/(l*min))[41]	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.

8.4.2.1 Displaying the Vent Status panel

The Vent Status panel can be displayed in layouts 2 and 3 (Table 8-2).

To display the Vent Status panel

1. Touch the area of the display where you wish to show the Vent Status panel (Section 8.3.2).
2. In the graphics selection window, touch the **Graphics** tab (Figure 8-7).

[41] Weaning zone defaults are based on normal values < 100/(l * min) for adult patients. Default values can be changed in Configuration.

3. Touch the **Vent Status** button.

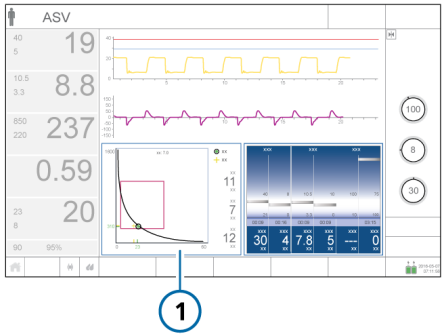
The Vent Status panel is displayed (Figure 8-23).

8.4.3 ASV Graph panel: real-time patient condition and targets

Available in ASV[42] 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 7-18 in Chapter 7 describes the graph in detail.

Figure 8-24. ASV Graph panel (1)



8.4.3.1 Displaying the ASV Graph

The ASV Graph can be displayed in layouts 2 and 3 (Table 8-2).

To display the ASV Graph

1. Touch the area of the display where you wish to show the ASV graph panel (Section 8.3.2).
2. In the graphics selection window, touch the **Graphics** tab (Figure 8-7).
3. Touch the **ASV Graph** button.

The ASV target graphic is displayed (Figure 8-24).

8.5 Monitoring transpulmonary/esophageal pressure

The Pes port allows you to use pressure readings other than airway pressure (Paw), for example, from an esophageal balloon catheter, for monitoring purposes. Using a combination of the Paw and Pes pressures, transpulmonary pressure is also calculated.

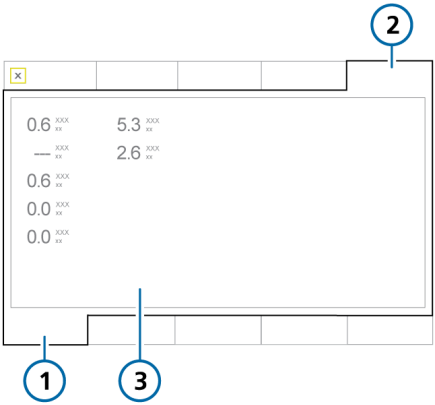
For connection details, see Section 3.5.

Once connected, the following parameter values are displayed in the Monitoring > Pes window: **Pes max**, **Pes plateau**, **Pes min**, **Pes P0.1**, **Pes PTP**, **Ptrans I**, and **Ptrans E** (see Table 8-6 for descriptions).

Pes and **Ptranspulm** values can also be viewed as waveforms (Section 8.3.3), loops (Section 8.3.5), and Graphs in P/V Tool (Section 11.6).

[42] Only for adult/pediatric patients.

Figure 8-25. Monitoring > Pes window



1 Monitoring

2 Pes

3 Pes-related parameter values

8.6 About the monitored parameters

The following table is an alphabetical list of the ventilator's monitored parameters.

You can review all parameter values in the Monitoring window (Figure 8.2.3). The display of monitored parameters is updated every breath or is time driven.

See Section 16.6 for parameter specifications. For details about SpO2-related parameters, see the *Pulse Oximetry Instructions for Use*.

Table 8-6. Monitored parameters

Parameter (unit)	Definition
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
Control Flow (l/min)	The set flow of gas to the patient in HiFlowO2 mode.
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.
Driving pressure, ΔP (cmH2O)	A calculated value showing the ratio of tidal volume to static compliance, which reflects the difference between Pplateau and PEEP.
Exp flow (l/min)	Peak expiratory flow.
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 into account the leakage.
fControl (b/min)	Mandatory breath frequency. The moving average of machine-delivered breaths per minute over the last 8 total breaths.
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.

Parameter (unit)	Definition
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.
IBW (kg)	Ideal body weight. A calculated value using height and sex, for adult and pediatric patients.
Insp flow (l/min)	Peak inspiratory flow, spontaneous or mandatory. Measured every breath.
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 into account the leakage.
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.
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**

Parameter (unit)	Definition
Pcuff (cmH2O)	*For IntelliCuff only.* See Section 12.2.8.
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.
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.
Pinsp (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 **Pinsp** parameter. Rather, this target pressure is set using the following parameters, depending on the selected mode: • APVcmv, APVsimv, ASV: Automatically calculated target pressure • PCV+: **Pcontrol** setting • PSIMV+, NIV-ST, nCPAP-PS: **Pinsp** setting • SPONT, NIV: **Psupport** setting • APRV, DuoPAP: **P high** setting
Pmean (cmH2O)	Mean airway pressure. The absolute pressure, averaged over the breath cycle. **Pmean** is an important indicator of the possible impact of applied positive pressure on hemodynamics and surrounding organs.
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. **Ppeak** is also used by IntelliCuff to control cuff pressure in Auto mode. For details, see Section 12.2.3.
Pplateau (cmH2O)	Plateau or end-inspiratory pressure. The pressure measured at the end of inspiration when flow is at or close to zero. Used as a rough representation of alveolar pressure. **Pplateau** is displayed for mandatory and time-cycled breaths.

Parameter (unit)	Definition
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-initiated 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
Pes max[43]	See Ppeak. The pressure is measured through the Pes port instead of using airway pressure.
Pes min[43]	See PEEP. The pressure is measured through the Pes port instead of using airway pressure.
Pes P0.1[43]	See P0.1. The pressure is measured through the Pes port instead of using airway pressure.
Pes PTP[43]	See PTP. The pressure is measured through the Pes port instead of using airway pressure.
Pes plateau[43]	See Pplateau. The pressure is measured through the Pes port instead of using airway pressure.
Ptrans E[43]	Calculated from the Ptranspulm waveform. The arithmetic mean value of Ptranspulm over the last 100 ms of the last expiration.
Ptrans I[43]	Calculated from the Ptranspulm waveform. The arithmetic mean value of Ptranspulm over the last 100 ms of the last inspiration.

[43] Data is available only when an esophageal catheter is connected to the Pes port on the ventilator.

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 Psupport 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.
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 > 40 kg and is only shown if 80% of the last 25 breaths were spontaneous.

Parameter (unit)	Definition
slopeCO2 (%CO2/l)	Slope of the alveolar plateau in the PetCO2 curve, indicating the volume/flow status of the lungs. Permits assessment of chronic hypercapnia, asthma, and inefficient ventilation. Available when a CO2 mainstream sensor is connected and enabled.
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.
T y-piece (°C)	*For HAMILTON-H900 humidifier only*. See Table 12-5.
T humidifier (°C)	*For HAMILTON-H900 humidifier only*. See Table 12-5.
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.
V'alv (ml/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.

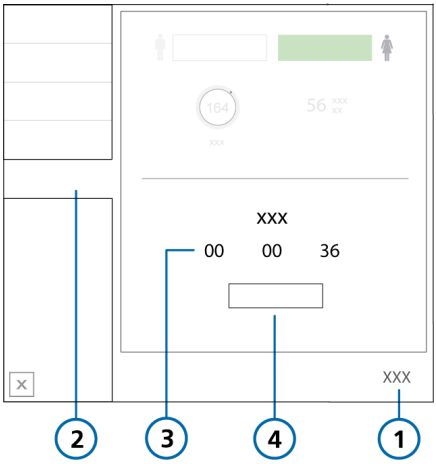
Parameter (unit)	Definition
VDaw/VTE (%)	Airway dead space fraction at the airway opening. Available when a CO2 mainstream sensor is connected and enabled.
VeCO2 (ml)	Exhaled CO2 volume, updated breath by breath. Available when a CO2 mainstream sensor is connected and enabled.
ViCO2 (ml)	Inspired CO2 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.
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.
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 into account the leakage.
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**.

Parameter (unit)	Definition
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.
Ventilation timer	Displayed in the Controls > Patient window, shows how long the patient has been ventilated. For details, see Section 8.7.

8.7 Viewing patient ventilation time

The Controls > Patient window displays a timer that shows how long the patient has been ventilated.

Figure 8-26. Ventilation timer



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 the **Reset** button, 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. Open the Controls > Patient window.
2. Touch the **Reset** button.

The timer starts again at 00d 00h 00min.

8.8 Viewing device-specific information

Open the System > Info 1 window to view device-specific information including serial number, model, software version, operating hours, hours since startup, and battery status.

The System > Info 2 window shows communication board details and information about connected devices.

The System > Info 3 window shows the installed options.

9 Responding to alarms

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9.1 Overview

Operator-adjustable and nonadjustable alarms together with a visual alarm indicator help ensure your patient's safety. These alarms notify you of conditions that require your attention.

These alarms can be categorized as high, medium, or low priority, as described in Table 9-1. Figure 9-1 shows the ventilator's visual alarm indications.

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.

Alarms are indicated in the color associated with the alarm priority as follows:

- The alarm lamp on top of the monitor lights and flashes.
- The alarm text is shown in color in the message bar on the ventilator display.
- 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 IntelliCuff and Humidifier quick access icons are shown in the associated color when a related alarm is active.
- The alarm text is displayed in the alarm buffer.
- The alarm status indicator on the front of the ventilator body flashes red when an alarm is generated. See Section 2.2.1.1.

When an alarm condition is serious enough to possibly compromise safe ventilation, the device defaults to the Ambient state (Section 7.7). The inspiratory valve closes, and the ambient and expiratory valves are opened, letting the patient breathe room air unassisted.

If communication between the ventilator monitor (referred to as the *interaction panel* in alarm messages) and the ventilator unit is disrupted, the status indicators on the front of the ventilator body provide a visual indication of the ventilator status. For details about the indicators, see Table 2-3.

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 5.6.

Table 9-1 describes the audio and visual characteristics of these types of alarms and provides guidance on how to respond.

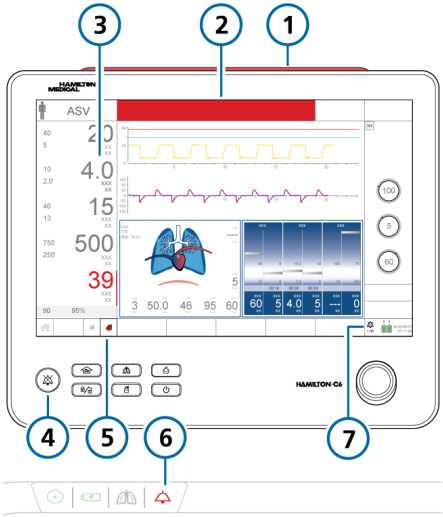
Table 9-1. Alarm indicators

Alarm type	Message bar	Alarm lamp / Alarm status indicator	Audio	Action required
High priority	Red, with alarm message	Red, flashing Alarm status indicator on the front of the ventilator body flashes	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 Alarm status indicator on the front of the ventilator body flashes	A sequence of 3 beeps, repeated periodically. If the audible alarm is not silenced during the first minute, the continuous-tone buzzer also sounds.	The patient needs prompt attention. For most alarms, press the **Audio Pause** key to reset the alarm. For some alarms, reset the alarm by opening the Alarms buffer (touch the Message bar or the **Audio Pause** indicator at the bottom right of the display).
Low priority	Yellow, with alarm message	Yellow, solid Alarm status indicator on the front of the ventilator body flashes	Two sequences of beeps. This is not repeated.	For most alarms, press the **Audio Pause** key to reset the alarm. For some alarms, reset the alarm by opening the Alarms buffer (touch the Message bar or the **Audio Pause** indicator at the bottom right of the display).

Alarm type	Message bar	Alarm lamp / Alarm status indicator	Audio	Action required
Panel communication error	Communication error between ventilator monitor and unit. No message can be displayed. For details, see Section 7.7.3.	Alarm status indicator on the front of the ventilator body flashes	Continuous buzzer tone after a 30-second delay. The buzzer cannot be silenced.	Check the Lung status indicator on the front of the ventilator body (Section 2.2.1.1). If it is flashing, ventilation continues until you turn off the device. If it is not flashing, no ventilation is being delivered. • Immediately provide alternative ventilation. • Turn off the ventilator by pressing the **Power/Standby** button on the back of the device for 10 seconds. • Have the ventilator serviced.
Panel connection lost	An error has occurred with the ventilator monitor. If the display is still visible, the Panel error mode window is shown. For details, see Section 7.7.3.	Alarm status indicator on the front of the ventilator body flashes	Continuous buzzer tone. The buzzer cannot be silenced.	Check the Lung status indicator on the front of the ventilator body (Section 2.2.1.1). If it is flashing, ventilation continues until you turn off the device. If it is not flashing, no ventilation is being delivered. • Immediately provide alternative ventilation. • Turn off the ventilator by pressing the **Power/Standby** button on the back of the device for 10 seconds. • Have the ventilator serviced.

Alarm type	Message bar	Alarm lamp / Alarm status indicator	Audio	Action required
Technical fault	Red, with the text, *Safety ventilation*, *Safety therapy*, or *Technical fault: xxxxxx*	Red, flashing Alarm status indicator on the front of the ventilator body flashes	Same as for high-priority alarm, if technically possible. At a minimum, a continuous buzzer tone. The buzzer cannot be silenced.	The ventilator enters the Safety mode, or, if it cannot safely ventilate, the Ambient state. • Provide alternative ventilation. • Turn off the ventilator. • Have the ventilator serviced.
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. 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	5	Humidifier icon with associated alarm
2	Message bar	6	Alarm status indicator flashes
3	MMP and colored bar with associated alarm	7	Audio Pause indicator and countdown
4	Audio Pause key		

9.1.1 Alarm limit indicators

Alarm limits are shown:

- In the Alarms > Limits windows
- On the main display to the left of the MMPs, when appropriate

When an alarm limit is disabled, that is, no limit applies, the device shows the following Alarm Off symbol:



9.1.2 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.

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.
3. Correct the alarm condition from the alarm messages.

   For most alarms, when the alarm triggering condition is corrected, the ventilator automatically resets the alarm. For some alarms, one more step is required: you must open the Alarms buffer (touch the Message bar or the Audio Pause indicator at the bottom right of the display) to reset the alarm.

   For a technical fault, remove the ventilator from use, note the fault code, and have the ventilator serviced.
4. If appropriate, readjust the alarm limit.

9.1.3 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 2 minutes at a time.

To temporarily silence an alarm

- Press the Audio Pause key on the front of the ventilator monitor (Figure 10-2).

  The audible ventilator alarm is muted for 2 minutes. Pressing the key a second time cancels the audio pause.

The Audio Pause key backlight is continuously lit in 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, the alarm sounds again.

9.2 About the alarm buffer

The alarm buffer shows up to seven 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 thick 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 thin 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).

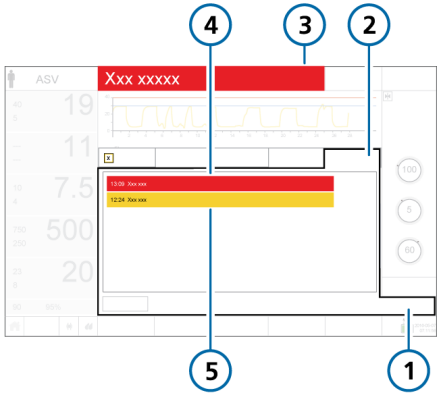
The most recent alarm is at the top of the list.

To clear the list of inactive alarms

- Touch the **Reset** button (Figure 9-3).

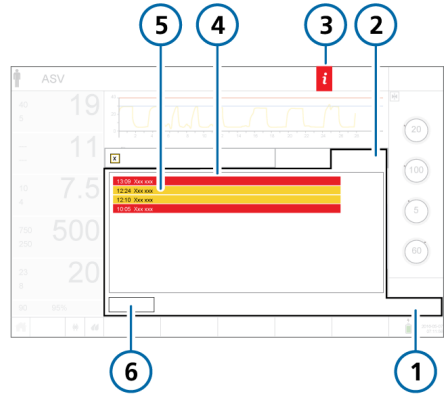
  Closing the buffer does not erase its contents.

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 appears in the buffer, providing troubleshooting information for the selected alarm.

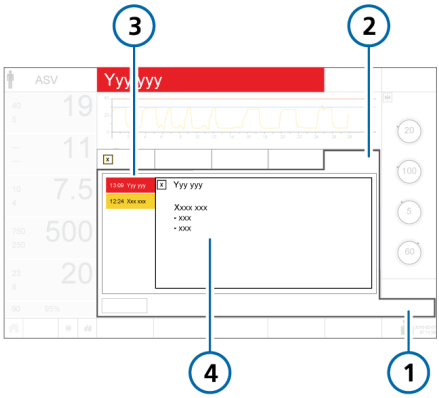
2. To view help for another alarm, touch the next alarm message.

   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 (**Adult/Ped**) or 3 (**Neonatal**). If you set the loudness below the default, the next time the ventilator is turned on, the loudness is reset to the default value.

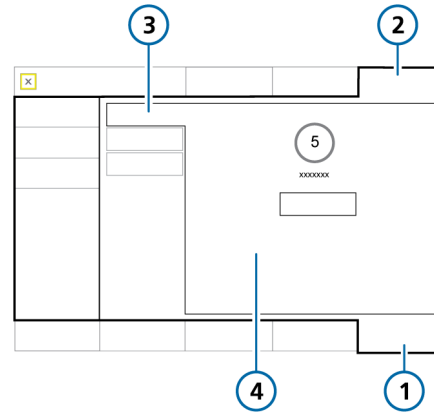
You cannot set the loudness below the minimum level configured for the device (Chapter 14).

To adjust the alarm loudness

1. Open the System > Settings window, and touch the **Loudness** button if the Loudness window is not already displayed.
2. Activate and adjust the **Loudness** control, as needed.
3. Touch **Test** to check the loudness level.

   Ensure the loudness level is above the ambient sound level.
4. 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 9-2 is an alphabetical list of the alarm messages displayed by the HAMILTON-C6, 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 external-device-related alarms, see:

- For SpO2-related alarms, see the *Pulse Oximetry Instructions for Use*.
- For INTELLiVENT-ASV-related alarms, see the *INTELLiVENT-ASV Operator's Manual*.
- For HAMILTON-H900-related alarms, see Section 12.1.6 and the *HAMILTON-H900 Instructions for use*.
- For IntelliCuff-related alarms, see Section 12.2.7 and the *IntelliCuff Instructions for use*.

Table 9-2. Alarms and other messages

Alarm	Definition	Action needed
Aerogen nebulizer disconnected	*Medium priority*. Any of the following conditions apply during active ventilation and nebulization: Aerogen is the selected nebulizer type and the countdown timer is running, but: • A nebulizer is not connected • The nebulizer is not properly connected and is not being powered	• Verify that an Aerogen nebulizer is connected to the breathing circuit set. • Check the connection of the nebulizer to the Aerogen port on the ventilator. • If the problem still persists, have the ventilator serviced.
Ambient state	The inspiratory and expiratory channels are opened, letting the patient breathe room air unassisted. See Section 7.7.	Provide alternative ventilation immediately.
Apnea	*High priority*. No patient trigger within the operator-set apnea time in APVsimv, SIMV, SPONT, DuoPAP, APRV, or NIV mode. Apnea backup is off.	• Check patient condition. • Check trigger sensitivity. • Consider changing the mode.
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 ventilation ended	*Low priority*. Backup mode was reset, and ventilator is again ventilating in its original support (pre-apnea) mode.	No action required.
ASV: Cannot meet the target	*Low priority*. The operator-set **%MinVol** cannot be delivered, possibly due to setting conflicts or lung-protective rules.	• Check patient condition. • Check the Pasvlimit settings and adjust if appropriate. • Consider a mode change. However, be aware that other modes may not enforce lung-protective rules.
Battery 1, 2: Calibration required	*Low priority*. The battery requires calibration. You may continue to use the battery.	Replace the battery with a properly calibrated battery to continue ventilation.

Alarm	Definition	Action needed
Battery communication error	*High priority*. Battery data is not available. Ventilation continues.	• Check the battery connectors and that the battery is installed correctly. • Make sure the battery lock is properly closed. • If the problem persists, replace the battery. • If the problem still persists, have the ventilator serviced.
Battery 1, 2: Defective	*High priority*. Battery defective. Ventilation continues if an alternative power source is connected.	• Replace battery. • Prepare alternative ventilation. • If the problem still persists, have the ventilator serviced.
Battery low	The low battery alarm has different levels of priority, depending on how much charge is left, and which power supply is in use. At 20% battery charge, the ventilator can generally continue operation for up to approx. 10 min, depending on battery and operating conditions. **High priority**. The ventilator is running on battery power, total battery charge is below 15%. **Medium priority**. The ventilator is running on battery power, total battery charge is below 20%. **Low priority**. The ventilator is running on primary power, total battery charge is below 20%.	• Connect the ventilator to a primary power source. • Install charged battery. • If necessary, be prepared to provide alternative ventilation.
Battery power loss	*High priority*. No battery is present.	• Connect the ventilator to primary power (AC). • Insert a battery.

Alarm	Definition	Action needed
Battery 1, 2: Replacement required	*Low priority*. Battery capacity is insufficient for reliable operation and must be replaced immediately.	• Connect the ventilator to primary power (AC). • Replace the battery. • If a replacement is not available, provide alternative ventilation until the issue is resolved. • If the problem still persists, have the ventilator serviced.
Battery 1, 2: Temperature high	*High priority*. The battery temperature is higher than expected.	• Remove the ventilator from the sun or other heat source. • Replace the battery. • Provide alternative ventilation until the issue is resolved. • If the problem still persists, have the ventilator serviced.
Battery 1, 2: Wrong battery	*Low priority*. The battery in use is not the correct battery for this ventilator.	• Replace the battery with the correct Li-ion battery. • Connect the ventilator to primary power (AC). • Provide alternative ventilation until the issue is resolved.
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 ventilation 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 ventilation. • Have the ventilator serviced.
Buzzer defective	*High priority*. A buzzer malfunction was detected. A technical alarm cannot typically be corrected by the operator.	• Restart device. • Provide alternative ventilation until the issue is resolved. • If the problem persists, have the ventilator serviced.

Alarm	Definition	Action needed
Check CO2 sensor 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 sensor sampling line	*Low priority*. CO2 sidestream sensor sampling line occluded by water.	• Check patient condition. • Replace sampling line.
Check flow sensor	*High priority*. Flow sensor measurements are out of expected range. The ventilator changes to PCV+ mode and displays the internal ventilator pressure (**Pvent**) instead of airway pressure (**Paw**). The ventilator returns to the previous mode when measurements are within the expected range.	• Make sure the flow sensor is the correct type for the patient (**Adult/Ped** vs **Neonatal**). • Check the flow sensor connection to the ventilator. • Connect and calibrate a new flow sensor.
Check flow sensor for water	*Medium priority*. *Neonatal only*. Flow sensor measurements are affected by water inside the sensor. You must confirm this alarm by pressing the **Audio Pause** key. If the alarm is not confirmed within 90 seconds, it is upgraded to a *high-priority* alarm.	• 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.
Check flow sensor tubing	*High priority*. The flow sensor tubes are disconnected or occluded. The ventilator switches to PCV+ mode and displays the internal ventilator pressure (**Pvent**) instead of airway pressure (**Paw**). The ventilator returns to the previous mode when measurements are within the expected range.	• Check the flow sensor connection to the ventilator. • Connect and calibrate a new flow sensor.

Alarm	Definition	Action needed
Check patient interface	*High priority*. Internal pressure too high during high flow oxygen therapy. Flow cannot be delivered to the patient.	• Check patient condition. • Check patient interface and/or reduce flow. • Check patient circuit for kinks.
Check settings	*Low priority*. A change to a control or alarm setting was not saved.	Check and confirm settings, including alarms.
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 defect	*Low priority*. 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*. Temperature at CO2 sensor too high.	• 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*. CO2 operating temperature not yet reached or unstable.	Wait for sensor to warm up.
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 ventilation. • 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/DuoPAP, only during pressure phase.	• Check patient condition. • Check the breathing circuit for a disconnection between the patient and the flow sensor, or for other large leaks (for example, ET tube).

Alarm	Definition	Action needed
Disconnection on ventilator side	*High priority*. Measured VTI at the flow sensor is less than one-half of the delivered VTI, and delivered VTI exceeds 50 ml.	• Check the expiratory valve: – Check the condition of the expiratory valve set. If anything is defective, replace. – 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.
Exhalation obstructed	*High priority*. Either the end-expiratory pressure is too high or the end-expiratory flow is too low. Note that you must use an inspiratory filter to prevent contamination. The ventilator may be contaminated if no inspiratory filter is used. Not active in HiFlowO2 mode.	• 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 ventilation until the issue is resolved. • Have the ventilator serviced.
External flow sensor failed	*High priority*. The external flow sensor doesn't work properly.	• Check flow sensor for excessive secretions and/or water accumulation. • Provide alternative ventilation and clean the flow sensor with sterile water. • Connect and calibrate a new flow sensor.

Alarm	Definition	Action needed
Fan failure	*Medium priority*. There is a problem with the cooling fan.	• Provide alternative ventilation until the issue is resolved. • Disconnect the ventilator from the patient. • Have the ventilator serviced.
Flow sensor calibration needed	*High priority*. The ventilator does not have correct calibration data or automatic recalibration of the flow sensor is impossible.	• Calibrate the flow sensor as soon as possible. • Flow, volume, and pressure readings are less accurate with an uncalibrated flow sensor.
Function key not operational	*Medium priority*. Function key defective. Ventilation continues.	• Turn off the ventilator using the **Power/Standby** button on the back of the device. • Have the ventilator serviced.
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 7.9.
High minute volume	*High priority*. The measured **ExpMinVol** exceeds the set alarm limit.	• Check patient condition. • Check and confirm settings, including alarms.
High oxygen	*High priority*. One of the following has occurred: • If the oxygen 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 in Configuration, the measured oxygen is above the set upper limit.	• Calibrate the O2 sensor. • Install a new O2 sensor. • Check alarm limits (if set manually). • If using a paramagnetic O2 sensor, calibrate the sensor or have the ventilator serviced.

Alarm	Definition	Action needed
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 two 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.
High pressure *Audio Pause is disabled for this alarm.*	*High priority*. The measured inspiratory pressure exceeds the set high **Pressure** alarm limit. The ventilator immediately closes the inspiratory valve to stop 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 and flow sensor tubes for kinks and occlusions. • Provide alternative ventilation once the ventilator enters the Ambient state.
High pressure during sigh	*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 and flow sensor tubes for kinks and occlusions. • Consider disabling the Sigh function.

Alarm	Definition	Action needed
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.	• Reduce the **Psupport** setting. • Adjust the high **Vt** alarm limit.
IRV	*Low priority*. The set **I:E** ratio is above 1:1, leading to inverse ratio ventilation. Does not apply in APRV.	Check the timing control settings.
Invalid communication board	*Low priority*. Installed communication board is invalid.	• Contact your Hamilton Medical technical representative. • Have the ventilator serviced.
Language not loaded	*Low priority*. The selected language data cannot be loaded.	• Restart device. • If the problem persists, have the ventilator serviced.
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 ventilation 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 – 3 cmH2O)** for two 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.

Alarm	Definition	Action needed
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 ventilation 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.
Low oxygen	*High priority*. One of the following has occurred: • If the oxygen 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 in Configuration, 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 ventilation and install a new O2 sensor. • If using a paramagnetic O2 sensor, calibrate the sensor or have the ventilator serviced.
Low pressure	*High priority*. Set pressure during inspiration 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*. A leak cannot be fully compensated. In APVsimv and APVcmv modes only.	• Inspect the system for leaks. • Suction the patient, if needed. • Ensure the high **Pressure** limit is appropriate. • Switch to a different ventilation mode.

Alarm	Definition	Action needed
No ventilation after power fail	*High priority*. An error has occurred due to a loss of power. Ventilation is not possible	• Provide alternative ventilation. • Contact you Hamilton Medical technical representative. • Have the ventilator serviced.
O2 sensor calibration needed	*Low priority*. O2 sensor calibration data is not within expected range, or 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. • If using a paramagnetic O2 sensor, calibrate the sensor or have the ventilator serviced.
O2 sensor defective	*Low priority*. The O2 sensor is depleted.	• Install a new O2 sensor. • If using a paramagnetic O2 sensor, calibrate the sensor or have the ventilator serviced.
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. • If using a paramagnetic O2 sensor, calibrate the sensor or have the ventilator serviced.
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.
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.	• 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 ventilation until the issue is resolved.

Alarm	Definition	Action needed
Panel connection lost	*High priority.* A problem has occurred either with the monitor and display or with communication between the monitor and the ventilator unit.	• Immediately provide alternative ventilation. • Turn off the ventilator by pressing the Power button on the back of the device for 10 seconds. • Have the ventilator serviced.
Panel settings file error	*Low priority*. An error has occurred with the monitor.	• Check ventilation settings and dismiss the alarm. Ventilation continues normally. • Restart device if possible. • If the problem persists, have the ventilator serviced.
Performance limited by high altitude	*Medium priority, Low after silence*. 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 ventilation until the issue is resolved.
PetCO2 high	*Medium priority*. **PetCO2** exceeds the set alarm limit.	• Check patient condition. • Check and confirm settings, including alarms.
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*. Applies in ASV. The Pasvlimit was changed. When this setting is changed, the device automatically adjusts the high **Pressure** alarm limit to 10 cmH2O above the specified Pasvlimit setting.	Make sure the pressure limit is high enough so that sufficient pressure can be applied for adequate breath delivery.

Alarm	Definition	Action needed
Pressure limitation	*Medium priority, Low after silence*. Inspiratory pressure, including PEEP/CPAP, is 10 cmH2O below **Pressure**. 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 ventilation until the issue is resolved. • Have the ventilator serviced.
Real-time clock failure	*Medium priority*. Date and time not set.	Set the date and time (System > Settings window).
Release valve defective	*Low priority*. During the routine check of the ambient valve during a tightness test, the valve was found to be defective. The alarm is reset when a tightness 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. • If using a paramagnetic O2 sensor, calibrate the sensor or have the ventilator serviced.
Safety therapy	*Technical fault*. A hardware or software issue was detected. The ventilator switches to Safety therapy.	• Provide alternative therapy 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 mode.	• Provide alternative ventilation until the issue is resolved. • Have the ventilator serviced.

Alarm	Definition	Action needed
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 ventilation and have the ventilator serviced.
Settings file error	*Low priority*. The ventilator settings information cannot be loaded.	• Check ventilation settings and dismiss the alarm. Ventilation continues normally. • Restart device if possible. • If the problem persists, have the ventilator serviced.
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 mode.	• Provide alternative ventilation until the issue is resolved. • Have the ventilator serviced.
Technical state failed	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.

Alarm	Definition	Action needed
Turn 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 silver connector.
Unknown part number	*Technical fault*. A hardware or software issue was detected. The ventilator switches to the Ambient state.	• Provide alternative ventilation until the issue is resolved. • Have the ventilator serviced.
Ventilation canceled	*Technical fault*. A hardware or software issue was detected. The ventilator switches to the Ambient state.	• Provide alternative ventilation until the issue is resolved. • Contact your Hamilton Medical representative. • Have the ventilator serviced.
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 ventilation until the issue is resolved. • Have the ventilator serviced if temperature cannot be reduced.
Vt high	*Medium priority*. Measured VTE exceeds the set limit for 2 consecutive breaths. In invasive modes, if the delivered tidal volume exceeds 1.5 times the Vt high limit (Vt > 1.5 * high Vt limit), the Inspiratory volume limitation alarm is generated.	• Check the pressure and volume settings for potential leaks and/or disconnections. • Check and confirm settings, including alarms.

Alarm	Definition	Action needed
Vt low	*Medium priority*. Measured VTE is below the set limit for 2 consecutive breaths.	• Check patient condition. • Check and confirm settings, including alarms. • Check the breathing circuit and artificial airway of the patient for leaks, kinked tubing, or disconnection.
Wrong flow sensor	*High priority*. The type of flow sensor connected does not match the selected patient group.	• Check the patient group selection. • Connect and calibrate the correct flow sensor.

10 Ventilation settings and functions

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10.1 Overview

This chapter describes changing ventilation settings during active ventilation, as well as how to perform special functions on the ventilator.

Before proceeding, review the safety information in Chapter 1.

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 automatically adjusts the following settings based on the recalculated **IBW**; other controls and alarm limits are not adjusted:

- Apnea backup setting (when Apnea backup is set to **Automatic**)
- Safety mode startup values

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, these controls are greyed out and unavailable.

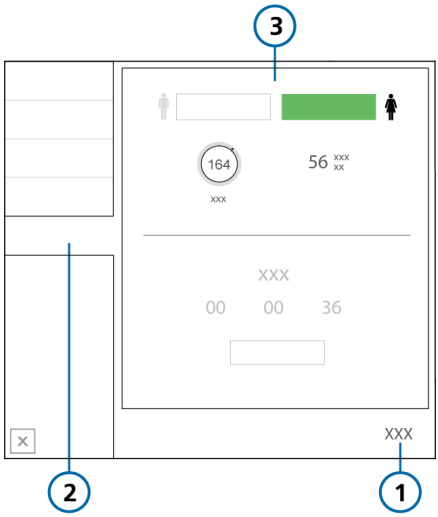
To change patient data during ventilation

- Do either of the following:

  – Touch the **Patient** icon at the top left of the display, next to the mode name (Figure 5-1).

  – In the Controls window, touch the **Patient** button, and adjust settings as needed.

Figure 10-1. Controls > Patient window (Adult/Ped shown)



1	Controls	3	Adult/Ped: Sex and height, calculated IBW; Neonatal: Weight
2	Patient		

10.2.2 Accessing settings during ventilation

At any time during ventilation, you can adjust settings, as needed. Changes are applied immediately.

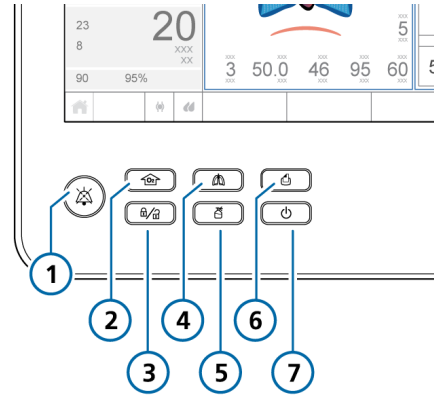
- Touch any MMP, the SpO2 parameter under the MMPs, or the **Alarms** button to access the alarm limit controls.
- Touch **Controls** to access the mode controls. Some controls are also available on the right side of the main display.
- Touch the mode name at the top left of the display (Figure 5-1) or the **Modes** button to change the selected ventilation mode.

  Note that you can only select the HiFlowO2 and nCPAP-PS modes when in Standby.
- Touch the **Patient** icon or open the Controls > Patient window to access patient settings.
- Touch the **Home** icon to reset the display to the default configuration set for the selected Quick Setup.
- Touch the **IntelliCuff** or **Humidifier** icons to access the respective settings windows.

The ventilator monitor also provides access to key functions.

Keys on the front of the ventilator provide access to important functions, including entering Standby mode and pausing the alarm sound.

Figure 10-2. Function keys



1	Audio Pause	5	Nebulizer on/off
2	O2 enrichment/ suctioning	6	Print screen
3	Screen lock/ unlock	7	Power/Standby
4	Manual breath		

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

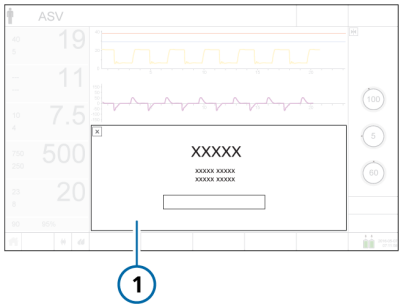
- Patient alarms are suppressed in Standby.
- Acoustic patient alarms are suppressed for 1 minute after starting ventilation from Standby.

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

To put the ventilator into Standby

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

   The Activate Standby window **(1)** opens.



2. Touch **Activate standby**.

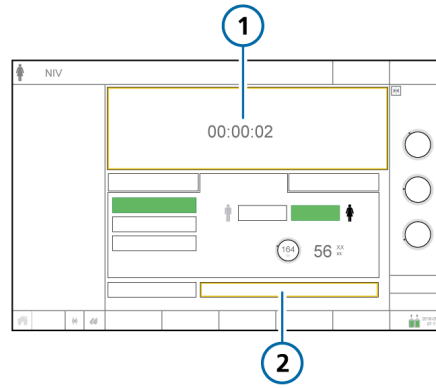
   The Standby window opens (Figure 10-3).

   When the device is in Standby, the **Power/Standby** key backlight is green.

While in Standby, the window 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. Standby window



1	Elapsed time in Standby	2	Start ventilation (**Start therapy** when HiFlowO2 is selected)

To end Standby and start ventilation

- Do either of the following:

  – Touch the **Start ventilation** button. If the mode selected is HiFlowO2, the button is labeled **Start therapy**.

  – Press and quickly release the **Power/Standby** key.

Ventilation resumes with the previous settings. During active ventilation, the **Power/Standby** key backlight is white.

10.4 O2 enrichment

NOTICE

Oxygen alarms are suppressed while O2 enrichment is active.

Oxygen enrichment is useful for pre- or post-oxygenation 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.** Current **Oxygen** setting + 25% of the current setting

When O2 enrichment is active, the key backlight is green and the **Oxygen** control turns green.

To start oxygen enrichment

- Press the **O2 enrichment** key (Figure 10-2).

  After a short time, the ventilator starts delivering increased oxygen (see above).

The **Oxygen** control, now green, displays the currently applied concentration, with a countdown timer.



When finished, the ventilator resets the concentration to the previous operator-set value.

To stop O2 enrichment manually

- Do either of the following:

  – Press the key again.

  – Using the **Oxygen** control, change the setting.

The ventilator resumes ventilation at the set concentration.

10.4.1 Suctioning maneuver

The suctioning maneuver is intended to withdraw an excess of tracheal and/or bronchial secretions in the patient's airways while protecting the user from possible contamination, as well as ensuring the patient's safety during the suctioning maneuver. This section describes an open-suctioning maneuver.[44]

Suctioning may affect measured values.

Note that suctioning is disabled during high flow oxygen therapy.

To perform the suctioning maneuver

1. Press the **O2 enrichment** key (Figure 10-2) for pre-oxygenation.
2. Disconnect the patient.

   Disconnecting the patient stops ventilation so that no gases are blown through the breathing circuit. 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.

   Post-oxygenation starts and all acoustic alarms are again suppressed for one minute. Alarm messages and alarm lamp are still active.

[44] A closed-suctioning maneuver is not described here since there is no breathing system disconnection.

To stop the maneuver manually

- Press the **O2 enrichment** key again.

10.4.2 Manual breath

You can prolong inspiration as well as deliver a manually triggered breath. See Figure 10-2.

When active, the key backlight is green.

Note that manual breath is disabled during high flow oxygen therapy.

To deliver a manual breath

- Press and release the **Manual breath** key during exhalation.

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 the **Manual breath** key (Figure 10-2) 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.

10.5 Inspiratory and expiratory hold

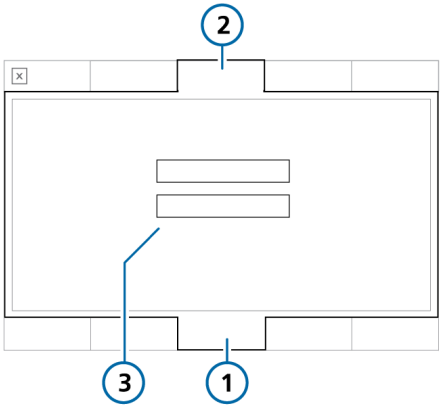
The ventilator supports both inspiratory and expiratory holds.

Note that holds are disabled during high flow oxygen therapy.

10.5.1 Inspiratory hold

An inspiratory hold closes the inspiratory and expiratory valves for a short time. Perform this maneuver to calculate true plateau airway pressure.

Figure 10-4. Hold window



1 Tools

2 Hold

3 Inspiration hold and Expiration hold

To perform an inspiratory hold

1. Open the Tools > Hold window.
2. Touch **Inspiration hold**.

   The ventilator performs an inspiratory hold as follows:

   – **Adult/Ped.** 10-second hold

   – **Neonatal.** 3-second hold

   To stop the inspiratory hold early, touch the **Inspiration hold** button again.

   A progress bar appears for the length of the hold.

   At the end of the hold, the window closes. The waveforms are frozen on the display.
3. Review the waveforms as appropriate.
4. Touch the **Freeze** button or press the P&T knob to unfreeze the display.

10.5.2 Expiratory hold

Perform this maneuver to measure the pressure within the patient airways and the patient's effort and strength for inspiration. It is used to calculate intrinsic PEEP.

The ventilator ambient valve opens at 3 cmH2O below ambient pressure. Note that pressure values below -3 cmH2O are not displayed.

To perform an expiratory hold

1. Open the Tools > Hold window.
2. Touch **Expiration hold**.

   The ventilator performs an expiratory hold as follows:

   – **Adult/Ped.** 10-second hold

   – **Neonatal.** 3-second hold

   To stop the expiratory hold early, touch the **Expiration hold** button again.

   A progress bar appears for the length of the hold.

   At the end of the hold, the window closes. The waveforms are frozen on the display.
3. Review the waveforms as appropriate.
4. Touch the **Freeze** button or press the P&T knob to unfreeze the display.

10.6 Working with a nebulizer

The ventilator supports the use of both pneumatic and Aerogen nebulizers. For setup details, see Section 4.7.

10.6.1 Pneumatic nebulization

Before proceeding, review the safety information in Chapter 1.

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.

Nebulization can be activated in all modes of ventilation except HiFlowO2 and during neonatal ventilation. When active, the key backlight is green.

For effective nebulization, use a pneumatic nebulizer jar.

For connection details, see Section 4.7.

To start and stop nebulization

- Press the **Nebulizer** key (Figure 10-2).

When active, the fixed nebulizer flow, using 100% O2, is synchronized with the inspiratory phase of each breath for 30 minutes.

10.6.2 Working with the Aerogen nebulizer

Before proceeding, review the safety information in Chapter 1 and the Aerogen Solo/Aerogen Pro Instructions for Use.

The Aerogen nebulizer system is available as an option.

You can use an Aerogen nebulizer for delivery of prescribed medications in the ventilator circuit. The nebulizer operates in-line with standard ventilator breathing circuits to aerosolize prescribed medications for inhalation without changing patient ventilator settings. It can be refilled without interrupting ventilation.

Nebulization can be activated in all modes of ventilation[45]. When active, the key backlight is green.

For activation and setup details, see Section 4.7 and the *Aerogen Solo/Aerogen Pro Instructions for Use*.

To start and stop nebulization

▸ Press the **Nebulizer** key (Figure 10-2).

When active, the Aerogen aerosol provides nebulization continuously for 30 minutes.

During ventilation, the ventilator may generate the **Aerogen nebulizer disconnected** alarm. For details, see Section 9.4.

10.7 Locking and unlocking the touch screen

You can lock the touch screen to prevent inadvertent entries.

When screen lock is active:

- The key backlight is 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

  – **Inactive controls.** Touch screen, Standby/Power, Print screen, P&T knob

To lock or unlock the screen

▸ Press the **Screen Lock/unlock** key (Figure 10-2).

10.8 Capturing a screen print

Before using a USB memory device with the ventilator, review the safety information in Chapter 1.

The **Print screen** key saves a JPG file of the current ventilator display to a USB memory drive.

To capture a screenshot of the display

1. Insert a USB memory drive into the USB port.
2. Press the **Print screen** key (Figure 10-2) when the desired display is shown.

   The device saves the image to the folder, **screenshot**, on the memory drive. The key backlight is green while the device saves the image.

[45] In the USA, not available during neonatal ventilation.

The filename uses the following format:

screenshot_yyyy-mm-dd_hh-mm-ss.jpg

where:

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

10.9 About the Event log

Once the ventilator is turned on, event logs collect data about clinically relevant ventilator activities, including 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**).

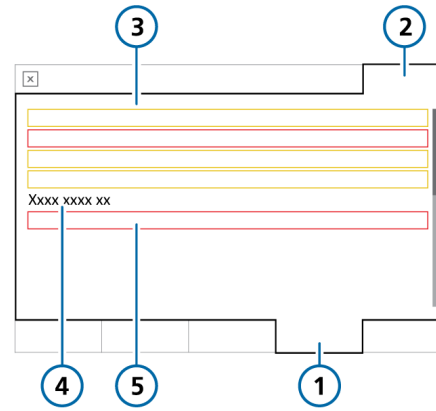
Event log data persists after shutting off the ventilator or in the event of a power loss. When a log buffer is full, new events overwrite the oldest log entries.

You can copy Event log data. See Section 10.9.1.

To display the Event log

- Touch the **Events** button.

Figure 10-5. Events window



1	Events	4	Informational message
2	All	5	High-priority alarm (red)
3	Low-/medium-priority alarm (yellow)		

10.9.1 Copying Event log data

Before using a USB memory device with the ventilator, review the safety information in Section 1.4.4.

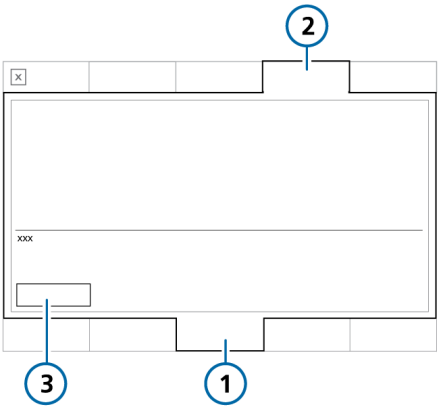
You can save the Event and Service logs to a USB memory device. The device must have a FAT or FAT32 format and it must *not* have an operating system or a security system installed.

To copy the log

1. Place the ventilator into Standby and insert a memory device into the USB port on the monitor (Figure 2-5).
2. Open the Tools > Utilities window (Figure 10-6), and touch **Export logs**.
3. Remove the memory device when **File transfer successful** is displayed.

   A folder named C6_sn<serial number> is created on the memory device containing all Event and Service log files.

Figure 10-6. Data transfer window



1	Tools	3	Export logs
2	Utilities		

10.10 Setting display options

You can set the day and night display brightness, as well as the device date and time.

10.10.1 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.

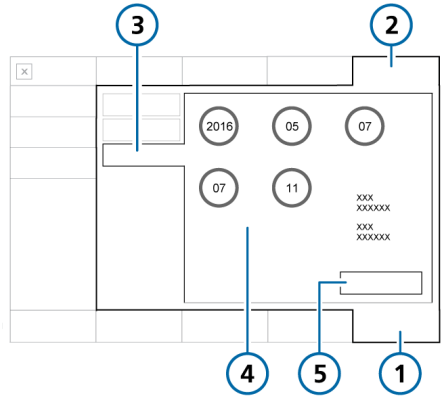
To set the date and time

1. Do either of the following:

   – Touch the Date/Time indicator at the bottom right of the display.

   – Touch **System**, then **Settings**.
2. Touch **Date & Time** (Figure 10-7).
3. Adjust the day and time, then touch **Apply** to save the changes.

Figure 10-7. Date & Time settings



1	System	4	Date and time settings
2	Settings	5	Apply
3	Date & Time		

10.10.2 Day and night display brightness

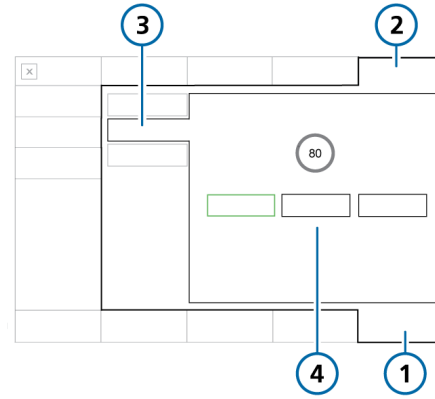
Use these settings to set the brightness of the display for use during the day and night.

To set the display brightness

1. Open the System > Settings window (Figure 10-8).
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 10-8. Day & Night window



1	System	3	Day & Night
2	Settings	4	Day, Night, Automatic, Brightness settings

Table 10-1. Day and Night settings

Setting	Brightness range	Default
Day	10% to 100%	80%
Night	10% to 100%	40%

11
Working with P/V Tool

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11.8 Performing a recruitment maneuver....226

11.1 Overview

P/V Tool™ Pro (referred to as *P/V Tool*) is a diagnostic and recruitment tool. It allows you to perform a maneuver to assess the total compliance for the entire respiratory system, including the lungs and the chest wall. Lung compliance is recorded in a quasi-static pressure volume curve.

P/V Tool helps the clinician:

- Determine the patient's lung characteristics and lung compliance.
- Define the maximum plateau pressure for ventilation.
- Determine the positive end expiratory pressure (PEEP) that will improve oxygenation, reduce end tidal CO2, avoid alveoli collapse after a recruitment maneuver, and improve lung compliance.
- Perform a P/V Tool maneuver to assess the total compliance for the entire respiratory system, including the lungs and the chest wall. Lung compliance is recorded in a quasi-static pressure volume curve.
- Perform a recruitment maneuver to open or reinflate collapsed alveoli in the lungs.
- Define recruited volume and calculate when there is no longer extra lung to recruit.

11.1.1 Conditions for use

The following conditions must be met before performing a P/V Tool maneuver:

- The patient is intubated and passive, that is, *not* breathing spontaneously.
- The breathing circuit is gas tight.

  There must be no gas leak throughout the entire system of the ventilator, the breathing circuit, or at the ventilated patient.
- Nebulization is deactivated.

  P/V Tool is disabled during nebulization and for five breaths following nebulization.
- The flow sensor must perform optimally.

  The accuracy of the information provided depends on the quality of the flow sensor connection. P/V Tool is disabled when the **Flow sensor calibration needed** alarm is active.
- P/V Tool is enabled in the following modes: (S)CMV, SIMV, APVcmv, APVsimv, PCV+, PSIMV+, DuoPAP, APRV, ASV, and INTELLiVENT-ASV.
- P/V Tool is disabled in the following modes: SPONT, NIV, NIV-ST, nCPAP-PS, Apnea backup modes, and HiFlowO2 therapy.
- The patient has received at least five breaths between P/V Tool maneuvers.
- P/V Tool option is activated on the ventilator.

11.1.2 Indications for use

Use of the P/V Tool is indicated for adult, pediatric, and neonatal patients provided that the required conditions are met as described in Section 11.1.1.

11.1.3 Contraindications for use

Use of the P/V Tool is contraindicated if any of the following conditions apply:

- Patients with unstable cardiovascular dynamics
- Patients with confirmed or suspected intracranial hypertension
- Patients who cannot tolerate high intrapulmonary pressure
- Patients vulnerable to barotrauma or volutrauma

11.2 Using the P/V Tool

Before proceeding, review the information in Sections 11.1.1 through 11.1.3.

Using the P/V Tool involves the following steps:

To ...	See ...
Open the P/V Tool	Section 11.3
Adjust control settings	Section 11.4
Perform a P/V Tool maneuver	Section 11.5
View the data	Section 11.5.1
Use reference curves	Section 11.7
Perform a recruitment maneuver	Section 11.8

Using the P/V Tool does not require any disconnection of the breathing circuit or changes to ventilation settings.

You can use the P/V Tool during active ventilation.

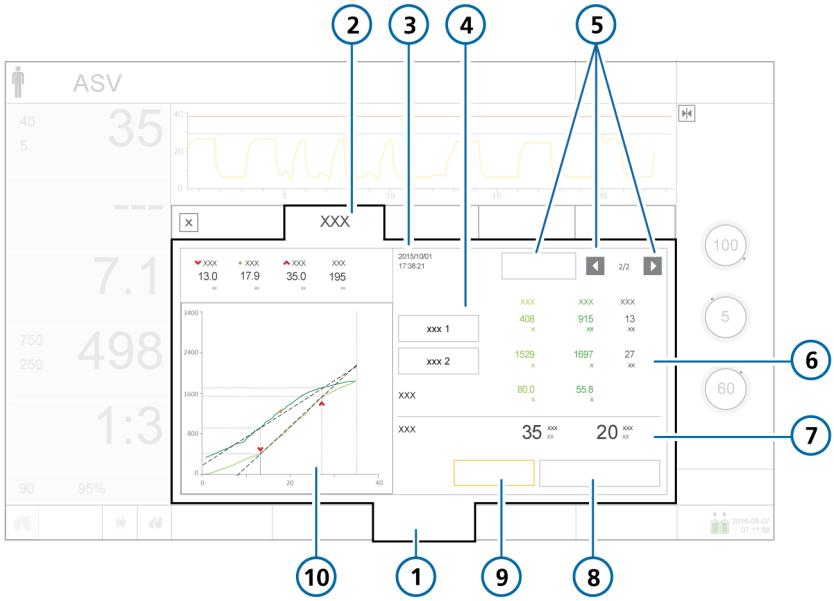
11.3 Opening the P/V Tool

To open the P/V Tool

1. Touch **Tools**, then **P/V Tool**.
2. Review the safety information, then touch **Confirm** to continue.

   The P/V Tool window opens (Figure 11-1).

Figure 11-1. P/V Tool window



1	Tools	6	Numerical data related to graph
2	P/V Tool	7	Current settings
3	Date and time of maneuver	8	Start/Stop maneuver
4	Cursors 1 and 2	9	Settings
5	Reference button and history navigation arrows	10	P/V Tool graphics panel

The next step is to adjust the control settings.

11.4 Adjusting the control settings

NOTICE

- Set **Ptop** to a low value to prevent generation of excessive volumes when performing a maneuver on patients with obstructive "soft lung" diseases, such as COPD.
- Set a low ramp speed to ensure accurate data when performing a P/V Tool maneuver. The ramp speed also dictates the length of the maneuver.

You can configure the control parameters listed in Table 11-1 for a P/V Tool maneuver.

To adjust control settings

1. In the P/V Tool window, touch the **Settings** button.

   The Settings window opens (Figure 11-2).

2. Review and, if needed, adjust the settings.

   The controls **Ptop**, **Tpause**, and **End PEEP** may require extra steps when adjusting them, as described in the following sections.

Table 11-1. P/V Tool control settings

Control	Description
Pstart (cmH2O)	Starting pressure. **Default value:** Current PEEP
Ptop (cmH2O)	Target high pressure during the maneuver. **Default value:** 35
End PEEP (cmH2O)	End pressure and PEEP to be applied after the maneuver. **Default value:** Current PEEP
Ramp speed (cmH2O/s)	Rate of pressure change; the time taken to reach the target pressure. **Default value:** 3
Tpause (s)	Length of the pause during the P/V Tool maneuver; time during which the target pressure will be applied. **Default value:** 0
Tmaneuver (s)	The length of the maneuver. This is a calculated value based on the settings of the above-listed controls. **Default value:** --

To set Ptop > 40 cmH2O or Tpause > 5 seconds

1. Touch the appropriate control to activate it and set it to the maximum allowed value (40 for **Ptop**, 5 for **Tpause**).
2. Press the P&T knob to accept the setting.
3. To set either parameter beyond this limit, touch the control again and turn the P&T knob to set the value as desired.
4. Press the P&T knob to accept the changed value.

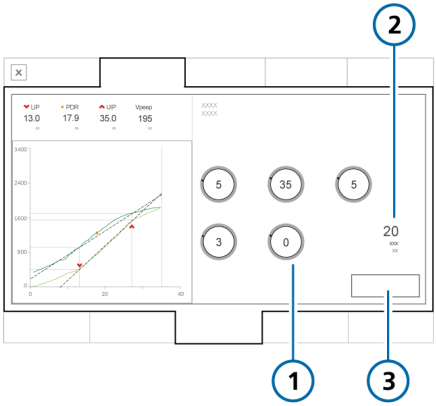
To set End PEEP to a different setting than PEEP/CPAP

If setting End PEEP to a different value than PEEP/CPAP, the device prompts you to confirm the new setting.

- If required, touch **Yes** or **No** to confirm the PEEP setting.

The next step is to perform a P/V Tool maneuver. See Section 11.5.

Figure 11-2. P/V Tool control settings



1 Control settings (Table 11-1)

2 Calculated Tmaneuver value

3 Close

11.5 Performing a P/V Tool maneuver

NOTICE

To avoid the risk of infection, if IntelliCuff is connected and being used, prior to performing a recruitment maneuver, inflate the cuff pressure to keep the airway tight.

To perform a P/V Tool maneuver

1. Touch the **Start/Stop maneuver** button.

   The device performs a recruitment maneuver for the length of time defined by the settings.

2. To stop the P/V Tool maneuver early, touch the **Start/Stop maneuver** button.

   At the end of the P/V Tool maneuver, ventilation continues and the results of the maneuver are displayed. See Figure 11-1.

The next step is to review the resulting data.

11.5.1 Viewing data

Data gathered during the P/V Tool maneuver is displayed both graphically and numerically.

To ...	See ...
Choose the data to display	Section 11.5.2
Display numerical data	Section 11.5.2.1
Analyze the curves	Section 11.6
Use a previous curve as reference for comparison	Section 11.7

11.5.2 Choosing the data to display

You can select from the following graph types.

Table 11-2. P/V Tool graph types

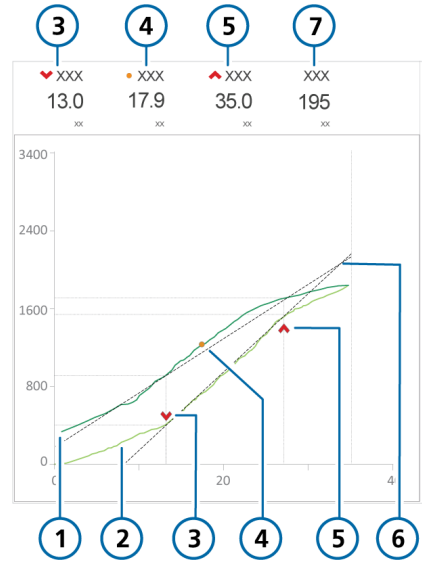
Graph type	Description
Paw/V	Airway pressure to airway volume. The airway pressure in relation to the lung volume. It shows how much pressure is required to inflate the lung at each volume step. See Figure 11-3.
Paw/V + Paw/dV	Airway pressure to airway volume and the difference in airway volume between the inspiratory limb and the expiratory limb. When this view is selected, the difference in airway volume values are displayed in orange on the right side of the P/V Tool window. See Figure 11-4.
Paw/Flow	Airway pressure to airway flow. See Figure 11-5.
Pes/Volume	Pressure measured through the Pes port to airway volume. See Figure 11-6.
Ptranspulm/ Volume	Transpulmonary pressure (Paw - Pes) to airway volume. See Figure 11-7.

To select a graph

1. Touch the P/V Tool graphics panel.
   The graph selection window opens, displaying buttons for each of the available options (Table 11-2).
2. Touch the desired button.

The window closes and the selected graph is displayed.

Figure 11-3. Paw/V graph



1		Deflation limb (dark green)
2		Inflation limb (light green)
3	⌄	Lower inflection point (LIP)
4	⌃	Point of de-recruitment (PDR)
5	●	Upper inflection point (UIP)
6		Guidelines between points
7		Vpeep (inflated lung volume when the set PEEP is reached)

Figure 11-4. Paw/V + PAW/dV (1) graph

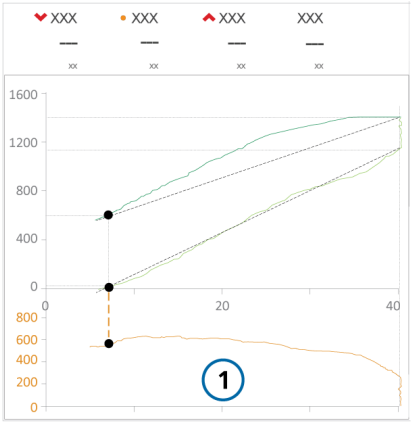


Figure 11-5. Paw/Flow graph

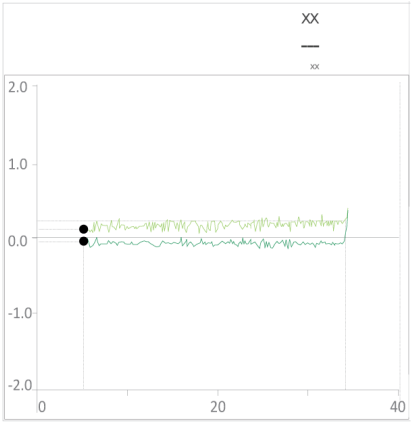


Figure 11-6. Pes/Volume graph

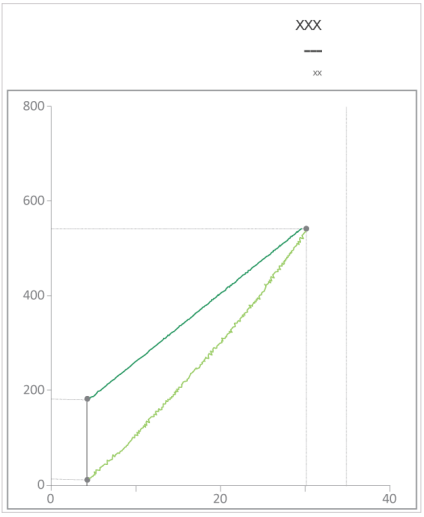
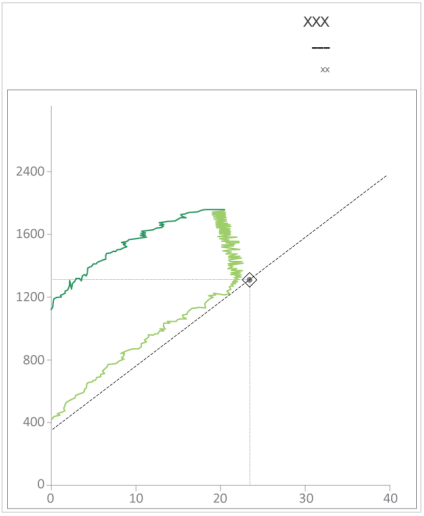


Figure 11-7. Ptranspulm/Volume graph



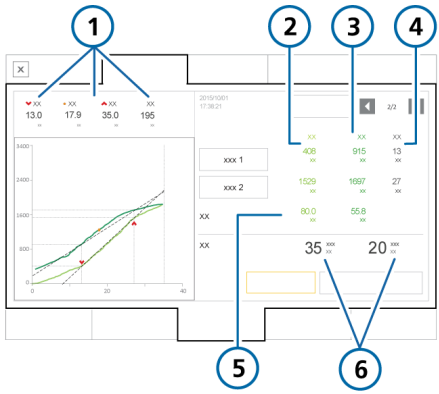
11.5.2.1 Numerical data

Data is also displayed numerically (Figure 11-8).

The data is dynamic. Depending on what you select in the P/V Tool window, values will change, allowing you to analyze data based on precise values.

For parameter specifications, including ranges and accuracy, see Tables 16-5 and 16-6.

Figure 11-8. Reviewing the data



1	LIP, UIP, PDR, vPEEP values *Includes dV when the Paw/V + Paw/dV view is selected.*	4	Airway pressure data
2	Inflation limb data (light green)	5	Compliance
3	Deflation limb data (dark green)	6	Current **Ptop** and **Tmaneuver** settings

11.6 Analyzing the data

Once the P/V Tool maneuver is complete, the inflation and deflation limbs of the maneuver are displayed in the P/V Tool graphics panel.

Use the cursors to move up and down the recorded curves to analyze in precise detail the recorded values on the inflation and deflation limbs.

To move the cursors

1. Touch the **Cursor 1** or **Cursor 2** button (Figure 11-1).
2. Move the cursor using the P&T knob.

   The displayed data is automatically updated as you move the cursor.
3. Touch the button again to deselect the cursor.

11.7 Using reference curves

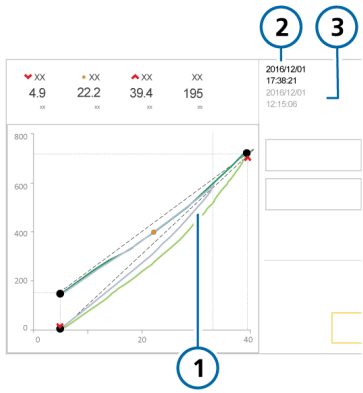
The reference curve is used to compare a patient's progress over time or before and after a recruitment maneuver.

Between 3 and 20 curves can be stored depending on the length of the stored maneuvers. The oldest curves are deleted as new recruitment maneuvers are performed.

You can select one inflation/deflation curve as the reference curve, which you can change at any time. This curve is overlaid in the P/V Tool graphics panel.

Stored settings, reference curves, and data are deleted when the device is restarted or when you start ventilation with a new patient.

Figure 11-9. Displaying a reference curve



1	Reference curve (gray)	3	Time and date associated with the reference curve
2	Current curve		

To display a reference curve

1. Touch the left or right navigation arrow keys (Figure 11-1) to scroll through the stored curves.

   As you scroll through the stored curves, each curve is displayed in gray in the P/V Tool graphics panel (Figure 11-9).

2. Touch the **Reference** button to set the displayed curve as the reference.

The reference curve is displayed in gray. The current inflation limb, deflation limb, and associated values are displayed in green.

To deselect a reference curve

- Touch the **Reference** button again to deselect a reference curve.

11.8 Performing a recruitment maneuver

The P/V Tool can also be used to perform a recruitment maneuver. For details, see Section 11.5.

Set Ptop to the desired pressure to perform a recruitment maneuver. The duration for the maneuver is determined by Tpause and the Ramp speed.

Upon completion of the recruitment maneuver, the resulting graph shows the volume of the lung that has been recruited.

12
Working with external devices

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12.1 Working with the HAMILTON-H900 humidifier

Before proceeding, review the safety information in Chapter 1.

Using the HAMILTON-H900 humidifier with the ventilator offers full integration of humidifier monitoring data and controls directly from the ventilator display.[46,47] In addition, functions between the devices are synchronized.

You can control the humidifier both 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 12-1. Operation overview

For details about ...	See ...
Accessing humidifier controls on the ventilator	Section 12.1.1
Humidifier modes	Section 12.1.2
Changing gas temperature and humidity settings	Section 12.1.3
Entering Standby	Section 12.1.4
Turning the humidifier on/off	Section 12.1.5
Humidifier-related alarms	Section 12.1.6
Humidifier-related parameters	Section 12.1.7

12.1.1 Accessing humidifier controls on the ventilator

The System > Humidifier window shows a visual representation of the breathing circuit, clearly indicating the inspiratory gas temperature at the water chamber exit and at the patient. It also provides access to the operations listed in Table 12-1.

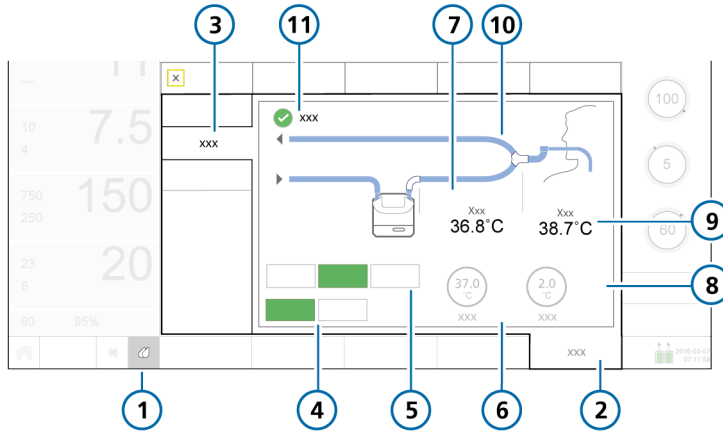
To open the Humidifier window

- Do either of the following (Figure 12-1):
  - Touch the **Humidifier** icon.
  - Touch **System > Humidifier**.

If communication between the humidifier and the ventilator is lost, the window is disabled.

[46] Supported for HAMILTON-H900 version 0.1.0.5b and later.
[47] Not available in all markets.

Figure 12-1. System > Humidifier window



1	Humidifier icon	7	T humidifier
2	System	8	T gradient control
3	Humidifier	9	T Y-piece
4	Invasive, NIV (noninvasive)	10	Breathing circuit
5	Off, Auto, Manual	11	Exp. temperature increase checkbox
6	Set temp control		

12.1.1.1 About the Humidifier button

The **Humidifier** button at the bottom left of the display provides quick access to the Humidifier window and indicates the state of the humidifier, including whether any alarms are active.

Table 12-2. 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.

12.1.2 About the humidifier operating modes

The Humidifier window offers the following modes: **Invasive** and noninvasive (**NIV**), for which you can use either automatic (**Auto**) or manual settings.

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.

12.1.2.1 Invasive and NIV modes

This mode selection determines the initial temperature settings, both at the water chamber exit (**Set temp**) and at the Y-piece (**T gradient**), as well as the allowed temperature ranges for each of these controls.

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*.

When connected to the ventilator, the humidifier *automatically* matches the mode selection 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.

Note, however, that when treating the patient using the noninvasive **HiFlowO2** therapy mode, the humidifier uses the same temperature and humidity specifications as the humidifier's **Invasive** mode.

The System > Humidifier window displays a breathing circuit diagram that reflects the selected humidifier mode, and displays the selected mode button in green.

Figure 12-2 shows the **Invasive** mode selected; Figure 12-3 shows the **NIV** mode selected.

You can change the humidifier mode at any time.

Note that 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 humidifier mode.

12.1.2.2 Auto and Manual control settings

The water 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 > Humidifier window are disabled. You must first enable **Manual** mode to change any settings.

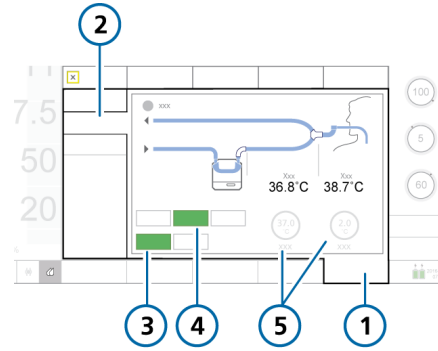
In both cases, the humidifier automatically controls the temperatures to reach the specified settings.

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 > Humidifier window are grayed out (disabled), but they display the configured **Auto** settings (Figure 12-2).

Figure 12-2. Auto mode



1	System	4	Auto
2	Humidifier	5	Grayed out (disabled) controls showing the configured Auto temperature settings
3	Invasive		

For details about these settings, see the *HAMILTON-H900 Instructions for use*.

Manual settings

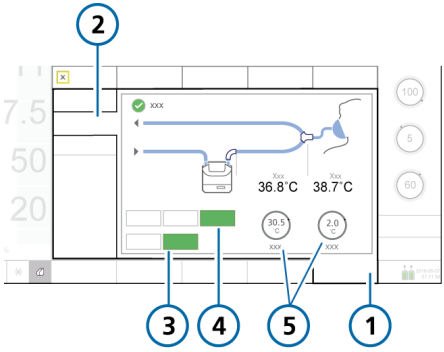
When set to **Manual**, you set the chamber exit temperature (**Set temp**) and temperature gradient values (**T gradient**) within the allowed ranges for each mode (**Invasive** or **NIV**).

The temperature controls in the ventilator System > Humidifier window are enabled (Figure 12-3).

You can change settings both in the System > Humidifier window as well as directly on the humidifier. When you change values on the humidifier, the values are also reflected on the controls in the System > Humidifier window.

Note that changing the mode between **Invasive** and **NIV** or vice versa automatically switches the control settings to **Auto** mode.

Figure 12-3. Manual mode



1	System	4	Manual
2	Humidifier	5	Available temperature controls
3	NIV		

12.1.3 Changing humidity using temperature controls

You can adjust the following controls on either device:

Table 12-3. Adjustable humidifier controls

Control	Description
Set temp	Temperature at the water chamber exit. The possible range of values for this control depends on the selected humidifier operating mode: **Invasive** or noninvasive (**NIV**). Higher values result in higher absolute humidity.
T gradient	The difference between the temperature at the water chamber exit and at the Y-piece. A higher value decreases condensation.
Exp. temperature increase	When selected, the humidifier provides additional heat in the expiratory limb to reduce condensation.

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 > 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.

To reduce condensation in the expiratory limb

- Increase the expiratory limb temperature by touching the **Exp. temperature increase** button.

  A checkmark indicates it is selected.

For details about working directly on the humidifier, see the *HAMILTON-H900 Instructions for use*.

12.1.4 Entering Standby

The humidifier automatically enters Standby mode when the ventilator enters Standby.

12.1.5 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 > Humidifier window, touch the **Off** button (Figure 12-1).

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 > Humidifier window, touch the **Manual** or **Auto** button to turn on the humidifier.
2. Check the settings and adjust, if needed.

When you start ventilation, the humidifier starts automatically.

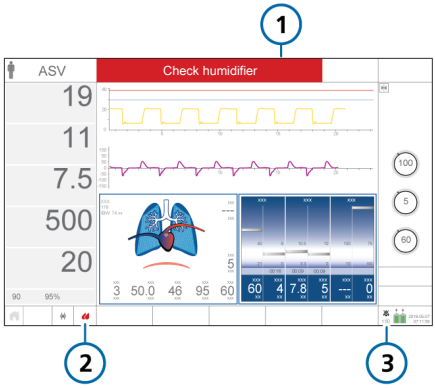
12.1.6 About humidifier-related alarms

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 12-2)

The alarms listed here may not be comprehensive. Be sure to review the *HAMILTON-H900 Instructions for use* for details and troubleshooting information.

Figure 12-4. Humidifier-related alarm indicators on ventilator (showing high-priority alarm)



1	Alarm message bar	3	Audio Pause indicator
2	Humidifier icon		

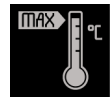
To pause the audible humidifier alarm

- Touch the **Audio Pause** key 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 12-4 lists the humidifier-related alarms shown on the ventilator and the associated graphical presentation on the humidifier.

Table 12-4. Humidifier alarms

Alarm text on ventilator	Alarm icon on HAMILTON-H900	Description
For detailed information about each alarm and actions to resolve each one, see the *HAMILTON-H900 Humidifier Instructions for Use*.		
Humidifier tilt *High priority.*		Humidifier dangerously inclined. The humidifier is at a 10° angle or higher relative to the floor.
Humidifier chamber temp high Humidifier Y-piece temp high *High priority.*		Temperature too high. The gas temperature at the water chamber exit or at the Y-piece is above the set value.
Humidifier water high *High priority.*		High water level in the water chamber. The water level in the water chamber is above the maximum level mark.
Humidifier error *High priority.*	n/a	• 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 having the humidifier 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.
Check humidifier communication *Low priority.* *On the ventilator only.* *Note that the humidifier information in the ventilator System > Info 2 window is absent, and the Humidifier quick access button is grayed out.*	The **Connection to ventilator** symbol is absent.	There is a problem with the connection between the humidifier and the ventilator. Ensure that the humidifier communication cable is securely connected to the humidifier and to the configured COM port on the ventilator. Open the alarm buffer by touching the message bar or the i-icon, if displayed, to reset the alarm.

Alarm text on ventilator	Alarm icon on HAMILTON-H900	Description
Humidifier chamber temp low Humidifier Y-piece temp low *Medium priority.*		Temperature too low. The gas temperature at the water chamber exit or at the Y-piece is below the set value.
Humidifier water low *Medium priority.*		Low water level in the water chamber. The water level in the chamber is below the low level mark. The water level in the chamber is low.
Humidifier check chamber *Medium priority.*		No chamber or invalid water chamber inserted. The chamber is either missing, incorrectly inserted, or is incompatible.
Humidifier check left tube Humidifier check right tube *Medium priority.*		No tube or defective tube connected. A circuit limb is not properly connected.

12.1.7 About humidifier-related parameters

Humidifier data is displayed in the following locations:

- Monitoring > General window
- System > Humidifier window
- As an MMP (if configured)
- As an SMP (if configured)
- System > Info 2 window

The following parameters are related to humidifier operation.

Table 12-5. HAMILTON-H900-related parameters

Parameter	Description
HAMILTON-H900	Indicates the humidifier is connected, and shows the current software version. Displayed in the System > Info 2 window.
Set temp	Control parameter. See Table 12-3.
T humidifier	Monitored parameter. Measured temperature at the water chamber exit. Displayed in Monitoring > General window and in System > Humidifier window. In Configuration, this parameter can be set as an MMP or SMP.
T gradient	Control parameter. See Table 12-3.
T y-piece	Monitored parameter. Measured temperature at the Y-piece. Displayed in System > Humidifier window. In Configuration, this parameter can be set as an MMP or SMP.
Exp. temperature increase	Control parameter. See Table 12-3.

12.2 Working with IntelliCuff

The ventilator offers integrated monitoring and control of IntelliCuff[48], both when the device is built into the ventilator and when it is used as a standalone device. For an overview of the connection methods, see Section 4.3.

This integration allows you to view key monitoring data and to control IntelliCuff operation and settings directly from the IntelliCuff window on the ventilator display.

For detailed information about IntelliCuff intended use, setup, operation, and specifications, see the *IntelliCuff Instructions for use*.

The following sections describe how to control IntelliCuff from the ventilator.

Table 12-6. IntelliCuff operations available on the ventilator

Setting	See ...
Access IntelliCuff controls on the ventilator	Section 12.2.1
Turn IntelliCuff on or off	Section 12.2.2
Select the settings control mode (**Auto/Manual**)	Section 12.2.3
Adjust the pressure	Section 12.2.4
Perform a hold maneuver	Section 12.2.5
Deflate the cuff	Section 12.2.6

12.2.1 Accessing IntelliCuff controls on the ventilator

The IntelliCuff window displays the cuff pressure setting and current value. It also provides access to the operations listed in Table 12-6.

To open the IntelliCuff window

1. Connect IntelliCuff, including the cuff tubing.

   The IntelliCuff window is available when the device is connected, regardless of whether IntelliCuff is on or off.

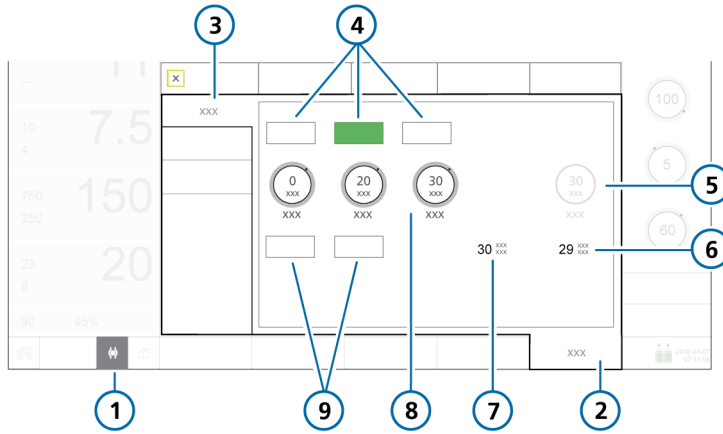
2. Do either of the following:

   – Touch the **IntelliCuff** icon (Section 12.2.1.1)

   – Touch **System > IntelliCuff**.

[48] Supported for IntelliCuff version 1.0.2.2 and later.

Figure 12-5. System > IntelliCuff window



1	IntelliCuff icon	6	Ppeak
2	System	7	Pcuff
3	IntelliCuff	8	Pressure controls: Relative (**Rel. pressure**), Minimum (**Min. pressure**), Maximum (**Max. pressure**)
4	Off, Auto, Manual	9	Deflate and Hold
5	Cuff pressure control (labeled *Hold pressure* when a hold is in progress)		

12.2.1.1 About the IntelliCuff button

The **IntelliCuff** button at the bottom left of the display provides quick access to the IntelliCuff window and indicates the state of the controller, including whether any alarms are active.

Table 12-7. IntelliCuff button icon states

Icon state	Description
	*Grayed out.* IntelliCuff is not connected.
	*Cuff is empty.* IntelliCuff is connected, turned off. If IntelliCuff is off or deflated and a high- or medium-priority alarm occurs, this icon is shown in the same color as the alarm priority (red or yellow).
	*White.* IntelliCuff is connected, operational.
	*Yellow.* IntelliCuff is connected and a low- or medium-priority IntelliCuff-related alarm is active.
	*Red.* IntelliCuff is connected and a high-priority IntelliCuff-related alarm is active.

12.2.2 Turning IntelliCuff on and off

Built-in IntelliCuff

The built-in IntelliCuff is always connected, but must be turned on or off from the IntelliCuff window on the ventilator.

By default, the device is OFF when starting the ventilator and setting up a new patient[49].

When choosing the **Last patient** setting in Standby, all IntelliCuff controls (**Cuff pressure**, **Rel. pressure**, **Min. pressure**, **Max. pressure**, and the selected mode) are set to the last-used selections. Note that if IntelliCuff is turned off and restarted, the default settings are used instead.

Before turning off the ventilator, you must deflate the cuff and turn off IntelliCuff.

Standalone IntelliCuff

You can turn the standalone IntelliCuff device on and off both from the device itself and from the ventilator.

To turn IntelliCuff ON from the ventilator

- In the System > IntelliCuff window, touch **Auto** or **Manual** (Section 12.2.3).

IntelliCuff starts with the settings as specified.

[49] *Exception.* If you set up a new patient without first turning off IntelliCuff from previous use, the ventilator generates the **Cannot turn off IntelliCuff** alarm when you touch **Adult/Ped** or **Neonatal** in the Standby window. Be sure to deflate and turn off IntelliCuff before setting up a new patient.

To turn IntelliCuff OFF from the ventilator

1. In the System > IntelliCuff window, touch **Deflate** (Section 12.2.6) or disconnect the cuff tubing.

   Attempting to turn off IntelliCuff before deflating or disconnecting the cuff generates the **Cannot turn off IntelliCuff** alarm.

2. Within 1 minute of cuff deflation, touch **Off**.

   If the cuff is deflated or disconnected, IntelliCuff turns off.

   If you do not turn off the device within 1 minute of deflation, the ventilator generates the **Cuff deflated** alarm.

   In this case, either touch **Off** or reinflate the cuff by touching **Auto** or **Manual** to continue use.

12.2.3 About IntelliCuff modes

The HAMILTON-C6 ventilator offers the ability to control the cuff pressure manually or automatically, described in the following sections.[50]

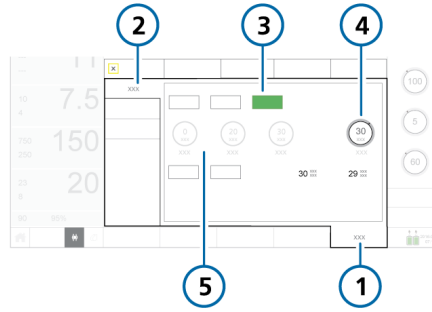
To select the mode to use

- In the System > IntelliCuff window, touch **Auto** or **Manual** (Figure 12-5).

12.2.3.1 Manual mode

In Manual mode, you set the desired cuff pressure directly (Section 12.2.4). IntelliCuff maintains this pressure at a constant rate independent of the current airway pressure.

Figure 12-6. System > IntelliCuff window, Manual mode



1	System	4	Cuff pressure control
2	IntelliCuff	5	Grayed out (disabled) controls showing the configured Auto pressure settings
3	Manual		

12.2.3.2 Auto mode

In Auto mode[51], the device adjusts cuff pressure dynamically to remain at the desired pressure within the set limits.

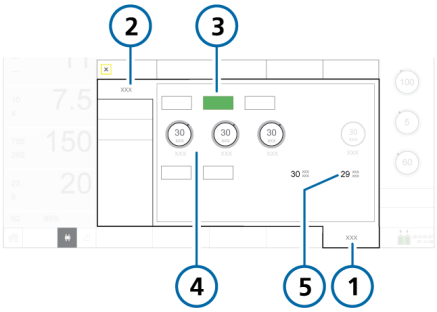
You specify the desired cuff pressure relative to the monitored peak pressure (**Ppeak**). The value you set is added to **Ppeak** to define the desired cuff pressure.

Cuff pressure = Ppeak + Rel. pressure.

You also specify the maximum and minimum pressure limits, as described next.

[50] Automatic control is available only from the ventilator IntelliCuff window; it is not available directly on the IntelliCuff device.
[51] Auto mode is not available during HiFlowO2 therapy.

Figure 12-7. System > IntelliCuff window, Auto mode



1	System	4	Available pressure controls
2	IntelliCuff	5	Ppeak
3	Auto		

12.2.4 Setting the cuff pressure

The process for setting cuff pressure differs between Manual and Auto modes.

To set the cuff pressure from the ventilator in MANUAL mode

- In the System > IntelliCuff window, touch the **Cuff pressure** control (Figure 12-6), and set it to the desired value.

IntelliCuff immediately starts adjusting the pressure to this setting, and maintains it at a constant level.

To set the cuff pressure from the ventilator in AUTO mode

1. In the System > IntelliCuff window, touch the **Rel. pressure** control and set it to the desired value.

   The set value is added to the Ppeak setting, resulting in the delivered cuff pressure.

   For example, by setting Rel. Pressure to 5 cmH2O with a Ppeak setting of 20 cmH2O, the maintained cuff pressure (Pcuff) is 25 cmH2O.

2. Touch the **Min. pressure** and **Max. pressure** controls to set the minimum and maximum pressures to apply, respectively.

IntelliCuff immediately starts adjusting the pressure to these settings.

12.2.4.1 Cuff pressure during a recruitment maneuver

NOTICE

- Recruitment maneuvers are only possible when IntelliCuff is in Auto mode.
- When performing a recruitment maneuver, cuff pressure is automatically set for the duration of the event.

During a recruitment maneuver, either using the P/V Tool or as part of INTELLiVENT-ASV auto-recruitment, cuff pressure is set as shown in Table 12-8.

Table 12-8. Cuff pressure during recruitment maneuver

Recruitment maneuver performed in...	Cuff pressure setting (set by device, non-adjustable)
P/V Tool	The highest of: • Ptop + 5 cmH2O[52] • Previous cuff pressure setting
INTELLiVENT-ASV auto-recruitment	The highest of: • Auto-recruitment pressure + 5 cmH2O[52] • Previous cuff pressure setting

12.2.5 Performing a hold

A hold temporarily increases the cuff pressure by a specified amount for a set period of time to completely seal the airway and prevent aspiration.

By default, the hold is active for 5 minutes, and applies 5 cmH2O above the currently set pressure. This setting is defined in IntelliCuff Configuration.

For details, see the *IntelliCuff Instructions for use*.

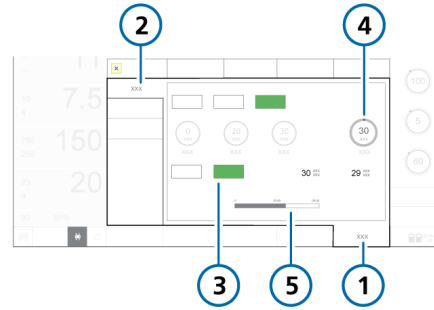
To perform a hold from the ventilator

- In the System > IntelliCuff window, touch the **Hold** button.

The pressure increases to the preset value shown in the **Hold pressure** control. The hold timer bar in the window shows the total hold time, and a progress bar counts down the time remaining.

The hold continues for the defined time even if the System > IntelliCuff window is closed. Once the hold is complete, IntelliCuff returns to the previously set mode (Auto or Manual).

Figure 12-8. IntelliCuff hold



1	System	4	Hold pressure
2	IntelliCuff	5	Hold timer progress bar
3	Hold		

To cancel an ongoing hold from the ventilator

- In the System > IntelliCuff window, touch **Auto** or **Manual** to return to normal operation.

At the end of the configured time

- The Intellicuff device beeps
- The **Hold** button on the ventilator turns gray and the hold bar is cleared
- The pressure returns to the pre-hold target pressure

Standalone IntelliCuff

If you modified the pressure setting on the IntelliCuff device during the hold maneuver, the cuff pressure is set to the new value after the hold is complete.

[52] The maximum allowed pressure is defined in IntelliCuff Configuration.

12.2.6 Deflating the cuff

Before turning off IntelliCuff or the ventilator, you must first deflate the cuff. Once it is deflated, you can turn off the device.

To deflate the cuff from the ventilator

1. In the System > IntelliCuff window, touch **Deflate** (Figure 12-5).
2. When prompted to confirm deflation, touch **Yes**.

The pressure in the cuff is released. When the cuff is fully deflated, the **Pcuff** value is 0.

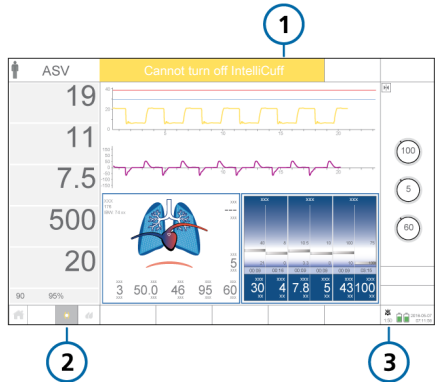
To turn off IntelliCuff, see Section 12.2.2.

12.2.7 About IntelliCuff-related alarms

Active IntelliCuff-related alarms are indicated in the following locations:

- On the IntelliCuff device (standalone)
- Alarm message on the ventilator main display
- The **IntelliCuff** icon changes color (Table 12-7)

Figure 12-9. IntelliCuff-related alarm indicators on ventilator (showing medium-priority alarm)



1	Alarm message bar	3	Audio Pause indicator
2	IntelliCuff icon		

To silence an IntelliCuff alarm

- Touch the **Audio Pause** key on either the ventilator (Figure 10-2) or the cuff controller (standalone only).

  Note that touching the **Audio Pause** key on the ventilator also temporarily silences the current alarm on IntelliCuff.

Table 12-9 lists the IntelliCuff-related alarms shown on the ventilator and the associated graphical presentation on the controller (standalone).

Table 12-9. IntelliCuff alarms

Alarm text on ventilator	Alarm icon on IntelliCuff (standalone)	Description/Actions
For detailed information about each alarm and actions to resolve each one, see the IntelliCuff Instructions for use.		
Cuff leak *High priority.*		The cuff loses pressure or is not properly connected. Actions *Built-in and standalone IntelliCuff:* • Check the cuff connections on the ventilator. • Check the cuff pressure tube, ET tubing, all cuff connections. • Change the ET tube, if needed. • Have the ventilator serviced to remove and replace IntelliCuff (built-in) or disconnect and replace IntelliCuff (standalone).
Check IntelliCuff *High, medium, and low priority.*		When the alarm is related to something other than the IntelliCuff alarms listed in this table, the ventilator displays the alarm message, **Check IntelliCuff**. Actions *Built-in IntelliCuff:* Have the ventilator serviced to remove and replace IntelliCuff. *Standalone IntelliCuff:* • Check IntelliCuff operation, alarm status, and all connections. • Check the IntelliCuff battery status and replace batteries if needed. • Disconnect and replace IntelliCuff.
Cuff deflated *Medium priority.*		The cuff has been deflated for over 1 minute. Actions *Built-in and standalone IntelliCuff:* Do either of the following, as appropriate: • Disconnect the cuff and turn off IntelliCuff. • Reinflate the cuff by selecting **Auto** or **Manual** mode in the System > IntelliCuff window.

Alarm text on ventilator	Alarm icon on IntelliCuff (standalone)	Description/Actions
Cuff pressure high *Medium priority.*		The pressure has been above the set cuff pressure for 2 or more seconds and cannot be reduced. Actions *Built-in and standalone IntelliCuff:* • Check the cuff connections on the ventilator. • Check the cuff pressure tube, ET tubing, all cuff connections. • Change the ET tube, if needed. • Have the ventilator serviced to remove and replace IntelliCuff (built-in) or disconnect and replace IntelliCuff (standalone).
Cannot turn off IntelliCuff *Medium priority.*		The cuff is still inflated while you are trying to turn off IntelliCuff. Actions *Built-in and standalone IntelliCuff:* Deflate the balloon or disconnect the cuff from the ET tube before turning off IntelliCuff.
Check IntelliCuff state *Medium priority.*	n/a	Either of the following has occurred: • The cuff is inflated and connected to IntelliCuff, but IntelliCuff is not turned on. For example, the patient is being ventilated and you have connected IntelliCuff to the breathing set and to the ventilator, but have not turned the device on. • You are attempting to turn off the ventilator while IntelliCuff is running. Actions *Built-in and standalone IntelliCuff:* • Turn IntelliCuff on by selecting **Auto** or **Manual** mode in the System > IntelliCuff window. • If you do not wish to turn on IntelliCuff, disconnect the cuff pressure tubing and manually control the cuff pressure. • If turning off the ventilator, first deflate the cuff and turn off IntelliCuff, or disconnect the cuff pressure tubing and manually control the cuff pressure.

Alarm text on ventilator	Alarm icon on IntelliCuff (standalone)	Description/Actions
Check IntelliCuff communication *Low priority.* *On the ventilator only.* *Note that the IntelliCuff information in the ventilator System > Info 2 window is absent, and the IntelliCuff quick access icon is grayed out.*	The Connection to ventilator symbol is absent.	The ventilator has not received a signal from IntelliCuff for more than 3 seconds. IntelliCuff continues to run and the cuff pressure is maintained, but the IntelliCuff window is not available. Actions *Built-in and standalone IntelliCuff:* • Disconnect and reconnect the IntelliCuff communication cable. • Manually maintain the cuff pressure as approved by your institution's protocol. • Open the alarm buffer by touching the message bar or the i-icon, if displayed, to reset the alarm. • Have the ventilator serviced to remove and replace IntelliCuff (built-in) or disconnect and replace IntelliCuff (standalone).

12.2.8 About IntelliCuff-related parameters

When IntelliCuff is operating, the following parameters are monitored; control parameters are so marked.

Table 12-10. IntelliCuff-related parameters

Parameter	Description
IntelliCuff	Shows the current software version. Displayed in the System > Info 2 window.
Cuff pressure (cmH2O)	Cuff pressure control. Can be directly set in Manual mode using the **Cuff pressure** control. During a hold maneuver, displays the Hold pressure setting.
Min. pressure (cmH2O)	Minimum cuff pressure control, used in Auto mode only.
Max. pressure (cmH2O)	Maximum cuff pressure control, used in Auto mode only.
Pcuff (cmH2O)	Monitored cuff pressure. Displayed in • IntelliCuff window • Monitoring window • Dynamic Lung panel • Main monitoring parameter (MMP), optional • Secondary monitoring parameter (SMP), optional
Ppeak (cmH2O)	Peak airway pressure control. See Table 8-6.
Rel. pressure (cmH2O)	Relative pressure control, used in Auto mode only. The pressure above **Ppeak** to achieve desired cuff pressure.

12.2.9 Last Patient settings with IntelliCuff

When using the **Last Patient** selection, the following IntelliCuff settings are in effect:

- If the device was turned on, it remains on.
- The last selected IntelliCuff mode (**Auto** or **Manual**)
- The last specified pressure settings

13 Maintenance

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13.1 Overview

You must comply with these maintenance procedures to ensure the safety and reliability of the ventilator. All the procedures in this manual are to be performed by the operator. For additional maintenance requirements, contact your Hamilton Medical service representative.

Documents referenced in this chapter are available on the MyHamilton website: https://www.hamilton-medical.com/MyHamilton

Before proceeding, review the safety information in Chapter 1.

13.2 Cleaning, disinfection, and sterilization

The following sections provide general recommendations for cleaning, disinfecting, and sterilizing parts. For parts not supplied by Hamilton Medical, comply with the manufacturers' recommendations.

Do *not* attempt decontamination procedures unless specified by Hamilton Medical or the original manufacturer.

If you have any questions about the use of a particular cleaning or disinfection agent, contact the manufacturer of the agent.

After cleaning and decontaminating parts, perform any required tests and calibrations described in Chapter 5.

13.2.1 General guidelines for cleaning

Additional information for cleaning each part is included in Table 13-1.

To clean the device parts

1. Disassemble parts.

   Note that breathing circuits must be disassembled completely and reprocessed as described in the associated *Reprocessing Guide*.
2. Wash parts in warm water and soap or an appropriate mild detergent solution.
3. Rinse parts thoroughly with clean, warm water.
4. Air dry.
5. Inspect all parts, and replace if damaged.
6. Sterilize or disinfect the parts, following the appropriate sterilization/disinfection procedure as described in the product documentation.
7. Reassemble and reinstall (if needed), and perform any required tests.

13.2.2 General guidelines for disinfection

Additional information for disinfecting each part is included in Table 13-1.

To disinfect the device parts

1. Clean, but do *not* re-assemble.
2. Disinfect with an appropriate mild bactericidal chemical solution.

   Carefully follow the manufacturer's recommendations, including exposure time.
3. Reassemble and reinstall parts, and perform any required tests before re-use.

The following table summarizes the cleaning and disinfection guidelines for each major system component.

Table 13-1. Cleaning and disinfection methods parts

Part	Remarks	Cleaning method
Ventilator exterior including: • Housing • Tray • Gas supply hose • Power cables • Trolley • Mounting systems • Basket • O2 cylinder holding system	*Do not* clean the ventilator interior. This can damage internal parts. **NOTICE!** Pay very close attention to the exposure times listed by the cleaning agent manufacturer. Failure to follow manufacturers' recommendations can lead to incomplete cleaning and disinfection. Be particularly careful with infectious patients, and follow your hospital infection control procedures.	After each patient use, wipe with a damp cloth using a registered and approved surface cleaning/disinfection solution, as approved by your institution's protocol. Follow the cleaning agent manufacturer's recommendations. *(USA only)* After each patient use, wipe with a damp cloth using an EPA-registered and approved surface cleaning/disinfection solution, as approved by your institution's protocol. Follow the cleaning agent manufacturer's recommendations.
Touch screen	• Lock the screen before cleaning. See Section 10.2. • Handle the touch screen with care. • *Do not* use any vinegar-based solutions and avoid using a gritty cloth.	Wipe the screen with a damp, soft cloth using an appropriate and approved surface cleaning/disinfection solution or a nonabrasive glass cleaner.

Part	Remarks	Cleaning method
Reusable accessories/ devices including: • Breathing circuits • Expiratory valves • Flow sensors • SpO2, CO2 sensors • Nebulizers • Masks • Filters and adapters • Water traps • IntelliCuff • Humidifier	For CO2 sensors, refer to Hamilton Medical's *Approved cleaning agents for CO2 components statement* for supported cleaning and disinfectant agents. For Aerogen nebulizers, see the *Aerogen Solo/Aerogen Pro Instructions for Use*. For IntelliCuff, see the *IntelliCuff Instructions for Use*. For the HAMILTON-H900 humidifier, see the *HAMILTON-H900 Instructions for Use*.	Follow the instructions provided in the manufacturer's *Instructions for Use* and corresponding *Reprocessing Guide*.

13.3 Preventive maintenance

Perform preventive maintenance on your ventilator according to the schedule shown in Table 13-2.

The System > Info window shows the number of hours the ventilator has been in operation.

This section describes how to:

- Replace the filters.
- Replace the galvanic O2 sensor.
- Replace the batteries.

Table 13-2. 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.
	Entire ventilator	Run the preoperational checks (Section 5.4).
Every month (or more often if required)	Fan filters (rear panel and on the bottom of the device)	Check for dust and lint. If needed, clean or replace. See Section 13.4.1.
Every 6 months	Batteries	Recharge batteries by plugging the ventilator into a primary power source for at least 4 hours.

Interval	Part/accessory	Procedure
Yearly or as necessary	Galvanic O2 sensor	Replace if depleted. See Section 13.4.4.
	Air intake HEPA filter	Replace. See Section 13.4.1.
	Ventilator	Perform service-related preventive maintenance.[53]
	CO2 sensor	If the CO2 option is installed, have a CO2 accuracy check performed.[53]
Yearly maintenance	IntelliCuff connection port[54]	Perform service-related preventive maintenance.[53]
For the HAMILTON-H900 Humidifier, see the *HAMILTON-H900 Service Manual*.		

13.3.1 Storage

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 6 months, depending on storage conditions. For details, see Section 16.4.

13.4 Performing maintenance tasks

The following sections describe how to clean and replace filters, a battery, and a galvanic O2 sensor.

13.4.1 Maintaining the air intake and fan filters

Figure 13-1 summarizes the steps to exchange the HEPA and fan filters in the back of the ventilator.

Figure 13-2 summarizes the steps to exchange the filter on the bottom of the ventilator.

[53] Must be performed by Hamilton Medical authorized service personnel according to instructions in the *Service Manual*.
[54] The IntelliCuff device itself is maintenance free or should be maintained according to your institution's protocols. The port must be serviced annually.

Figure 13-1. Replacing the back filters

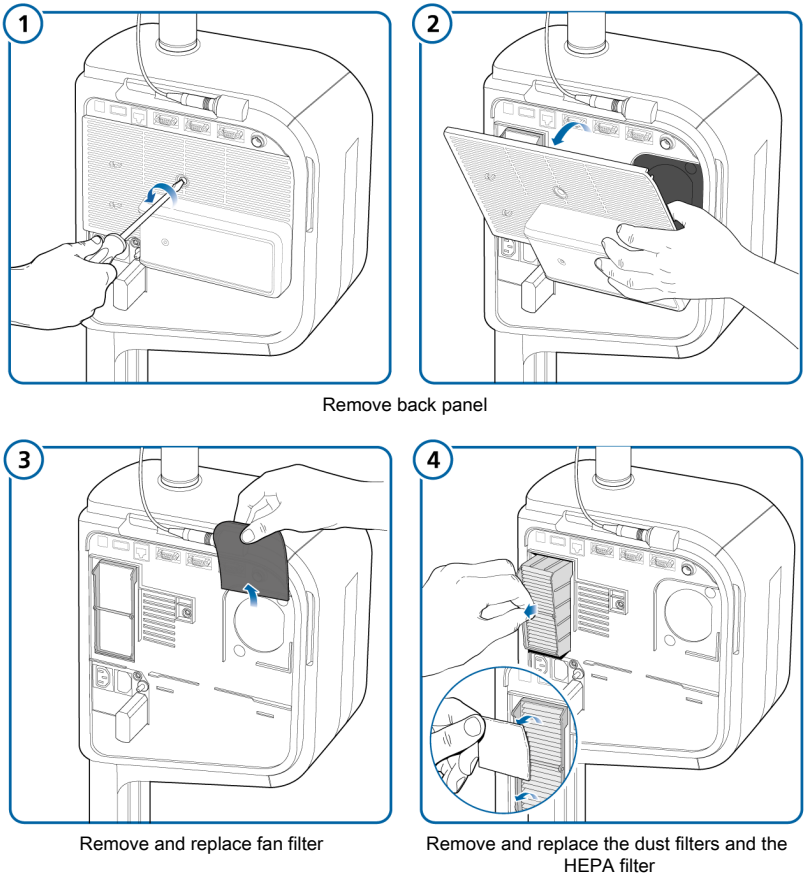
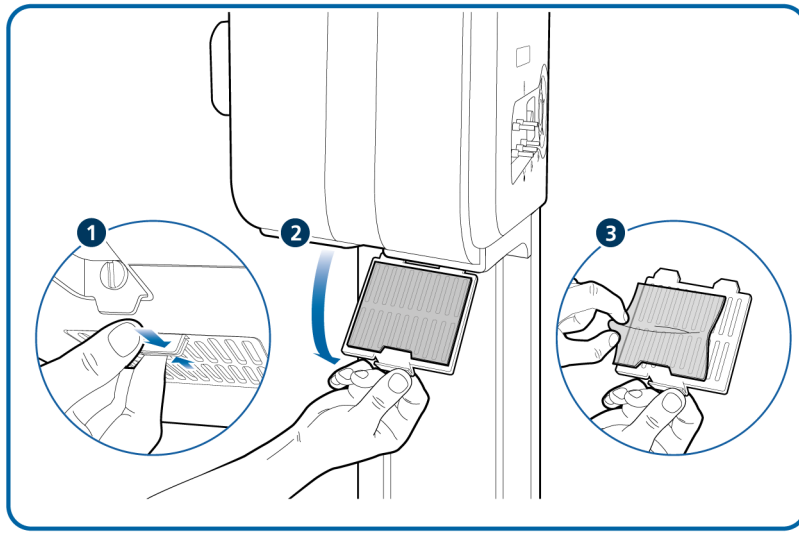


Figure 13-2. Replacing the bottom dust filter



To replace the HEPA and fan filters (back of device)

See Figure 13-1 for an overview.

1. Unscrew the back cover and pull it down (**1** and **2**).
2. Lift up and remove the fan filter (**3**).
3. Pull up the retaining clip and pull out the HEPA filter (**4**).
4. Replace with a new filter or wash the existing filter in a mild soap solution, rinse, dry, and replace.

   Be sure to pull down the retaining clip, locking the filter in place.
5. Reattach the back cover.

To replace the dust filter (bottom of device)

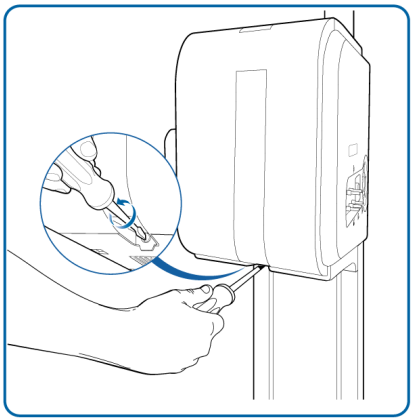
See Figure 13-2 for an overview.

1. Pinch the securing clip and pull down the cover (**1** and **2**).
2. Remove the filter (**3**).
3. Replace with a new filter or wash the existing filter in a mild soap solution, rinse, dry, and replace.
4. Close the cover, ensuring it clicks into place.

13.4.2 Removing the side cover

Removing the side cover provides access to the O2 sensor and ventilator batteries.

Figure 13-3. Removing the side cover

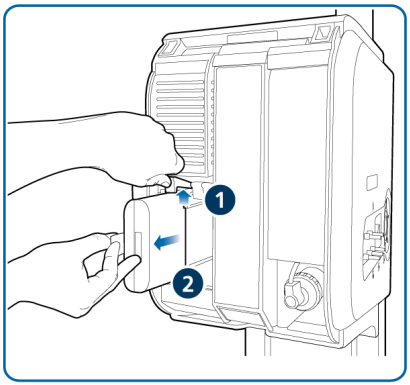


13.4.3 Replacing a battery

Figure 13-4 summarizes the steps to replace a battery.

Remove the side cover first.

Figure 13-4. Exchanging the battery



Push up retaining clip, exchange battery

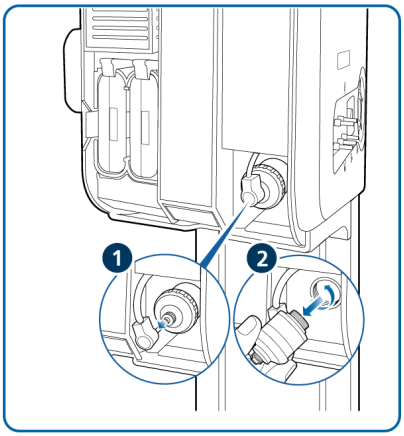
13.4.4 Replacing the galvanic O2 sensor

Before proceeding, review the safety information in Chapter 1.

Figure 13-5 summarizes the steps to replace a galvanic O2 sensor.

Remove the side cover first.

Figure 13-5. Replacing a galvanic O2 sensor



Remove connection cable (1)
Unscrew and remove sensor (2)

13.5 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.

14 Configuration

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14.1 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.

14.2 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** at the bottom of the display, and then touch the **Configuration** tab.
2. Touch the text field and, 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.

14.3 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.

14.3.1 Selecting the default language

To select the user interface language

- Open the General > Language window and select the desired language.

14.3.2 Selecting the units of measure

To select the units of measure

- Open the General > Units window and select the unit of measure for pressure, length, and CO2.

14.3.3 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.

For further setup and configuration details, see the *Communication Interface User Guide*, available on MyHamilton.

To select the communication interface

- Open the General > More window and select the desired communication protocol for the desired COM port.

  By default, the COM ports are configured as follows:

  – COM1: Hamilton P2

  – COM2: Hamilton Block

  – COM3: HAMILTON-H900 (not configurable)

14.3.4 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. Open the General > More window.
2. Touch the **Min. Loudness** button and choose the minimum alarm volume to allow on the device. By default, it is set to 1.

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 window.

14.3.5 Setting the flow sensor sensitivity for the 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. Open the General > More window.
2. Activate the **FS alarm sensitivity** control and set it to the desired value.

   Increasing the value lowers sensitivity; decreasing the value increases sensitivity.

14.3.6 Setting oxygen alarm limits manually

By default, the Oxygen high/low alarms are automatically set to the current Oxygen setting ± 5% and cannot be manually adjusted.

To enable manual adjustment of Oxygen alarm limits

1. Open the General > More window.
2. Touch the Set Oxygen alarm limits manually checkbox.

The Oxygen alarm limits are enabled in the Alarms > Limits 1 window and can be set manually.

14.4 Selecting breath timing, mode naming, and ASV version

You can set the following:

- Mandatory breath timing philosophy to use for PCV+ and APVcmv modes
- Mandatory breath timing philosophy to use for PCV+, APVcmv, (S)CMV, and SIMV modes
- Naming convention for volume-controlled, pressure-adaptive modes
- ASV version

14.4.1 Setting breath timing options

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

For two modes, PCV+ and APVcmv, you can set the ventilator to use any of the following combinations to control breath timing: I:E/Pause, TI/Pause, or Peak flow/Tip

To change the breath timing selection

- In the Modes > General > Philosophy window, touch the desired breath timing option.

14.4.2 Choosing the mode naming convention

You can select the naming convention used for adaptive modes: *APVcmv / APVsimv* or *(S)CMV+ / SIMV+*.

By default, *APVcmv/APVsimv* are used.

To select the mode naming convention

- In the Modes > General > Philosophy window, select the desired option.

14.4.3 Choosing the ASV version

By default, the device uses ASV version 1.1.

To select the ASV version

- In the Modes > General > Philosophy window, select the desired version.

14.5 Configuring MMPs and SMPs

You can specify which MMPs to always display on the ventilator, as well as which parameters to show in the Monitoring panel (Section 8.2.2) as SMPs.

The list of entries in the Configuration window is shown in the same order as the MMPs appear on the main display.

Ppeak must always be displayed as an MMP, but you can choose where to display it. By default, it is shown as the top entry.

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 display in that position on the screen.

To select the SMPs to display in the Monitoring panel

1. In Configuration, touch **Graphics**, then the **SMP** tab.
2. In each dropdown list, select the parameter to show in the Monitoring panel.

14.6 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, nebulizer selection[55], and weaning zone limits.

The settings saved with a Quick setup are automatically applied when the setup is selected in the Standby window.

[55] Only for adult/pediatric patients.

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.

14.6.1 Configuring individual setup settings

To configure a Quick setup

1. In Standby mode, 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

   – Nebulization selection (when applicable)

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. Open the Mode Ctrls > Controls window 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 high, T low, 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 intelligent 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.

14.6.2 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 setup to use as the default.

14.7 Enabling Aerogen

To use an Aerogen nebulizer with the ventilator, you must first activate the Aerogen hardware connection. For details, see Section 14.10.2.

14.8 Configuring SpO2 and INTELLiVENT-ASV

For SpO2 configuration options, see the *Pulse Oximetry Instructions for Use*.

For INTELLiVENT-ASV configuration options, see the *INTELLiVENT-ASV Operator's manual*.

14.9 Copying configuration settings to a USB memory device

Before proceeding, review the safety information in Chapter 1.

You can copy the configuration settings to a USB memory device and quickly transfer the settings to other HAMILTON-C6 devices.

If you remove the USB drive before the files are successfully transferred, you must start over and repeat the export.

To copy configuration settings to a memory device

1. Insert a USB drive into the USB port on the side of the ventilator monitor. See Figure 2-5.
2. In Configuration, touch **Transfer**.
3. In the Transfer window, touch **Import** or **Export** to transfer configuration data to or from a USB drive.

14.10 Configuring device options

Before use, you must enable any installed hardware options (for example, CO2 and SpO2), and add and enable software options.

14.10.1 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 available all required keys 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.

14.10.2 Enabling hardware options

Communication board-related functions (CO2, SpO2, Aerogen) are enabled at two levels:

- The hardware itself must be enabled 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 enable 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 enable.

   A green checkmark indicates the option is enabled.

Upon exiting Configuration, the enabled hardware is available for use. When Aerogen is enabled, the **Aerogen** button is available in the System > Nebulizer window.

14.10.3 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 also treated as options. Clearing options removes them and the associated ventilation modes. You must re-add them before using the ventilator on a patient.

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.

14.10.3.1 Disabling hardware options

To disable hardware options

- In the HW options window, clear the check boxes for the hardware to disable.

15
Parts and accessories

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15.1 Overview

This chapter lists the parts available for the HAMILTON-C6 ventilator. Note that not all parts are available in all markets.

For additional parts and accessories and ordering information, refer to the e-catalog on the Hamilton Medical website or contact your Hamilton Medical representative.

Figure 15-1. Ventilator parts and accessories

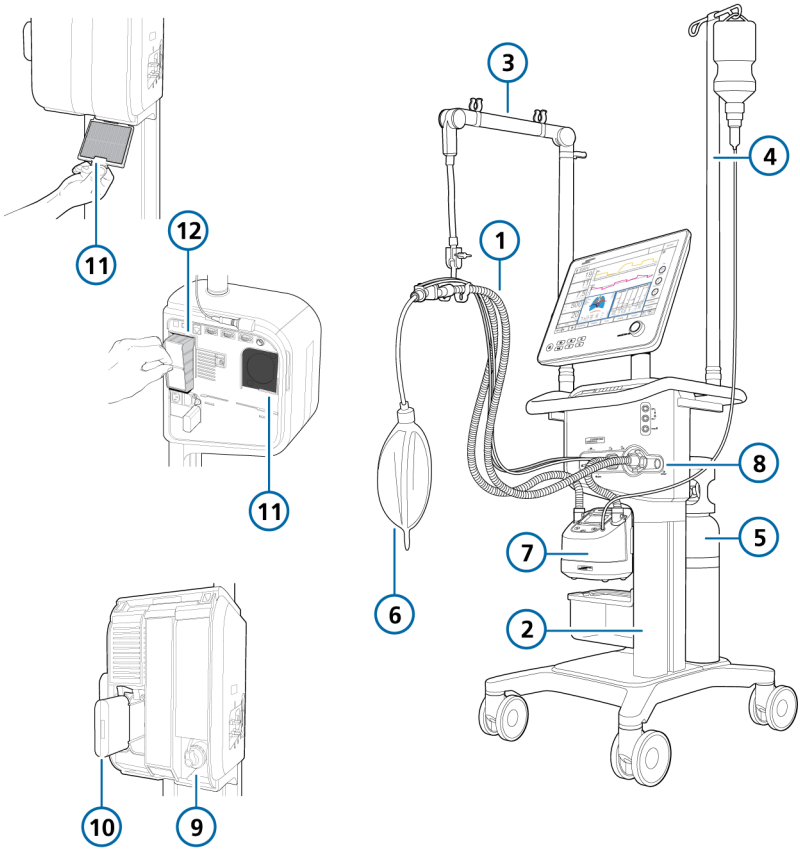


Table 15-1. Ventilator parts and accessories

Item no. (ref to Fig 15-1)	Description	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 BC8022-A, dual limb, autoclavable, preassembled, box of 1	260188
	Breathing circuit set BC4022, single limb, single use, preassembled, box of 15	260186
	HAMILTON-H900 breathing circuit set, neonatal	
	Breathing circuit set BC-8010, dual limb, single use, preassembled, box of 15	260185
	Breathing circuit set BC-8010-A, dual limb, autoclavable, preassembled, box of 1	260189
	Breathing circuit set BC-4010, single limb, single use, preassembled, box of 15	260187
1	**Breathing circuit set, coaxial, single use, adult/pediatric**	
	Preassembled, length 1.80 m, box of 20	260206
	Preassembled with flow sensor, length 1.80 m, box of 20	260207
	Preassembled, length 2.40 m, box of 10	260239
	Preassembled, with flow sensor, length 2.40 m, box of 10	260240
	Preassembled, with expiratory valve set and flow sensor, length 1.80 m, box of 20	260257
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 1.50 m, box of 20	260180
	With Y-piece, length 1.50 m, box of 20	260241
1	**Breathing circuit sets, autoclavable** *See the online Hamilton Medical e-catalog.*	
1	**Flow sensors, adult/pediatric**	
	Flow sensor, single use, adult/pediatric, 1.88 m, box of 10	281637
	Flow sensor, single use, adult/pediatric, 1.88 m, box of 240	282092

Item no. (ref to Fig 15-1)	Description	PN
1	Flow sensor, single use, adult/pediatric, 2.60 m, box of 10	282049
	Flow sensor, autoclavable, adult/pediatric, 1.88 m, box of 1	950185
	Flow sensor calibration adapter, autoclavable, adult/pediatric, box of 10	282323
1	**Flow sensors, neonatal**	
	Flow sensor, single use, neonatal, 1.60 m, box of 10	260177
	Flow sensor, single use, neonatal, 1.88 m, box of 10	155500
	Flow sensor calibration adapter, single use, neonatal, box of 10	279964
8	**Expiratory valve**	
	Expiratory valve set, autoclavable, box of 1	160245
	Membrane, expiratory valve, autoclavable, box of 5	160500
	Expiratory valve set, single use, box of 10	160176
not shown	**Nasal cannula for high flow oxygen therapy (adult and adult/pediatric)**	
	Size L, box of 10	282497
	Size M, box of 10	282496
	Size S, box of 10	282495
not shown	**NHF nasal prong for high flow oxygen therapy (adult and adult/pediatric)**	
	Size 1, box of 10	282521
	Size 2, box of 10	282522
	Size 3, box of 10	282523
	Size 4, box of 10	282524
not shown	**Nasal cannula adapter**	
	Adapter, ID22/ID22, box of 30	282509
	Adapter, OD10/OD15, box of 30	282519
not shown	**Masks and accessories, adult/pediatric** *See the Hamilton Medical e-catalog.*	
	NIV full face mask, single use, non-vented, size S	282507
	NIV full face mask, single use, non-vented, size M	282506
	NIV full face mask, single use, non-vented, size L	282505

Item no. (ref to Fig 15-1)	Description	PN
not shown	**Masks and accessories, neonatal**	
	nCPAP-PS Starter kit, large (10 sets, incl. mask, prongs, and bonnets)	281975
	nCPAP-PS Starter kit, small (1 set, incl. mask, prongs, and bonnets)	282330
	Neonatal circuit adapter	160595
not shown	**CO2 mainstream measurement**	
	HAMILTON CAPNOSTAT-5 CO2 sensor	281718
	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 *See the Hamilton Medical e-catalog.*	
	HAMILTON-H900 Integration kit for HAMILTON-C6	160783
not shown	**IntelliCuff**	
	IntelliCuff cuff pressure controller *See the Hamilton Medical e-catalog.*	

Item no. (ref to Fig 15-1)	Description	PN
not shown	IntelliCuff Integration kit for HAMILTON-C6	160784
2	**Trolley**	
	Humidifier trolley support	160969
	Basket	160177
	Basket for suctioning catheter	160178
3	Tubing support arm, for use with quick lock	160153
	Water bottle holder with quick lock (max. 1 kg per side)	160162
5	Oxygen cylinder holder (two bottles)	160971
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, 0.5 liter, with OD15/OD22 connector (pediatric)	151816
	Demonstration lung, neonatal, 15 mm *A passive lung simulator with two independent compartments for simulating neonatal patients.*	R53353
12	**Filter**	
	Filter set *Includes 5 sets. Each set includes 2 air intake dust filters and a fan filter for each fan.*	160735
11	Filter, air intake (HEPA)	160216
not shown	**Patient filter**	
	HMEF, single use, adult/pediatric	279963
	HME filter (HMEF), single use, adult/pediatric	279974
	Expiratory bacteria filter	279204
	Inspiratory bacteria filter	279211

Item no. (ref to Fig 15-1)	Description	PN
not shown	**Power cord**	
	Power cord with US plug, 2.5 m	355190
	Power cord with British angled plug, 2.5 m	355191
	Power cord with continental European plug, 2.5 m	355192
	Power cord with Swiss plug, 2.5 m	355181
9	**Oxygen sensor**	
	Galvanic O2 sensor	396200
	Paramagnetic O2 sensor kit	160169
not shown	**Communication**	
	Extended communication board CO2, SpO2, Aerogen	160184
	Extended communication board CO2, SpO2	160185
	Cable, Nurse Call	160166
10	**Battery**	
	Li-Ion battery	369130
not shown	**High-pressure oxygen connector**	
	DISS – diameter index safety standard	160470
	NIST – no interchangeable screw thread	160471
not shown	**Equipotential grounding cable**	
	Equipotential cable, POAG EU	160374
	Equipotential cable, USA	160577
not shown	**SpO2 sensors and accessories (Masimo and Nihon Kohden)** *See the Hamilton Medical e-catalog.*	
not shown	**Aerogen nebulizer, pneumatic nebulizer, and accessories** *See the Hamilton Medical e-catalog.*	
not shown	**Tools and test equipment** *See the Hamilton Medical e-catalog.*	

Item no. (ref to Fig 15-1)	Description	PN
	Language kit	
	English	160773
	German	160774
	Spanish	160775
	French	160776
	Italian	160080
	Russian	160777
	Chinese	160778
	Portuguese	160779
	Ventilator and hardware configuration options	
	Ventilation unit and monitor (interaction panel)	160021
	Trolley solution	160029
	Shelf mount solution	160030
	Pole mount solution	160031
	Rail mount solution	160032
	Monitor cable, 0.65 m	952300
	Monitor cable, 3 m, including cable wrap	160785
	Monitor cable, 10 m, including cable wrap	160786
	Extended warranty	
	Extended warranty of 1 year	700703
	Extended warranty of 2 years	700704
	Extended warranty of 3 years	700705

16 Specifications

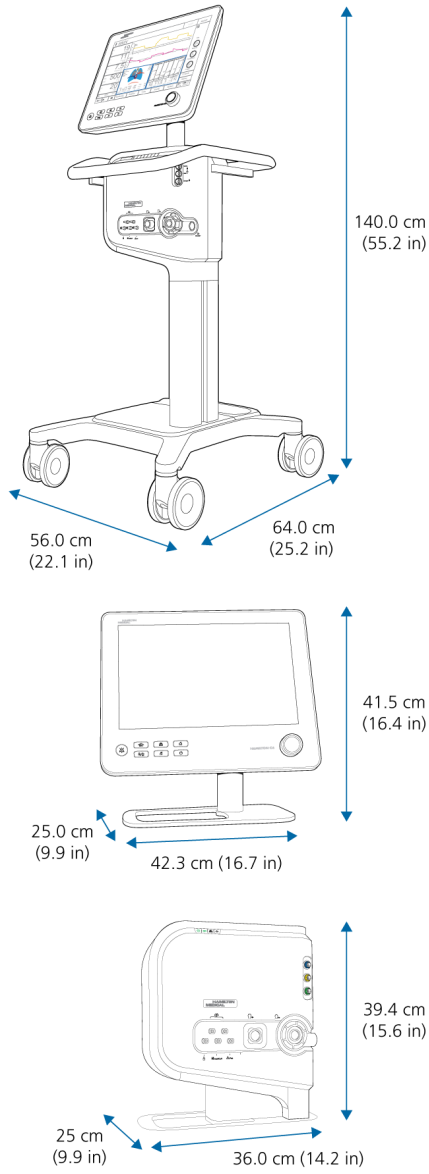
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16.1 Physical characteristics

Table 16-1. Physical characteristics

Dimension	Specifications
Weight	Monitor without shelf mount: 7.8 kg Monitor (interaction panel) with shelf mount: 10.0 kg (22.0 lb) Ventilation unit with shelf mount: 10.5 kg (23.15 lb) 46 kg (101 lb) with trolley, monitor, and ventilation unit The trolley can accommodate a maximum safe working load of 80 kg (176 lb).[56]
Dimensions	See Figure 16-1.

Figure 16-1. HAMILTON-C6 dimensions



[56] The maximum safe working load applies to a stationary properly load-balanced trolley.

16.2 Environmental requirements

Table 16-2. Environmental requirements

Environment		Specifications
Temperature	Operation:	5°C to 40°C (41°F to 104°F)
	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 9-2.
Atmospheric pressure	Operation and storage:	620 to 1100 hPa
Relative humidity	Operation and storage:	10% to 95%, noncondensing
Water protection		IP21

16.3 Pneumatic specifications

Table 16-3. Pneumatic specifications

Component	Specifications	
High-pressure oxygen inlet	Pressure:	2.8 to 6 bar / 41 to 87 psi
	Flow:	Maximum of 150 l/min
	Connector:	DISS (CGA 1240) or NIST
Air supply	Integrated blower	
Gas mixing system	Delivered flow:	• > 260 l/min ±10% against ambient pressure (at sea level) • > 150 l/min with 100% O2
	Delivered pressure:	0 to 100 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
IntelliCuff port	Dedicated connection port for IntelliCuff. For details, see the *IntelliCuff Instructions for use*.	

16.4 Electrical specifications

Table 16-4. Electrical specifications

Element	Specifications	
Input power	100 to 240 VAC ±10%, 50/60 Hz	
Power consumption	60 VA typical, 485 VA maximum	
HAMILTON-H900 power connection	The power socket on the HAMILTON-C6 ventilator body is for the HAMILTON-H900 humidifier only.	
Battery	Hamilton Medical provides a high-capacity battery. An optional second battery is available.	
	Electrical specifications:	14.4 V, 6.8 Ah, 98 Wh, 35 W typical, 115 W maximum
	Type:	Lithium-ion, supplied by Hamilton Medical only
	Normal operating time:	≥ 1.5 hours with one battery Operating time is measured with one fully charged battery, the blower in use, without communication board, and with the following settings: Mode = PCV +, Rate = 10 b/min, Pcontrol = 10 cmH2O, I:E = 1:4, PEEP = 5 cmH2O, Flow trigger = 5 l/min, Oxygen = 40%, backlight = 10%. This operating time applies to new, fully charged Li-ion batteries that have not been exposed to extreme temperatures. The actual operating time depends on battery age and on how the battery is used and re-charged. To ensure maximum battery life, maintain a full charge and minimize the number of complete dis-charges.
	Recharge time:	Allow a minimum of 2.5 hours to fully charge one battery, or 5 hours to fully charge two batteries. At temperatures over 43°C, the charge time is doubled (a minimum of 5 hours to charge one bat-tery, 10 hours to charge two).
	Storage:	-20°C to 50°C, ≤ 95% 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.

16.5 Control settings

Table 16-5 provides the control parameter ranges, default settings, and accuracy of measurements.

For details about HAMILTON-H900 humidifier control settings, see the *HAMILTON-H900 Instructions for use*.

For details about IntelliCuff control settings, see the *IntelliCuff Instructions for use*.

Table 16-5. Control settings, ranges and accuracy

Parameter or setting (unit)	Range: Adult/Ped	Range: Neonatal	Default: Adult/Ped	Default: Neonatal	Accuracy[57]
Apnea backup	On, Off	On, Off	On	On	
ETS[58, 59] (%)	5 to 80	5 to 80	25 *In noninvasive modes:* 35	25 *In noninvasive modes:* 35	
Flow[60] (l/min)	2 to 80	2 to 12	15	2	±10% or 1 l/min whichever, is greater
Flow pattern[61]	Square, 50% decelerating, Sine, 100% decelerating	--	50% decelerating	--	
Flow trigger[62] (l/min)	*APVcmv, (S)CMV, PCV+*: 0.5 to 20/Off *Other modes*: 0.5 to 20	*APVcmv, PCV+, (S)CMV*: 0.1 to 5.0/Off *Other modes*: 0.1 to 5.0	5	0.5	±10%
I:E[63]	1:9 to 4:1	1:9 to 4:1	1:4	1:3	--

[57] The stated accuracy includes the tolerance interval for each measurement.
[58] Expiratory trigger sensitivity, in % of inspiratory peak flow.
[59] When selecting a noninvasive mode, the device uses the ETS value used in the previous mode, if available. If the previous mode did not use ETS, the device sets ETS to default values.
[60] Only for HiFlowO2 therapy.
[61] Parameter depends on selected ventilation timing philosophy, set in Configuration.
[62] Flow trigger is leak compensated.
[63] In PCV+, (S)CMV, SIMV, and APVcmv 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.

Parameter or setting (unit)	Range: Adult/Ped	Range: Neonatal	Default: Adult/Ped	Default: Neonatal	Accuracy[57]
%MinVol[64] (%)	25 to 350	--	100	--	
Mode	APVcmv APVsimv PCV+ (S)CMV ASV SIMV PSIMV+ APRV SPONT NIV INTELLiVENT-ASV NIV-ST DuoPAP HiFlowO2	APVcmv APVsimv PCV+ PSIMV+ SPONT nCPAP-PS NIV NIV-ST DuoPAP APRV HiFlowO2	ASV	PSIMV+	
Oxygen (%)	21 to 100	21 to 100	50 *HiFlowO2*: 40	40	± (volume fraction of 2.5% + 2.5% gas level)
Pause[65] (%)	0 to 70	--	0	--	
Pasvlimit[64] (cmH2O)	5 to 100	5 to 100	30	30	±5% or ±1 cmH2O, whichever is greater
Pat. height (cm) (in)	30 to 250 12 to 98	n/a	174 69	n/a	
Pcontrol[66] (cmH2O)	5 to 100	3 to 60	15	15	±5% or ±1 cmH2O, whichever is greater

[64] Only in ASV mode.
[65] Limited to 25% of TI.
[66] Control pressure, added to PEEP/CPAP.

Parameter or setting (unit)	Range: Adult/Ped	Range: Neonatal	Default: Adult/Ped	Default: Neonatal	Accuracy[57]
Peak flow[67] (l/min)	1 to 195	--	60	--	
PEEP/CPAP (cmH2O)	0 to 50	0 to 25	5	5	±5% or ±1 cmH2O, whichever is greater
Pinsp[68] (cmH2O)	3 to 100	*nCPAP-PS*: 0 to 60 *Other modes*: 3 to 60	15	15	±5% or ±1 cmH2O, whichever is greater
P high (cmH2O) *in DuoPAP*	0 to 100 *absolute pressure*	0 to 60 *absolute pressure*	20	20	±5% or ±1 cmH2O, whichever is greater
P high (cmH2O) *in APRV*	0 to 100 *absolute pressure*	0 to 60 *absolute pressure*	20 startup setting = PEEP + 15	20 startup setting = PEEP + 15	±5% or ±1 cmH2O, whichever is greater
P low (cmH2O) *in APRV*	0 to 50	0 to 25	5	5	±5% or ±1 cmH2O, whichever is greater
P-ramp[69] (ms)	0 to 2000 *ASV, NIV, NIV-ST, SPONT, SIMV*: max = 200	0 to 600 *NIV, NIV-ST, SPONT, nCPAP-PS*: max = 200	70	50	±10 ms
Pressure trigger (cmH2O)	*APVcmv, (S)CMV, PCV+*: -0.1 to -15.0/ Off *Other modes*: -0.1 to -15.0	*APVcmv, (S)CMV, PCV+*: -0.1 to -15.0/ Off *Other modes*: -0.1 to -15.0	-2.0	-1.0	±10%

[67] Limitation changes based on flow pattern and Vt.
[68] Inspiratory pressure, added to PEEP/CPAP.
[69] 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-PS: max 200 ms.

Parameter or setting (unit)	Range: Adult/Ped	Range: Neonatal	Default: Adult/Ped	Default: Neonatal	Accuracy[57]
Psupport[70] (cmH2O)	0 to 100	0 to 60	15	15	±5% or ±1 cmH2O, whichever is greater
Rate[71] (b/min)	*APVcmv, (S)CMV, PCV+*: 4 to 80 *PSIMV+, NIV-ST*: 5 to 80 *Other modes*: 1 to 80	*APVcmv, PCV+, PSIMV+ PSync, NIV-ST, PSIMV, Apnea Backup*: 15 to 150 *PSIMV+, nCPAP-PS*: 5 to 150 *Other modes*: 1 to 150	*3.0 to 5.9 IBW*: 38 *6 to 8.0 IBW*: 32 *8.1 to 20.0 IBW*: 25 *20.1 to 29.9 IBW*: 19 *30 to 39 IBW*: 17 *40 to 59 IBW*: 15 *60 to 139 IBW*: 12	*0.2 to 1.25 kg*: 60 *1.26 to 3.0 kg*: 45 *3.1 to 5.9 kg*: 35 *6.0 to 8.9 kg*: 30 *9.0 to 20.5 kg*: 25 *21 to 30 kg*: 20	Adult: ±1 Neo: ±1 (< 100) ±3 (≥ 100)
Sex	Male, Female	n/a	Male	--	
Sigh[72]	On, Off	--	Off	--	--
T high[71] (s) *in DuoPAP*	0.1 to 40	0.1 to 40	Based on rate (**IBW**)	Based on rate (**Weight**)	±0.01
T high[71] (s) *in APRV*	0.1 to 40	0.1 to 40	Based on rate (**IBW**)	Based on rate (**Weight**)	±0.01
TI[63, 71,73] (s)	0.1 to 12	0.1 to 12	Based on rate (**IBW**)	Based on rate (**Weight**)	±0.01
TI max[74] (s)	0.5 to 3	0.25 to 3.0	1.5	1.0 (≤ 10 kg) 1.5 (> 10 kg)	± 0.1
T low (s) *in APRV*	0.2 to 40	0.2 to 40	Based on rate (**IBW**)	Based on rate (**Weight**)	± 0.01

[70] Pressure support, added to PEEP/CPAP.
[71] Startup setting derived from IBW (adult/pediatric), body weight setting (neonatal). Does not apply in ASV mode.
[72] Sigh is disabled in DuoPAP, APRV, HiFlowO2, and for neonates.
[73] Inspiratory time; used with Rate to set the breath cycle time.
[74] Maximum inspiratory time for spontaneous breaths during noninvasive ventilation.

Parameter or setting (unit)	Range: Adult/Ped	Range: Neonatal	Default: Adult/Ped	Default: Neonatal	Accuracy[57]
Tip[75] (s)	0 to 8	--	0	--	--
TRC compensation[76] (%)	0 to 100	0 to 100	80	80	--
TRC expiration	On, Off	On, Off	On	On	--
TRC Tube type	ET tube, Trach tube, Disable TRC	ET tube, Trach tube, Disable TRC	Disable TRC	Disable TRC	--
TRC ID (tube size) (mm)	3 to 10	2.5 to 5.0	7	3.5	--
Vt[71] (ml)	20 to 2000	2 to 300	Based on **IBW**	Based on **Weight**	Adult: ±10% or ±10 ml, whichever is greater Neo: ±10% or ±2 ml, whichever is greater
Vt/kg[77] (ml/kg)	5 to 12	5 to 12	8	5	--
Weight[77] (kg)	--	0.2 to 30.0	--	2.0	
P/V Tool related					
Pstart (cmH2O)	0 to 20	0 to 20	startup setting = PEEP	startup setting = PEEP	--
Ptop (cmH2O)	25 to 60	25 to 60	35	35	--
End PEEP (cmH2O)	0 to 35	0 to 35	startup setting = PEEP	startup setting = PEEP	--
Ramp speed (cmH2O/s)	2 to 5	2 to 5	3	3	--
Tpause (s)	0 to 30	0 to 30	0	0	--

[75] Applicable only when the *Peak flow - Tip* breath timing option is selected.
[76] Set to 0% to have Ptrachea displayed without compensation.
[77] 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.

16.6 Monitored parameters

Table 16-6 provides the monitored parameter ranges, default settings, and accuracy of measurements.

Table 16-7 lists 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).

Table 16-6. Monitored parameters, ranges, and accuracy

Parameter (units)	Range: Adult/Ped	Range: Neonatal	Accuracy[78]
Pressure			
AutoPEEP (cmH2O)	0 to 80	0 to 80	± (2 cmH2O + 4% of actual reading)
Driving pressure, ΔP (cmH2O)	0 to 100	0 to 100	± (2 cmH2O + 4% of actual reading)
PEEP/CPAP (cmH2O)	0 to 100	0 to 100	± (2 cmH2O + 4% of actual reading)
Pinsp[79] (cmH2O)	0 to 50	0 to 50	± (2 cmH2O + 4% of actual reading)
Pmean (cmH2O)	0 to 120	0 to 120	± (2 cmH2O + 4% of actual reading)
Ppeak (cmH2O)	0 to 120	0 to 120	± (2 cmH2O + 4% of actual reading)
Pplateau (cmH2O)	0 to 120	0 to 120	± (2 cmH2O + 4% of actual reading)
Pes max[80] (cmH2O)	0 to 120	0 to 120	± (2 cmH2O + 4% of actual reading)
Pes plateau[80] (cmH2O)	0 to 120	0 to 120	± (2 cmH2O + 4% of actual reading)
Pes min[80] (cmH2O)	-120 to 120	-120 to 120	± (2 cmH2O + 4% of actual reading)
Ptrans I[80] (cmH2O)	-120 to 120	-120 to 120	± (2 cmH2O + 4% of actual reading)

[78] The stated accuracy includes the tolerance interval for each measurement, except for measurements displayed from external sensors (CO2). See Section 16.11.1 for details.
[79] Inspiratory pressure displayed in the Vent Status panel.
[80] If Pes option is activated.

Parameter (units)	Range: Adult/Ped	Range: Neonatal	Accuracy[78]
Ptrans E[80] (cmH2O)	-120 to 120	-120 to 120	± (2 cmH2O + 4% of actual reading)
Flow			
Insp flow, peak (l/min)	0 to 260	0 to 260	*Adult/Ped*: ±10% or ±20 ml/s, whichever is greater *Neo*: ±10% or ±2 ml/s, whichever is greater
Exp flow, peak[81] (l/min)	0 to 260	0 to 260	*Adult/Ped*: ±10% or ±20 ml/s, whichever is greater *Neo*: ±10% or ±2 ml/s, whichever is greater
Control Flow (l/min)	2 to 80	2 to 12	--
Volume			
ExpMinVol[82] MinVol NIV[83] (l/min)	0 to 99.9	0 to 99.9	±10% or ±0.3 l/min, whichever is greater
MVSpont[82] MVSpont NIV[83] (l/min)	0 to 99.9	0 to 99.9	±10% or ±0.3 l/min, whichever is greater
VTE[82] VTE NIV[83] (ml)	0 to 9000	0 to 9000	*Adult/Ped*: ±10% or ±10 ml, whichever is greater *Neo*: ±10% or ±2 ml, whichever is greater
VTESpont (ml)	0 to 9000	0 to 9000	±10% or ±10 ml, whichever is greater

[81] Not available in HiFlowO2 or if speakvalve is active.
[82] Only for invasive modes.
[83] NIV is used with noninvasive modes.

Parameter (units)	Range: Adult/Ped	Range: Neonatal	Accuracy[78]
VTI (ml)	0 to 9000	0 to 9000	*Adult/Ped*: ±10% or ±10 ml, whichever is greater *Neo*: ±10% or ±2 ml, whichever is greater
Vt/IBW (ml/kg)	2 to 20	--	--
Vt/Weight (ml/kg)	--	2 to 20	--
VLeak (%) MVLeak (l/min)	0 to 100 0 to 99.9	0 to 100 0 to 99.9	±10% (for leak volumes between 100 and 2000 ml) ±10% or ±0.3 l/min, whichever is greater
Time			
I:E	9.9:1 to 1:99	9.9:1 to 1:99	--
fControl (b/min)	0 to 999	0 to 999	±1 b/min
fSpont (b/min)	0 to 999	0 to 999	±1 b/min
fTotal (b/min)	0 to 999	0 to 999	±1 b/min
TI (s)	0 to 60	0 to 60	±100 ms
TE (s)	0 to 60	0 to 60	±100 ms
Pause (s)	0 to 60	0 to 60	--
Ventilation counter (days/hours/minutes)	0 to 999	0 to 999	--

Parameter (units)	Range: Adult/Ped	Range: Neonatal	Accuracy[78]
Other calculated and displayed parameters			
Cstat (ml/cmH2O)	0 to 300	0 to 300	--
IBW[84] (kg)	3 to 139 *default*: 70	--	--
P0.1 (cmH2O)	-99 to 0	-99 to 0	--
PTP (cmH2O * s)	0 to 99	0 to 99	--
Pes P0.1 (cmH2O)	-99 to 0	-99 to 0	--
Pes PTP (cmH2O*s)	0 to 99	0 to 99	--
RCexp[85] (s)	0.0 to 99.9	0.0 to 99.9	--
Rinsp (cmH2O/l/s)	0 to 999	0 to 999	--
Trigger	No or Yes	No or Yes	
RSB (1/l*min)	0 to 400	0 to 400	--
Weight (kg)	--	0.2 to 30	
Oxygen			
Oxygen (%)	18 to 105	18 to 105	± (volume fraction of 2.5% + 2.5% of gas level)
CO2[86]			
FetCO2 (%)	0 to 20	0 to 20	CO2 (BTPS): 0 to 40 mmHg: ±2 mmHg 41 to 70 mmHg: ±5% of reading 71 to 100 mmHg: ±8% of reading 101 to 150 mmHg: ±10% of reading For sidestream CO2 sensor above 80 b/min: ±12% of reading
PetCO2 (mmHg)	0 to 150	0 to 150	

[84] IBW is calculated using height and sex, and is used for adult and pediatric patients. Actual body weight is used for neonates.
[85] Least square fit method.
[86] Only available if the CO2 communication board is installed and the CO2 sensor is enabled.

Parameter (units)	Range: Adult/Ped	Range: Neonatal	Accuracy[78]
slopeCO2[87] (%CO2/l)	0 to 99.9	0 to 99.9	--
Vtalv[87] (ml)	0 to 9999	0 to 9999	--
V'alv[87] (l/min)	0 to 20	0 to 20	--
V'CO2[87] (ml/min)	50 to 9999	50 to 9999	--
VDaw[87] (ml)	0 to 999	0 to 999	--
VDaw/VTE[87] (%)	0 to 100	0 to 100	--
VeCO2[87] (ml)	0 to 999	0 to 999	--
ViCO2[87] (ml)	0 to 999	0 to 999	--
P/V Tool related			
Pressure at cursors (cmH2O)	0 to 99	0 to 99	--
Volume at cursors (ml)	0 to 9999	0 to 9999	--
Volume difference at cursors (ml)	0 to 9999	0 to 9999	--
Flow at cursors (l/min)	-300 to 300	-300 to 300	--
Compliance at cursors (ml/cmH2O)	0 to 999	0 to 999	--
Ptop (cmH2O)	0 to 99	0 to 99	--
Tmaneuver (s)	0 to 99	0 to 99	--
Lower inflection point (cmH2O)	0 to 99	0 to 99	--
Upper inflection point (cmH2O)	0 to 99	0 to 99	--
Point of derecruitment (cmH2O)	0 to 99	0 to 99	--
Vpeep (ml)	0 to 9999	0 to 9999	--

[87] Only for mainstream CO2.

Parameter (units)	Range: Adult/Ped	Range: Neonatal	Accuracy[78]
Humidifier related			
T humidifier[88] (°C)	0 to 99.9	0 to 99.9	--
T y-piece[88] (°C)	0 to 99.9	0 to 99.9	--
IntelliCuff related			
Pcuff[89] (cmH2O)	-100 to 150	-100 to 150	--

Table 16-7. Real-time waveforms and loops

Parameter	X-axis scale	Y-axis scale
Real-time waveforms *All waveforms show time on the x-axis.* *Full-screen waveforms: 11, 22, 33, 66; Half-screen waveforms: 5.5, 11, 22, 33*		
Volume[90] (V) (ml) / time (s)	-9000 to 9000	0 to 5, 0 to 10, 0 to 25, 0 to 50 (*Neonatal default*), 0 to 100, 0 to 200, 0 to 400, 0 to 800 (*Adult/Ped default*), 0 to 1600, 0 to 3200
Flow[90] (l/min) / time (s)	-400 to 400	±2.5, ±5, ±10 (*Neonatal default*), ±15, ±25, ±45, ±75 (*Adult/Ped default*), ±150, ±300
Pressure (cmH2O) / time (s)	-10 to 120	-5/20, -5/40 (*default*), -5/80, -5/120
FetCO2[91] (%) / time (s)	0 to 20	0 to 6 (*default*), 0 to 10
PetCO2[91] (mmHg) / time (s)	0 to 150	0 to 60 (*default*), 0 to 100
Ptrachea[92] (cmH2O) / time (s)	-120 to 120	-5/20, -5/40, -5/80, -5/120

[88] Activated upon connection of a HAMILTON-H900 humidifier.
[89] Activated upon connection of an IntelliCuff cuff pressure controller.
[90] Scaled automatically. Not leak compensated.
[91] Available with CO2 option.
[92] Scaled automatically. Shown together with the pressure/time waveform in the same window (different color waveform). Only active when TRC is enabled.

Parameter	X-axis scale	Y-axis scale
Real-time Pes (cmH2O)	-30 to 120	-5/20, -5/40 (*default*), -5/80, -5/120 -20/20, -20/40 (*default*), -20/80, -20/120 -40/20, -40/40 (*default*), -40/80, -40/120
Real-time Ptranspulm (cmH2O)	-120 to 120	-5/20, -5/40 (*default*), -5/80, -5/120 -20/20, -20/40 (*default*), -20/80, -20/120 -40/20, -40/40 (*default*), -40/80, -40/120 -80/20, -80/40 (*default*), -80/80, -80/120 -120/20, -120/40 (*default*), -120/80, -120/120
ASV graphs		
ASV target graphics: Vt/Rate x-axis: ml y-axis: b/min	0 to 5, 0 to 10, 0 to 25, 0 to 50, 0 to 100, 0 to 200, 0 to 400, 0 to 800 (*default*), 0 to 1600, 0 to 3200	0 to 60
Loops[90]		
Pressure/Volume x-axis: cmH2O y-axis: ml	-10 to 120	0 to 3200
Volume/Flow x-axis: ml y-axis: l/min	0 to 3200	-300 to 300
Pressure/Flow x-axis: cmH2O y-axis: l/min	-10 to 120	-300 to 300
Volume/PCO2[91] x-axis: ml y-axis: mmHg	0 to 3200	0 to 100
Volume/FCO2[91] x-axis: ml y-axis: %	0 to 3200	0 to 10
Pes/Volume x-axis: cmH2O y-axis: ml	-10 to 120	0 to 3200

Parameter	X-axis scale	Y-axis scale
PTranspulm/Volume x-axis: cmH2O y-axis: ml	-120 to 120	0 to 3200

16.7 Alarms

Table 16-8 provides details about the adjustable alarms, including priority, upper and lower limit range, and default settings.

For additional details about alarms, see Chapters 5 and 9.

Table 16-8. Adjustable alarm priority, range, defaults, and resolution

Alarm (units)	Priority	Range: Adult/Ped	Range: Neo	Default: Adult/Ped	Default: Neo	Resolution
Apnea time[93] (s)	High	15 to 60	*in nCPAP-PS*: 5 to 60/ OFF *all other modes*: 5 to 60	20	5	*Adult/Ped*: 5 *Neonatal*: 1 (< 15) 5 (≥ 15)
ExpMinVol, high[94] (l/ min)	High	*in NIV, NIV-ST*: 0.1 to 50/ OFF *other modes*: 0.1 to 50	0.03 to 10/OFF	Based on **Rate** and **Vt** *1.5 * Rate * Vt*	Based on **Rate** and **Vt** *1.5 * Rate * Vt*	*Adult/Ped*: 0.1 (< 1) 0.5 (≥ 1) 1 (≥ 10) *Neonatal*: 0.01 (< 1) 0.1 (≥ 1)
ExpMinVol, low[94] (l/min)	High	*in NIV, NIV-ST*: OFF/0.1 to 50 *other modes*: 0.1 to 50	OFF/0.01 to 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) *Neonatal*: 0.01 (< 1) 0.1 (≥ 1)

[93] The default setting is configurable.
[94] Startup setting derived from IBW (adult/pediatric), body weight setting (neonatal). Does not apply in ASV mode.

Alarm (units)	Priority	Range: Adult/Ped	Range: Neo	Default: Adult/Ped	Default: Neo	Resolution
fTotal, high (b/min)	Medium	0 to 99	2 to 210	40	70	1
fTotal, low (b/min)	Medium	0 to 99	0 to 200	0	0	1
Oxygen, high[95, 96] (%)	High	18 to 105	18 to 105	55	55	--
Oxygen, low[95, 96] (%)	High	18 to 97	18 to 97	45	45	--
PetCO2, high[97] (mmHg)	Medium	1 to 100	1 to 100	60	60	1
PetCO2, low[97] (mmHg)	Medium	OFF/0 to 100	OFF/0 to 100	30	30	1
Pressure, high (Pmax) (cmH2O)	High	15 to 110	15 to 70	40	40	1
Pressure, low (cmH2O)	High	4 to 100	*nCPAP-PS*: 2 to 60 *other modes*: 4 to 60	PEEP	*nCPAP-PS*: 5 *other modes*: PEEP	1
Pressure limitation[98] (cmH2O)	Medium; Low after silence	5 to 100	5 to 60	Pmax - 10	Pmax - 10	1

[95] Active only when O2 monitoring (O2 sensor) is enabled.
[96] The high and low oxygen alarm limits are automatically set in relation to the current oxygen setting: O2 setting + 5 (high Oxygen limit) and O2 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.
[97] CO2 option required.
[98] Can also be adjusted using Pasvlimit. 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[99] (ml)	Medium	10 to 3000/ OFF	0.1 to 300/OFF	**Vt** is based on **IBW** *1.5 * Vt*	**Vt** is based on **Weight** *1.5 * Vt*	*Adult/Ped*: OFF 5 (< 100) 10 (≥ 100) 50 (≥ 500) *Neo*: OFF 0.1 (< 10) 1 (≥ 10) 5 (≥ 100)
Vt, low[99] (ml)	Medium	OFF/10 to 3000	OFF/0.1 to 300	Based on **IBW** *0.5 * Vt*	Based on **Weight** *0.5 * Vt*	*Adult/Ped*: OFF 5 (< 100) 10 (≥ 100) 50 (≥ 500) *Neo*: OFF 0.1 (< 10) 1 (≥ 10) 5 (≥ 100)

[99] In ASV mode, this alarm only applies for spontaneous breaths.

16.8 Configuration

The following table lists the parameters and settings that can be specified in the Configuration windows. For details, see Chapter 14

Table 16-9. Configuration specifications

Parameter	Configuration range	Default setting
General		
Language	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	English
Units	Pressure: hPa, mbar, cmH2O CO2: mmHg, Torr, kPa Length: cm, inch	cmH2O mmHg cm
More	Communication protocol: Hamilton, Galileo compatible, Hamilton P2, Philips VUELink Open, DrägerTestProtocol, Hamilton Block Protocol, HAMILTON-H900	COM1: Hamilton P2 COM2: Humidifier COM3: Hamilton Block
	Min. loudness	1
Modes		
Philosophy	Inspiratory time philosophy: I:E/Pause, TI/Pause, Peak flow/Tip Mode label: APVcmv/APVsimv or (S)CMV ASV: ASV, ASV 1.1	I:E/Pause APVcmv/APVsimv ASV 1.1

Parameter	Configuration range	Default setting
Graphics		
Main Monitoring Parameters (MMP)[100]	MMP 1 to 5: Pmean, PEEP/CPAP, Ppeak, ExpMinVol, VTI, VTE, VLeak, fTotal, fSpont, Oxygen, Cstat, Rinsp, Driving pressure, I:E, TI, TE, MVSpont, AutoPEEP, P0.1, PTP, RCexp, Pplateau, VTESpont, MVLeak, Insp Flow, Exp Flow, Vt/IBW, Vt/Weight, Pcuff (IntelliCuff), T humidifier and T y-piece (HAMILTON-H900), PEEP (Pes), Ppeak (Pes), Pplateau (Pes), Pmin (Pes), P0.1 (Pes), PTP (Pes), Ptrans I (Pes), Ptrans E (Pes)	Ppeak[101], ExpMinVol, VTE, fTotal, I:E
Settings	For all mode, control, and alarm settings, see the appropriate tables in this chapter.	
Setups	This information applies to the default adult Quick setup configurations. You can also specify default neonatal settings.	
Mode Ctrls	Vt/IBW (Adult/Ped): 5 to 12 ml/kg Vt/Weight (Neonatal): 5 to 12 ml/kg	Adult/Ped: 8 ml/kg Neonatal: 5 ml/kg
Vent Status		
Oxygen[102] (%)	22 to 80	40
PEEP[103] (cmH2O)	1 to 20	8
Pinsp (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[104] (%)	0 to 99	75

[100] Additional parameters available when the CO2 or SpO2 options are installed.
[101] The default setting is configurable. However, Ppeak is always set as an MMP.
[102] The low Oxygen setting is always 21%.
[103] The low PEEP setting is always 0 cmH2O.
[104] The high %fSpont setting is always 100%.

16.9 ASV technical data

Table 16-10 provides technical data related to ASV.

Table 16-10. ASV technical data

ASV-related data	Specifications
ASV-related operator settings	
%MinVol	25% to 350%
Patient height	**Adults:** 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 gender (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 7-19.
fTotal	In b/min
VDaw	2.2 ml/kg **IBW**
Vt (target)	**MinVol/ f(target)**
ASV monitor	
Target values (numerical)	**MinVol**, **Vt**, **fTotal**
Current achieved values (numerical)	**MinVol**, **Vt**, **fTotal**, **Vt = (VTI+VTE)/2**
Status of patient (numerical)	**fSpont**, **fControl**, **Pinsp**
Graphics display (curve)	**fTotal** versus **Vt**, target value, current value, safety boundaries
Alarms	
All alarms are functional except apnea alarms	See Chapter 9
Special	**ASV: Cannot meet the 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	2 cmH2O
Settling time	< 120 seconds
Steady state deviation	< 10 %
Lung-protective rules	
Minimum Vt	4.4 ml/kg x **IBW**
Maximum Vt depends on	• High **Pressure** alarm limit • Volume/ pressure ratio (V/P) • Always < 15 ml/kg x **IBW** • Limited to 1.5 x high **Vt** limit
Maximum machine rate	The maximum rate in ASV is the smallest value of the following conditions: • 60 b/min • 23 b/min * **%MinVol**/100 / (**IBW** = 30 kg) • 23 b/min * **%MinVol**/ (0.5 to 100 depending on **IBW**) (**IBW** < 30 kg) • 20/**RCexp**
Minimum target rate	5 to 15 b/min (depending on **IBW**)
Minimum Pinsp	5 cmH2O above **PEEP/CPAP**
Maximum Pinsp	High **Pressure** alarm limit - 10 cmH2O - PEEP
Minimum inspiratory time (TI)	0.5 s or **RCexp**, whichever is longer
Maximum inspiratory time (TI)	**IBW** = 30 kg: 2 seconds **IBW** < 30 kg: 1.5 seconds
Minimum expiratory time (Te)	2 x **RCexp**
Maximum expiratory time (Te)	12 seconds
I:E range	1:4 to 1:1

16.10 Ventilator breathing system specifications

Table 16-11 lists specifications for the HAMILTON-C6 ventilator breathing system.

Table 16-11. Ventilator breathing system specifications

Parameter	Specification	
Resistance[105]	Adult circuit (ID22, flow of 30 l/min):	Inspiratory limb: < 0.06 cmH2O/l/min Expiratory limb: < 0.06 cmH2O/l/min
	Pediatric circuit (ID15, flow of 15 l/min):	Inspiratory limb: < 0.12 cmH2O/l/min Expiratory limb: < 0.12 cmH2O/l/min
	Coaxial circuit (ID15, flow of 30 l/min):	Inspiratory limb: < 0.06 cmH2O/l/min Expiratory limb: < 0.06 cmH2O/l/min
	Neonatal circuit (ID12, flow of 2.5 l/min):	Inspiratory limb: < 0.74 cmH2O/l/min Expiratory limb: < 0.74 cmH2O/l/min
Compliance[105]	Adult circuit (ID22):	2 ml/cmH2O
	Pediatric circuit (ID15):	~ 1.5 ml/cmH2O
	Coaxial circuit (ID15):	~ 2.5 ml/cmH2O
	Neonatal circuit (ID12):	~ 0.8 ml/cmH2O
Volume[105]	Adult circuit (ID22):	~127 ml
	Pediatric circuit (ID15):	~75 ml
	Coaxial circuit (ID15):	~150 ml
	Adult/pediatric flow sensor:	9 ml (single use), 11 ml (reusable)
	Neonatal circuit (ID12):	~ 45 ml
	Neonatal flow sensor:	~ 1.3 ml
Bacteria filter	Particle size:	Captures particles of 0.3 mm (micron) with > 99.99% efficiency
	Resistance:	< 1.3 cmH2O at 20 l/min
Flow sensor dead space	Adult/pediatric:	< 9 ml (single use), < 11 ml (reusable)
	Neonatal:	< 1.3 ml additional dead space

[105] 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.

16.11 Technical performance data

Table 16-12 lists technical performance data for the ventilator.

Table 16-12. Technical performance data

Description	Specification
Patient ideal body weight (**IBW**, determined from **Pat. height** setting)	3 to 139 kg (6.6 to 306 lb)[106]
Weight (used for neonatal patients)	0.2 to 30 kg (0.44 to 66 lb)
Inspiratory pressure	0 to 100 cmH2O
Maximum limited pressure	110 cmH2O
Maximum working pressure	115 cmH2O (**PEEP/CPAP** + **Pinsp**). Ensured through pressure limiting.
Maximum inspiratory flow	260 l/min
Tidal volume/target tidal volume	*Adult/Ped.* 20 to 2000 ml *Neonatal.* 2 to 300 ml
Minute volume capability	Up to 60 l/min
Inspiratory time (spontaneous breaths)	0.25 to 3 seconds
Minimum expiratory time	20% of cycle time; 0.2 to 0.8 seconds
Automatic expiratory base flow	Fixed at 6 l/min
Means of inspiratory triggering	Flow trigger control, pressure trigger control, or optional IntelliSync+ control
Oxygen mixer accuracy	± (volume fraction of 2.5% + 2.5% of actual reading)
O2 input flow	80 l/min (at 2.8 bar / 280 kPa / 41 psi input pressure)

[106] 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 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:	≤ 2.5% at 60% Oxygen over 6 hours
	Storage temperature:	To maximize the shelf life of unused galvanic O2 sensors, store them between 5°C and 15°C (41°F and 59°F) in a refrigerator.
Continuous oxygen measurement	*Type of sensor: Paramagnetic 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:	≤ 2.5% at 60% Oxygen over 6 hours

Description	Specification	
Continuous oxygen measurement	Storage temperature:	To maximize the shelf life of unused galvanic O2 sensors, store them between 5°C and 15°C (41°F and 59°F) in a refrigerator.
Pressure and volume measurements	Type:	Differential pressure transducer, variable orifice
	Sensing position:	Patient y-piece
	Measurements:	See Table 16-6
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 16-6
	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[107]:	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 temperature:	0°C to 45°C (32°F to 113°F)
	Storage temperature:	-40°C to 70°C (-40°F to 158°F)

[107] 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 16-6
	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[107]:	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 16-6
	Operating temperature:	0°C to 40°C (32°F to 104°F)
	Storage temperature:	-40°C to 70°C (-40°F to 158°F)
Tests and special functions	Tightness test, flow sensor/O2 sensor/CO2 sensor zero calibration, O2 enrichment, manual breath, inspiratory hold maneuver, nebulization, leak compensation, communication interface, compensation of breathing circuit resistance and compliance, Pes measurement	

Description	Specification
Display device	Display of settings, alarms, and monitored data: Type: Color TFT Size: 1920 x 1200 pixels, 17 in (431.8 mm) diagonal
Brightness setting for display	The range is 10% to 100% brightness. By default, Day is set to 80%; Night is set to 40%.
Alarm volume (Loudness[108])	The range is 1 to 10. The default for the Adult/Ped patient group is 5; for Neonatal, 3.
Sound power level[109]	50 dB(A) ±3 dB(A)
Sound pressure level[109]	35 dB(A) ±3 dB(A)

16.11.1 Accuracy testing

The ventilator's parameter and measurement accuracy is tested using an IMT FlowAnalyser™. The tolerance intervals for the data generated by the FlowAnalyser are as specified below, and are included in the accuracy information provided in this manual.

Table 16-13. Tolerance intervals for accuracy testing

Parameter type	Tolerance interval of measurement
Volume	≤ 50 ml: ±1% > 50 ml: ±1.75%
Pressure	±0.5% or ±0.1 cmH2O, whichever is greater
Flow	±1.75% or ±0.5 l/min, whichever is greater
O2	±1%

16.11.2 Essential performance

Table 16-14. 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, this must be detected and the operator informed through an alarm.
CO2 level alarm condition[110]	If CO2 is higher or lower than the set alarm limits, this must be detected and the operator informed through an alarm.
SpO2 level alarm condition[110]	If SpO2 is higher or lower than the set alarm limits, this must be detected and the operator informed through an alarm.

[108] Volume at 1 meter distance from ventilator. A setting of 1 = 54 dB(A), and 10 = 73 dB(A), with accuracy of ±6 dB(A).
[109] Per ISO 80601-2-12.
[110] If option is installed.

Component	Requirement
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 last 5 min prior to depletion, an alarm must be issued.

16.12 Functional description of ventilator system

The HAMILTON-C6 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-C6 microprocessor system through a touch screen, keys, and a press-and-turn knob. These inputs become instructions for the HAMILTON-C6'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 graphic 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 prevent simultaneous failure of these two main functions and minimizes 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 mode ensures basic minute ventilation while giving the operator time for corrective actions.

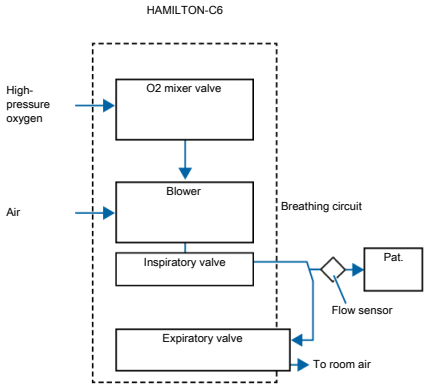
When a condition is critical enough to possibly compromise safe ventilation, the HAMILTON-C6 is placed into the Ambient state. The inspiratory channel and expiratory valves are opened, letting the patient inspire room air through the inspiratory channel and exhale through the expiratory valve.

The HAMILTON-C6 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 100 cmH2O.

16.12.1 Gas supply and delivery

The HAMILTON-C6 uses room air and high-pressure oxygen (Figure 16-2). Air enters through a fresh gas intake port and is compressed together with the oxygen by the blower. Oxygen enters through a high-pressure[111] inlet.

Figure 16-2. Gas delivery in the HAMILTON-C6



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.

Gas is supplied to the patient via the inspiratory valve. The microprocessor controls the inspiratory valve opening and the length of time it is open 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, including 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 either a galvanic (included with the ventilator) or paramagnetic O2 sensor.

The galvanic O2 sensor generates a voltage proportional to the partial pressure of oxygen in the delivered gas.

The paramagnetic O2 sensor monitors the oxygen based on the volume magnetic susceptibility of the delivered gas. The paramagnetic O2 sensor is maintenance free.

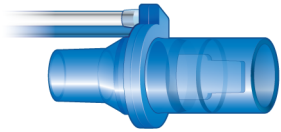
The operations of the blower and expiratory valve are coordinated to maintain system pressure levels.

[111] High-pressure oxygen: Maximum allowed pressure is 600 kPa.

16.12.2 Gas monitoring with the flow sensor

The HAMILTON-C6 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.

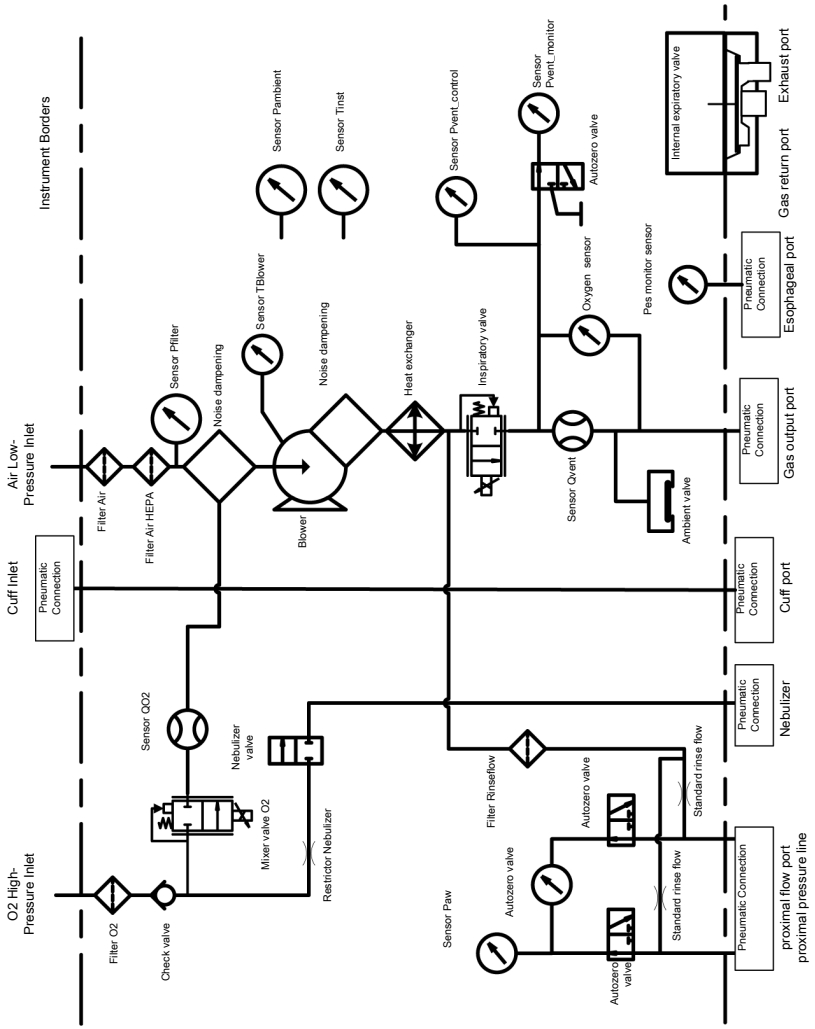
The flow sensor contains a thin, diamond-shaped membrane within the outer housing and has a pressure port on either side. The membrane allows bidirectional flow through its variable orifice.



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.

16.12.3 Pneumatic diagram



16.13 Symbols used on device labels and packaging

Table 16-15. Symbols used on device, device labels, and packaging

Symbol	Definition
	Power/Standby key
	Female patient
	Male patient
	Neonatal patient
	Alarm Off
	Manufacturer
	Date of manufacture
	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)
	Refer to the operator's manual for complete information.

Symbol	Definition
	Symbol for "Caution". Applied parts not protected against defibrillation.
CE 0197	CE Marking of Conformity, seal of approval guaranteeing that the device is in conformance with the Council Directive 93/42/EEC concerning medical devices
	Terminal for the connection of a potential equalization conduction.
	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.
	Dispose according to Council Directive 2002/96/EC or WEEE (Waste Electrical and Electronic Equipment)
SN	Serial number
	This way up at transport and storage
	Fragile, handle with care at transport and storage
	Keep dry at transport and storage
	Temperature limitations at transport and storage

Symbol	Definition
	Humidity limitations at transport and storage
	Atmospheric pressure limitations at transport and storage
	Stacking limitations at transport and storage
	Recyclable material
	Mass
IP21	Protected against dripping water and solid particles larger than 12.5 mm.
	HAMILTON-C6 poses unacceptable risks to the patient, medical staff, or other persons within the MR environment.
	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
	Single use
	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.
	Reusable. A reusable part is a medical device or part of a medical device that can be reused if it undergoes some sort of reprocessing between use on different patients. The correct way to reprocess reusable parts is described in the *Reprocessing Guide* provided by the manufacturer. Parts that Hamilton Medical terms as *reusable* cannot be autoclaved with steam sterilization.

Symbol	Definition
	Chinese RoHS
	EurAsian Conformity (EAC) mark

16.13.1 Symbols used on the trolley

Table 16-16. HAMILTON-C6 trolley warning labels

	Do not lean on the trolley. **Mass** The maximum safe working load applies to a stationary properly load-balanced trolley.

16.14 Standards and approvals

The HAMILTON-C6 was developed in accordance with pertinent international standards and FDA guidelines.

The ventilator is manufactured within an EN ISO 13485 and EN ISO 9001, Council Directive 93/42/EEC, Annex II, Article 3 certified quality management system.

The ventilator meets the Essential Requirements of Council Directive 93/42/EEC, Annex I.

Where standards are mentioned, the HAMILTON-C6 complies with the versions listed in Table 16-18.

The ventilator meets relevant parts of the following standards, listed in Table 16-17.

Table 16-17. Standards

IEC 60601-1	Medical electrical equipment, Part 1: General requirements for basic safety and essential performance. The device classification is: Class I, Type B applied part (ventilator breathing system, VBS), type BF applied part (CO2 sensor including CO2 module connector, humidifier, Aerogen system, nebulizer, 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 compatibility • Requirements and tests
ISO 80601-2-12	Medical electrical equipment - Part 2-12: Particular requirements for the basic safety and essential performance of critical care ventilators
CAN/CSA-C22.2 No. 601.1	Medical electrical equipment: General requirements for safety
ANSI/AAMI 60601-1	Medical electrical equipment - Part 1: General requirements for basic safety and essential performance
EN ISO 5356-1	Anaesthetic and respiratory equipment - conical connectors - Part 1: Cones and sockets
EN ISO 5359	Low-pressure hose assemblies for use with medical gases

EN ISO 80601-2-55: 2011	Medical electrical equipment - Part 2-55: Particular requirements for the basic safety and essential performance of respiratory gas monitors

Table 16-18. Standards and approvals, valid versions

IEC 60601-1-2:2014
IEC 60601-1:2005/A1:2012
ANSI/AAMI ES60601-1:2005/(R)2012
CAN/CSA-C22.2 No. 60601-1:14
IEC 60601-1-2:2007
ISO 80601-2-12:2011 + Cor.:2011
ISO 80601-2-55:2011
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
EN ISO 13485:2012/AC:2012
IEC 60950-1:2005 + AMD1:2009 + AMD2:2013
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 9001:2008
EN ISO 5356-1:2015
ISO 4135:2001

16.15 Disposal and year of manufacture

Disposal

The device must be disposed of according to your institution's protocols and Directive 2002/96/EC.

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-C6 ventilation unit.

16.16 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 and the manufacturer 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 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.

%MinVol
Percentage of minute ventilation; a control setting in ASV mode

(S)CMV
Synchronized controlled mandatory ventilation; a ventilation mode

(S)CMV+
See APVcmv

A
Ampere; a unit of current

AC
Alternating current; a primary power source for the ventilator

alarm buffer
Contains information on recent alarm occurrences

alarm lamp
Lamp atop the ventilator that lights in a color corresponding to the active alarm

Alarm Off symbol
Displayed when the associated alarm limit is disabled (set to Off).

ambient state
An emergency state in which the ventilator opens the inspiratory channel and expiratory valve; this allows the patient breathe room air unassisted by the ventilator

apnea
Cessation of breathing

Apnea time
The maximum time allowed without a breath trigger; an alarm setting

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.

Audio Pause key
Temporarily silences the audible alarm sound for 2 minutes

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
Includes the inspiratory-expiratory limbs, humidifier, filters, flow sensors, and any water traps

bronchial tree
The part of the Dynamic Lung that shows lung resistance

BTPS
Body temperature, barometric pressure at sea level, saturated with water vapor

C
Compliance

CE
A certification mark that indicates compliance with the Medical Device Directive, 93/42/EEC

cm
Centimeter, a unit of length

cmH2O
Centimeters of water, a unit of pressure; 1 cmH2O is approximately equal to 1 mbar, which equals 1 hPa

Control Flow
Set flow of gas to the patient in HiFlowO2 mode; a monitored parameter

COPD
Chronic obstructive pulmonary disease

CPAP
Continuous positive airway pressure

CSA
Canadian Standards Association

Cstat
Static compliance, a monitored parameter

db(A)
Decibel, a unit of acoustic power

DISS
Diameter index safety standard, a standard for high-pressure gas inlet fittings

Driving pressure (ΔP)
A calculated value showing the ratio of tidal volume to static compliance, which reflects the difference between Pplateau and PEEP. 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, patient triggering, and resistance in real time

E
Exhalation

EMC
Electromagnetic compatibility

EMI
Electromagnetic interference

EN
European norm, a European standard

ET
Endotracheal

ETS
Expiratory trigger sensitivity, a control setting

event log
A record of clinically relevant ventilator occurrences, including alarms, settings changes, calibrations, maneuvers, and special function uses that have occured 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

fSpont
Spontaneous breathing frequency; a monitored parameter

ft
Foot; a unit of length

fTotal
Total breathing frequency; a monitored parameter and alarm setting

HEPA
High efficiency particle air filter

HiFlowO2
High flow oxygen therapy; a ventilation mode

HME, HMEF
Heat and moisture exchanger (artificial nose), heat and moisture exchanging filter

hPa
Hectopascal, a unit of pressure; 1 hPa is equal to 1 mbar, which is approximately equal to 1 cmH2O

HPO
High-pressure oxygen

Hz
Hertz, or cycles per second; a unit of frequency

I
Inspiration

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 gender and height; used as the basis for the initial settings of various parameters

ID
Inner diameter

IEC
International Electrotechnical Commission

in
Inch; a unit of length

Insp Flow
Peak inspiratory flow; a monitored parameter

inspiratory hold
An inspiratory hold closes the inspiratory and expiratory valves for a short time. Perform this maneuver to calculate true plateau airway pressure.

IntelliCuff
Cuff pressure controller

Intelligent Panel
A type of graphic display on the ventilator comprising the Dynamic Lung, Vent Status, ASV Graph, ASV monitoring, and Monitoring (SMP) panels

IntelliSync+
Option that allows the device to dynamically update the inspiratory or cycling trigger. It does so by using a complex set of algorithms to analyze and process incoming sensor signals, allowing the ventilator to set values that are appropriate for the patient and system conditions

IntelliTrig
Intelligent trigger; a feature that ensures that the set trigger sensitivity can trigger a breath independent from leakage and breath pattern

INTELLiVENT-ASV
Fully closed loop ventilation solution, automatic MinVol, PEEP, and Oxygen adjustment based on physiological patient conditions.

Interaction panel (IP) or panel
The technical term used for the ventilator monitor

IRV
Inverse ratio ventilation

ISO
International Organization for Standardization; a worldwide federation of national standards bodies

kg
Kilogram; a unit of mass

kPa
Kilopascal; a unit of pressure

l
Liter; a unit of volume

l/min
Liters per minute; a unit of flow

lb
Pound; a unit of weight

Loops
A special graphic type

loudness
Sets the volume for the audible ventilator alarms

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

m
Meter; a unit of length

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.

ml
Milliliter; a unit of volume

monitor
The physical hardware that has the touch screen and function keys; also referred to as the interaction panel

ms
Millisecond; a unit of time

MVLeak
Total minute volume leakage; MVLeak shows VLeak * frequency (respiratory rate)

MVSpont
Spontaneous expiratory minute volume; a monitored parameter

nCPAP-PS
A neonatal ventilation mode that offers nasal continuous positive airway pressure - pressure support through a nasal interface (mask or prongs) for infants and neonates

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

O2
Oxygen

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

Pasvlimit
Maximum pressure to be applied in ASV; a control setting

Pat. height
Patient height; a control setting used to compute the patient's ideal body weight (IBW) in calculations for ASV and start-up settings.

patient group
A control setting used to define initial start-up settings for the patient. Options are Adult/Ped (adult and pediatric patients) and Neonatal.

Paw
Airway pressure

Pcontrol
Pressure control, a control setting in PCV+ and PSIMV+ modes. Pressure (additional to PEEP/CPAP) to be applied during the inspiratory phase.

Pcuff
Cuff pressure; a monitored parameter (For IntelliCuff cuff pressure controller)

PCV+
Pressure controlled ventilation

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

Pinsp
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.

Pmean
Mean airway pressure; a monitored parameter

PN
Part number

Ppeak
Peak airway pressure; a monitored parameter

Pplateau
Plateau or end-inspiratory pressure; The pressure measured proximally during the last 200 ml of inspiration when flow is at, or close to, zero

P-ramp
Pressure ramp; a control setting

Press-and-turn knob
See P&T knob

Pressure
Maximum pressure allowed in the patient breathing circuit; an alarm setting

pressure control
Maintenance of a consistent transrespiratory pressure waveform despite changing respiratory system mechanics

pressure trigger
The patient's inspiratory effort that causes the ventilator to deliver a breath; a control setting

psi
Pounds per square inch; a unit of pressure

PSIMV+
Pressure-controlled synchronized intermittent mandatory ventilation; a ventilation mode

Psupport
Pressure support; a control setting valid during spontaneous breaths in SPONT, SIMV+, APVsimv, PSIMV +PSync, DuoPAP, and NIV modes. Psupport is pressure (additional to PEEP/CPAP) to be applied during the inspiratory phase.

PSync
Applies the same pressure for spontaneous and controlled breaths; allows patients to breath spontaneously if they are able to keep the set guaranteed rate.

PTP
Inspiratory pressure time product; a monitored parameter

Ptranspulm
Transpulmonary pressure: distending force applied to the lung, which is the pressure difference between the alveoli and the esophagus. Calculated from the esophageal pressure (measured using the Pes port) and airway pressure. Available as numerical parameters, waveform, loop, and graph in P/V Tool.

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

s
Second; a unit of time

Safety mode
An emergency state that ensures a basic minute ventilation while giving the operator time for corrective actions if certain technical faults occur. The default inspiratory pressure is maintained and the expiratory valve opens as needed to switch system pressure levels between PEEP and inspiratory pressure. Sensor data is not monitored in this mode.

Safety therapy
An emergency state specific to ventilation with high flow oxygen therapy. See Safety mode.

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
Synchronized internittent mandatory ventilation; a ventilation mode

SIMV+
See APVsimv

slopeCO2
Slope of the alveolar plateau in the PetCO2 curve; a monitored parameter

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

T high
Set time interval for the high pressure level in the APRV and DuoPAP modes.

T humidifier
Measured temperature at the humidifier water chamber exit; a monitored parameter (for HAMILTON-H900 humidifier only)

T low
Set time interval for the low pressure level in APRV mode

T y-piece
Measured temperature at the humidifier Y-piece; a monitored parameter (for HAMILTON-H900 humidifier only)

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
A special graphic type

trigger
The patient's inspiratory effort that causes the ventilator to deliver a breath; a control setting, controlled by flow, pressure, or IntelliSync+

V
Volt; a unit of electric potential or volume

VA
Volt-ampere; a unit of electric power

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

Vt
Tidal volume; a control setting, an alarm setting and a 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

Waveforms
A special graphic type

Icons

%MinVol 96, 279
(S)CMV mode 112, 114

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