HAMILTON·G5

Intelligent Ventilation

Operator's manual

624074/07

Software version 2.2X

CE 0197

HAMILTON MEDICAL

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HAMILTON MEDICAL will make available on request circuit diagrams, component parts lists, descriptions, calibration instructions, or other information that will assist the user's authorized trained personnel to repair those parts of the equipment deemed by HAMILTON MEDICAL to be repairable.

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The software version for the HAMILTON-G5 is visible in the **`System -> Info window`**. The software version for the VUP (ventilator unit processor) (that is, the digit to the left of the decimal point for VUP) should match the version on the title page of this manual. See section 4.3.1 for details.

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. It also describes potential serious adverse reactions and safety hazards.

CAUTION

A CAUTION alerts the user to the possibility of a problem with the device associated with its use of misuse, such as device malfunction, device failure, damage to the device, or damage to other property. It also alerts against unsafe practices. This includes the special care necessary for the safe and effective use of the device.

NOTE:

A NOTE emphasizes information of particular importance.

Displayed only when the P/V Tool maneuver option is installed

Displayed only when the adaptive support ventilation (ASV) option is installed.

Displayed when the heliox option is installed

Displayed only when the CO_2 sensor option is installed

Displayed only when the SpO_2 sensor option is installed

Displayed only when neonatal option is installed

Displayed when the INTELLiVENT-ASV option is installed

Displayed when the intelliCuff option is installed

This manual shows screenshots and hardware with several options installed.

General warnings, cautions, and notes

Intended use

CAUTION

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

NOTE:

- Not all options are available in all markets.
- ASV® and INTELLiVENT®-ASV for adult and pediatric use only.

The HAMILTON-G5 ventilator is designed for intensive care ventilation of adult and pediatric patients, and optionally infant and neonatal patients. The device is intended for use in the hospital and institutional environment where health care professionals provide patient care. The HAMILTON-G5 ventilator is intended for use by properly trained personnel under the direct supervision of a licensed physician. The HAMILTON-G5 ventilator may be used for transport within a hospital or hospital type

facility provided compressed gas is supplied. The device is not to be used in the presence of flammable anesthetic agents or other ignition sources. The ventilator is not to be used in an environment with magnetic resonance imaging (MRI) equipment. The device is not intended for transportation outside the hospital or for use in the home environment.

General notes for operators

- Operators must familiarize themselves with this manual before using the ventilator on a patient. For training options of the HAMILTON-G5, please contact the HAMILTON MEDICAL representatives.
- The displays shown in this manual may not exactly match what you see on your own ventilator. Your ventilator may not include all the modes and features described in this manual.

Monitoring and alarms

- The HAMILTON-G5 is not intended to be a comprehensive vital sign monitor for patients on life-support equipment. Patients on life-support equipment must be appropriately monitored by qualified medical personnel and suitable monitoring devices. The use of an alarm monitoring system does not give absolute assurance of warning for every form of malfunction that may occur with the ventilator. Alarm messages may not exactly pinpoint a problem; the exercise of clinical judgment is necessary.
- An alternative means of ventilation shall be available whenever the ventilator is in use. If a fault is detected in the ventilator or its life-support functions are in doubt, disconnect the HAMILTON-G5 from the patient and immediately start ventilation with such a device (for example, a resuscitation bag), using PEEP and/or increased oxygen concentration when appropriate. The ventilator must be removed from clinical use and serviced by HAMILTON MEDICAL authorized service personnel.
- It is recommended that additional independent monitoring devices be used during mechanical ventilation. The opera-

tor of the ventilator must still maintain full responsibility for proper ventilation and patient safety in all situations.

- Do not silence the audible alarm when leaving the patient unattended.
- Do not use the exhaust port of the expiratory valve for spirometry. Due to the HAMILTON-G5's base flow, the exhaust gas output is larger than the patient's actual exhaled volume.
- Heliox gas is not compatible with INTELLiVENT®-ASV use.
- The Masimo Rainbow SpHb sensor is valid for a total of 66 hours of operation. Once this time expires, you must connect a new SpHb sensor. For details, see Appendix F, Pulse oximetry.

Fire and other hazards

- To reduce the risk of fire or explosion, do not place the HAMILTON-G5 in a combustible or explosive environment (for example, around flammable anesthetics or other ignition sources). Do not use it with any equipment contaminated with oil or grease.
- To minimize the risk of fire, do not use high-pressure gas hoses that are worn or contaminated with combustible materials like grease or oil.
- 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.
- In case of fire, immediately secure the patient's ventilatory needs, switch off the HAMILTON-G5, and disconnect it from its gas and electrical sources.
- Do not put a vessel filled with a liquid on the ventilator. If a liquid enters the product, a fire and/or electric shock may occur.

Service and testing

- To ensure proper servicing and to prevent possible physical injury, only qualified personnel should attempt to service the ventilator.
- To reduce the risk of electrical shock, do not remove the ventilator housing. Refer the ventilator for servicing by qualified personnel.
- To reduce the risk of electrical shock, disconnect electrical power from the ventilator before servicing. Be aware that battery power remains even after the mains is disconnected. Be aware that if the power switch is off, some parts still carry high voltage.
- Do not attempt service procedures other than those specified in the service manual.
- Use replacement parts supplied by HAMILTON MEDICAL only.
- Any attempt to modify the ventilator hardware or software without the express written approval of HAMILTON MEDICAL automatically voids all warranties and liabilities.
- The preventive maintenance program requires a general service every 5000 hours or yearly, whichever comes first.
- To ensure the ventilator's safe operation, always run the tests and calibrations prescribed in Chapter 4, Tests, calibrations, and utilities, before using the ventilator on a patient. If the ventilator fails any tests, remove it from clinical use immediately. Do not use the ventilator until necessary repairs are completed and all tests have passed.

Electromagnetic susceptibility

For further information see Appendix A.

Electromagnetic emissions

For further information see Appendix A.

Units of measure

Air and oxygen pressures are indicated on the HAMILTON-G5 in cmH2O or mbar. Hectopascals (hPa) are used by some institutions instead. Since 1 mbar equals 1 hPa, which equals 1.016 cmH2O, the units may be used interchangeably.

CO_2 measurements are indicated in mmHg, Torr, and kPa. These units are user configurable.

SpO_2 measurements are indicated in %.

Disposal

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 an electronic device or parts of it (for example, oxygen cell, batteries).

Year of manufacture

The year of manufacture is shown on the serial number label on the HAMILTON-G5 ventilation unit.

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1 General information

1.1 Introduction

The HAMILTON-G5 (hereafter referred to as the "device") provides for intensive care ventilation of adult, pediatric and neonatal patients. This device must be operated only by trained personnel under the supervision of a licensed physician.

Fully closed-loop control. Optional. On the HAMILTON-G5, you can install the world's first and unique "fully closed-loop control" option. The device is intended only for adult and pediatric patients. With the HAMILTON-G5 this feature is referred to as INTELLiVENT®-ASV.

The physiological inputs come from the patient. The physician establishes targets and a strategy that are matched with the patient inputs, or what the INTELLiVENT®-ASV feature has automatically established. Then the ventilator automatically adjusts the ventilator settings (output) to get the patient within the target ranges. This automatic input and output continues, each influencing the other, resulting in a "closed-loop" system.

This feature is an improvement on older conventional devices that needed frequent manual intervention to maintain satisfactory ventilation. With this device, when you enter specific patient conditions (with INTELLiVENT®-ASV), the device uses the data received from sensors (CO_2, flow, and SpO_2) to make suitable automatic adjustments.

In closed-loop ventilation, information from the patient is collected and analyzed by the device in a continuous manner, adjusting the ventilator without frequent human intervention (see Figure 1-1).

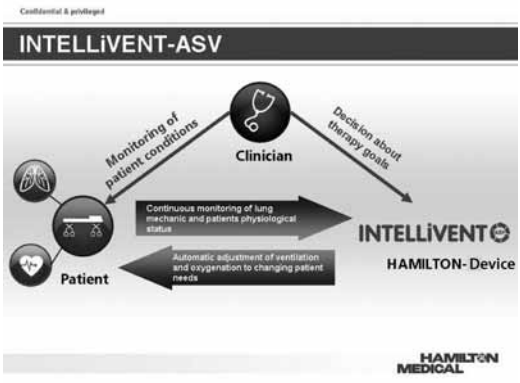


Figure 1-1. Closed-loop ventilation

The device incorporates three main closed-loop control inputs:

- Automatic minute volume
- PEEP
- Automatic oxygen adjustment

As the situation requires, the operator can control them manually or automatically. This means the operator can let the adjustment controllers in the device determine oxygenation and ventilation for the patient solely on the basis of input from the sensors, or can intervene and determine treatment parameters derived from a clinical judgment.

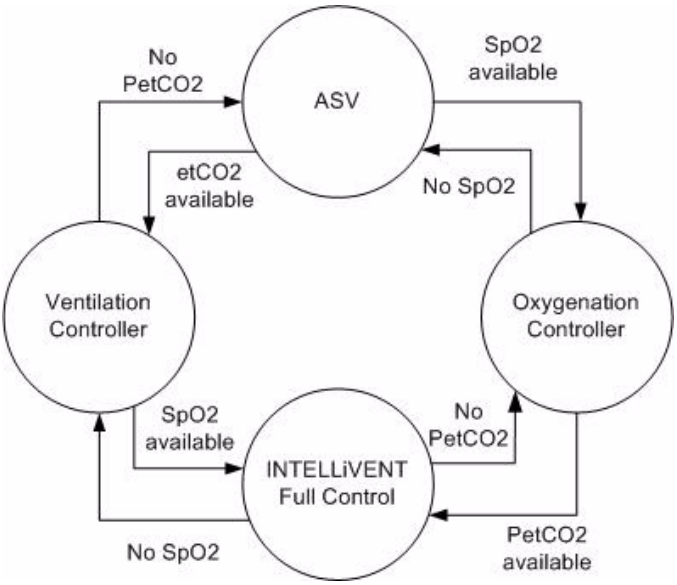


Figure 1-2. Controller conceptual design

Ventilation modes. This device offers a fully featured intensive care ventilator and uses conventional volume- and pressure-controlled and spontaneous modes, plus other advanced modes. The three conventional modes include:

- (S)CMV+ and SIMV+, delivered by an adaptive volume controller, combine the attributes of pressure-controlled with volume-targeted ventilation.
- P-CMV and P-SIMV are conventional pressure-controlled modes.
- SPONT is a conventional pressure-controlled mode.

The advanced modes include:

- ASV®(adaptive support ventilation) ensures the patient receives selected minute ventilation with the optimal breath pattern (lowest pressure and volume, optimal rate to minimize work of breathing and intrinsic PEEP).

- Optional. INTELLiVENT®-ASV is a complete fully closed-loop ventilation solution for oxygenation and ventilation. It relies on ASV® to perform the first step to a fully closed loop solution. It covers all applications from intubation until extubation with simplicity for an early weaning.
- DuoPAP® and APRV are two related pressure-controlled modes where the operator sets two pressure levels and the patient can breathe spontaneously at either level. This is similar to having an upper and lower level of continuous positive airway pressure (CPAP). Both modes provide a combination of controlled and spontaneous breaths at either level, while letting the patient breathe freely throughout the entire breath cycle.
- NIV (noninvasive ventilation) and NIV-ST (spontaneous/timed noninvasive ventilation) provide pressure support ventilation through a mask or other noninvasive interface.
- APVcmv and APVsimv are dual-control adaptive pressure ventilation modes that combine the attributes of pressure- and volume-controlled ventilation.
- nCPAP-PS provides pressure support ventilation through nasal interface for infants and neonates.

Patient triggered breaths may be flow triggered or pressure triggered. To reduce the patient's work of breathing while on this device, the ventilator's tube resistance compensation (TRC) feature offsets the resistance imposed by the tracheal (ET) or tracheostomy tube.

Monitor window. The Monitoring window on the Cockpit offers the operator a clear view of the various displays showing the patient's status during ventilation. The device offers a variety of monitoring capabilities. This window displays monitored parameters as numbers. To display individual data elements the Monitoring window displays data in various forms. These include:

- Graphics (as a combination of real-time waveforms (curves))
- Dynamic loops
- Trend waveforms
- Intelligent Panels

The Intelligent Panels allow the operator to select various elements for display, to include:

- Global Dynamic Lung/Haemodynamics with haemodynamics-lung interactions (refer to section 8.2 and the INTELLiVENT®-ASV manual) and show the current status of the lung and the activity and interaction of the patient's lungs and haemodynamics
- Vent status

The Vent Status displays the patient's level of ventilator dependency. The Ventilation Horizon, Map and Guide allow the operators to view and keep track of the patient's situation and the controllers' actions. The data window provides this information in a numeric form. The device's trending function lets you view up to 96 hours of previously collected data. You can freeze trend waveforms, real-time waveforms, or loops and use the cursor measurement function to determine a value at a selected point.

The Ventilation Map provides additional trending to get an overview in time of changes of physiological input and ventilator actions (modifications of setting) while in automatic ventilation. Additionally you can use the optional P/V Tool Pro®. The P/V Tool Pro® is an automated function to measure and display the inflation and deflation pressure-volume curves of the lungs for determination of the lower and upper inflection points and the deflation limb derecruitment point.

The device's monitored data is based on pressure and flow measurements collected by the HAMILTON MEDICAL proximal flow sensor, placed between the Y-piece and the patient and shows:

- Oxygen measurements by integrated oxygen monitor
- Proximal CO_2 measurement by the mainstream and sidestream CO_2 sensor
- Measurement of arterial O_2 saturation (SpO_2) by one or two pulse oximeters

Optionally the pressure measurements can come from an auxiliary pressure sensing site (Paux) or from an esophageal pressure measurement.

Alarms. The operator can adjust the device alarms; they can be set individually or automatically using the Auto button shown in the Alarms window (refer to Chapter 10, Responding to alarms). You can switch OFF some alarms. Other alarms are considered critical and you cannot switch these alarms OFF. This restriction helps ensures the patient's safety.

User interface. The device uses a combination of a 15 inch (38 cm) touch screen display with a separate press-and-turn knob and key buttons. The key buttons (referred to as 'keys'), when activated are a momentary backlit push buttons. Each element of the user interface is designed for ease of operation and offers ergonomic benefits.

Configuration. The language, ventilation philosophy, alarms, default patient group, default mode and settings (for each patient group individually) and options and default graphics layout (for each patient group individually) can be preselected in the configuration mode.

Power. The device is normally powered from AC mains, offering a voltage range of 100 to 240 Volt AC, 50/60 Hz. In the event of an AC power failure, the ventilator power source automatically switches to backup battery. A single optional, hot-swappable extended battery pack can power the device for a minimum of 1 hour, so multiple packs permit operation for a longer period. If the extended battery pack is not installed or is depleted, the internal battery provides power for a minimum of 1 hour.

Mounting. Variations for mounting the device include:

- Trolley-mount version with space for a VENTILAIR II medical air compressor
- Version suitable for shelf or pendant

The Ventilation Cockpit is detachable and can be attached to the top, front, or side of the ventilation unit, or the device can be installed on a hospital rail system.

Nebulization function. The ventilator offers pneumatic and micropump nebulization (using Aerogen® technology). The nebulization function allows the device to power an Aeroneb® nebulizer or a pneumatic nebulizer connected to the pneumatic nebulizer outlet.

The **P/V Tool Pro®** feature is an automated process that lets you measure and display the inflation and deflation pressure-volume curves of the lungs for determination of inflection points. This option is preinstalled on the device.

The **Minute Volume Adjustment** feature enables automatic control of %MinVol (Ventilation adjustment).

The **PEEP Adjustment** feature enables automatic control of PEEP (as part of the Oxygenation Adjustment).

The **Oxygen Adjustment** feature enables automatic control of Oxygen.

The **CO_2 sensor** with an associated MinVol controller feature continuously monitors airway carbon dioxide and reports $EtCO_2$ and inhaled/exhaled CO_2 for display and alarm purposes.

The **SpO_2 sensor** is a sensor attached to the patient which continuously monitors the oxygen saturation of the blood.

The **neonatal** feature lets you ventilate neonates.

Added features. These additional features are available for the device:

- The **communications interface** lets you monitor the patient from a remote workstation, transmits alarms through a nurse call relay system, and transmits I:E timing signals. This feature is preinstalled on the device.
- The **power strip** (multiple-socket outlet, MSO) provides AC power to the VENTILAIR II medical air compressor, and a humidifier.
- **Integrated humidifier.** With the use of the HAMILTON-H900 humidifier, you can monitor and control humidifier settings directly from the ventilator screen. The HAMILTON-H900 also provides a breathing circuit with integrated heater wires and temperature probe, improving ease of use. In addition, all humidifier data can be transmitted to any connected PDMS. You can still use other humidifiers, without full system integration.

- **nCPAP-PS.** This feature applies nasal continuous positive airway pressure with additional pressure support to neonates.
- The **heliox** feature provides for heliox delivery, with adjustments of inspired and exhaled volumes.

1.2 Functional description

The following paragraphs describe the operation of the device hardware.

1.2.1 System overview

In Figure 1-3 the conceptual overview of the HAMILTON-G5 device is shown. The principle functions are to ventilate the patient and implement the physician's ventilation strategy for a particular patient.

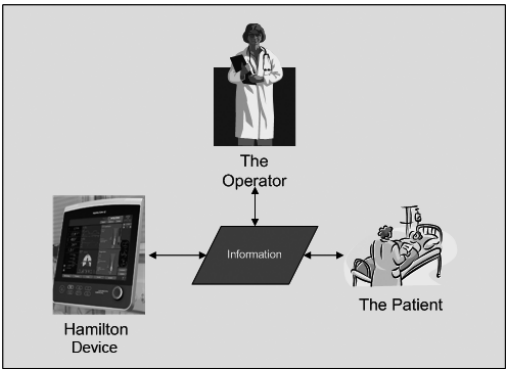


Figure 1-3. HAMILTON-G5 system overview

The important element in the system operations is the exchange of information between the device and the patient and the operator and the device. This interaction provides for both the patient's needs and permits the operator to control the system. As the device works, the operator has the tools to execute the orders of the physician. The following list describes in general terms the basic elements and features of the device.

- The device acts as an electronically controlled pneumatic ventilation system. Power comes from an AC source with internal battery backup. There is an optional extended battery backup available to order which protects against power failure or unstable power and aids in intra-hospital transport.
- The device's pneumatic system delivers gas, while its electrical systems control the pneumatics, monitor alarms, and distribute power.
- When you input instructions or settings you use the device's microprocessor system accessing features by way of a touch screen, push button keys, and a press-and-turn knob. Your inputs become instructions for the device's pneumatics to deliver precisely controlled gas mixtures to a patient. The device receives inputs originating from several sources such as sensors within the ventilator. As the device receives this monitored data, it adjusts gas delivery to the patient. The graphic user interface (GUI) displays this data via the touch screen display using various windows.
- The device'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-check feature helps prevent simultaneous failure of these two main functions and minimizes the possible hazards of software failure.

1.2.2 Gas supply and delivery

The device uses high-pressure oxygen, air and heliox from wall supplies, cylinders, or the VENTILAIR II medical air compressor (Figure 1-4). These gases enter though water traps with integrated high-efficiency particle filters at the gas inlets.

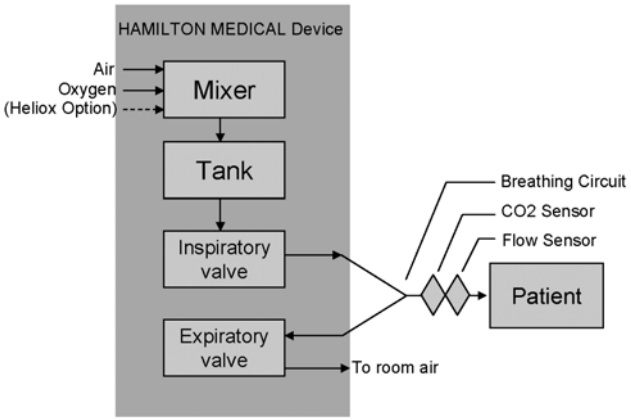


Figure 1-4. Gas delivery in the device

Within the ventilator, the gas enters the device's pneumatic system. An electronic mixer combines oxygen and air/heliox according to the user-set concentration. This mixture fills a reservoir, which is maintained within a prescribed pressure range. As the gas mixture is delivered to the patient, the pressure drops, and the reservoir is refilled.

Gas in the reservoir supplies the inspiratory valve. The microprocessor controls the size of the inspiratory valve opening and the length of time it is open to meet the user settings. The opening of the valve is then adjusted based on feedback in the form of monitored data.

The device delivers gas to the patient through the inspiratory limb breathing circuit parts, including possibly the inspiratory filter, flex tubes, the humidification system, a water trap, the Y-piece, the CO_2 sensor and the flow sensor. An internal high pressure valve supplies the nebulizer flow (oxygen).

Gas exhaled by the patient passes through the expiratory limb breathing circuit parts, including flex tubes, the flow sensor, the Y-piece, a humidifier or HME, and an expiratory valve cover and membrane. Gas is vented through the expiratory valve cover such that no exhaled gas comes into contact with any internal components of the device. Measurements taken at the flow sensor are used in the pressure, flow, and volume measurements.

An oxygen cell (sensor) monitors the oxygen concentration of the gas to be delivered to the patient, which is the same as the reservoir concentration. This galvanic cell generates a voltage proportional to the partial pressure of oxygen in the delivered gas. Neither the pressure nor the humidity of the inspired gas affects the oxygen measurement. The ventilator alarms if the monitored oxygen concentration is more than 5% above or below the oxygen setting, less than 18%, or more than 105%.

The mainstream/ sidestream CO_2 sensor continuously monitors carbon dioxide and reports $EtCO_2$ and inhaled/exhaled CO_2.

The SpO_2 sensor attached to the patient continuously monitors the saturation of hemoglobin with oxygen in the blood and a plethysmographic curve which is used to assess heart-lung interaction. A second sensor may be used to secure the SpO_2 information.

The operations of the inspiratory and expiratory valves are coordinated to maintain system pressure levels.

1.2.3 Gas monitoring with the flow sensor

The device accurately measures flow, volume, and pressure in the patient's airway with the HAMILTON MEDICAL flow sensor. This proximal flow sensor lets the device sense even weak patient breathing efforts. Between its highly sensitive flow trigger and fast response time, the device 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 (Figure 1-5).

Figure 1-5. Flow sensor

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 device calculates volume from the flow measurements.

The flow sensor is highly accurate even in the presence of secretions, moisture, and nebulized medications. The device continuously flushes the sensing tubes with mixed gases (rinse flow) to prevent blockage.

1.3 Physical description

1.3.1 Breathing circuits and accessories

NOTE:

To ensure proper ventilation operation, use parts and accessories specified in Table 1-1 only.

Figure 1-6 shows the device with its breathing circuit and accessories. See Appendix H, Parts and accessories, for details on breathing circuits and accessories supplied by HAMILTON MEDICAL. See Table 1-1 for information on other compatible breathing circuits and accessories.

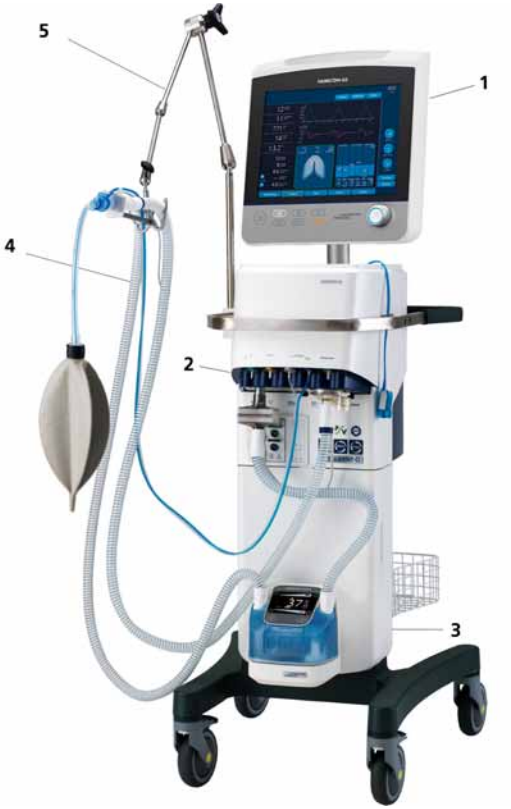


Figure 1-6. Ventilator with accessories

1 Ventilation Cockpit
2 Breathing circuit connections
3 Trolley (option)
4 Breathing circuit
5 Support arm

Table 1-1. Compatible parts and accessories

Part	Use only
Patient tubing circuit	• HAMILTON MEDICAL reusable patient tubing circuits • Other circuits that meet the ventilator breathing system specifications in Appendix A, Specifications.
Inspiratory filter	• HAMILTON MEDICAL reusable inspiratory bacteria filter • Other filters that have a 22 mm female conical inlet connector, a 22 mm male conical outlet connector, and that meet the ventilator breathing system specifications in Appendix A, Specifications.
Humidification device	• HAMILTON-H900 humidifier, which offers full integration with the ventilator (see Chapter 2, Preparing for ventilation, and Chapter 3, Hardware options) • HAMILTON-HC 180, 200 humidifier • Any active humidifier with a flow capability of up to 120 l/min • Heat and moisture exchanger
Flow sensor	**CAUTION** **Use HAMILTON MEDICAL parts only.**
Expiratory valve membrane and cover	Use HAMILTON MEDICAL parts only. See Appendix H, Parts and accessories.
Compressor	HAMILTON MEDICAL VENTILAIR II medical air compressor

Table 1-1. Compatible parts and accessories

Part	Use only
Nebulizer	• Internal nebulizer: Pneumatic nebulizer specified for approximately 6 to 7 l/min • Integrated Aeroneb® nebulizer: The integrated Aeroneb® nebulizer system consists of the Aeroneb® nebulizer and the Aeroneb® module. It is used during the mechanical ventilation of patients to nebulize physician-prescribed medications which are approved for use with a general purpose nebulizer. For the Aeroneb®, reusable as well disposable consumables are available.
CO_2 sensor	• HAMILTON MEDICAL CAPNOSTAT 5™ mainstream sensor • HAMILTON MEDICAL LoFlo™ sidestream sensor
SpO_2 pulse oximeters	• Masimo SpO_2 pulse oximeter with accessories • Masimo Rainbow SET options for use with Masimo SpO_2 pulse oximeter (offers additional monitoring parameters) • Nihon Kohden SpO_2 pulse oximeter with accessories For details on SpO_2 pulse oximeters, see Appendix F, Pulse oximetry.
CO_2 airway adapter	• Philips CAPNOSTAT 5 mainstream airway adapter • Philips CO_2 sidestream airway adapter/sampling kits
CompactFlash® and USB storage device	HAMILTON MEDICAL parts recommended

1.3.2 Ventilation cockpit

The screen of the Ventilation Cockpit (interaction panel), shown in Figure 1-7 and Figure 1-8, provides information about the status of the patient and ventilator. The basic screen (Figure 1-9) is the default screen. You can directly access all the windows for mode, controls, alarms, and monitoring from the basic screen, even during normal ventilation. The special function keys at the bottom of the Cockpit are typically backlit in white. When the key is pressed and the selected function is active, the color of the backlight changes. For example, during the 2-minute alarm silence, the alarm silence key turns red.

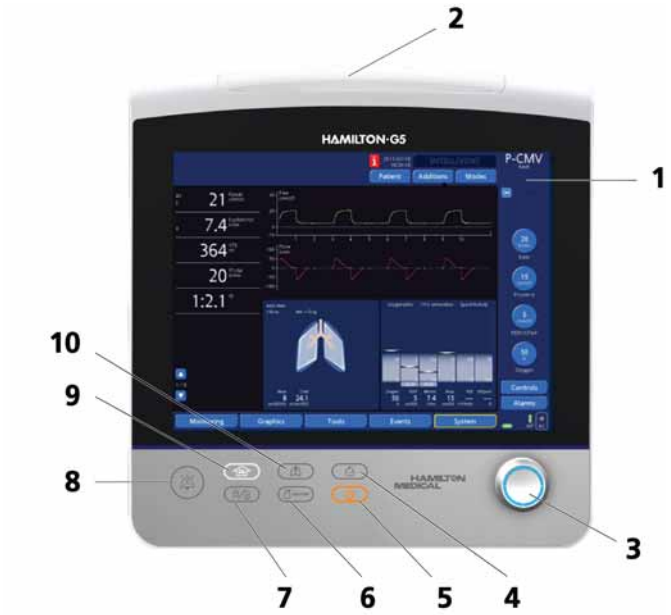


Figure 1-7. Ventilation Cockpit front view

1 Touch screen

2 Alarm lamp. Lights when an alarm is active. Red = high-priority alarm. Yellow = medium- or low-priority alarm. Blue = heliox application.

3 **Press-and-turn (P&T) knob.** Selects and adjusts ventilator settings and selects monitored data.

4 **Print screen key.** Saves a JPG file of the current ventilator screen to a CompactFlash or USB storage device.

5 **Standby key.** Activates the standby (waiting) mode. When the mode is activated, the standby activated screen is displayed. For details, see Section 12.1.

6 **Nebulizer on/off key.** Activates nebulization during the breath phases and for the duration selected during configuration. You can switch nebulization off earlier by pressing the key again.

7 **Screen lock/unlock key.** Prevents inadvertent touch screen entries. By touching the locked screen an acoustic BEEP sounds and a notice "screenlock active" appears.

8 **Alarm silence key.** Silences the ventilator audible alarm for 2 min. Pushing a second time cancels the alarm silence.

9 **O2 enrichment key/suctioning tool.**

Adults and Pediatric: Delivers 100% oxygen for 2 min. The backlighting changes color to green and the actually applied oxygen concentration is displayed on the oxygen control (green). Pushing the key a second time or manually changing the oxygen concentration ends the 100% oxygen enrichment period.

Neonatal option:[1] Delivers 125% of the last oxygen setting for 2 min. The backlit color changes to green and the currently applied oxygen concentration is displayed on the oxygen knob (green). Pushing the key a second time or manually changing the oxygen concentration ends the oxygen enrichment period. For further information on the suctioning tool, see Section 12.3.

10 **Manual breath key.** Triggers a mandatory breath when pressed and released during exhalation. The mandatory breath is delivered using the currently active settings.

1. In Japan, 100% oxygen is also applied for the neonatal option

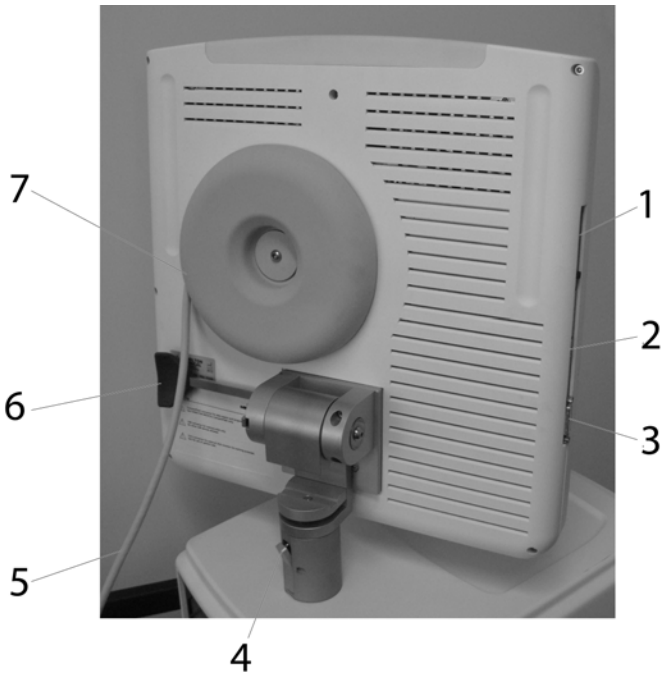


Figure 1-8. Ventilation Cockpit rear view

1 CompactFlash connector. Used to save a JPG file of the current ventilator screen to CompactFlash storage device and for software updates.

NOTE:

The CompactFlash connector is for data export and program update only! HAMILTON MEDICAL CompactFlash is recommended.

2 USB device. Used to save a JPG file of the current ventilator screen to USB storage device and for software updates.

NOTE:

The USB device is for data export and program update only! HAMILTON MEDICAL USB memory is recommended.

3 DVI-I connector. Outputs video signals to digital display devices such as flat panel LCD computer displays and digital projectors.

CAUTION

The DVI-I connector for an external XGA monitor is for training purposes. It is not intended for use on the patient side.

4 Ventilation Cockpit tilt assembly

5 Ventilation Cockpit cable assembly

6 Ventilation Cockpit swivel assembly

7 Storage for Ventilation Cockpit cable assembly

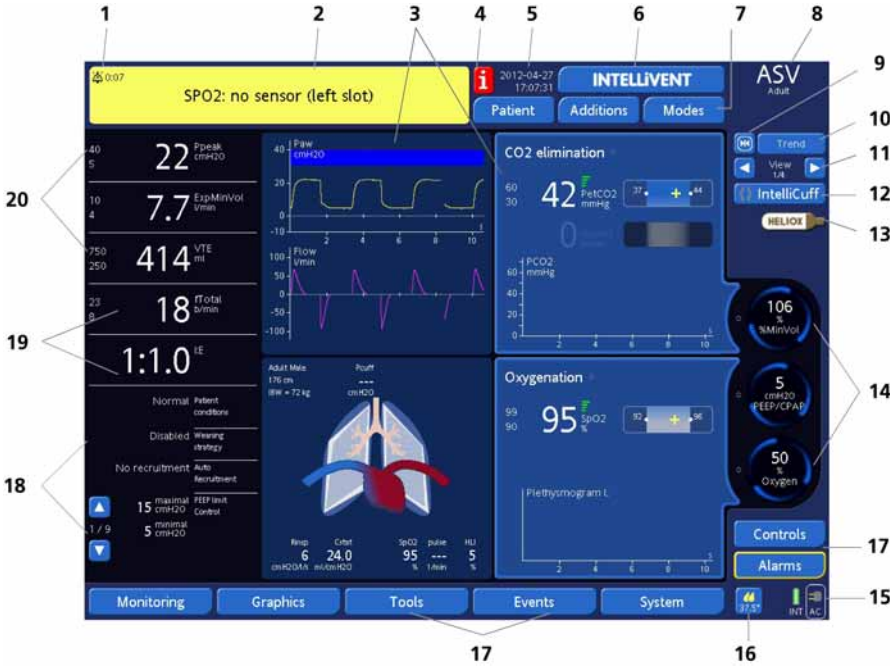


Figure 1-9. Default screen

1 **Alarm silence countdown.** Shows when alarm silence has been activated. Displays the remaining silence time.

2 **Message bar**. Displays alarm and other messages for user guidance and status report. See Chapter 10, Responding to alarms, for further information.

3 **Graphic display.** Real-time waveforms (curves), loops, trend waveforms, or Intelligent Panel, depending on user selection.

4 **I-icon.** Displayed when alarms have been activated, but not reviewed. Click the icon to display the Alarm buffer.

5 **Date and time.** Current date and time.

6 **INTELLiVENT tab**. Opens the INTELLiVENT window. (Available as an option.)

7 **Access to Patient, Additions, and Mode windows**. Patient window allows you to view/update patient data, and view the ventilator timer; Additions window gives access to sigh and tube resistance compensation (TRC); Mode window allows you to update the ventilation mode.

8 **Active mode, patient type, weaning, recruitment and apnea backup status (if active).**

9 **Freeze button.** Lets you freeze or unfreeze graphics.

10 **Trend button.** Additional option to display trends in INTELLiVENT®-ASV. (Available as an option.)

11 **View cursor.** Changes between oxygenation and ventilation horizons, maps and guides.

12 **IntelliCuff button.** Access to automatic cuff pressure controller settings. (Available as an option.)

13 **Heliox icon.** Indicates the heliox option is active.

14 **Controller buttons** for ventilation (%MinVol) and oxygenation (PEEP/CPAP and oxygen). When these are functioning automatically they pulse with a blue circle.

15 **Input power.** Shows all available power sources. The framed symbol indicates the current source (AC = mains, INT = internal battery, EXT = extended battery pack). The green part of the battery symbols shows the level of battery charge, while the red shows the level of discharge. The AC mains symbol and the internal battery symbol are always displayed, but are crossed out if that source is not available. The extended battery symbol is shown only if the external battery is installed.

16 **Humidifier button.** Provides quick access to the Humidifier visualization window (same as touching **`System > Humidifier`**). (Available as an option.)

17 **Window tabs.** Open the associated windows.

18 **Secondary monitoring parameters (SMP).** A group of numeric patient data. You can display other groups using the group scrolling arrows. The data is divided into groups for display purposes.

19 **Main monitoring parameters (MMP).** Five numeric parameters set during configuration.

20 **Alarm limits.** Upper and lower alarm limits, where applicable, for each MMP.

1.3.3 Ventilation unit

Figure 1-10 and Figure 1-11 show the patient breathing circuit connections and other important parts of the ventilation unit.

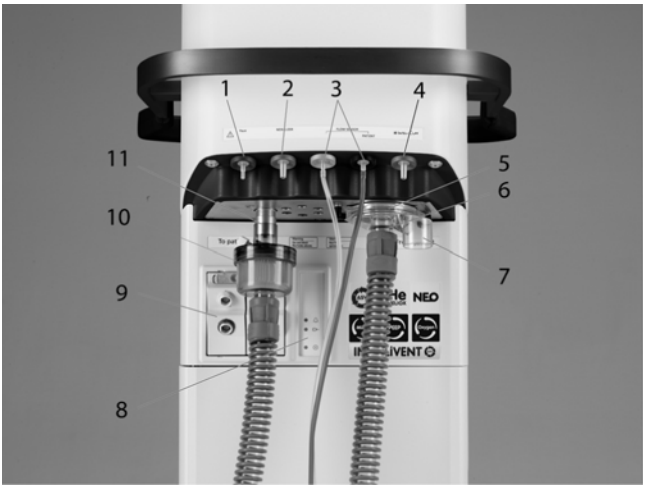


Figure 1-10. Front of ventilation unit (patient breathing circuit connections)

1 **Paux connector.** Connects to an auxiliary pressure sensing site, for use as the pressure input in addition to the proximal flow sensor measurement. By default there is no rinse flow through the Paux connector.

2 **Pneumatic NEBULIZER connector**

3 **FLOW SENSOR connection.** Always attach the blue tube to the blue connector and the clear tube to the silver connector. The blue tube should always be toward the patient.

4 **Cuff pressure controller** with luer connection[1]

5 **Expiratory valve cover and membrane**

6 **From patient port.** The expiratory limb of the patient breathing circuit and the expiratory valve are connected here.

7 **Exhaust port.** Expiratory valve cover opening to ambient air.

8 **Ventilation unit LED panel.** Redundant display of ventilator status. It is intended to provide status information when the Ventilation Cockpit is disconnected, as follows:

 An emergency situation exists (red LED)

 The ventilator is connected to AC mains power (blue LED)

 Power switch is on (green LED)

9 **Sensor or Aeroneb option module with connector**

10 **Inspiratory filter**

11 **To patient port (inspiratory outlet).** The inspiratory filter and the inspiratory limb of the patient breathing circuit are connected here.

1. Not available in all markets.

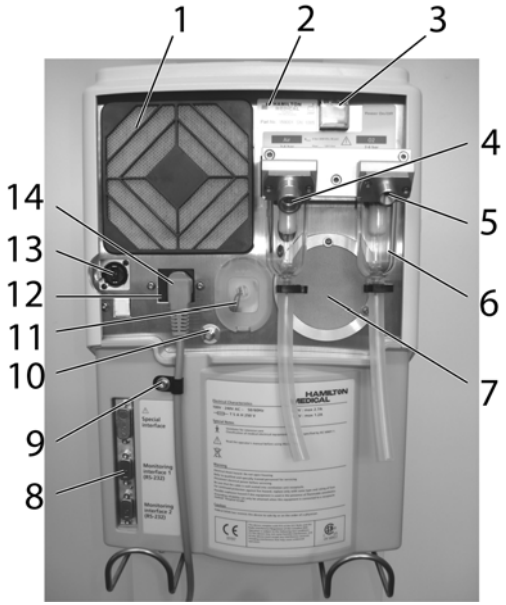


Figure 1-11. Rear of ventilation unit

1 Fan filter

2 Serial number label

3 Power switch

4 High-pressure air inlet, DISS or NIST fitting

5 High-pressure oxygen inlet DISS or NIST fitting (for heliox option, see section 2.13)

6 High-pressure gas water trap with filter

7 Reservoir pressure relief valve exhaust

8 Communications interface connectors (COM1, COM2)

9 Power cord with retaining clip

10 Potential equalization terminal

11 Oxygen cell with cover

12 Fuse drawer; holds two mains fuses

13 Ventilation Cockpit cable connector

14 Power receptacle

1.4 Symbols

Table 1-2 describes the symbols used on the back panel.

Table 1-2. Symbols

Symbol	Definition
	Fuse
	Power switch on position
	Terminal for the connection of a potential equalization conductor
	Manufacturer

Table 1-2. Symbols

Symbol	Definition
	Date of manufacture
	Classification of Medical Electrical Equipment, type B, as specified by IEC 60601-1.
	Classification of Medical Electrical Equipment, type BF, as specified by IEC 60601-1.
	Refer to the operator's manual for complete information.
	CE Marking of Conformity, seal of approval guaranteeing that the device is in conformance with the Council Directive 93/42/EEC concerning medical devices.
	The CSA marks with the indicators "C"and "US" mean 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.

Table 1-2. Symbols

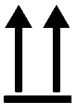
Symbol	Definition
	Serial number
	This way up
	Fragile, handle with care
	Keep dry
	Temperature limitations
	Humidity limitations for transport and storage
	Atmospheric limitations for transport and storage

Table 1-2. Symbols

Symbol	Definition
	Stacking limitations for transport and storage
	Temperature limitations for transport and storage
	Recyclable materials
	Consult accompanying documents
	To patient
	From patient

2 Preparing for ventilation

2.1 Introduction

WARNING

- **Additional equipment connected to medical electrical equipment must comply with the respective IEC or ISO standards. Furthermore, all configurations must comply with the requirements for medical electrical systems (see IEC 60601-1-1 or clause 16 of the 3Ed. of IEC 60601-1, respectively). Anybody connecting additional equipment to medical electrical equipment configures a medical system and is therefore responsible that the system complies with the requirements for medical electrical systems. Also be aware that local laws take priority over the above mentioned requirements. If in doubt, consult your local representative or Technical Support. To prevent possible patient injury, do not block the holes between the HAMILTON-G5's To patient and From patient ports. These holes are vents for the overpressure and ambient valves.**
- **To prevent back pressure and possible patient injury, do not attach parts not expressly recommended by HAMILTON MEDICAL to the exhaust port of the exhalation valve housing (for example, spirometer, tube, or other device).**
- **To prevent interrupted operation of the HAMILTON-G5 or any accessories, use only accessories or cables that are expressly stated in this manual and supplied by HAMILTON MEDICAL.**
- **To prevent interrupted operation of the HAMILTON-G5 due to electromagnetic interference, avoid using it adjacent to or stacking other devices on it. If adjacent or stacked use is necessary, verify the HAMILTON-G5's normal operation in the configuration in which it will be used.**

- **To prevent possible personal injury and equipment damage use two persons to lift when crossing thresholds and ensure the device is attached securely to the trolley or shelf with screws.**

CAUTION

- **To prevent ventilator components from overheating, do not obstruct the cooling fan vents.**
- **To prevent possible equipment damage, avoid overloading the HAMILTON-G5's basket and tray or placing objects on the HAMILTON-G5 that might compromise its stability.**
- **To prevent possible equipment damage, lock the trolley's wheels when parking the ventilator**

NOTE:

- Before using the ventilation for the first time, HAMILTON MEDICAL recommends that you clean its exterior and sterilize its components as described in Chapter 11, Maintenance.
- To electrically isolate the HAMILTON-G5 circuits from all poles of the supply mains simultaneously, disconnect the mains plug.

2.2 Installing and positioning the Ventilation Cockpit

2.2.1 Mounting the Ventilation Cockpit

CAUTION

Handle the touchscreen with care. Do not pull on or place stress on the cable.

With the correct mounting rails you can mount the Ventilation Cockpit to the top, front, or side of the ventilation unit or to a hospital rail system (Figure 2-1). Dismount and reinstall the cockpit as follows:

1. If necessary, disconnect the Cockpit from the ventilation unit by pushing on the cable release tab with a small screwdriver or similar utensil to disengage cable (Figure 2-2).
2. Dismount the Cockpit by loosening the knob in the clamp assembly (Figure 2-3).
3. Reinstall the Cockpit by positioning it over the rail or top mounting assembly and tightening the knob. Reconnect the cable as necessary.

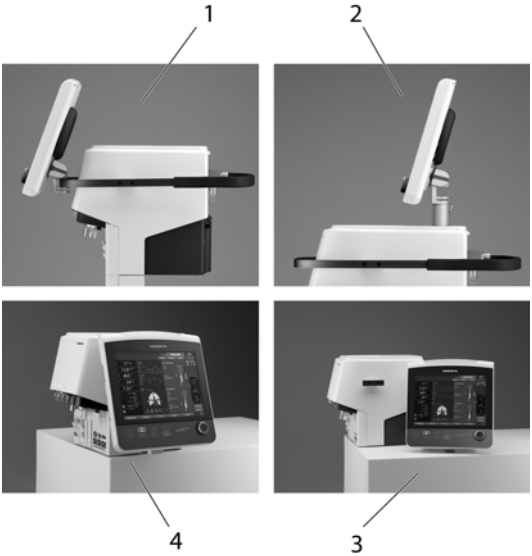


Figure 2-1. Ventilation Cockpit mounting positions

1 Front mounting on rail

2 Top mounting

3 Hospital rail mounting

4 Side mounting for use on shelf or pendant installation

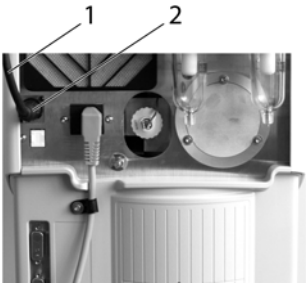


Figure 2-2. Disconnecting the Ventilation Cockpit

1 Ventilation Cockpit cable

2 Cable release tab

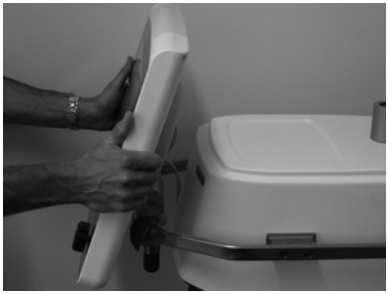


Figure 2-3. Mounting the Ventilation Cockpit

2.2.2 Adjusting the Ventilation Cockpit (tilt and swivel)

Adjust the position of the Ventilation Cockpit by releasing either the tilt or swivel handle, positioning the Cockpit as desired, then locking the handle (Figure 2-4 and Figure 2-5).

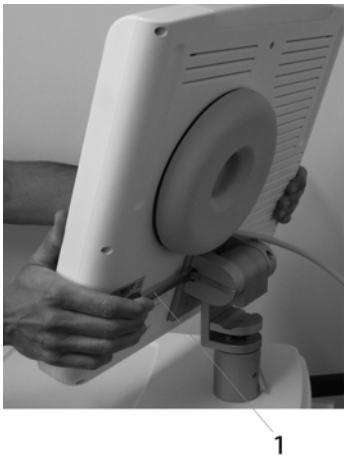


Figure 2-4. Tilting the Ventilation Cockpit

1 Tilt assembly locking handle

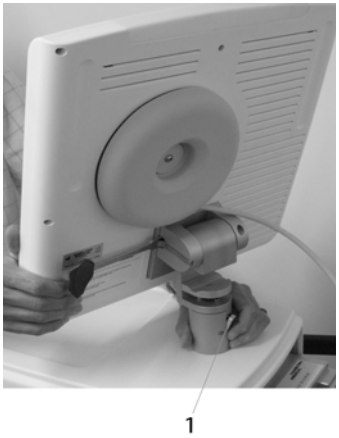


Figure 2-5. Swiveling the Ventilation Cockpit

1 Swivel assembly locking handle

2.3 Installing the patient tubing support arm

Install the patient tubing support arm on either side of the HAMILTON-G5 (Figure 2-6). Attach the patient tubing support arm only on the straight parts of the rail.

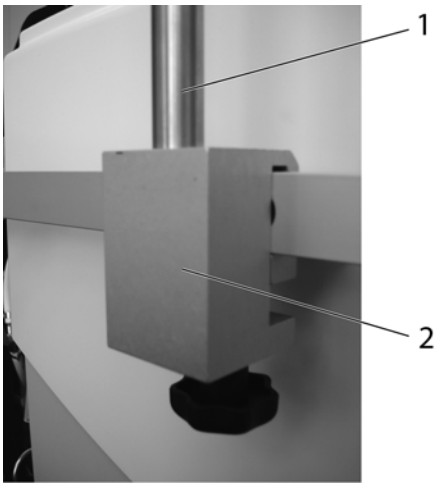


Figure 2-6. Installing the patient tubing support arm

1 Support arm

2 Support arm bracket

2.4 Installing the humidifier

CAUTION

To prevent possible patient injury and possible water damage to the HAMILTON-G5, make sure the humidifier is set to appropriate temperature and humidification settings.

NOTE:

- Once installed, you can configure and monitor the HAMILTON-H900 humidifier data and main settings directly on the ventilator screen, in the **System** -> **Humidifier** window. You can also access the Humidifier window using the Quick Access button on the main screen. For details, see Section 3.6.
- The integrated humidifier is not available in all markets. Check with your distributor to determine availability.
- Before proceeding with installation, be sure to read the HAMILTON-H900 Operating Instructions, and the installation/configuration information in this section and in Chapter 3, Hardware Options.

Installation involves the following steps:

1. Connecting the power cord, and the communication cable between the humidifier and the ventilator. See Section 2.4.1.
2. Installing the humidifier onto a mounting bracket. See Section 2.4.1.
3. Configuring the humidifier. See the HAMILTON-H900 Operating Instructions.

For details on the integration between the HAMILTON-H900 humidifier and the ventilator, see Section 3.6.

2.4.1 Connecting and attaching the humidifier

NOTE:

When connecting the HAMILTON-H900 humidifier to the optional internal power socket on the ventilator, be sure to connect the grounding cable to the potential equalization terminal on the back of the ventilator and to a grounding connection in the ICU.

The power and communication cable sockets are located on the bottom of the humidifier. The mounting bracket is on the back.

Two options are available for mounting the humidifier to the trolley:

- A fixed mount on the front of the trolley
- An adjustable-height mount on the side of the trolley

Figure 2-7. Back of humidifier

1 Mounting bracket

2 AC mains power socket

3 COM port and communications cable (see detail in Figure 2-8)

4 Potential equalization terminal

Figure 2-8. Power, communication connections (bottom)

1 AC mains power socket

2 COM port and communications cable

1. Attach the power cord to the power socket on the bottom of the humidifier. For details on AC power requirements, refer to the HAMILTON-H900 Operating Instructions. See Figure 2-8.
2. Attach the communication cable to the COM port on the bottom of the humidifier. See Figure 2-8.
3. Attach the humidifier to the trolley or other designated location by sliding the bracket on the rear of the humidifier onto the mounting bracket from the top down.

   For details on attaching the adjustable-height mount to the trolley, see the Adjustable Humidifier Kit Installation Guide.
4. Connect the humidifier power cable to AC mains power. For details on AC power requirements, refer to the HAMILTON-H900 Operating Instructions.
5. Connect the communications cable to the RS-232 port on the ventilator. See Figure 2-9.

Figure 2-9. HAMILTON-900 communications cable connected to RS-232 port on ventilator

For details on setting up the water chamber and connecting the rest of the humidifier tubes to the ventilator, see the HAMILTON-H900 Operating Instructions.

For details on the integration between the HAMILTON-H900 humidifier and the ventilator, see Section 3.6.

2.5 Installing the modules (CO_2, SpO_2, Aeroneb, HAMILTON-H900 humidifier)

Install a module (Figure 2-10) by pushing it into its slot until the connector engages and is locked.

Remove a module by pressing the release handle, then pulling the module out by its handle until the module disengages from the connector.

Figure 2-10. CO_2, SpO_2, Aeroneb modules

1 CO_2 or SpO_2 connector

2 Aeroneb connector (Aeroneb/HAMILTON-H900 humidifier module not shown)

2.6 Verifying the oxygen cell installation

This device uses an integrated oxygen cell to monitor the delivered oxygen concentration. Before operating the ventilator, verify the cell is present and properly connected (Figure 2-11). If a cell is not present, install one according to the instructions found in section 11.3.3.

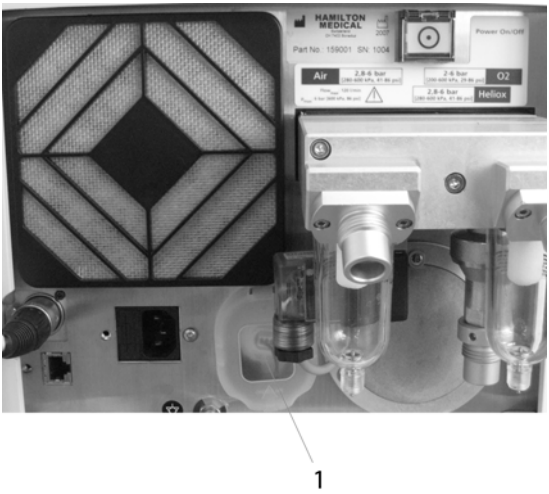


Figure 2-11. Check for the oxygen cell

1 Oxygen cell

2.7 Installing the patient breathing circuit

WARNING

- **To minimize the risk of bacterial contamination or physical damage, handle bacteria filters with care.**
- **To prevent patient or ventilator contamination, always use a bacteria filter between the ventilator and the inspiratory limb of the patient breathing circuit.**
- **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.**

NOTE:

- For optimal ventilator operation, use HAMILTON MEDICAL breathing circuits or other circuits that meet the specifications given in Appendix A, Specifications. When altering the HAMILTON MEDICAL breathing circuit configurations (for example, when adding accessories or components), make sure not to exceed these inspiratory and expiratory resistance values of the ventilator breathing system, as required by EN 794-1/IEC 60601-2-12: adult, 6 cmH2O at 60 l/min; pediatric, 6 cmH2O at 30 l/min; and infant, 6 cmH2O at 5 l/min).
- Any bacteria filter, HME, or additional accessories in the expiratory limb may substantially increase flow resistance and impair ventilation and lead to alarms.
- To ensure that all breathing circuit connections are leak-tight, perform the tightness test every time you install a circuit or change a circuit part.
- Regularly check the water traps and the breathing circuit hoses for water accumulation. Empty as required.

- For neonatal patients with body weights > 7 kg, you may want to select the pediatric patient type. This prevents the need to change circuits and calibrate the flow sensor should you later decide that your patient requires more support.
- Do not combine the Infant CO_2 airway adapter and the adult flow sensor. Artifacts during the measurement are possible.

Install the breathing circuit as follows:

1. Determine the patient type (adult, pediatric or neonatal) from Table 2-1. Select the correct breathing circuit parts for your patient. Note that the type of CO_2 airway adapter depends on tracheal tube size.

Table 2-1. Breathing circuit parts and patient types

Patient height	IBW (kg)	Tracheal tube ID (mm)	Breathing circuit tube OD (mm)	Flow sensor	CO_2 airway adapter	Patient type
< 50 cm (19 in.)	≤ 10	≤ 5	10	Infant	Infant	Neonatal
30 to 150 cm (11 to 59 in.)	3 to 42	3 to 7	15	Pediatric/ adult	Pediatric/ adult	Pediatric
> 130 cm (51 in.)	> 30	≥ 5	22			Adult

2. Assemble the patient breathing circuit. Figure 2-12 through Figure 2-14 show four typical circuit configurations; for ordering information, contact your HAMILTON MEDICAL representative. Follow the specific guidelines for the different parts.
3. Properly position the breathing circuit after assembly. Make sure the hoses will not be pushed, pulled, or kinked during the patient's movement, nebulization, or other procedures.

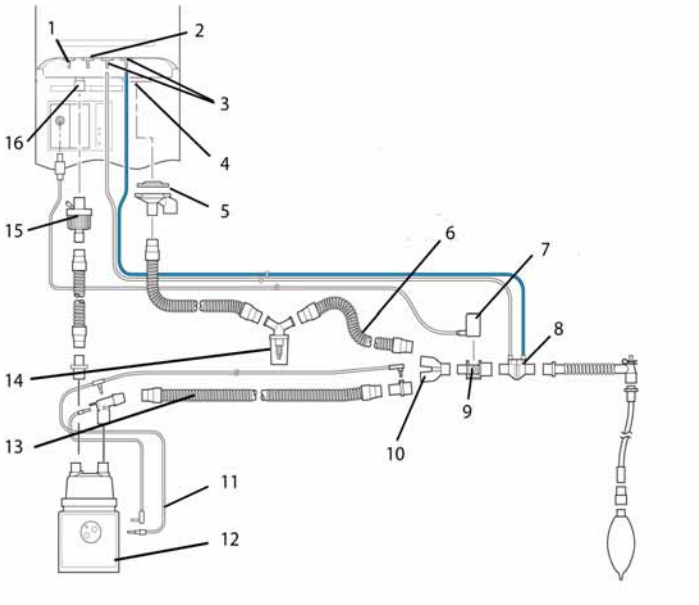


Figure 2-12. Patient breathing circuit for use with heater wire (pediatric/adult)

1 Paux connector
2 Nebulizer outlet
3 Flow sensor connectors
4 From patient
5 Expiratory valve membrane/ valve cover
6 Expiratory limb
7 CO_2 sensor
8 Flow sensor
9 CO_2 airway adapter
10 Y-piece
11 Heater wire
12 Humidifier
13 Inspiratory limb

14 Water trap/heater wire

15 Inspiratory filter

16 To patient

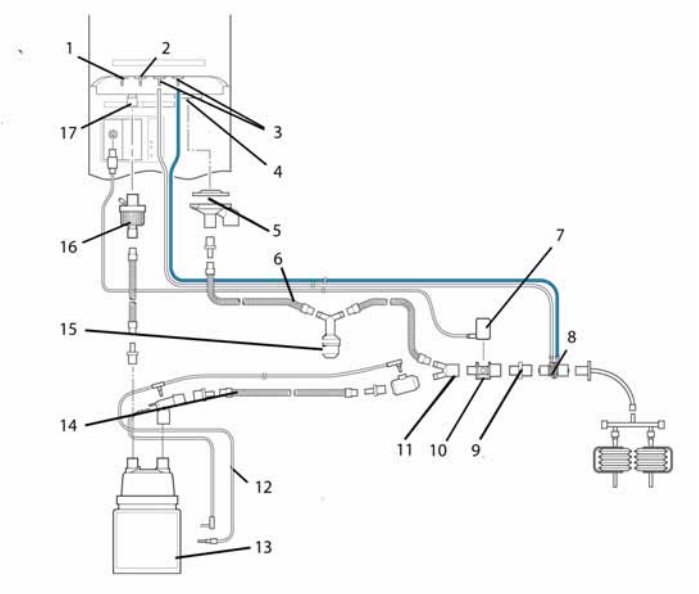


Figure 2-13. Patient breathing circuit for use with heater wire (neonatal)

1 Paux connector

2 Nebulizer outlet

3 Flow sensor connectors

4 From patient

5 Expiratory valve membrane/ valve cover

6 Expiratory limb

7 CO_2 sensor

8 Flow sensor

9 15M x 15F adapter

10 CO_2 airway adapter

11 Y-piece

12 Heater wire

13 Humidifier

14 Inspiratory limb

15 Water trap/heater wire

16 Inspiratory filter

17 To patient

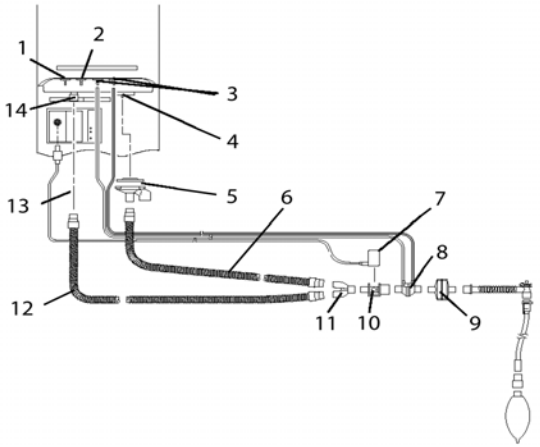


Figure 2-14. Patient breathing circuit for use with HME

1 Paux connector

2 Nebulizer outlet

3 Flow sensor connectors

4 From patient

5 Expiratory valve membrane/ valve cover

6 Expiratory limb

7 CO_2 sensor

8 Flow sensor

9 HME

10 CO_2 airway adapter

11 Y-piece

12 Inspiratory limb

13 Inspiratory filter

14 To patient

Expiratory valve membrane:

NOTE:

Place the silicone membrane into the valve cover with the metal plate upward (Figure 2-15). The side that is marked DOWN must be placed downward.

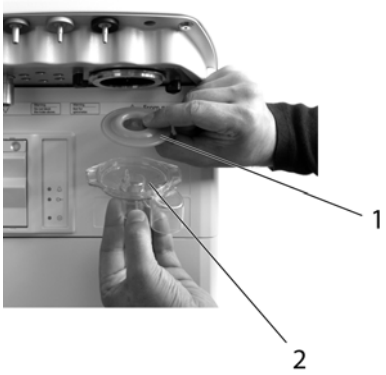


Figure 2-15. Installing the expiratory valve membrane

1 Expiratory valve membrane

2 Expiratory valve cover

Position the cover and twist clockwise into place (Figure 2-16).

Figure 2-16. Installing the expiratory valve cover

WARNING

To prevent inaccurate flow sensor readings, make sure the flow sensor is correctly installed:

- **The flow sensor tubings must not be bent.**
- **The flow sensor tubings must be secured with clamp (included with flow sensor).**
- **Use HAMILTON MEDICAL flow sensors only.**

Flow sensor: Insert a flow sensor for the proper patient type between the Y-piece of the breathing circuit and the patient connection (Figure 2-17). Connect the blue and colorless tubes to the flow sensor connectors in the front panel. The blue tube goes to the blue connector. The colorless tube goes to the silver connector.

Figure 2-17. Installing the flow sensor

CO2 CO_2 sensor and airway adapter (optional): Refer to Chapter 3.

2.8 Using the auxiliary pressure (Paux) measurement

WARNING

- **To use the pressure at the end of the tracheal tube as the Paux pressure input, you must have the rinse flow enabled (disabled by default). This must be done by an authorized HAMILTON MEDICAL service person. When the rinse flow is enabled, the device generates a weak flow of about 9 ml/min in the patient's direction to help keep the lumen of the carina clear of mucus.**
- **When the rinse flow is enabled, an esophageal balloon CANNOT be used to provide the Paux pressure input. If the rinse flow is enabled, the esophageal balloon can overinflate, resulting in possible patient injury.**

The device uses the airway pressure (Paw) as it's standard pressure input. You can reassign the device's pressure input, so monitored numeric parameters are based on a pressure from a different site, such as the esophageal balloon catheter end

of the tracheal tube. (This auxiliary pressure input can be particularly useful when conducting scientific studies.) For ARDS patients use the esophageal balloon catheter to determine the trans-pulmonary pressure. PEEP can be adjusted to maintain oxygenation and this action prevents damage to the lungs. You must connect the site to the ventilator through the Paux connector to use the auxiliary pressure input. To make the connection, use at minimum of 1 m (of 3 mm ID) tubing (flow sensor tubing works) for the connection. You must also set up the device's monitoring functions to recognize the Paux input; otherwise, the ventilator will continue to use the standard Paw input.

2.9 Using an expiratory filter

WARNING

- **The use of an expiratory filter can lead to a significant increase in expiratory circuit resistance. Excessive expiratory circuit resistance can compromise ventilation and increased patient work of breathing or AutoPEEP or both.**
- **Nebulization of drugs can cause an occlusion and an increased resistance of the filter.**

NOTE:

Monitored parameters for increased expiratory resistance are not specific to the breathing circuit and may indicate increased patient airway resistance and/or increased resistance of the artificial airway (if used). Always check the patient and confirm adequate ventilation.

An expiratory filter is not required on the HAMILTON-G5, but you may use one according to your institution's protocol. An expiratory filter is not required, because the expiratory valve design prevents internal ventilator components from contact with the patient's exhaled gas.

If you do use an expiratory filter:

1. Place it on the patient side of the expiratory valve cover.
2. Remove any expiratory filter or HME during nebulization. See the Warnings and Notes in this section for guidance.
3. You must monitor closely for increased expiratory circuit resistance.

An **Exhalation obstructed** alarm can also indicate excessive expiratory circuit resistance. If the **Exhalation obstructed** alarm happens repeatedly, then remove the expiratory filter immediately. If you suspect increased expiratory circuit resistance, remove the expiratory filter or install a new filter to eliminate it as a potential cause.

2.10 Connecting to AC power

WARNING

- **To minimize the risk of electrical shock, plug the ventilator power cord into a grounded AC power receptacle. It is the hospital's responsibility to ensure that the receptacle is properly grounded (earth).**
- **To ensure grounding reliability, use a special hospital-grade receptacle (USA only).**

NOTE:

To prevent unintentional disconnection of the power cord, make sure it is well seated into the ventilator's socket and secured with the power cord retaining clip.

Connect the device to a grounded AC outlet using power of 100 to 240 Volt, 50/60 Hz. Always verify the reliability of the AC outlet. The AC power symbol in the bottom right-hand corner of the screen is displayed with a frame around it. The AC power LED on the ventilation unit will also be lit.

2.11 Using the optional power strip

WARNING

- **Connect only these devices to the power strip:**
  - **HAMILTON MEDICAL VENTILAIRII medical air compressor**
  - **HAMILTON-HC 180/200**
  - **HAMILTON-H900 humidifier**
  - **Fisher & Paykel MR 850 humidifier**
  - **Aeroneb-Pro**
- **Connection of other electrical equipment to the power strip is responsibility of the operator to ensure that the power system complies with the requirements for medical electrical systems (for details, see Section 2.1) as well as local regulations.**
- **Do not connect additional auxiliary mains socket outlets or an extension cord to the system.**

The device is optionally equipped with a power strip containing auxiliary mains socket outlets. These outlets can power up to three devices comprising the ventilator system.

2.12 Using the backup batteries

NOTE:

- The backup batteries are not intended to be a primary power source. They are intended for short-term use only.
- HAMILTON MEDICAL recommends the ventilator's batteries be fully charged before you begin to ventilate a patient. If the batteries are not fully charged you must pay close attention to the battery charge levels in the event the AC power fails.

2.12.1 Introduction

Backup batteries, both the internal battery and the optional extended battery pack, protect the device from low or failure of AC power. When AC mains fail to provide power during ventilation, the ventilator power supply automatically switches to backup battery without an interruption in ventilation. An alarm sounds to signal the switchover. The alarm will continue sound until you silence the alarm. Silencing the alarm confirms operator notification of the power system change and resets the alarm.

When the device AC power supply is interrupted the ventilator shifts to the optional extended battery pack. If this is not available or adequately charged, the ventilator power supply will choose to switch to internal battery.

Important: The batteries power the ventilator until AC power is again adequate or until the batteries are depleted.

As a further safeguard, the device provides a "low-battery" alarm. The low-battery alarm is operated by a capacitor-driven buzzer that sounds for at least 2 minutes when either type of battery power is completely lost.

Both the internal and extended batteries power the ventilator for a minimum of 1 hour each (for new, fully charged batteries with the device at default settings and a 2 liter demonstration lung).

When the ventilator is connected to the AC mains power, the batteries are charged, with or without the ventilator power being switched ON.

The power source symbols are displayed in the bottom right-hand corner of the screen (Figure 2-18) indicating the available power sources. A frame around a symbol indicates the current ventilator power source (AC mains, internal battery, or extended battery).

Figure 2-18. Electrical power symbols

1 Frame indicates current power source

2 AC mains symbol

3 Internal battery symbol

4 Extended battery symbol

Observe the battery charge level before the ventilator is used on a patient, and before unplugging the ventilator for transport or other purposes.

- A green symbol indicates a fully charged battery.
- A red and green symbol indicates a partially charged battery.
- If a battery symbol is crossed out with a red X, the battery is discharged or defective.

If the batteries are not fully charged, recharge them by plugging in the ventilator for a minimum of 15 hours (for the internal battery) or 7 hours (for an extended battery pack), or until the battery charge level is 80 to 100%. If the internal battery is not fully charged at this time, have the ventilator serviced by authorized service personnel.

The extended battery pack requires a periodic recalibration. Use the designated battery calibrator for the extended battery.

2.12.2 Replacing the optional extended battery pack

CAUTION

Use HAMILTON MEDICAL batteries only.

Replace the extended battery pack as described below:

1. Open the ventilator's front cover by grasping the indent on your right-hand side and swinging the front cover door open (Figure 2-19).
2. Press on the tab, and slide the extended battery pack out of the housing. When removed, replace with a freshly charged battery pack (Figure 2-20).

Figure 2-19. To open the front cover

1 Indent for opening cover

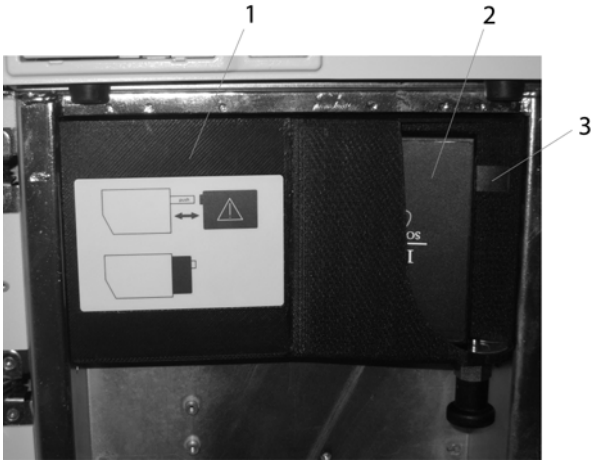


Figure 2-20. To remove the extended battery pack

1 Battery housing

2 Extended battery pack

3 Tab

2.13 Connecting gas supplies

WARNING

- **Always check the status of the gas cylinders before using the HAMILTON-G5 during transport.**
- **Ensure the gas cylinders are equipped with pressure-reducing valves.**
- **To minimize the risk of fire, DO NOT use high-pressure gas hoses that are worn or contaminated with combustible materials like grease or oil.**
- **To prevent possible hypoxia or death, connect the heliox gas supply containing at minimum of 20% oxygen.**

CAUTION

- **To prevent damage to the ventilator, connect only clean, dry medical-grade gases. Inspect for water and particle build-up in the gas supply water traps before each use.**
- **To prevent heliox entering the wall supply, connect compressed air with a minimum pressure of 2.8 bar.**

NOTE:

- When using a compressor with the device ventilator, connect a HAMILTON MEDICAL VENTILAIRII medical air compressor only.
- Use heliox blend of 78% (He)/ 22% (O_2)! The 78/22 mixture is preferred, as it allows the maximum amount of helium to be used yet consumes less gas when used in conjunction with mechanical ventilation (80/20 and 79/21 mixtures are also permitted).
- Only use the HAMILTON MEDICAL mixer block with inlet fittings for oxygen, air and heliox.
- Select the appropriate gas source in the **System -> Gas source** window. A mismatch of selected and actual source gas can result in inaccurate gas delivery and volume monitoring.
- After switching between air and heliox, it is recommended that you calibrate the flow sensor.
- After significant changes in oxygen concentration during heliox ventilation, it is recommended that you recalibrate the flow sensor.
- During heliox administration, O_2 monitoring is enabled and CANNOT be disabled.

- Inspect heliox cylinder pressure, and keep the cylinder at a level sufficient for ventilation (> 2.8 bar (280 kPa/41 psi)).
- To prevent under- or overheating during heliox therapy, use a patient circuit with heater wire and carefully monitor heated humidifier performance. Heliox's thermal conductivity, which is greater than that of nitrogen/oxygen mixtures, can affect the humidification device output. A febrile patient may transfer heat via the gas column to a proximal temperature sensor, leading to decreased humidifier output and desiccated airway secretions. In a heater wire breathing circuit, heat transfer from the patient can affect the heater wire output and result in increased condensation in the breathing circuit. In some humidifiers, you possibly need to reduce humidifier settings to prevent overheating of the breathing gas.
- Disconnect all gases if the device is not in use.

The device uses compressed air and oxygen (Table A-3). The gas fittings available are DISS, NIST or NF. Alternatively, you can select the heliox option in standby. The compressed gases can come from central gas supplies, from gas cylinders, or from the VENTILAIRII medical air compressor. The device's universal trolley provides space for the compressor or two cylinders (if you have the optional VENTILAIR II medical air compressor mounting kit or cylinder holder installed).

If you are using gases from cylinders, secure the cylinders to the trolley with the accompanying straps. Connect the gas hoses to the device's inlet fittings, shown in Figure 2-21.

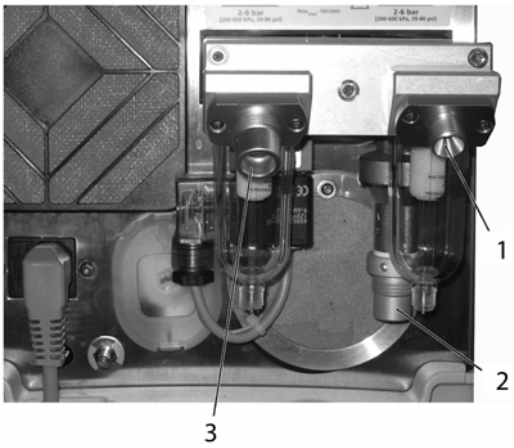


Figure 2-21. HAMILTON-G5 inlet fittings

1 Oxygen inlet fitting

2 Heliox inlet fitting

3 Air inlet fitting

He HELIOX

If you intend to use heliox, select the appropriate gas source in the **`System-> Gas source`** window. In standby, you can switch choices between air and heliox without exchanging the gas hoses.

2.14 Connecting to an external patient monitor or other device

NOTE:

All devices connected to the HAMILTON-G5 must be for medical use and meet the requirements of standard IEC 60601-1.

With the communications interface, you can connect your device to a patient monitor, to a PDMS or computer (via an RS-232 port), or to a nurse call device. See Appendix I for details on the communications interface. Before connecting any other device, ensure your device is properly configured (see Appendix J).

2.15 Starting up the ventilator

WARNING

To ensure the ventilator's safe operation, always run the prescribed tests and calibrations before using the ventilator on a patient. If the ventilator fails any tests, remove it from clinical use immediately. DO NOT use the defective ventilator until necessary repairs are completed and all tests passed.

NOTE:

- To shut down the device in an orderly manner, avoid switching the power quickly OFF and ON. If the ventilator buzzer sounds continuously upon power ON, switch the power OFF, then wait for several seconds before switching the power ON again.
- If your device is new, be sure it has been properly configured for default language, ventilation philosophy, alarms, and others factors (see Appendix J).
- The Ventilation Cockpit must be connected to the ventilator unit.

1. Turn the ventilator power switch ON (Figure 2-22). The ventilator will run a self-test. You will hear the emergency buzzer alarm momentarily activated.

   The patient setup window load for a few moments (Figure 5-1).

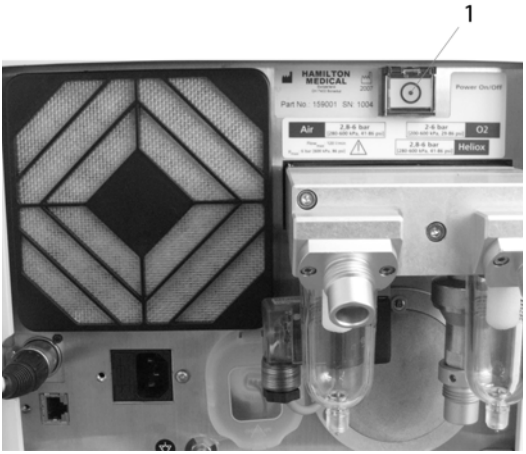


Figure 2-22. Power switch

1 Power switch

2. Run the required tests and calibrations listed in Table 4-1, as described in Chapter 5, Setting up the ventilator.
3. Set up the ventilator as described in Section 5.2.

2.16 Shutting down the ventilator

NOTE:

When you turn OFF the device, wait at least 2 seconds to permit an orderly shutdown before turning the ventilator back ON.

To shut down of the device, turn the power switch OFF.

Battery charging continues even when power is switched OFF, as long as the ventilator remains connected to AC mains.

2.17 Ventilation cockpit navigation guidelines

Use the touch screen and the press-and-turn knob (referred to as the P&T knob) to access the device ventilation parameters and monitored data. You can use a combination of touching the screen attributes, rotating the knob, and pressing the knob to activate your configuration choices. The knob can be rotated in either direction (clockwise CW, or counter-clockwise CCW), allowing you to scroll through choices displayed in the Cockpit windows.

To open a window (other than a pop-up window), touch a window tab to select and activate your selection; or scroll to it by rotating the P&T knob and then press the P&T knob to activate your selection. The selected item is framed in yellow.

To close a window (other than a pop-up window), touch the window tab or the X (close) in the upper left-hand corner; or scroll to the X by rotating the P&T knob and then press the P&T knob to activate your selection. The selected item is framed in yellow.

To adjust a control, touch the control to select and activate it; or rotate the P&T knob to select the control, then press it to activate your selection. The selected control is framed in yellow. The activated control turns red. Rotate the P&T knob to increment or decrement the value. Press the P&T knob, or touch the control, activating the adjustment.

Pulsing circle. When in automatic control, the circles turn blue and rotates using a pulsing motion. The speed with which the pulses move indicates a rapid or steady change in rate.

When the circle rotates to the right, the controlled value is increasing toward the target range. When the circle moves to the left, the controlled value is decreasing toward the target range.

When the circle turns red and stops moving, the patient parameters cannot be identified or are invalid. The adjusted parameters remain as set. The remaining time is also shown: for oxygen, 60 seconds, for PEEP, 360 seconds.

During **O_2 enrichment**, the oxygen control displays the currently applied oxygen concentration (value displayed in green) and the elapsed time.

To make a selection in a pop-up window, turn the P&T knob to scroll to and select the desired parameter, then press the P&T knob or touch the panel to activate your selection. The window closes automatically.

To scroll through a log using the scroll bar or arrows, touch the scroll bar to select and activate it; or turn the P&T knob to select the scroll bar and then press it to activate your selection. Your selection is framed in yellow, and it becomes red when activated. Now turn the P&T knob to scroll through the log. Touch the scroll bar or turn the P&T knob to deactivate.

Alternatively, touch a scroll arrow repeatedly to scroll up or down, or turn the P&T knob to select one of the scroll directional arrows and then press it repeatedly to scroll up or down.

To scroll through secondary monitoring parameters or P/V Tool History, touch a scroll arrow repeatedly.

3 Hardware options

3.1 Set up CO_2 sensor monitoring

CO2

WARNING

- **Ensure the integrity of the patient breathing circuit after insertion of the airway adapter by verifying a proper CO_2 waveform (capnogram) on the ventilator display.**
- **If the capnogram appears abnormal, calibrate the CO_2 sensor, inspect the CO_2 airway adapter and replace if needed.**
- **Monitor the capnogram for higher-than-expected CO_2 levels during ventilation. These can be caused by either the sensor or patient problems.**
- **DO NOT use the CO_2 sensor if it appears to have been damaged or if it fails to operate properly. Refer servicing to HAMILTON MEDICAL authorized personnel.**
- **To reduce the risk of explosion, DO NOT place the CO_2 sensor in a combustible or explosive environment (for example, around flammable anesthetics or other ignition sources).**
- **DO NOT operate the CO_2 sensor when it is wet or has exterior condensation.**
- **Nebulization may influence CO_2 measurement.**
- **Avoid permanent contact of the CO_2 sensor with the body.**
- **Always use the correct CO_2 adapter. In adult patients smaller geometrics induce low tidal volumes and intrinsic PEEP. In neonatal patients large geometrics detain effective CO_2 removal.**
- **The sensor cable must face away from the patient. Safely secure the sensor cable out of the way, to do so, attach the sensor cable holding clips to the airway tubing, and then connect the sensor cable to the clips.**

- **Inspect CO_2 cuvettes/sensors regularly. Patient secretions in airway curvettes might lead to wrong PetCO_2 reading.**
- **DO NOT use the sidestream CO_2 sensor with the automatic management of the %MinVol.**

CAUTION

- **Only position airway adapters with windows in a vertical position. This helps keep patient secretions from pooling on the windows.**
- **To prevent premature failure of the CO_2 sensor, HAMILTON MEDICAL recommends you remove it from the circuit whenever an aerosolized medication is delivered. (This is due to the increased viscosity of the medication, which may contaminate the airway adapter window.)**
- **All devices are not protected against the effect of the discharge of a cardiac defibrillator.**
- **Inspect the CO_2 cuvettes/sensors regularly. Patient secretions in airway cuvettes might lead to a wrong PetCO_2 reading.**
- **DO NOT use sidestream CO_2 with automatic management of %MinVol.**
- **The Alarm Silence button suppresses the physiological CO_2 alarm for <120 s.**

CO_2 monitoring is used for various applications to gain information, such as the assessment of the patients airway integrity or the proper endotracheal tube placement. For this device there are two methods used to monitor the CO_2:

- mainstream CO_2 measurement
- sidestream CO_2 measurement

The clinical settings determine regardless of the method, mainstream or sidestream, the end-tidal CO_2.

A volumetric capnogram (as described in Appendix E) is only possible with a mainstream CO_2 sensor.

3.1.1 Enabling CO_2

To operate CO_2 select **`Configuration -> Options`**.

Figure 3-1. Selecting CO_2

3.1.2 CO_2 mainstream measurement

3.1.2.1 Introduction

The CO_2 sensor is a mainstream, solid-state infrared sensor. It is attached to an airway adapter that connects to an tracheal (ET) tube or other airway. From this point it measures gases flowing through these breathing circuit components.

The sensor generates infrared light and beams it from one side through the airway adapter or sample cell to a detector on the opposite side. CO_2 from the patient, flowing through the mainstream airway adapter or aspirated into the sample cell, absorbs some of this infrared energy. The HAMILTON-G5 determines the CO_2 concentration in the breathing gases by measuring the amount of light absorbed by gases flowing through the airway or sample cell.

The device can display measurements derived from the CO_2 sensor in the form of numeric values, waveforms, trends, and loops.

The waveform is a valuable clinical tool used to assess patient airway integrity and proper endotracheal (ET) tube placement.

The CO_2 sensor can be easily transferred from one ventilator to another.

3.1.2.2 Connecting the CO_2 mainstream sensor

To set up the device for CO_2 mainstream monitoring, use these steps:

1. Plug the sensor cable into the CO_2 module connector (Figure 3-2), observing the orientation of the indexing guides on the connector body. The cable will snap into place.
2. Attach the airway adapter to the CO_2 sensor:

   A. Verify that the adapter windows are clean and dry. Clean or replace the adapter when required.

   B. Align the arrow on the bottom of the adapter with the arrow on the bottom of the sensor.

Figure 3-2. Connecting the CO_2 sensor cable

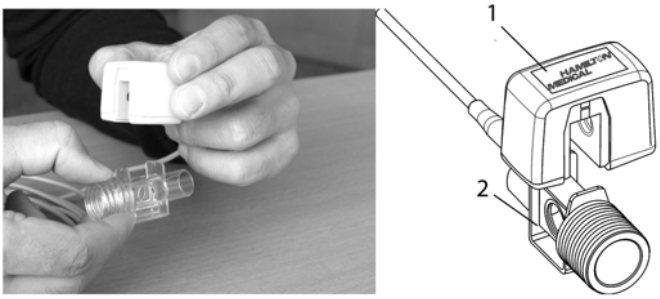


Figure 3-3. Attaching the CO_2 sensor to the airway adapter

1 CO_2 sensor

2 Adapter

3. Press the sensor and the adapter together until they click (Figure 3-3).
4. To connect the sensor/airway adapter to the patient circuit: (Figure 3-4):

   A. Place the sensor/airway adapter assembly at the proximal end of the airway circuit as shown. Do not place the airway adapter between the ET tube and the elbow, as this could allow patient secretions to accumulate in the adapter.

   B. Position the airway adapter with its windows in a vertical position. This helps keep patient secretions from pooling on the windows. If pooling does occur, the airway adapter can be removed from the circuit, rinsed with water and reinserted into the circuit. To prevent moisture from draining into the airway adapter, do not place the airway adapter in a gravity-dependent position.

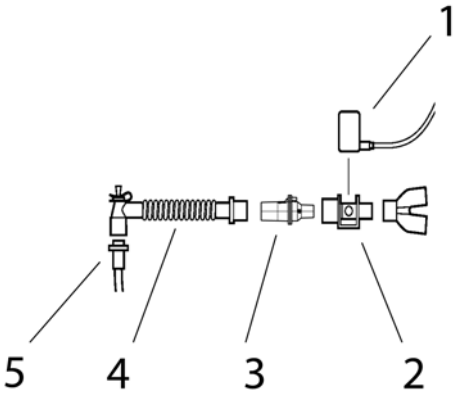


Figure 3-4. Connecting the CO_2 sensor/airway adapter to the patient circuit

1 CO_2 sensor
2 Adapter
3 Flow sensor
4 Elbow tube
5 ET tube

5. Inspect that all connections have been made correctly by verifying the presence of a proper CO_2 waveform (capnogram) on the Cockpit display. Monitor the capnogram for higher-than-expected CO_2 levels. If CO_2 levels are higher than expected, verify the patient's condition first. If you determine that the patient's condition is not contributing, then calibrate the sensor.
6. The sensor cable must face away from the patient. Safely secure the sensor cable out of the way, to do so, attach the sensor cable holding clips to the airway tubing, and then connect the sensor cable to the clips.
7. To remove the sensor cable, pull back on the connector sheath to disengage from the CO_2 module connector (Figure 3-2).

3.1.3 CO_2 sidestream measurement

3.1.3.1 Using the LoFlo™ CO_2 Module

CAUTION

- **DO NOT use if the patient cannot tolerate the removal of 50ml/min from their total minute ventilation. In adaptive modes (such as ASV®, APVcvm and APVsimv) the removal is fully compensated.**
- **Only use the LoFlo™ CO_2 Module with HAMILTON-G5/S1 IPP/VUP software version 2.0 or newer.**

3.1.3.2 Module mounting

A mounting bracket is delivered together with the LoFlo™ CO_2 Module. This mounting bracket can be attached to the rail of the ventilator.

Figure 3-5. Mounting bracket

3.1.3.3 Module exhaust

The exhaust port on the rear of the module contains barbs for attaching scavenging tubing. The port contains two different sized barbs, small and large.

The small barb is sized for 0.060 inch (1.524 mm) ID and up to 0.100 inch (2.54 mm) OD.

The large barb is sized for 0.125 inch (3.175 mm) ID and up to 0.375 inch (9.525 mm) OD.

3.1.3.4 Connecting the CO_2 sidestream sensor

WARNING

- **Always ensure the integrity of the patient breathing circuit after insertion of the sample kit by verifying a proper CO_2 waveform (capnogram) on the ventilator display.**
- **If the capnogram appears abnormal, calibrate the CO_2 sensor, inspect the CO_2 sample kit and replace if needed.**
- **Monitor the capnogram for higher-than expected CO_2 levels during ventilation. These can be caused by sensor or patient problems.**
- **Do not use the CO_2 sensor module if it appears to have been damaged or if it fails to operate properly. Refer servicing of the module to HAMILTON MEDICAL authorized personnel.**
- **To reduce the risk of explosion, DO NOT place the CO_2 sensor in a combustible or explosive environment (for example, around flammable anesthetics or other ignition sources).**
- **DO NOT operate the CO_2 sensor when it is wet or has exterior condensation.**

To set up the device for CO_2 sidestream monitoring:

1. Plug the LoFlo CO_2 Module cable into the CO_2 module connector (yellow), observing the orientation of the indexing guides on the connector body. The cable must snap into place.

Figure 3-6. Connecting the CO_2 sensor cable

2. The sample cell of the sampling kit must be inserted into the sample cell receptacle of the LoFlo™ CO_2 Module as shown in the figure below. A "click" sound will be heard when the sample cell is properly inserted.

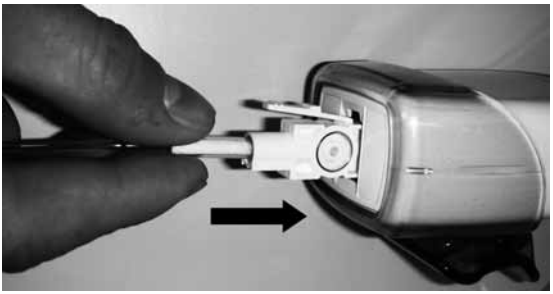


Figure 3-7. Inserting the sample cell into the receptacle

3. When you insert the sample cell into the receptacle the sampling pump automatically turns ON. Removal of the sample cell turns the sample pump OFF.
4. Install the airway adapter between flow sensor and ET tube.
5. The sensor cable must face away from the patient. Safely secure the sensor cable out of the way, to do so, attach the sensor cable holding clips to the airway tubing, and then connect the sensor cable to the clips.

Figure 3-8. Attaching the CO_2 sensor to the airway adapter

1 CO_2 sensor

2 Adapter

To remove the sampling kit sample cell from the sample cell receptacle, press down on the locking tab and pull the sample cell away from the sample cell receptacle.

3.1.3.5 Sidestream sample kit

CAUTION

- **The Adult/Pediatric and the Pediatric/Infant on-airway adapters are intended for single patient use. DO NOT reuse or sterilize the adapter kit as system performance will be compromised.**
- **Always insert the Sample Cell of the LoFlo™ sampling kit into the Sample Cell Receptacle on the LoFlo™ Module before inserting the on-airway adapter into the ventilator circuit. Failure to follow this, can introduce a leak in the circuit, thereby reducing set minute volume.**
- **Remove the LoFlo™ sampling kit sample cell from the receptacle when not in use.**
- **DO NOT place the on-airway adapter between the ET tube and the elbow as this can allow patient secretions to accumulate in the adapter. If pooling does occur, the on-airway adapter may be removed from the circuit, rinsed with water (or sterile water) and reinserted into the circuit. If rinsed, ensure that no water has entered the sampling tubing. If water is present, blow out water or replace the kit. To prevent moisture from draining into the on-airway adapter kit tubing, always place the on-airway adapter tubing in an up position.**

For monitoring CO_2, select a sidestream on-airway adapter kit appropriate for the patient size and application. Then attach the LoFlo CO_2 Module to the ventilator and sample kit as described above.

Table 3-1. Airway adapter kit

Airway adapter kit Adult/Pediatric	Weight: 4.5 grams Dead space – adds approximately 7 ml of dead space **Intended for use when monitoring patients with ET Tube sizes > 4.0 mm**.
Airway adapter kit/ w Dehumidification tubing Adult/Pediatric	Weight: 4.5 grams Dead space – adds approximately 7 ml of dead space **Intended for use when monitoring patients with ET Tube sizes > 4.0 mm**.
Airway adapter kit Pediatric/Infant	Weight: 5.8 grams Dead space – adds approximately 1 ml of dead space **Intended for use when monitoring patients with ET Tube sizes ≤ 4.0 mm**.
Airway adapter kit/ w Dehumidification tubing Pediatric/Infant	Weight: 5.8 grams Dead space – adds approximately 1 ml of dead space **Intended for use when monitoring patients with ET Tube sizes ≤ 4.0 mm**.

3.2 SpO_2 monitoring options

The SpO_2 probe is connected to an adapter to measure patient's SpO_2 and pulse rate and send measured data (SpO_2 real time value, plethysmograph, pulse rate and status) to the device.

SpO_2 measurement begins after the sensor is configured, the SpO_2 adapter and the sensor are connected to the ventilator, the sensor is attached to the patient, and the SpO_2 sensor is activated.

The HAMILTON-G5 supports SpO_2 monitors from two manufacturers: Masimo and Nihon-Kohden.

For detailed information about the options, configuration, installation, monitored parameters, alarms, and so on, see Appendix F, Pulse oximetry.

3.3 Installing the pneumatic nebulizer

WARNING

- **Do not use an expiratory filter continuously or an HME in the patient's breathing circuit during nebulization. Nebulization can cause an expiratory side filter to clog, substantially increasing flow resistance and impairing ventilation.**
- **To prevent the expiratory valve from sticking due to nebulized medications, use only medications approved for nebulization and regularly check and clean or replace the expiratory valve membrane.**
- **Connect the nebulizer in the inspiratory limb per your institution's policy and procedures. Connecting the nebulizer between the flow sensor and the tracheal tube increases dead space ventilation.**
- **Be aware that nebulization affects delivered oxygen concentration.**

NOTE:

- In the configuration mode you can view and change the nebulizer settings.
- Nebulization is disabled during heliox administration and in the infant/neonatal application.

The nebulization feature provides a stable driving pressure to power a pneumatic nebulizer connected to the nebulizer outlet, optimally specified for 6 to 7 l/min flow. Be aware that nebulization affects delivered oxygen concentration.

Connect the nebulizer and accessories as shown in Figure 3-9. Table 1-1 has information about compatible nebulizers.

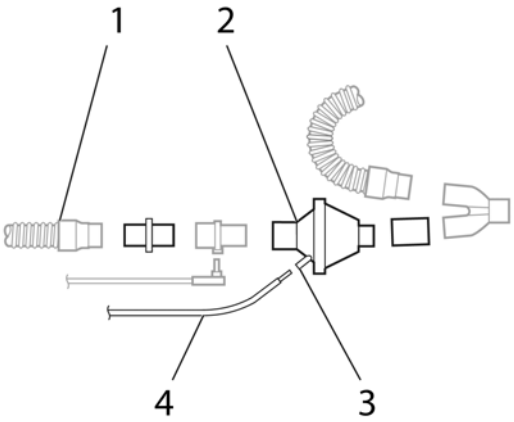


Figure 3-9. Installing a pneumatic nebulizer

1 Inspiratory limb
2 Nebulizer
3 Connector
4 Tube

3.4 Integrated Aeroneb® system

WARNING

- **Do not use an expiratory filter continuously or an HME in the patient's breathing circuit during nebulization. Nebulization can cause an expiratory side filter to clog, substantially increasing flow resistance and impairing ventilation.**
- **Install the nebulizer in the inspiratory limb according to your institution's policy and procedures. DO NOT connect the nebulizer between the flow sensor and the endotracheal tube, this can increase dead space ventilation.**
- **To prevent the expiratory valve from sticking due to nebulized medications, use only medications approved for nebulization and regularly check and clean or replace the expiratory valve membrane.**

3.4.1 Introduction

The integrated Aeroneb® system, which consists of the Aeroneb® nebulizer and the Aeroneb® module of the device ventilator.

The Aeroneb Nebulizer System is designed for use with mechanically ventilated patients to aerosolize physician prescribed medications for inhalation which are approved for use with a general purpose nebulizer.

For the Aeroneb, reusable as well disposable consumables are available.

The integrated Aeroneb system is suitable for use with neonate, pediatric and adult patients as described in this manual. It is a latex-free system for intermittent and continuous nebulization that incorporates Aerogen's OnQ™ Aerosol Generator.

The Aeroneb nebulizer operates in-line with standard ventilator circuits in acute and sub-acute care environments. It operates without changing patient ventilator parameters and can be refilled without interrupting ventilation.

3.4.2 Indications for use

The integrated Aeroneb System is part of the device ventilator for multiple patient use. Use the system to aerosolize physician prescribed solutions for inhalation to patients on ventilation.

3.4.3 System description

CAUTION

To avoid damage to the nebulizer:

- **DO NOT apply undue pressure to the domed aperture plate in the center of the nebulizer.**
- **DO NOT push out the OnQ™ Aerosol generator.**
- **DO NOT use a syringe with a needle to add medication.**
- **DO NOT use abrasives.**

NOTE:

- Inspect all parts before use, and DO NOT use if any parts are missing, cracked or damaged. If parts are missing, malfunction or are damaged, contact your HAMILTON MEDICAL sales representative.
- Use components specified by HAMILTON MEDICAL only. DO NOT use or store outside of specified environmental conditions.
- To avoid mechanical or electrical damage, DO NOT drop the nebulizer unit or the control module. Do not use in the presence of devices generating high electromagnetic fields such as magnetic resonance imaging (MRI) equipment.

The Aeroneb system is integrated into the HAMILTON-G5 ventilator includes the following components: HAMILTON-G5 Aeroneb Module, nebulizer unit (Aerosol Generator and plug), Aerogen T-adapter (adult)[1] supplied by HAMILTON MEDICAL, control cable.

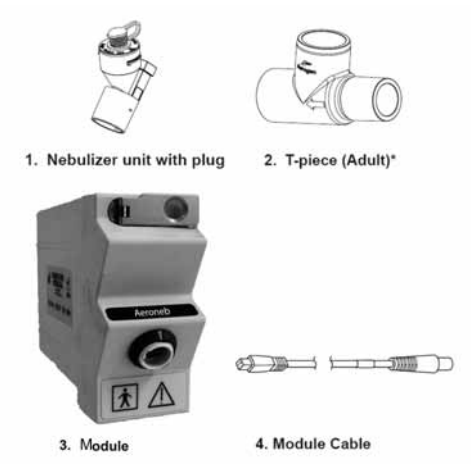


Figure 3-10. System components

1 The nebulizer unit holds up to 6 ml of liquid medication. The nebulizer unit is transparent to allow viewing of medication levels and aerosolization. After the nebulizer unit is connected into the ventilator circuit, the silicone plug can be opened and closed in between doses without causing loss of circuit pressure. Inside the nebulizer unit is an OnQ Aerosol Generator. This consists of a domed aperture plate with precision-formed holes to control the size of the aerosol droplets and a vibrational element that creates a micro-pumping action to aerosolize medication. Gravity brings the medication in contact with the aerosol generator; where the liquid is drawn through the aperture plate and converted into an aerosol.

2 The T-piece securely connects the nebulizer unit into the breathing circuit. The T-piece connections are standard male and female 22mm conical ports and connect to standard patient breathing circuits. It is recommended that the Aeroneb nebulizer be used in conjunction with a relevant T-piece supplied by HAMILTON MEDICAL.

1. Pediatric and neonatal T-adapters are sold separately.

3 The Aerogen module can be inserted into a free module bay on the device ventilator. The module is powered by the ventilator and provides one socket (green) to connect the Aerogen Module Cable. Also there is a combined Aerogen Module with a blue socket for SpO_2 monitoring and a green socket to connect a Aeroneb nebulizer.

3.4.4 Enabling the Aeroneb option

To operate Aeroneb, select **`Configuration -> Options`**.

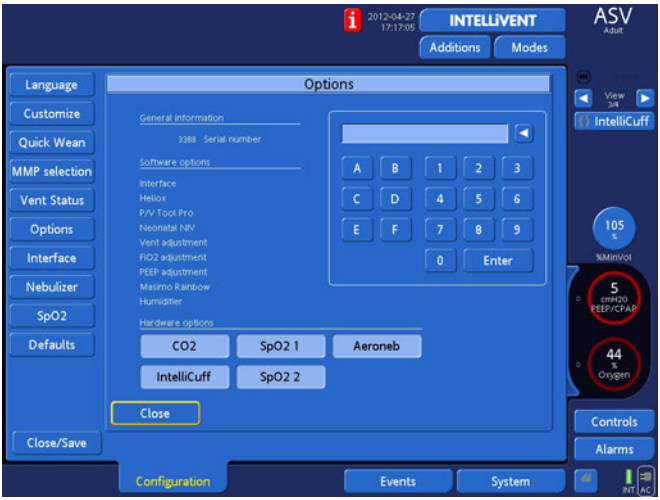


Figure 3-11. Selecting Aeroneb

3.4.5 Connecting the nebulizer

Before use, you must perform a functional test of the Aeroneb System. This is described in the functional test section of this chapter.

1. Connect the nebulizer unit to the T-piece by pushing the nebulizer unit firmly into the T-piece.

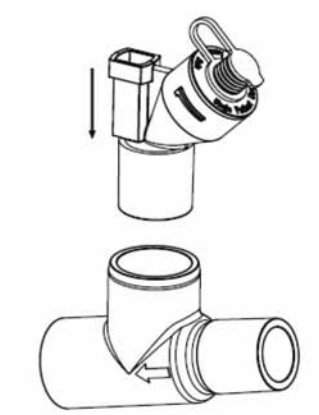


Figure 3-12. Connecting nebulizer to T-adapter

2. Insert the nebulizer and the T-piece into the breathing circuit with the arrow on the T-piece pointing in the direction of the air-flow within the circuit.
3. Connect the Aeroneb nebulizer to the Aerogen module using the nebulizer cable.

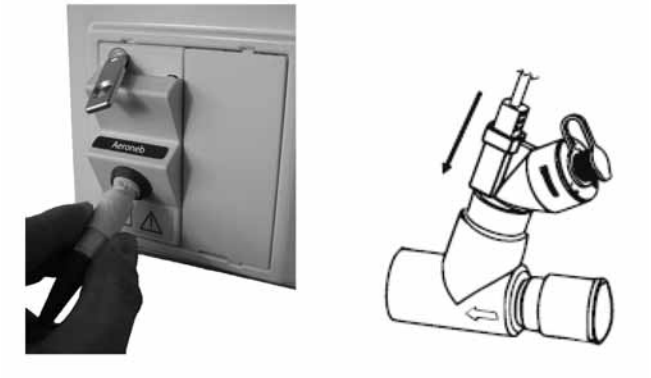


Figure 3-13. Connecting HAMILTON-G5 Aeroneb module

3.4.6 Continuous nebulization

NOTE:

DO NOT remove silicone plug from nebulizer body.

Before use perform a functional test of Aeroneb use as described here. Connect the nebulizer (Section 3.4.5) before proceeding.

1. Ensure the nebulizer unit is firmly fitted into the Aeroneb Solo T-piece in the breathing circuit.
2. Remove the cap from the medication-filled syringe.
3. Attach the syringe end of the tubing onto the syringe.
4. Prime the tubing completely.
5. Screw the nebulizer end of the tubing onto the top of the nebulizer.
6. Insert the syringe of medication into the infusion pump.
7. Turn on the continuous mode option on the Aeroneb module.
8. Observe nebulizer for proper operation. During continuous nebulization, the nebulizer is on continuously and the medication is nebulized on a drop by drop basis. Nebulization should be visible with regular intermittent pauses. Medication level in the nebulizer reservoir should not rise during use.

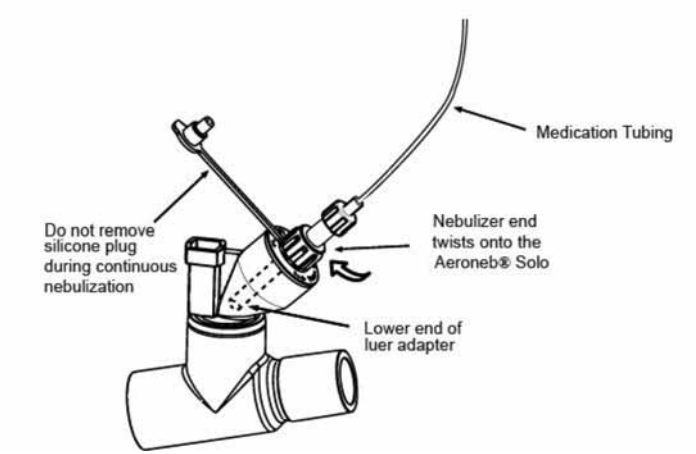


Figure 3-14. Aeroneb solo nebulizer

3.4.6.1 Setting the flow-rate for continuous nebulization

1. The input rate of medication into the Aeroneb nebulizer during continuous nebulization must not exceed 0.2 ml per minute or 12 ml per hour. Dose volumes and concentrations must be calculated accordingly.
2. Observe nebulizer for proper operation. Nebulization is visible with regular intermittent pauses.
3. During continuous nebulization operation, the nebulizer is ON continuously and the medication is nebulized on a drop-by-drop basis as it reaches the aerosol generator.

3.4.7 Installation in breathing circuit

WARNING

Condensation can collect and occlude ventilator circuits. Always position ventilator circuits so that fluid condensate drains away from the patient.

1. For adult breathing circuits, connect the nebulizer unit with adult T-piece into the inspiratory limb of the breathing circuit before the patient Y-piece.

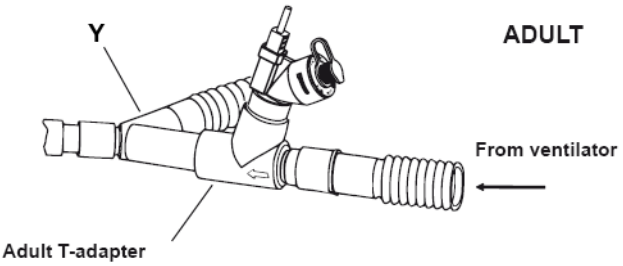


Figure 3-15. Nebulizer for adult breathing circuit

2. For pediatric breathing circuits, connect the nebulizer unit with pediatric T-piece into the inspiratory limb of the breathing circuit before the patient Y-piece.

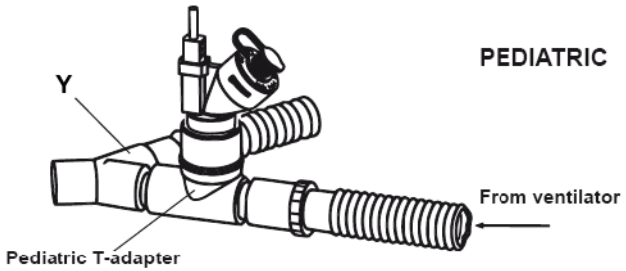


Figure 3-16. Nebulizer for pediatric breathing circuit

3. For neonatal breathing circuits, connect the nebulizer unit with the pediatric T-piece and the neonate adapters approximately 12 inch (30 cm) back from the patient Y-piece, or neonatal set-up.

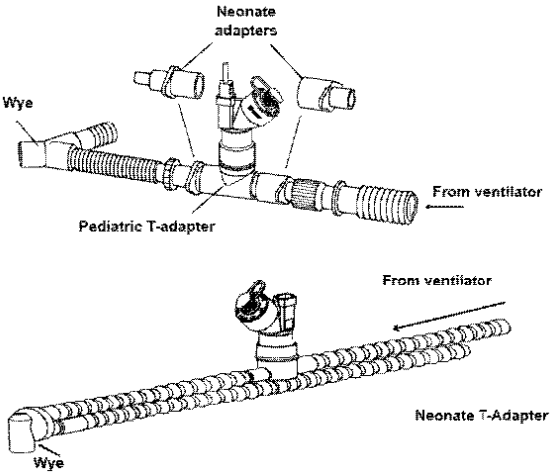


Figure 3-17. Nebulizer for neonatal breathing circuit

4. Always perform a tightness test of the breathing circuit after inserting or removing the nebulizer unit.

3.4.8 Adding medication

CAUTION

- **To avoid damage to the nebulizer unit, DO NOT use a syringe with needle.**
- **The maximum capacity of the nebulizer unit is 6 ml.**
- **Use only medication approved for nebulization during mechanical ventilation. If you use medication with inappropriate viscosity or inappropriate physical properties this can alter the performance of the ventilator system and lead to frequent alarms.**

NOTE:

Medication can also be added in this manner during nebulization. This does not interrupt nebulization or ventilation.

1. Open the plug on the nebulizer unit.
2. Use a pre-filled ampoule or syringe to add medication into the filler port of the nebulizer.
3. Close the plug.

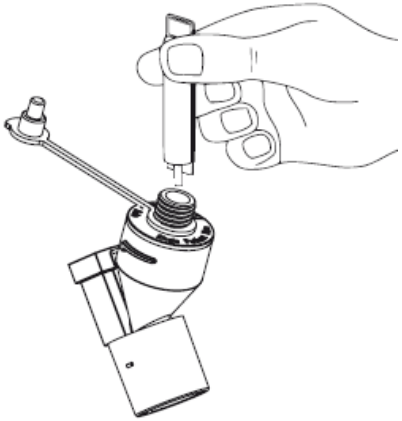


Figure 3-18. Add medication

3.4.9 Configuring nebulization

CAUTION

- **Synchronized nebulization may increase efficiency of drug delivery.**
- **Due to the aerosol deposition in the ET tube during nebulization the resistance can increase.**

3.4.9.1 Configuring nebulization for intermittent doses less than or equal to 6 ml

1. To configure nebulization, open **`System -> Nebulization`** and select **`Aeroneb`** as the active nebulizer type. The default nebulization time is 30 minutes, but can be adjusted

by the operator. Also, the operator can chose to set the synchronization of aerosol delivery.

Figure 3-19. Intermittent nebulization

2. To start an operator defined nebulization cycle, add the medication and press the **`Nebulizer`** key on the ventilation cockpit.

   During active nebulization the key is illuminated (green) to indicate a nebulization cycle is in progress. In **`System -> Nebulization`** a timer indicates the elapsed nebulization time.

3.4.9.2 Configuring nebulization for continuous doses

1. Open **`Systems -> Nebulizer`** and choose **`Aeroneb`** or **`Pneumatic`** as the active nebulizer type. Also, the operator can chose to set the synchronization of aerosol delivery.

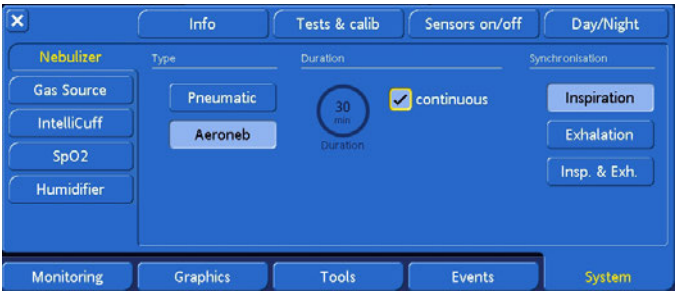


Figure 3-20. Continuous nebulization

2. To stop the nebulizer at any time, press the Nebulizer key on the cockpit. The green backlight changes on the key to white indicating the nebulization has stopped.

3. To begin the continuous nebulization cycle: connect the luer adaptor to the filler port, connect the medication supply to the luer fitting and press the **Nebulizer** key on the cockpit.

   During active nebulization the key is backlit (green) showing the nebulization cycle is in progress. In **Systems -> Nebulizer** a timer indicates the elapsed nebulization time.

4. To stop the nebulizer at any time, press the **Nebulizer** key on the cockpit. The green backlight on the key changes to white indicating the nebulization has stopped.

3.4.10 Functional test

Perform a functional test of the Aeroneb System before first use (or at any time to verify proper operation). Complete the test using these steps:

1. Visually inspect each part of the System for cracks or damage. Remove and replace parts if any defects are visible.

2. Pour 1-6 ml of sterile water or normal saline into the nebulizer unit.

3. Connect the nebulizer unit to the control module using the control module cable.

4. Select **System -> Nebulization**. Start Aerogen as active nebulizer.

5. Press the **Nebulizer** key on the Ventilation Cockpit and verify that the key is illuminated green and that aerosol activity is visible.

6. Press the **Nebulizer** key again to turn the System OFF and verify that the indicator backlight turns white to indicate that nebulization has stopped.

3.4.11 Alarms

During nebulization, if the cable is disconnected from the Aeroneb nebulizer or the integrated Aerogen Module, the ventilator will alarm with **`AERONEB disconnected`**. When the connection is re-established the alarm will automatically turn OFF.

3.5 IntelliCuff®

3.5.1 Introduction

IntelliCuff®, the integrated automatic cuff pressure controller, provides the operator with continuous monitoring and the means to adjust cuffed tracheal tubes and cuffed tracheostomy tubes.

3.5.2 Indications for use

The cuff controller is used on cuffed tracheal tubes and tracheotomy tubes for mechanical ventilation of patients. The cuff pressure controller can also be used for applications where a constant cuff pressure or an automatic adjustment to the actual ventilation conditions is necessary.

3.5.3 System description

WARNING

- **Never connect the tubing to any other device or connector other than to the automatic cuff pressure controller port on the ventilator and to the inflating tube on the tracheal tube or tracheostomy tube.**
- **Disconnect the automatic cuff controller tubing from the tracheal or tracheostomy tube if the automatic cuff pressure controller is switched off.**

CAUTION

- **Use only disposable connection tubings from HAMILTON MEDICAL. Use of any other connection tubing between ventilator and tracheal tube or tracheostomy tube will result in immediate loss of cuff pressure, in case of disconnection on the ventilator side.**
- **Check tubing regularly. Bent or kinked tubes can present incorrect monitoring information.**

The automatic cuff pressure controller for the HAMILTON-G5 ventilator includes the following components:

a) An automatic cuff pressure controller module (integrated in the ventilator and not visible from outside).

b) Disposable tubing to connect the inflating tube of a cuffed tube.

c) The ventilator.

The disposable tubing is equipped with luer connectors and a shutoff valve on the ventilator side that allows a disconnect of the tubing without loss of cuff pressure. The integrated cuff controller consists of a miniaturized pump (generating the required cuff pressure), and a pressure monitoring device with two independent pressure sensors.

When in use, the cuff controller increases the cuff pressure if required, or compensates for leakages. If the cuff pressure needs to be reduced it will actively release excessive pressures to maintain the set pressure level. To aid in intubation and extubation the cuff pressure controller can generate a small vacuum to completely deflate the cuff.

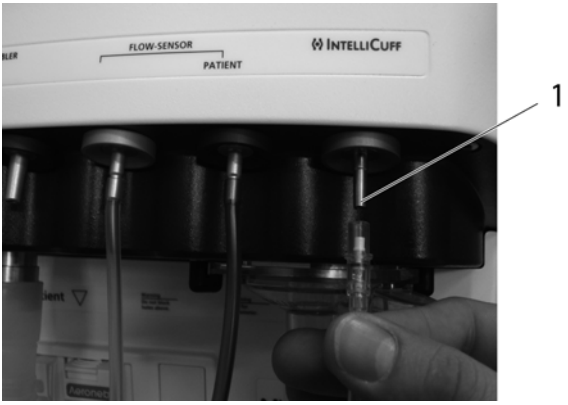


Figure 3-21. Connecting cuff tubing

1 Cuff connector

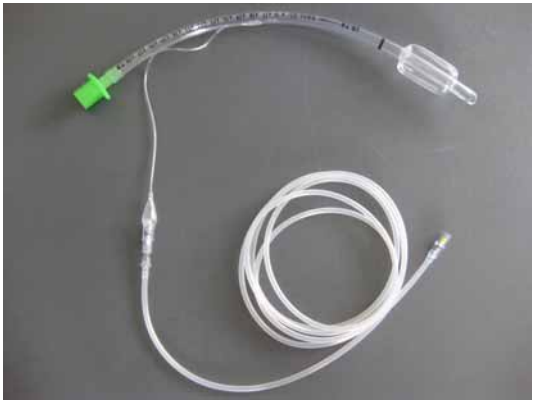


Figure 3-22. Cuff tubing connected to cuff inflating tube

1. The luer conical fitting on the ventilator securely connects the cuff tubing to the ventilator. Proper use of the connector avoids an incorrect connection with flow sensor connectors. The green color coded ring and a label INTELLICUFF on the front indicates that a automatic cuff pressure controller

is installed. The connector will work on only one end of the disposable tubing provided by HAMILTON MEDICAL.

2. On the ventilator side of the disposable tubing a shut-off valve is built into a luer connector. The shut-off valve prevents loss of cuff pressure in case of a disconnect of the tubing from the ventilator. The luer connector fits on the ventilator only at the automatic cuff pressure controller port.
3. The patient side of the disposable tubing is designed to fit the connector (pilot balloon) for cuff pressure measurement on the ET tube or the tracheotomy cannula.

Inspect all parts before use, and do not use if parts are missing, cracked or damaged. If there are missing parts, malfunction or damage, contact your HAMILTON MEDICAL product sales representative for replacements. Use only with components specified by HAMILTON MEDICAL.

3.5.4 Enabling the integrated cuff pressure controller option

1. To operate the cuff controller select **`Configuration -> Options`**.
2. Select **`IntelliCuff`** to activate the controller.

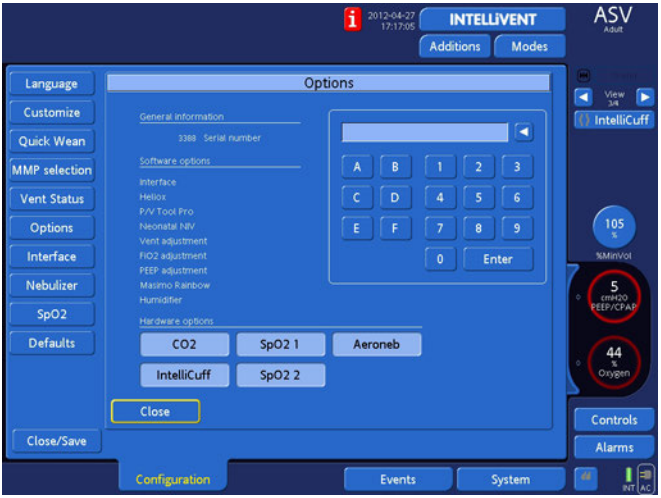


Figure 3-23. Selecting the cuff pressure controller

3.5.5 Operation of the automatic cuff pressure controller

WARNING

Cuff pressure will only be generated and adjusted if the operator has activated the cuff pressure adjustments in the System -> IntelliCuff window.

CAUTION

Use regularly the inflating tube, if available on the tracheal tube and tracheostomy tube to check proper operation of the automatic cuff pressure controller.

The device is designed to be immediately used without any calibrations.

1. First, connect the disposable tubing on the ventilator.
2. Then connect the open end of the disposable tubing to the inflating tube of the tracheal tube or tracheostomy tube.

3. Then open the **`System -> IntelliCuff`** window, make necessary adjustments, and activate cuff pressure adjustments.

3.5.6 Operating modes

The automatic cuff pressure controller works in different modes of operation allowing the operator to find the suitable solutions for most clinical situations.

3.5.6.1 Cuff pressure control OFF

CAUTION

The inflating tube will remain initially pressurized and will not indicate that the automatic adjustment is deactivated and switched OFF. When the cuff pressure control is switched OFF then all alarms related to the automatic cuff pressure controller are disabled.

Selecting the **OFF** button deactivates automatic cuff pressure adjustments. When OFF, the cuff pressure is not released, however, leakage of the cuff will no longer be compensated.

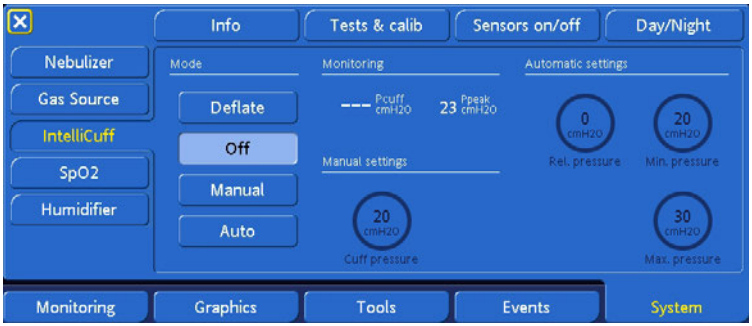


Figure 3-24. User Interface for automatic cuff pressure control (manual or no automatic adjustment activated)

3.5.6.2 Setting constant cuff pressure (MANUAL)

CAUTION

Set the cuff pressure carefully to avoid damages of the trachea as well as airway leak or aspiration which can increase the risk of ventilator associated pneumonia. Use the inflating tube of the tracheal tube or tracheostomy tube to verify that the cuff pressure controller is generating pressure and reacts immediately on squeezing the pilot balloon.

Select the **`Manual`** button to set the cuff pressure and maintain the actual cuff pressure at this level. To adjust the cuff pressure setting, press the **`IntelliCuff`** button and modify the setting. The set cuff pressure will be constant independent of actual airway pressures. During P/V Tool and automatic recruitment maneuvers, the cuff pressure is set automatically – in case of P/V Tool equal to Ptop + 5 cmH2O and in case of automatic recruitment applied by INTELLiVENT® to 45 cmH2O.

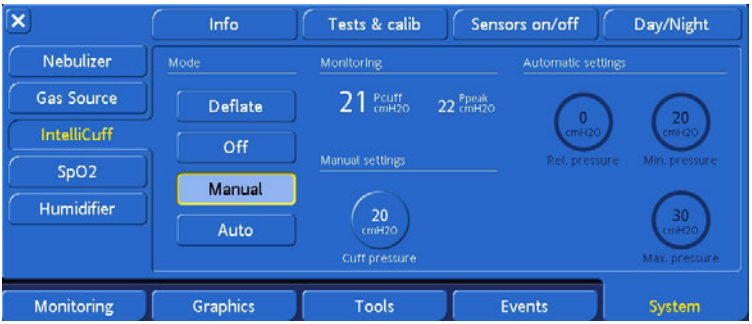


Figure 3-25. User Interface for cuff controller, showing cuff pressure kept constant at manually set level.

3.5.6.3 Setting cuff pressure relative to airway pressure (AUTO)

WARNING

Set the minimum and maximum pressure carefully to avoid damages of the trachea as well as airway leak or aspiration which can increase the risk of ventilator associated pneumonia occurring.

CAUTION

Use the inflating tube of the tracheal tube or tracheostomy tube to verify that the cuff pressure controller is generating pressure and reacts immediately on squeezing the pilot balloon.

Selecting the **Auto** button switches on the automatic cuff pressure adjustments and maintains the actual cuff pressure at the automatically adapted level.

Figure 3-26. User Interface for cuff controller, cuff pressure automatically adapted to actual airway pressure

The operator sets the cuff pressure relative to the averaged airway pressure (Ppeak). This difference between Ppeak and Pcuff is kept constant (Rel. Pressure difference) to provide a tight sealing of the cuff. The applied cuff pressure will vary between the operator-set adjustable minimum and maximum pressure limits, avoiding excessive pressure which can harm the trachea or too low pressure risking aspirations and airway leaks.

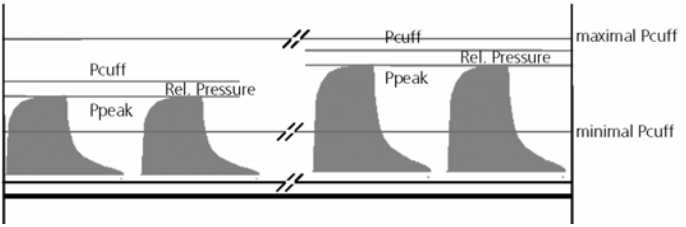


Figure 3-27. Concept of automatically set Pcuff based on patient's airway pressure

During PV Tool and automatic recruitment maneuvers in order to avoid airway leaks the cuff pressure is set automatically equal to Ptop + 5 mbar in case of PV Tool and to 45 mbar in case of automatic recruitment applied by INTELLiVENT®.

3.5.6.4 Full deflation of the cuff

WARNING

Verify after successful intubation that the cuff is properly inflated and the automatic cuff pressure controller is switched ON.

To support intubation and extubation the operator can fully deflate the cuff by activating **`Deflate`**. In this mode of operation a negative pressure is temporarily applied to allow full deflation of the cuff during intubation and extubation. After pressing Deflate a window asking the user to confirm the deflation is popping up. In this way avoiding a deflation and loss of pressure by accidental pressing of **`Deflate`**.

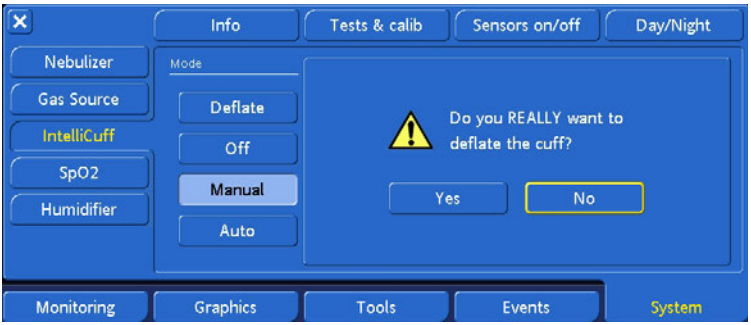


Figure 3-28. User Interface for cuff controller, showing full deflation of cuff

3.5.7 Alarms

If during automatic or manual cuff-pressure adjustment a leaking cuff is detected, the ventilator alarms with a low-priority alarm. After pressing **`Deflate`**, a window asking the user to confirm the deflation appears. This helps avoid unintentional deflation and loss of pressure by accidentally pressing **`Deflate`**. Disconnection of the connecting tubing between tracheal tube and ventilator results in a medium-priority disconnection alarm (see section 10.5).

3.6 Working with the integrated HAMILTON-H900 humidifier

NOTE:

- Integration with the ventilator system is available only with the HAMILTON-H900 humidifier. You can use other supported humidifiers with the system, without the integration.
- The integrated humidifier is not available in all markets. Check with your distributor to determine availability.

3.6.1 Introduction

Using the HAMILTON-H900 humidifier with the HAMILTON-G5 ventilator offers full integration of the humidifier controls, providing easy visibility of, and access to, humidifier operation and settings directly from the ventilator cockpit.

In addition, functions are synchronized. When the ventilator goes into Standby, the humidifier also automatically enters Standby mode. Alarms appear on both devices. The humidifier also integrates with any installed nebuliser. When the nebulizer is active, the humidifier goes into Standby to prevent rainout.

3.6.2 Humidifier overview

The HAMILTON-H900 is a next-generation humidifier offering a cable-free, easier-to-use experience, among other innovations and benefits.

When connected and activated, data from the humidifier is transmitted to the ventilator and can be controlled from the system. The humidification data can also be transmitted from the ventilator to a connected PDMS.

For detailed information about the humidifier and its operation, refer to the HAMILTON-H900 Operating Instructions provided with the humidifier.

Figure 3-29. HAMILTON-900 humidifier, front view

1 Water chamber and filler tube

2 Breathing circuit with integrated heater wire and temperature probe

3 Connection quality indicator lights (green, orange, red)

4 Large LCD display showing temperature and humidity, and alarms, also provides access to humidifier controls

5 On/Off key

6 Alarm silence key

7 Connection and power ports (bottom of device; for detail view, see Figure 2-8)

3.6.3 Setting up the humidifier

NOTE:

- When the humidifier is properly installed and connected, the connection arrows (item 3 in Figure 3-29) are green. When the connection is faulty, the arrows are orange.
- Ensure the water chamber is properly filled with sterile water. If the water level is too low, an alarm message is displayed both on the ventilator and on the humidifier.

Humidifier set up involves the following main steps:

- Attaching and connecting the humidifier. See Section 2.4.
- Connecting the breathing circuit and water chamber. See the HAMILTON-H900 Operating Instructions.
- Activating humidifier operation on the ventilator. See the ventilator Service Manual.
- Configuring humidifier settings. See Section 3.6.4 and the HAMILTON-H900 Operating Instructions.

3.6.4 Humidifier display on the ventilator

Once activated, the humidifier visualization is available in the **`System -> Humidifier`** window.

This window displays information on the state of the humidifier. You can control the humidifier from both the ventilator screen and at the humidifier directly.

Further, all humidifier-specific alarms are integrated with ventilator alarms. For details on humidifier-specific alarms, see Section 3.6.6. For general details on ventilator alarms, see Chapter 10, Responding to alarms.

Sensors in the breathing circuit measure mist temperature at the humidifier and at the patient Y piece. A visual representation of the humidifier breathing circuit is displayed on the ventilator screen, and displays the current temperature. This screen also provides access to humidifier controls.

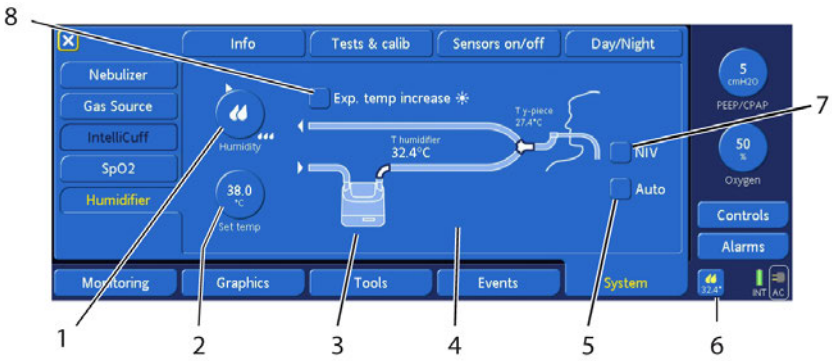


Figure 3-30. Humidifier window

1 **Humidity control.** Shows the humidity setting. This control provides the same function as the humidity bar on the humidifier, in manual mode.

2 **Temperature control.** Shows the set temperature. This control provides the same function as the temperature bar on the humidifier, in manual mode.

3 **Humidifier visualization.** Shows the circuit, and the temperature at the humidifier and at the Y piece.

4 **Alarm message area.** Alarm messages appear in this space, as well as in the ventilator alarm area and alarm buffer. All alarms are saved to the Event log.

5 **Auto mode.** When selected, the humidifier adapts to the ambient conditions and automatically adjusts humidity and temperature settings to meet the default settings.

6 **Humidity window Quick Access button.** Select to quickly display this window.

7 **NIV mode.** Select this option when using a noninvasive interface.

8 **Expiratory limb temperature increase option.** Select this option when condensation appears in the expiratory limb to increase the temperature.

3.6.5 Controlling humidifier options

Detailed information about controlling the humidifier settings are in the HAMILTON-H900 Operating Instructions. We provide here an overview of how to control the humidifier from the ventilator screen.

The water temperature is monitored, and the data can be transmitted to a connected PDMS.

Table 3-2. Controlling humidifier options on the ventilator

To ...	Do this ...
Change the humidity	Select the Humidity control (item 1 in Figure 3-29), then, using the P&T knob, select and set the desired humidity level.
Change the temperature	Select the Temperature control (item 2 in Figure 3-29), then, using the P&T knob, select and set the desired temperature.
Switch between Auto and Manual mode	To enable Auto mode, select the **Auto** check box (item 5 in Figure 3-29). To enable **Manual** mode, ensure the **Auto** check box is clear.
Quickly display the Humidifier window from any screen	Select the Humidifier Quick Access button in the bottom right of the screen (item 6 in Figure 3-29). 
Specify noninvasive ventilation mode	Select the NIV check box (item 7 in Figure 3-29). **CAUTION** **Only use this mode for noninvasively ventilated patients.**
Reduce condensation in expiratory tube	Select the **Exp. temp increase** check box (item 8 in Figure 3-29). This increases the heat in the expiratory limb.

3.6.6 Alarms

When an alarming condition occurs on the humidifier, the alarm is displayed in the following locations: both on the humidifier and in the ventilator alarm area.

- On the humidifier display
- Ventilator alarm area
- **`System -> Humidifier`** window on the ventilator

To silence the alarm, press the Alarm Silence key on the humidifier or on the ventilator.

Table 3-3 lists the humidifier-related alarms.

Table 3-3. Humidifier-related alarms

Alarm	Do this ...
High water level in the humidifier chamber	Possible causes: The autofeed mechanism is defective, the pressure in the water reservoir is too high or humidifier is mounted at an excessive angle. • Empty humidifier to reduce water level. • Replace the humidifier chamber. • Check the mounting of the humidifier to avoid excessive angles.
Low water level in the humidifier chamber	Possible causes: Empty water reservoir, water level below minimum, tilted humidifier, defective autofeed mechanism or no chamber inserted. • Insert humidifier chamber and check water reservoir. • Refill empty humidifier chamber. • If the water reservoir is empty, connect a new water reservoir. • Check the mounting of the humidifier to avoid excessive angles.

Table 3-3. Humidifier-related alarms

Alarm	Do this ...
Temperature too high near the patient	Possible cause: Ambient temperature too high. • Check whether the circuits are covered by the patient's bed covers. • Check whether the circuit or the humidifier chamber is directly exposed to sunlight. • Check whether the temperature settings are correct.
Temperature too low/ target humidity not reached	Possible causes: The device was just turned on, ambient conditions outside recommended range or flow beyond specified range. • Wait until the system heats up completely (up to 30 minutes). • Check whether all settings are correct. • Avoid direct air flow from air conditions, etc. to the humidifier and breathing circuits.
Humidifier: Check (left or right) tube + orange light on connection indicator on humidifier (item 3 in Figure 3-29)	Check the breathing circuit connection on the specified side. A green light indicates a good connection.
Humidifier: Red light on connection indicator on humidifier (item 3 in Figure 3-29)	Service the humidifier. See the HAMILTON-900 Operating Instructions and the Service Manual.

4 Tests, calibrations and utilities

4.1 Introduction

The tests and calibrations described in this section help verify the safety and reliability of the device. Perform the tests and calibrations as described in Table 4-1.

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

Ensure the device passes the tests before you return the ventilator to clinical service.

Table 4-1. When to perform tests and calibrations

When to perform	Test or calibration
Before placing a new patient on the ventilator. **WARNING** **To ensure the ventilator's safe operation, always run the full pre-operational check before using the ventilator on a patient.** **If the ventilator fails any tests, remove it from clinical use immediately. DO NOT use the ventilator until necessary repairs and tests are completed and device is returned to clinical service.**	Preoperational check
1. Required after changing patient type. 2. Recommended after switching between air and heliox.	Flow sensor calibration
1. Required after installing a new or decontaminated breathing circuit or component (including a flow sensor). 2. Recommended before performing a P/V Tool maneuver.	Tightness test, flow sensor calibration
After installing a new oxygen cell or when a related alarm occurs.	Oxygen cell calibration

Table 4-1. When to perform tests and calibrations

When to perform	Test or calibration
1. Required after installing a new, previously unused CO_2 sensor, or when a related alarm occurs. 2. Recommended after switching between different airway adapter types. **NOTE:** • Calibrate only if prompted by the device. • All calibration data is saved in the sensor head. Therefore, when a previously used sensor is reconnected, you need not recalibrate the sensor unless you have changed the adapter type.	CO_2 sensor/adapter calibration
Periodically, as desired.	Alarm tests

4.2 Pre-operational checks

WARNING

DO NOT perform this check while a patient is connected to the ventilator. Ensure that another source of ventilatory support is available.

NOTE:

Ensure that O_2 monitoring is enabled before starting this check (when O_2 monitoring is disabled, the message **O_2 `alarms off`** is displayed in the alarm limits window).

When to perform: Before placing a new patient on the ventilator.

Required materials: Use the set up below appropriate to your patient type. To ensure that the ventilator also functions according to specifications on your patient, we recommend that your test circuit be equivalent to the circuit used for ventilation.

Adult patients	• Breathing circuit, 19 mm ID with 22F connectors • Flow sensor, pediatric/adult • Demonstration lung, 2 l, with adult ET tube between flow sensor and lung • CO_2 and SpO_2 sensors, adapters, accessories
Pediatric patients	• Breathing circuit, 15 mm ID with 22F connectors • Flow sensor, pediatric/adult • Demonstration lung, 0.5 l, with pediatric ET tube between flow sensor and lung • CO_2 and SpO_2 sensors, adapters, accessories
 Neonatal patients	• Breathing circuit, 10 mm ID with 10F connectors • Flow sensor, infant • Lung model, infant/neonatal, with infant/neonatal ET tube between flow sensor and lung model (An IngMar neonatal lung model is recommended) • CO_2 and SpO_2 sensors, adapters, accessories

Procedures:

Do or observe...	Verify...	Notes
1. Connect ventilator to AC power, compressed air and oxygen supplies. 2. Assemble the patient breathing circuit.	Breathing circuit is assembled correctly.	Complete this task.
1. Switch power ON.	When ventilator is switched ON, an audio alarm sounds and the alarm lamp is red. After the self-test is passed the alarm lamp turns red again.	The audio alarm sounds briefly after the device is switched ON.
1. 1. Open **System** and **Tests & calib** window (Figure 4-3). 2. 2. Select and run **Flow Sensor** calibration. 3. Select and run **Tightness** test. 4. Follow all system prompts.	Each test result is positive.	For details on running these tests and calibrations, refer to Figure 4-3.
1. When necessary, run **O_2 cell calibration**. 2. Close window.	Each test result is positive.	

Do or observe...	Verify...	Notes
Generate an alarm (for example, generate an **Air supply failed** alarm by disconnecting the air supply and then starting ventilation).	Corresponding alarm message appears in the message bar (in this example: **Air supply failed**).	After standby, all alarms except **Air supply failed** and **Loss of mains power** are suppressed for 1 min.
Resolve the alarm situation (for example, reconnect air supply).	Alarm reset.	

4.2.1 Pre-operational check with heliox

WARNING

Always perform this test before using the device on a patient.

Do or observe...	Verify...	Notes
1. Connect ventilator to AC power, heliox, compressed air and oxygen supplies. 2. Assemble the patient breathing circuit.	Breathing circuit is assembled correctly.	Complete task.
Switch on power.	When ventilator is switched on, an audio alarm sounds and the alarm lamp is red. After the self-test is passed the alarm lamp turns red again.	The audio alarm sounds only briefly in the beginning.

Do or observe...	Verify...	Notes
If necessary, run **O_2 cell calibration**. Close window.	These tests pass.	
Open **System** and **Gas source** window and select **Air**. Close window.		
Generate an alarm **Air supply failed** alarm by disconnecting the air supply and then starting ventilation.	Corresponding alarm message in message bar **Air supply failed**.	After standby, all alarms except **Air supply failed** and **Loss of mains power** are suppressed for 1 min.
Return to standby. Open **System** and **Gas source** window and select **Heliox**. Close window.		The Heliox symbol is displayed and the alarm lamp is blue.
Generate a **Heliox supply failed** alarm by disconnecting the Heliox supply and then starting ventilation.	Corresponding alarm message in message bar (**Heliox supply failed**).	After standby all alarms except **Heliox supply failed** and **Loss of mains power** are suppressed for 1 min.
Resolve the alarm situation by connecting the valve at the Heliox bottle.	Alarm is reset.	
Open **System** and **Tests & calib** window (Figure 4-3). Select and run **Flow Sensor** calibration, then **Tightness** test. Follow all prompts.	These tests pass.	For details on running these tests and calibrations, refer to Figure 4.2.

4.3 System functions

NOTE:

The audible alarm is silenced during the calibration functions and for 30 seconds thereafter.

You can perform ventilator utilities from the **System** window.

4.3.1 Info: Viewing ventilator operating hours, options, and versions

Open the **System -> Info** window (Figure 4-1) to view the date and time, ventilator operating hours, configuration settings, options, and version information.

Figure 4-1. Info window, screen 1

1 Navigation arrows between window 1 and 2

2 Configuration settings

3 Software options

4 Software revisions:
IPP: interaction panel processor
VUP: ventilator unit processor
VRC: ventilator real-time controller
VIP: ventilator interface processor

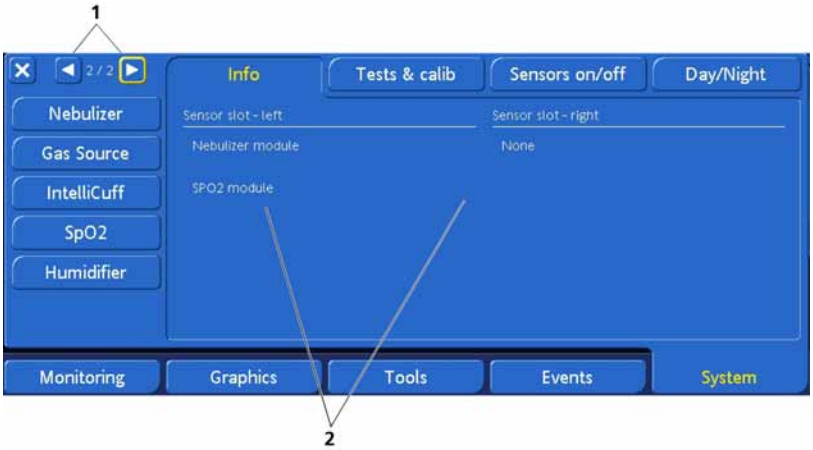


Figure 4-2. Info window, screen 2

1 Navigation arrows between window 1 and 2

2 Contents of module slots

4.3.2 Tests & calib: Running sensor calibrations and the tightness test

Touch the **`System -> Tests & calib`** window (shown in Figure 4-3) to view and access the tests and calibrations.

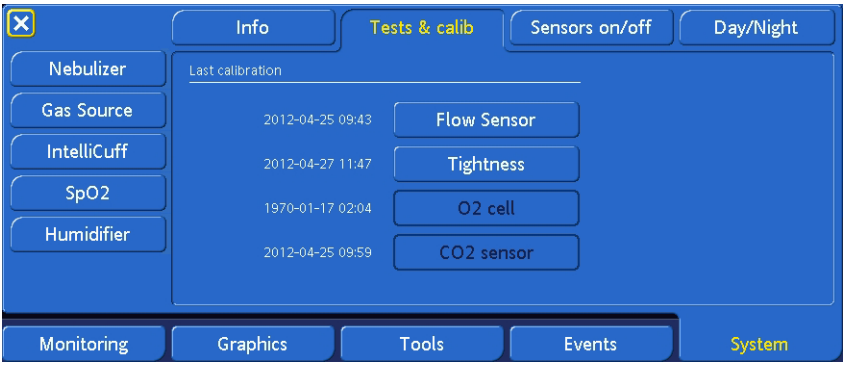


Figure 4-3. Tests & calib window

4.3.2.1 Flow sensor calibration

NOTE:

- Ensure another source of ventilatory support is available during this calibration. The patient must be disconnected from the ventilator during the calibration process.
- Wait 2 minutes before calibrating the flow sensor following a switch between air and heliox or a significant change in Oxygen setting. This allows the mixture to stabilize.
- Patient alarms are suppressed during flow sensor calibration.
- To cancel the flow sensor calibration while in progress, touch **`Flow Sensor`** a second time, or close the **`Tests & calib`** window.
- To ensure valid results, DO NOT touch the screen during the calibration operations.

- After the flow sensor calibration is complete, there can occur a transitional **Apnea** alarm. This alarm will disappear after 5 seconds.
- If you close the **Tests & calib** window when the calibration has failed, the device starts ventilating but continues to display **Flow Sensor Cal. needed.** This can result in inaccurate monitoring.
- During flow sensor calibration, the device can recognize a mismatch between the active patient profile and the flow sensor type you are using. If this happens, the **Wrong Flow Sensor** type alarm will be activated.
- The flow sensor must be in the correct position. If you intend to ventilate with nCPAP-PS, the flow sensor calibration has to be done with the flow sensor at the proximal side of the patient and not at the expiration valve of the ventilator.

Description: This calibration checks and resets the calibration points specific to the flow sensor you are using.

Procedure for pediatric/adult flow sensor:

1. Set the ventilator for normal ventilation including a breathing circuit, flow sensor, and expiratory membrane and cover. Confirm you have, a) selected the correct patient profile, and b) installed the appropriate flow sensor type (pediatric/adult).
2. From the **Tests & calib** window, touch **Flow Sensor** to activate.
3. The message bar now displays **Disconnect patient**. Disconnect the breathing circuit at the patient side of the flow sensor. DO NOT block the open end of the flow sensor.
4. When the message bar displays **Turn the Flow sensor**, reverse the ends of the flow sensor so the tubes are closest to the Y-piece.
5. When the message bar again displays **Turn the Flow sensor**, reverse the ends of the flow sensor so the tubes are now away from the Y-piece.

6. Verify that the message bar displays **Flow Sensor calibrated OK**.
7. Reconnect the patient, and close the **Tests & calib** window.

Possible corrective action: If the message bar displays **Flow Sensor Cal. needed**, repeat the calibration. If you receive a second calibration failure, you MUST install a new flow sensor.

Procedure for infant/neonatal flow sensor:

NOTE:

- DO NOT turn the infant flow sensor during calibration.

1. Configure the ventilator for normal ventilation, complete with breathing circuit, flow sensor, and expiratory membrane and cover. Ensure the **Infant** patient profile is selected and that an infant flow sensor type is installed.
2. From the **Tests & calib** window, touch **Flow Sensor**.
3. The message bar now displays. Disconnect the breathing circuit at the patient side of the flow sensor. DO NOT block the open end of the flow sensor.
4. Verify that the message bar displays **Flow Sensor calibrated OK**.
5. Reconnect the patient, and close the **Tests & calib** window.

Possible corrective action: If the message bar displays **Flow Sensor Cal. needed**, run the calibration again. If you receive a second calibration failure, you MUST install a new flow sensor.

4.3.2.2 Tightness test

NOTE:

- Ensure another source of ventilatory support is available during this test. The patient must be disconnected from the ventilator while performing this test.
- Patient alarms are suppressed during the tightness test.
- To cancel the tightness test while in progress, select Tightness again, or close the **Tests & calib** window.
- To ensure valid results, DO NOT touch the screen during the test.

Description: This test checks for leakage in the patient breathing circuit and determines the circuit's compliance compensation factor. The device uses this factor to compensate the volume lost due to circuit compliance. The ventilator is pressurized to 50 cmH2O. The circuit is considered tight if this pressure can be maintained. If there is a leak, the pressure falls in proportion to the size of leak.

Procedure:

1. Set the ventilator up as for normal ventilation, complete with breathing circuit.
2. From the Tests & calib window, select **Tightness**.
3. If you have not already disconnected the patient, the message bar displays Disconnect patient. Disconnect the breathing circuit on the patient side of the flow sensor.
4. The message bar displays **Tighten patient system**. Block the opening (a finger covered with an alcohol pad may be used).
5. Wait for a few seconds, and Verify that the message bar displays **Patient system tight**.
6. Reconnect the patient, and close the **Tests & calib** window.

Possible Corrective action: If the test does not proceed or if the message bar displays **Check patient system**, inspect the circuit connections. Replace leaking parts and repeat the tightness test.

4.3.2.3 Oxygen cell calibration

NOTE:

- Disconnecting the patient from the ventilator is not required when performing the oxygen cell calibration.
- The oxygen cell calibration requires that an oxygen cell be installed, that the device`s oxygen monitoring is enabled, and that oxygen be available.
- Oxygen alarms are suppressed during oxygen cell calibration.

Description: During this 2 minute calibration of the oxygen cell, the device delivers the operator-set oxygen percentage to the patient. It tests the cell and resets the calibration points specific to the cell in use.

Procedure:

1. Ensure the appropriate gas supplies are connected to the device.
2. From the **Tests & calib** window, touch the **O_2 cell** button.
3. Verify that, after 2 min, **O_2** cell calibration OK is displayed. Close the **Tests & calib** window.

Possible corrective action: If **O_2 cell cal. needed** is displayed, the cell could not be calibrated. Verify that the oxygen cell is correctly installed and the cable connected and that oxygen is available. Repeat the calibration. If the calibration fails a second time, you must install a new oxygen cell. If **O_2 cell defective** is displayed, you must install a new cell.

4.3.2.4 CO_2 sensor/adapter zero calibration

CAUTION

- **Always calibrate the CO_2 sensor with the airway adapter installed.**
- **DO NOT close both connectors of the airway adapter with your fingers.**

NOTE:

- The CO_2 sensor and airway adapter must be removed from the patient circuit and connected to each other during the CO_2 sensor/adapter calibration.
- The CO_2 sensor/adapter calibration requires a CO_2 sensor be installed, the CO_2 hardware be activated (see Appendix J, Configuration), and that CO_2 monitoring be enabled.
- Wait at least 2 minutes to perform the CO_2 sensor/adapter calibration after removing the adapter from the patient's airway. This time allows any CO_2 remaining in the adapter to dissipate and provides best results for the test.
- If you close the **`Tests & calib`** window when the calibration has failed, the device continues ventilation but displays **`CO2 sensor calibration needed`**. This may result in inaccurate monitoring.
- To calibrate the sidestream sensor disconnect the adapter from the patient circuit.

Description: The CO_2 sensor/adapter zero calibration compensates for the optical differences between airway adapters and for sensor drift.

Procedure:

1. Connect the CO_2 sensor with adapter to the ventilator (Figure 4-4). Do not connect the adapter to the patient circuit. Place the sensor with the adapter installed away

from all sources of CO_2 (including the patient's – and your own exhaled breath) and exhaust port of expiratory valve. DO NOT agitate the sensor during calibration.

Figure 4-4. CO_2 sensor/adapter calibration setup

2. From the **Tests & calib** window, touch the **CO_2 sensor button**. The message display shows **CO_2 calibration in progress.**
3. Verify that the message bar displays **CO_2 sensor calibrated OK**.
4. Close the **Tests & calib** window.

Possible corrective action: If the calibration fails, refer to Table 10-2 to troubleshoot.

4.3.2.5 SpO_2 sensor/adapter test

SpO_2 sensors cannot be calibrated, but must be tested for proper functioning before use.

To test for proper functioning, connect the sensor to your finger, and verify a plethysmographic curve and an SpO_2 value are displayed.

4.3.3 Sensors on/off: Enabling/disabling SpO_2, O_2, and CO_2 monitoring

WARNING

The HAMILTON-G5's oxygen monitoring function can be disabled. To prevent possible patient injury due to nonfunctional alarms and monitoring, however, HAMILTON MEDICAL recommends oxygen monitoring always be enabled.

NOTE:

- For automatic oxygen adjustment, O_2 monitoring must be enabled.
- O_2 monitoring is enabled and cannot be disabled during heliox administration.
- To enable CO_2 and SpO_2 monitoring, configure this hardware option first (see Appendix J). When this option is disabled, the corresponding alarms and monitoring values are not displayed.
- Not all controllers are operational if SpO_2, O_2 and CO_2 are disabled.

To enable sensors:

1. Touch the tab **`System -> Sensors on/off`** window (Figure 4-5).
2. When required, touch the **O_2 monitoring**, **CO_2 monitoring**, and/or appropriate **SpO_2 monitoring** check boxes to enable/disable these monitoring functions.

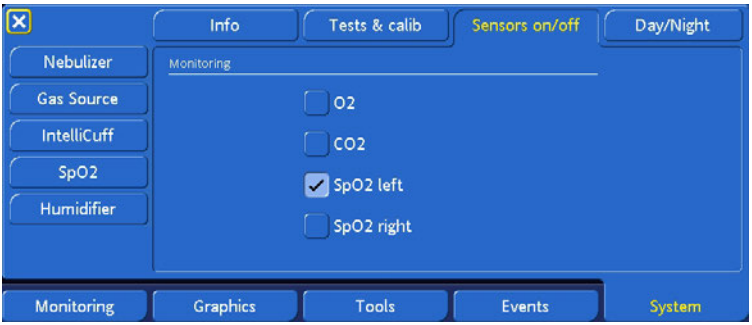


Figure 4-5. Sensors on/off window

When SpO_2, O_2 or CO_2 monitoring is disabled, the appropriate Alarms Off message is displayed in the Alarm limits window.

4.3.3.1 Gas source: Assigning air or heliox

WARNING

A mismatch of selected and actual source gas causes inaccurate gas delivery and volume monitoring.

NOTE:

- The ventilator must be in standby to change the source gas assignment.
- Use heliox of 78% (He)/ 22% (O_2). This 78/22 mixture is recommended as this allows the maximum amount of helium to be used while consuming less gas when used in conjunction with a mechanical ventilation (you can also use 80/20 and 79/21 mixtures).
- After switching between air and heliox, it is recommended you calibrate the flow sensor.
- During heliox administration O_2 monitoring is enabled and cannot be disabled.

Heliox is a mixture of helium and oxygen, and can be indicated for patients in cases of acute and life-threatening upper airway obstruction. This action is taken as a temporary measure to provide a decrease in the patient's work of breathing while the cause of the obstruction is treated.

Administering heliox can make it easier to ventilate, because its lower density can allow a patient to produce inspiratory and expiratory flows with less turbulence.

To select the desired gas:

1. Put the ventilator in standby.
2. Open the **System -> Gas source** window (Figure 4-6). choose the **Air** or **Heliox** button. Close the window.
3. Close the window.

   The message **Flow Sensor Cal. needed** is displayed.
4. Calibrate the flow sensor.

When heliox is selected, the alarm lamp on top of the cockpit displays a blue color. If the ventilator alarms while heliox is being delivered, the blue lamp alternates with red or yellow.

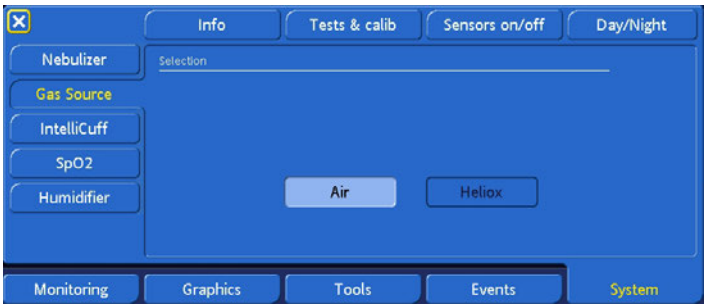


Figure 4-6. Gas Source window

4.3.4 Setting day and night

1. Open the **System -> Day/Night** window.
2. Switch from day mode to night mode by touching the **Night** button or from night mode to day mode by touching the **Day** button.

Change the brightness of the screen for the day or night mode with the **Display** control knob. To dim the alarm lamp use the **Alarm Lamp** button. The default illumination settings of the (ICU) unit can be stored in the configuration. To set the (ICU) units default illumination settings use the **Restore** button.

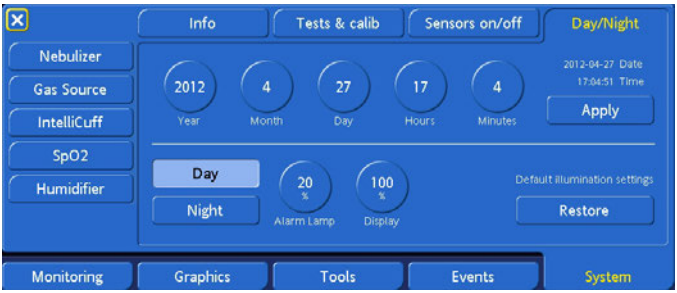


Figure 4-7. Day/Night window

4.3.5 Setting date and time

NOTE:

Correctly set the date and time so that event log entries reflect accurate time and date stamps.

1. Open the **System -> Day/Night** window.
2. Adjust the date and time. **Apply** the changes.

4.4 Alarm tests

The HAMILTON-G5 performs a self-test at startup and continuously during operation. The self-test verifies alarm function. You can choose to run alarm tests confirming an alarm's operation.

Before performing the alarm tests, set the device up as for normal ventilation, complete with breathing circuit and 2 l demonstration lung assembly with ET tube.

4.4.1 High pressure

1. Ensure a 2 l demonstration lung assembly is connected to the device.
2. Set the device in the P-CMV mode.
3. Set the high Pressure alarm limit to 15 cmH2O above the measured Ppeak.
4. Squeeze the demonstration lung hard during inspiration
5. Verify that the **High pressure** alarm activates, inspiration ceases, and pressure falls to the PEEP/CPAP level.

4.4.2 Low minute volume

1. Let the ventilator deliver 10 breaths with no alarms.
2. Adjust the low ExpMinVol alarm limit so it is higher than the measured value.
3. Verify that the **Low minute volume** alarm activates.

4.4.3 Oxygen supply failed and low oxygen alarms

1. Set the Oxygen control to 50%.
2. Wait for 2 minutes.
3. Disconnect the oxygen supply.
4. Verify that the **Oxygen supply failed** alarm activates and the Oxygen concentration displayed in the monitoring window (**1**) decreases. Verify that the **Low oxygen** alarm activates.
5. Then wait 30 seconds, or until the oxygen concentration falls below 40%.
6. Reconnect the oxygen supply.
7. Verify that the **Oxygen supply failed** and the **Low oxygen** alarms reset. The **Low oxygen** alarm resets when the measured oxygen exceeds 45%.

4.4.4 Disconnection

1. Disconnect the inspiratory limb or the demonstration lung.
2. Verify that the **Disconnection** alarm activates.
3. Reconnect the inspiratory limb or the demonstration lung.
4. Verify the alarm resets and the device automatically resumes ventilation.

4.4.5 Loss of mains power

1. Turn the device ON (AC power source).
2. Disconnect the power cord.
3. Verify that the **Loss of mains power** alarm activates and that the power source shifts to the backup battery without interruption of service.
4. Reconnect the to AC power.
5. Verify that the alarm resets and the device show the power source is again AC mains.

4.4.6 Exhalation obstructed

1. Block the expiratory valve exhaust port.
2. Observe the pressure rise.
3. Verify the **Exhalation obstructed** alarm activates after the **High pressure** alarm.

4.4.7 Apnea

1. Put the device into the SPONT mode.
2. Switch apnea backup ventilation OFF.
3. Squeeze the demonstration lung several times to trigger a breath. Wait for the set apnea time.
4. Verify that the **Apnea** alarm activates.
5. Squeeze the demonstration lung again.
6. Verify that the trigger indicator is displayed and the **Apnea** alarm resets.

5 Ventilator settings

5.1 Introduction

WARNING

- **To ensure the ventilator's safe operation, always run the prescribed tests and calibrations before using the ventilator on a patient. If the ventilator fails any tests, remove it from clinical use immediately. DO NOT use the ventilator until necessary repairs are completed and all tests are successful. Ensure the ventilator is set up for the appropriate patient conditions with the appropriate breathing circuit parts, including the appropriate flow sensor, as described in Chapter 2.**
- ***Confirm a flow sensor calibration has been performed before you use the ventilator*.**
- **It is the clinician's responsibility to ensure that all ventilator settings are appropriate, even when "automatic" features such as automatic alarm setting, ASV, MinVol adjustment, PEEP adjustment or Oxygen adjustment are used.**

This section introduces how to set up the device for ventilation on a patient. Prepare the ventilator as instructed in Chapter 2, Setting up the ventilator. Be familiar with the Ventilation Cockpit. Use the touch screen and buttons comfortable to select, activate, and confirm parameters. For details, see section 2.17.

5.2 Setting up the patient

WARNING

- **Ensure you choose the correct patient profile of gender, adult, pediatric, and neonatal. Correct selections prevent possible hyper- or hypo-ventilation.**
- **Entering a substantially wrong height/IBW input will lead to a deviation of rate setting. Please check your entered value carefully on the standby window, or after start of the ventilation on the dynamic lung screen.**

NOTE:

- If you selected **New patient**, the basic screen will open with the default settings for mode, control, and the alarm settings. If you selected **Last patient**, the settings you see are the last active ventilator parameters in use.
- Default patient group for **New patient** and default settings for each patient group (mode and controls) are operator-configurable. See the Configuration chapter.
- If an inadvertent setting is made but has not yet been confirmed, it will automatically be canceled after 30 seconds. Alternatively, the setting window closes after 3 min, again canceling your settings.
- Start up values for automatic buttons are not user configurable.

To set up the ventilator for a new patient:

1. Start up the ventilator (Figure 5-1).
2. Make sure the ventilator is configured with the appropriate breathing circuit parts, as described in section 2.7. Chapter 6, Neonatal ventilation, includes additional information you might find valuable when ventilating a neonatal patient.

3. Start up the ventilator (Figure 5-1). The default settings are displayed.
4. Choose the appropriate patient setting:
   - Select **New patient** to start with new settings.
   - Select **Last patient** to start up with the last active ventilation parameters in use.
5. If you selected **New patient**, adjust the settings for the patient type, gender, and height. The ideal body weight (IBW) is automatically calculated and displayed[1].
6. Select **Start** to begin ventilation.

The device sets defaults and makes assumptions based on the patient profile (neonatal, pediatric, or adult). See the top right-hand corner of the screen to verify the mode and patient profile. To determine the patient profile, see Table 2-1.

The ventilation counter also starts.

Figure 5-1. Patient setup window

1. The IBW, based on Pennsylvania Medical Center (adults) and Traub SL. Am J Hosp Pharm 1980 (pediatric patients), is calculated as:
   Pediatric: IBW (kg) = 0.0033 x Patient height 2 (cm) + 0.3237 x Patient height (cm) + 14.386 cm x kg/cm
   Adult male: IBW (kg) = 0.9079 x Patient height (cm) – 88.022 cm x kg/cm
   Adult female: IBW (kg) = 0.9049 x Patient height (cm) – 92.006 cm x kg/cm

5.3 Patient window

Once you have started ventilation, the **Patient** window provides the basic patient profile, include gender, height, and time on ventilator. The following sections provide details.

5.3.1 Patient window: Changing patient gender and height

You can change the patient's gender or height from the **Patient** window.

1. Open the **Patient** window (Figure 5-2).
2. Change **Gender**, or select **Patient height** to adjust the value.

   For details on the Ventilation Timer, see the next section, 5.3.2.
3. Close the window.

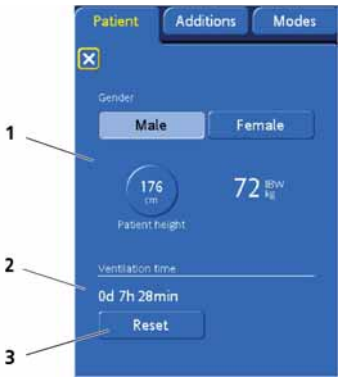


Figure 5-2. Patient window

1 Patient information (gender and IBW)

2 ventilation timer

3 Reset button resets ventilation timer to 0

5.3.2 Patient window: Ventilation timer

The **Patient** window displays a timer that shows how long the patient has been ventilated. See Figure 5-2.

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 select **New Patient** in the Patient Setup window, the timer resets to 0.
- When you select **Last Patient** in the Patient Setup window, the timer continues from the last total time recorded.
- When you select the **Reset** button, the timer resets to 0.

  To get an accurate count of how long a patient has been ventilated, we recommend you reset the timer to 0 once the patient is initially connected to the ventilator.

  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 **Patient** window (Figure 5-2).
2. Select the **Reset** button. The timer starts again at 0d 0h 0min.
3. Close the window.

5.4 Modes window: Setting the ventilation mode

NOTE:

- For details on modes, see the following chapters or materials:

  Adaptive Support Ventilation (ASV®)

  INTELLiVENT®-ASV

  Noninvasive ventilation

  Modes of ventilation

- Table 5-1 describes which modes apply to which patient profiles.

See the top right-hand corner of the screen for the active ventilation mode. To change the mode use these steps:

1. Open the **Modes** window.
2. Select a mode. The mode framed in the color yellow within the mode group is the apnea backup mode for that particular group of modes.

   A. **Confirm** the mode. The **Controls** window opens automatically. Review and confirm the control settings (see Section 5.5.2). If the control settings are not confirmed after 3 minutes, the window automatically closes. If this happens, the new mode selection will not be valid, and the previous settings remain in effect.

Figure 5-3. Modes window

1 Active mode

2 Backup mode for mode group framed in yellow

3 New selected mode

4 Boxes enclose mode group

Table 5-1. Ventilation modes and patient types

Mode	Adult (> 30 kg IBW)	Pediatric (3 to 42 kg IBW)	Infant/neonatal (≤ 10 kg IBW)
(S)CMV – Synchronized controlled mandatory ventilation	X	X	
SIMV – Synchronized intermittent mandatory ventilation	X	X	
SPONT – Pressure support mode	X	X	X
P-CMV – Pressure-controlled mandatory ventilation	X	X	X

Table 5-1. Ventilation modes and patient types

Mode	Adult (> 30 kg IBW)	Pediatric (3 to 42 kg IBW)	Infant/neonatal (≤ 10 kg IBW)
APVcmv – Pressure-controlled mandatory ventilation with adaptive pressure ventilation	X	X	X
P-SIMV – Pressure-controlled synchronized intermittent mandatory ventilation	X	X	X
APVsimv – Pressure-controlled synchronized intermittent mandatory ventilation with adaptive pressure ventilation	X	X	X
ASV® – Adaptive support ventilation	X	X	
DuoPAP – dual positive airway pressure mode	X	X	X
APRV – airway pressure release ventilation	X	X	X
NIV – noninvasive ventilation	X	X	
NIV-ST	X	X	
nCPAP-PS			X

5.5 Controls window: Settings including apnea backup ventilation

NOTE:

- The Controls window displays control settings applicable to the mode; apnea backup ventilation (Backup) control settings, and timing parameters based on timing settings (for control breaths only); see Figure 5-4. If INTELLiVENT®-ASV is active the Controls window further shows calculated MinVol, Vt, IBW and the controllers; see Figure 5-5.
- To use adaptive support ventilation (ASV), INTELLiVENT®-ASV or noninvasive ventilation (NIV and NIV-ST), see Appendix C and Appendix D for more details. For INTELLiVENT, see the INTEL-LiVENT®-ASV manual.

Description: Set controls and apnea backup ventilation from the **Controls** window. For control setting ranges and standard settings, see Table A-5. For control settings applicable to the different ventilation modes, see Table A-6.

5.5.1 Adjusting and confirming control settings without mode change

NOTE:

If INTELLiVENT®-ASV is active the ventilation and oxygenation controllers are displayed on the pulsing circles on the right of the cockpit screen.

Procedure: Change the control settings at any time as described:

1. Open the **Controls** window.
2. Select a parameter and adjust the value. As this change does not involve apnea, the change takes effect as soon as you confirm the setting change. Repeat this step for other parameters.

3. Select or deselect **Backup** when required (for details see apnea backup functions).

   If **Backup** is selected, check and modify (when required) the active settings for apnea backup ventilation, which are displayed in the window. **Backup** will be displayed at the top right-hand corner of the screen after the window is closed.

Figure 5-4. Controls window

1 Control settings applicable to the mode

2 Trigger type selector (select and activate to select type)

3 Apnea backup ventilation enabled or disabled, and if enabled, backup mode and selected control settings for backup ventilation

4 Timing parameters, based on the timing settings (if control breaths are permitted in the selected mode):

- **Rate and I:E:** Equivalent to the settings in Table 5-2
- **Ttotal:** Total breath cycle time
- **TI:** Duration of inspiratory phase, including any Pause

- **TE:** Duration of expiratory phase
- **Pause:** Duration of pause or plateau
- **IRV** (when applicable): Indicates that the insufflation + Pause time settings > 50% of total breath time
- **Vt/kg:** Tidal volume per kg Ideal Body Weight

5.5.2 Adjusting and confirming control settings after mode change

NOTE:

After a mode change, the apnea backup settings are immediately activated without confirmation. This occurs immediately even when the mode change is canceled.

Description: After you select a different mode, the **Controls** window automatically opens (Figure 5-5). Review and confirm these proposed settings, or the mode change will not be accepted.

Procedure: Change the control settings at any time as described:

1. Select a parameter and adjust the value. Repeat for any other desired parameters.
2. Select or deselect **Backup** as desired (see Section 5.5.3 for details on how apnea backup functions).
   If **Backup** is selected, check and modify as desired the active settings for apnea backup ventilation, which are displayed in the window. **Backup** will be displayed at the top right-hand corner of the screen after the selection is confirmed.
3. **Confirm** your entire selection.

Figure 5-5. Controls window after mode change

Figure 5-6. INTELLiVENT®-ASV mode window

5.5.3 About apnea backup ventilation

WARNING

HAMILTON MEDICAL recommends that apnea backup ventilation be enabled whenever a mode that allows spontaneous breathing is selected.

NOTE:

- When enabling apnea backup ventilation, verify appropriate apnea backup control settings in the **`Controls`** window.
- ASV® and INTELLiVENT®-ASV always work with lung-protective rules strategies (C.3.3) and therefore do not require additional backup ventilation.

This device provides apnea backup ventilation, a mechanism that minimizes possible patient injury due to apnea or cessation of respiration. Apnea can occur in all modes except (S)CMV, P-CMV, APVcmv, and ASV®. When the device is set to one of these modes and no inspiratory efforts are detected, or control breaths are delivered during an operator-set interval, it declares apnea.

If apnea backup ventilation is enabled, ventilation continues. The device's apnea backup is bi-directional. This mean that ventilation automatically resumes in the original support mode if the apnea episode ends.

When apnea backup ventilation is enabled, **`Backup`** is displayed at the top right-hand corner of the touch screen. Apnea backup ventilation provides ventilation after the apnea time passes with no breath attempts detected (set the **`Apnea`** time in the **`Alarms -> Limits 1`** window). When this occurs, the device automatically (and immediately) switches into apnea backup ventilation.

This action sounds a medium-priority alarm, displays Apnea ventilation, and provides ventilation as described in this table:

If the original support mode is...	the HAMILTON-G5 enters this backup mode	and ventilates using these settings
SIMV	(S)CMV	Control settings shown in the **Controls** window. (Settings shown are from original mode (where possible), or they are standard settings.)
SPONT, P-SIMV, DuoPAP, APRV, NIV	P-CMV	
APVsimv	APVcmv	
NIV-ST	P-CMV	

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

After 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.

When apnea backup ventilation is disabled, the high-priority alarm message **Apnea** is displayed when apnea occurs.

To verify a setting or to change backup control settings, open the Controls window.

5.6 Additions window

This section discusses the Additions window and the choices you can select. You can enable or disable the sigh function, set tube resistance compensation (TRC) or use the cuff pressure controller, IntelliCuff®, function from the Additions window. For detailed information on the cuff pressure function, see Section 3.5.

5.6.1 Sigh: Enabling/disabling the sigh function

Description: The sigh function delivers a sigh breath every 50 breaths, with a higher-than-normal pressure or volume. In volume-controlled modes, sigh breaths have a tidal volume 50% higher than non-sigh breaths, up to a maximum of 2000 ml.

In pressure-controlled modes, sigh breaths are delivered at a pressure up to 10 cmH2O higher than non-sigh breaths, as permitted by the high Pressure alarm limit. During sigh breaths, the high Pressure and Vt alarm limits remain active to help protect the patient from excessive pressures and volumes.

Procedure: Enable or disable the sigh function as follows:

1. Open the **`Additions -> Sigh`** window.

Figure 5-7. Sigh window

2. Select or deselect the **`Sigh`** function.
3. **`Close`** the window.

5.6.2 TRC: Setting tube resistance compensation

WARNING

- **Always use the correct tube type and size setting to avoid endangering the patient. To prevent possible patient injury due to inappropriate compensation, make sure to set these appropriately.**
- **TRC can induce autotriggering. If autotriggering occurs, first check the patient, breathing circuit, and other settings as possible causes before lowering the Compensate setting or disabling TRC.**

NOTE:

- TRC is intended for use with spontaneously breathing patients.
- TRC is disabled during heliox administration.
- When TRC is enabled, the displayed Ppeak can be higher than the set PEEP/CPAP plus Pcontrol/Psupport. This is due to the additional pressure required to work against the tube resistance. Observe closely at the calculated tracheal pressure, which is simultaneously displayed as an orange-colored waveform.
- The tracheal pressure waveform displayed is *calculated* from the proximal flow and pressure signals rather than *measured*.
- 100% compensation means that all resistance due to the tube itself is compensated. Internal resistance (for example, from secretions) and the external resistance (for example, from a tube kink) is not compensated.

Description: To reduce the patient's work of breathing while on the HAMILTON-G5, the ventilator's tube resistance compensation (TRC) feature offsets the flow resistance imposed by the tracheal (ET) or tracheostomy tube.

TRC is active during exhalation in volume modes, and in both inspiration and exhalation in the other modes. It is available for neonatal, pediatric and adult patients.

Procedure: Enable or disable TRC and adjust the settings as described:

1. Open the **`Additions -> TRC`** window.

Figure 5-8. TRC window

2. Select **`ET tube`** (endotracheal tube), **`Trach tube`** (tracheostomy tube), or **`Disable TRC`**.
3. If you selected **`ET tube`** or **`Trach tube`**, adjust the **`Tube size`** (tube ID) and **`Compensate`** settings. If the ET tube is shortened, lower the **`Compensate`** setting.
4. **`Confirm`** the entire selection.

When TRC is enabled, this displays the orange tracheal pressure waveform. Ptrach is shown with the yellow airway pressure waveform, Paw (Figure 5-9), and **`Et tube`** or **`Trach tube`** is displayed toward the bottom of the right-hand corner of the Cockpit touch screen.

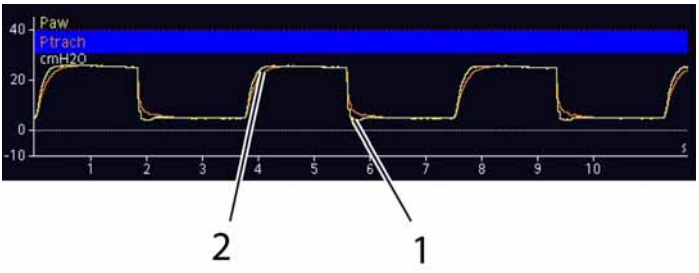


Figure 5-9. Ptrach and Paw waveforms (with TRC active)

1 Paw waveform (shown in yellow)

2 Calculated Ptrach waveform (shown in orange)

5.6.3 Table of control settings, additions, and ranges

Table 5-2. Control settings, mode additions, and ranges

Parameter	Definition	Range
Backup	Provides ventilation after the adjustable apnea time passes without breath attempts. Applies in SIMV, P-SIMV, APV-SIMV, SPONT, DuoPAP, APRV, and NIV modes.	Enabled or disabled
ETS	(Expiratory trigger sensitivity) Represents the percent of peak inspiratory flow at which the ventilator cycles from inspiration to exhalation. When you increase the ETS setting this results in a shorter inspiratory time, which can be beneficial in patients with COPD. The ETS setting lets you match the inspiratory time of pressure-supported breaths to the patient's neural timing. Applies to spontaneous breaths.	5 to 70% (of inspiratory peak flow)

Table 5-2. Control settings, mode additions, and ranges

Parameter	Definition	Range
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.	Sine, square, 100% decelerating, 50% decelerating
Flowtrigger (l/min)	The patient's inspiratory flow triggers the ventilator to deliver a breath. When the Flowtrigger is selected, the device generates a continuous and constant base flow from the inspiratory outlet to the expiratory outlet during the later part of exhalation. Base flow is essential for flow trigger. This base flow ranges from 4 to 30 l/min, as follows: • For Flowtrigger values < 1 l/min: 2 l/min • For Flowtrigger values > 2 l/min: 2 x Flowtrigger setting Applies to all breaths in all modes, if selected. **NOTE:** If autotriggering occurs, first check the patient, breathing circuit, and other settings as possible causes before decreasing the trigger sensitivity.	0.1 to 15 l/min
Gender (Adults only!)	Sex of patient. Used to compute ideal body weight (IBW).	Male, Female

Table 5-2. Control settings, mode additions, and ranges

Parameter	Definition	Range
I:E[1]	Ratio of inspiratory time to expiratory time. Applies to mandatory breaths, if the ventilator is so configured.	1:9.0 to 4.0:1
Loudness	Alarm loudness. **NOTE:** If the alarm loudness was set to < 5 before the ventilator was powered OFF, the loudness setting will default to 5 when the device is powered ON.	1 to 10
%MinVol	Percentage of minute volume to be delivered. The device uses the %MinVol, Patient height, and Gender settings to calculate the target minute ventilation. The %MinVol for a normal patient might be 100% (100 ml/min/kg body weight for adults and 200 ml/min/kg body weight for pediatric patients); for a COPD patient, 90%; for an ARDS patient, 120%; and for other patients, 110%. Add 20% if body temperature > 38.5 °C (101.3 °F) and 5% per 500 m (1640 ft) above sea level. Applies in ASV® mode (see Appendix C) and in INTELLiVENT®-ASV. In INTELLiVENT®-ASV the %MinVol can be set manual or automatic (range in automatic mode: 50%-200% (see the INTELLiVENT®-ASV manual).	25 to 350%

Table 5-2. Control settings, mode additions, and ranges

Parameter	Definition	Range
Oxygen	Oxygen concentration to be delivered. Applies to all breaths in all modes. In INTELLiVENT®-ASV Oxygen can be set manual or automatic (see the INTELLiVENT®-ASV manual). **NOTE:** Oxygen alarms are suppressed for 30 seconds after an Oxygen setting change.	21 to 100%
P-ASV limit	Maximum pressure set by ASV® and INTELLiVENT®-ASV, always equal to Pmax-10. Thus P-max and P-ASV limit co-vary.	PEEP+5 to 110 cmH2O
Patient	Patient Profile.	Adult, Pediatric, Neonatal, Male, Female
Patient height (Adults only!)	Patient height. It determines the ideal body weight (IBW), which is used in ASV®, INTELLiVENT®-ASV and Intelligent Panel calculations.	30 to 250 cm (12 to 100 inch.)
Pause[1]	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 way.	0 to 70% (of cycle time)

Table 5-2. Control settings, mode additions, and ranges

Parameter	Definition	Range
Pcontrol	Pressure (above PEEP/CPAP) to be applied during the inspiratory phase. Applies to mandatory breaths in P-CMV and P-SIMV.	3 to 100 cmH2O
Peak flow[1]	Peak (maximum) inspiratory flow. Applies to volume-controlled mandatory breaths, when the device is configured in this way.	1 to 180 l/min
PEEP/CPAP	PEEP (positive end expiratory pressure) and CPAP (continuous positive airway pressure), baseline pressures applied during the expiratory phase. Applies to all breaths in all modes except APRV. In INTELLiVENT®-ASV, PEEP can be set to manual or automatic. For details, see the INTELLiVENT®-ASV manual.	0 to 50 cmH2O
Phigh	High positive airway pressure level. P high setting is total desired airway pressure, including PEEP/CPAP or P low. Applies to all breaths in DuoPAP and APRV modes.	0 to 50 cmH2O
Plow	Low positive airway pressure level. Applies to all breaths in APRV mode.	0 to 50 cmH2O
P-ramp	Pressure ramp. Time constant required for inspiratory pressure to rise to the set (target) pressure. 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.	25 to 200 ms

Table 5-2. Control settings, mode additions, and ranges

Parameter	Definition	Range
P-ramp (*count.*)	Short P-ramp settings (50 ms) provide higher initial flow rates and result in faster attainment of the target pressure. This can benefit patients with elevated respiratory drive. Short P-ramp settings have been correlated with reduced work of breathing in certain patients. Set P-ramp to achieve a square (rectangular) pressure profile. Applies to all breaths in pressure modes. **NOTE:** To prevent possible pressure overshoot in pediatric applications, it is recommended that P-ramp be set to at least 75 ms.	25 to 200 ms
Psupport	Pressure (above PEEP/CPAP) to be applied to a patient-triggered breath during the inspiratory phase. Applies to spontaneous breaths.	0 to 100 cmH2O
P-trigger	Pressure trigger. The pressure drop below PEEP/CPAP required to begin a patient-initiated breath. Applies to all breaths in all modes, if selected. **NOTE:** If autotriggering occurs, first check the patient, breathing circuit, and other settings as possible causes before decreasing the trigger sensitivity.	0.1 to 10 cmH2O (below PEEP/CPAP)

Table 5-2. Control settings, mode additions, and ranges

Parameter	Definition	Range
Rate	Respiratory frequency or number of breaths per minute. Applies to mandatory breaths in (S)CMV, P-CMV, SIMV, P-SIMV, APVcmv, APVsimv, and DuoPAP modes.	1 to 150 b/min
Sigh	Breaths delivered at a regular interval, with a higher-than-normal pressure or volume.	enabled or disabled
T high	Duration of high airway pressure level. Applies to all breaths in DuoPAP and APRV modes.	0.1 to 30 s
TI[1]	Time to deliver the required gas (time to reach the operator-set Vt or Pcontrol value). Applies to mandatory breaths, if the ventilator is so configured. The high limit on the TI value is 10 seconds. This is due to a safety algorithm ensuring a minimum exhalation phase.	0.1 to 10 s
%TI[1]	Time to deliver the required gas (time to reach the operator-set Vt or Pcontrol value), as a percentage of the total breath cycle. Applies to mandatory breaths, if the ventilator is so configured. The high limit on the TI value is 10 seconds. This is due to a safety algorithm ensuring a minimum exhalation phase.	10 to 80% (of cycle time)
Ti max[1]	Maximum inspiratory time. Adult/Pediatric/ Neonatal: Applies for spontaneous breaths in non-invasive ventilation modes. Neonatal: Applies for all spontaneous breaths.	0.25 to 3.0 s

Table 5-2. Control settings, mode additions, and ranges

Parameter	Definition	Range
Tip[1]	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 a Tip increases the residence time of gas in the patient's lungs. Applies to volume-controlled mandatory breaths, when the device is configured in this way.	0 to 8 s
Tlow	Duration of low airway pressure level. Applies to all breaths in APRV mode.	0.1 to 30 s
TRC	Tube resistance compensation. Reduces the patient's work of breathing by offsetting tube resistance. **NOTE:** If autotriggering occurs, first check the patient, breathing circuit, and other settings as possible causes before lowering the Compensate setting or disabling TRC.	
Tube type/TRC disabledTube	Endotracheal (ET) tube, tracheostomy (Trach) tube, or TRC off.	ET tube, Trach tube, Disable
size	Inner diameter (ID) of tube.	3.0 to 10.0 mm (adult), 2.5 to 5.0 mm (neonates)
Compensate	Percentage of compensation.	10 to 100%

Table 5-2. Control settings, mode additions, and ranges

Parameter	Definition	Range
Trigger off	Prevents the ventilator from recognizing a patient trigger. Applies to all breaths in (S)CMV, P-CMV, and APVcmv modes, if selected. **WARNING** **Never set the trigger off for spontaneously breathing patients without sound clinical reasons, as this will minimize patient-ventilator asynchrony.**	Enabled or disabled
Vt	Tidal volume delivered during inspiration. Applies to volume-controlled mandatory breaths.	2 to 2000 ml
Vtarget	Target tidal volume to be delivered during inspiration. The device meets the Vtarget by adjusting the inspiratory pressure by 1 cmH2O per breath. Applies to breaths in APVcmv and APVsimv modes.	2 to 2000 ml

1. Refer to Appendix B for details on breath timing profiles in the HAMILTON-G5.

5.7 Alarms window

You can set alarm limits, adjust the alarm loudness, and view active alarms at the **Alarms** window.

5.7.1 Limits: Setting alarm limits

WARNING

- **Ensure the alarm limits are appropriately set before you place the patient on the device preventing possible patient injury.**
- **Although you can set all alarms rapidly using the Auto alarm function, some settings are not appropriate under all clinical conditions. HAMILTON MEDICAL recommends: you set the alarms manually when possible. If circumstances require to use the Auto alarm function, verify the correctness of the settings at the earliest opportunity.**

NOTE:

- Always ensure the high pressure alarm is correctly set. 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 for INTELLiVENT®-ASV, ASV®, APVcmv and APVsimv is 10 cmH2O below the high pressure limit, indicated by a blue colored band on the pressure waveform display. Set the high pressure limit to a safe value (example, 45 cmH2O, this limits the pressure target to a maximum of 35 cmH2O). When the high pressure alarm is set too low, it can lack enough margin for the device to adjust its inspiratory pressure to deliver the target tidal volume.
- In the ASV® and the INTELLiVENT®-ASV controls window, the high pressure alarm will be changed by adjusting the Pasv limit (pressure target 10 cmH2O below high pressure alarm limit).

- You can selectively enable or disable some adjustable alarms during configuration (see Appendix J, Configuration). At the minimum, the high pressure, low ExpMinVol, and apnea time alarms are always active.
- The number to the left of the line through each alarm column is the current measured value. The circled numbers at the top and bottom of the alarm columns represent the alarm settings.
- After a power interruption of up to 30 seconds, the device restores the last settings, including alarm settings.

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

The device offers two alarm-setting options:

- Manually set individual alarm limits.
- Use the **Auto** alarm function. Choosing **Auto** sets all alarm limits. Table 5-3 lists the Auto alarm settings.

To review and adjust alarms:

1. Open the **Alarms** window (Figure 5-10). The **Limits 1** window is displayed.

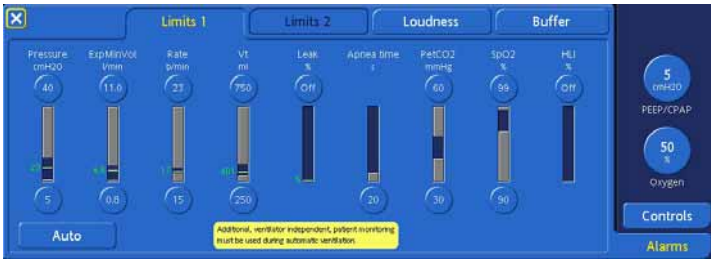


Figure 5-10. Alarm Limits 1 window

If the Pulse Rate alarm and/or one or more of the Masimo parameters is enabled in configuration, the **Alarms -> Limits 2** window is active. Select the **Limits 2** tab to display the window.

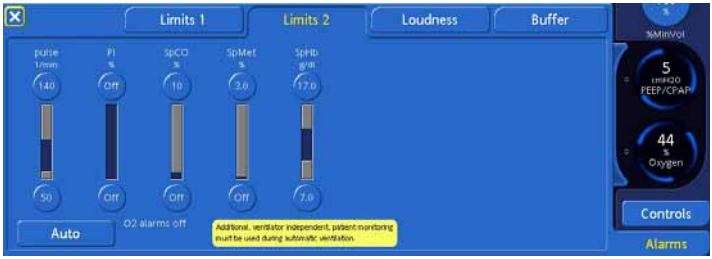


Figure 5-11. Alarm Limits 2 window

2. To set an alarm individually, select the alarm button and adjust the value. Repeat for any other alarm.

   To set the alarms automatically, select the **`Auto`** button.

3. Close the window.

5.7.2 Loudness: Adjusting alarm loudness

NOTE:

- If the alarm loudness was set to < 5 before the ventilator was powered off, the loudness setting will default to 5 when the HAMILTON-G5 is powered on.
- If you decrease the alarm loudness during the night shift, do not forget to return it to its daytime setting!

Adjust the alarm loudness as follows:

1. Open the **`Alarms -> Loudness`** window (Figure 5-12).
2. Adjust the **`Loudness`** value as desired.
3. Optionally, select **`Test`** to check the loudness.

Figure 5-12. Alarm Loudness window

4. Repeat the process as required.
5. Close the window.

5.7.3 Buffer: Viewing active alarms

See Section 10.3 for a description of the active alarm buffer.

5.7.4 Table of alarm limit settings and ranges

Table 5-3 lists the **`Alarms -> Limits 1`** window alarm settings and ranges. As the **`Alarms -> Limits 2`** window displays pulse oximeter-related parameters, see Section F.6.3 for these alarm limits.

Table 5-3. Alarm limit settings and ranges

Parameter	Definition	Range
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, an alarm is annunciated. Apnea backup ventilation will begin, if enabled. The Apnea alarm is suppressed under these conditions: • When the ventilator is in the ambient state, standby, or any of these modes is active: (S)CMV, P-CMV, APVcmv, or ASV®. • During flow sensor calibration or the tightness test. If apnea backup ventilation is not enabled, apnea is detected, and the alarm silence is active, the alarm silence is terminated immediately.	10 to 60 s
ExpMinVol (low and high)	Low and high expiratory minute volume. If either limit is reached, a high-priority alarm is annunciated. **NOTE:** If you do set the ExpMinVol alarm to Off, the pressure alarms become critical, so pay close attention to them and set the low Pressure alarm to an appropriately sensitive level.	Low: Off, 0.01 to 49 l/min High: Off, 0.03 to 50 l/min
HLI (high)	High HLI.	Off, 0 to 40%
Leak	High leakage. Leak is the percentage of delivered inspiratory volume that is not returned during exhalation on the patient side of the flow sensor.	Off, 5 to 80%

Table 5-3. Alarm limit settings and ranges

Parameter	Definition	Range
$PetCO_2$ (low and high)	Low and high monitored $PetCO_2$. If either limit is reached, a medium-priority alarm is annunciated.	Low: Off, 0 to 99 mmHg/0 to 13.2 kPa High: Off, 1 to 100 mmHg/1 to 13.3 kPa
Pressure (low and high)	Low and high monitored pressures at the patient airway (Ppeak). If either limit is reached, a high-priority alarm is annunciated. In addition, if the high Pressure limit is reached, the HAMILTON-G5 immediately stops gas flow to the patient and relieves pressure until pressure falls to the PEEP/CPAP level. If the airway pressure continues to rise above 120 cmH_2O, the mechanical overpressure relief valve opens and the ventilator enters the ambient state. The HAMILTON-G5 ventilator uses the high Pressure limit as a safety boundary for its inspiratory pressure adjustment. ASV®, INTELLiVENT®-ASV, APV-cmv and APV-simv do not apply inspiratory pressures higher than 10 cmH_2O below the high Pressure limit. An exception is sigh breaths, when ASV®, INTELLiVENT®-ASV, APV-cmv and APV-simv can apply inspiratory pressure 3 cmH_2O below the high Pressure limit. In the ASV® and INTELLiVENT®-ASV controls window the high Pressure alarm can also be changed by adjusting the Pasv limit (maximally applicable pressure target 10 cmH_2O below high Pressure alarm limit).	Low: 2 to 119 cmH_2O High: 10 to 120 cmH_2O

Table 5-3. Alarm limit settings and ranges

Parameter	Definition	Range
Rate (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 annunciated. **NOTE:** Respiratory rate monitoring on the ventilator requires breath delivery followed by detection of expiratory flow at the proximal flow sensor.	Low: 0 to 128 b/min High: 2 to 130 b/min
SpO_2 (low and high)	Low and high. Make sure that the SpO_2 measurements is activated and the corresponding alarms are correctly set.	Low: 70 to 99% High: 71 to 100%
Vt (low and high)	Low and high expiratory tidal volume, for two consecutive breaths. If either limit is reached, a medium-priority alarm is annunciated.	Low: Off, 0 to 2950 ml High: Off, 1 to 3000 ml

6 Neonatal ventilation

6.1 Introduction

WARNING

- **Ensure the ventilator is set up correctly for a neonatal patient to prevent possible patient injury.**
- **The ventilator must have the appropriate breathing circuit parts, including the infant flow sensor, as described in Chapter 2, Preparing for ventilation.**
- **Confirm the flow sensor calibration is performed before you use the ventilator on the neonate.**

NOTE:

For patients with body weights > 7 kg, you may want to select the pediatric patient type. This prevents the need to change circuits and calibrate the flow sensor should you later decide that your patient requires more support.

You can use the device to ventilate neonatal patients weighing up to 10 kg. Although the procedure for ventilating neonates is almost identical to that for ventilating other patients, there are some important differences.

This section points out these differences, and is intended to supplement the rest of the manual.

6.2 Breathing circuit

WARNING

- **To prevent breathing difficulties resulting from blocked gas passages, visually inspect for possible kinking of the very thin neonatal ET tubes.**
- **Dead space ventilation is harmful and can happen at any tidal volume settings.**

NOTE:

You must consider (anatomic) dead space when determining the appropriate tidal and minute volumes for neonatal patients. Artificial airways (such as: Y-piece, flow sensor, ET tube, CO_2 airway adapter) can increase the dead space slightly.

Use an neonatal breathing circuit with 10 mm ID tubes to ventilate your neonatal patient. Do not use an adult or pediatric breathing circuit.

A heating wire can noticeably increase the inspiratory resistance of the neonatal breathing circuit.

6.3 Flow sensor

CAUTION

When a change of patient profile is necessary from from `Neonatal` to `Pediatric`, you must first change and calibrate the flow sensor.

The Infant flow sensor can only be used when the `Neonatal` patient profile is selected. You CANNOT use the Infant flow sensor for pediatric applications.

The infant flow sensor has a dead space of < 1.3 ml.

Calibrate the infant flow sensor between patients, after installing a new flow sensor, or whenever the **`Flow Sensor Cal.needed`** alarm activates.

Unlike for the pediatric/adult flow sensor calibration, you DO NOT turn the infant flow sensor during calibration. During flow sensor calibration, the device can recognize a mismatch between the set patient type and the flow sensor in use.
In response it actuates a **`Flow Sensor Mismatch`** alarm.

6.4 Test and calibration

Just as you would do for any patient, you must conduct a pre-operational check described in Section 4.2 before placing your infant/neonatal patient on the ventilator.

The instructions include:

- A test for leak-tightness of the breathing circuit
- Calibration of the infant flow sensor
- A pre-operational check of the device to support an infant/neonate. The pre-operational check does require an infant/neonatal lung model.

6.5 Ventilation modes and mode additions

WARNING

Auto triggering is harmful and can easily occur at sensitive trigger settings (flow or pressure) from gas leaks around the ET tubes.

NOTE:

As neonatal ET tubes normally do not have a cuff, leakage can be significant (that is, VLeak can be much greater than the measured expiratory tidal volume (VTE). Check the VLeak parameter in the Monitoring window from time to time; such a leak is not be predictable.

To begin ventilating neonatal patients, you must first select and activate the neonatal patient profile.

All the neonatal modes available from the device are pressure modes. These include: P-CMV, APVcmv, APVsimv, DuoPAP, APRV, nCPAP-PS and SPONT.

The standard mode setting is P-CMV.

Volume-controlled modes, including (S)CMV and SIMV, are not available.

Adaptive support ventilation (ASV) is not available.

Noninvasive ventilation (NIV and NIV-ST) are not available.

6.6 Controls

This section discusses controls that require special consideration when setting up the ventilator for an infant/neonatal patient.

See Table A-5 for standard settings for neonatal patients.

See Table A-6 for the control settings for all modes and patient types.

6.6.1 Ti max

Ti max (maximum inspiratory time) is set for spontaneous breaths, in P-SIMV, APVsimv, SPONT, nCPAP-PS, DuoPAP, APRV, NIV and NIV-ST modes. For all patient types, the switchover from inspiration to exhalation in spontaneous breaths is normally controlled by the ETS. If gas leakage is significant, however, it is possible that the setting of ETS could not be reached. The Ti max setting provides a backup so inspiration can be terminated. The HAMILTON MEDICAL ventilator switches over to exhalation when the set Ti max is reached.

6.6.2 Flowtrigger

The default trigger type for infant/neonatal patients is flow triggering.

When flow triggering is active, at the late stage of exhalation the ventilator delivers a constant base flow from the inspiratory limb to the expiratory limb. The base flow is minimally 1 l/min and can be as high as 30 l/min, depending on what is the Flowtrigger sensitivity setting. If the leak flow is higher than the Flowtrigger setting, autotriggering occurs. To solve the problem, you can raise the Flowtrigger setting (that is, decrease the sensitivity) until the autotriggering stops (for details, see Appendix D).

Leakages are compensated automatically over IntelliTrig (see Appendix D).

6.6.3 P-ramp

If a neonatal patient has stiff lungs (for example, RDS), be careful when using a short P-ramp (pressure rise time). A very short P-ramp in this case may cause pressure overshoot.

6.7 Others

WARNING

- **Prolonged exposure to high oxygen concentrations could cause irreversible blindness and pulmonary fibrosis in pre-term infants.**
- **High rate settings, very short TI or TE can cause incomplete inspiration or expiration.**

NOTE:

For integrated Aeroneb® nebulization of neonatal patients, see Section 3.4.

Pneumatic nebulization is disabled in the infant/neonatal application.

During the O_2 enrichment maneuver the applied oxygen concentration is increased by 25% of the last oxygen setting (for example: last oxygen setting 40%, resulting oxygen concentration during O_2 enrichment maneuver 50%).

The actual applied oxygen concentration is displayed on the oxygen control knob (green). Oxygen enrichment continues for 2 minutes unless you terminate it by pressing the O_2 enrichment key again, or manually activating and confirming the oxygen control knob

The maximum inspiratory or expiratory breath hold time in infant/neonatal modes is 3 seconds, compared to 10 seconds in the adult or pediatric modes.

7 Monitoring

7.1 Introduction

WARNING

- **The device's oxygen monitoring function can be disabled in the system window. To prevent possible patient injury due to nonfunctional alarms and monitoring, however, HAMILTON-MEDICAL recommends that oxygen monitoring always be enabled.**
- **In case of malfunction of the ventilator's built-in monitoring and to maintain an adequate level of patient monitoring at all times, it is mandatory that additional independent monitoring devices be used. Regardless, it always remains the full responsibility of the operator to ensure proper ventilation and patient safety in all situations.**

NOTE:

- To ensure that oxygen monitoring is always fully functional, replace an exhausted or missing oxygen cell as soon as possible or use an external monitor that complies with EN ISO 21647.
- Dashes displayed in place of monitored data indicate that valid values are not yet available, or do not apply.
- Selections with a gray background are not active and cannot be selected.
- If a ventilator control does not respond when selected by touch, or by the turn of a P&T knob, the control is not active in this particular instance or the function is not implemented.

During monitoring, you can view patient data on the device's cockpit. You can configure the monitoring layout with waveforms and graphics to suit hospital protocols. Using the touch screen or knob, you can view the monitoring windows without affecting breath delivery.

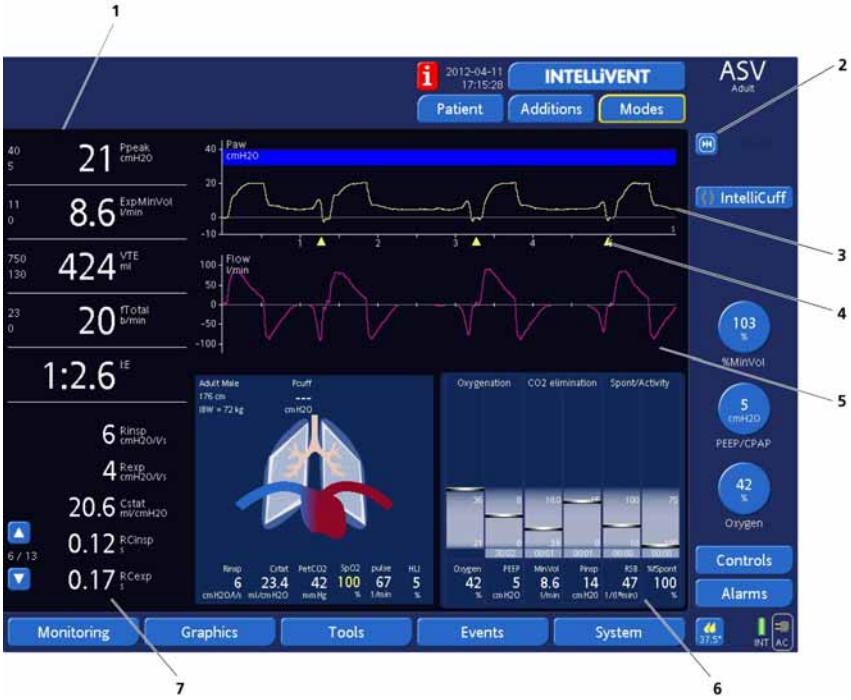


Figure 7-1. Basic display with monitoring windows

1 Main monitoring parameters (MMP) are freely configurable (selected during configuration)

2 **Freeze** button

3 Waveforms

4 Patient trigger indicator

5 Ventilation Cockpit panels

6 Intelligent panels

7 Secondary monitoring parameters (SMP)

7.2 Monitoring window

This section discusses the attributes and functionality of the Monitoring window. View numeric patient data or assign an auxiliary pressure input from the **Monitoring** window. Table 7-1 describes the monitored parameters.

The header of the cockpit basic monitoring screen displays the current date and time.

7.2.1 Monitored parameter windows and sensor data window: Viewing numeric patient data

With the **Monitoring** button open:

- Open window **1** (Figure 7-2) to view most patient data
- Open window **2** (Figure 7-3) to view patient data derived from CO_2 and SpO_2 sensor measurements. This step must be done with the appropriate sensors ON, from the **System -> Sensors ON/OFF** window.

Figure 7-2. Monitored parameter window 1

Figure 7-3. Monitored window 2, with sensor data

For details about the **`SpO2raw`** tab, see Section F.3.1.

7.2.2 Paw/Paux: Assigning Paw or Paux as pressure input for numeric patient data

The device uses the airway pressure (Paw) as its standard pressure input. You can reassign the device's pressure input, so that monitored numeric parameters are based on a pressure from a different site, such as the end of the tracheal tube. (This auxiliary pressure input can be particularly useful when conducting scientific and clinical studies.)

Change the pressure source for monitored data as follows:

1. **`Monitoring -> Paw/Paux`** (tab color changes to yellow) window (Figure 7-4).
2. Select **`Paw`** or **`Paux`**.
3. Close the window.

Figure 7-4. Paw/Paux window

When the Paux pressure input is active, the color of the pressure-based parameters changes to orange. This signifies that the parameters are based on the Paux input. These pressure-based parameters are as follows:

Ppeak	Rinsp	RCinsp
Pplateau	Rexp	PTP
Pmean	Cstat	
PEEP/CPAP		
Pmin		
AutoPEEP		
P0.1		
WOBimp		

For connecting Paux see Section 2.8.

7.3 Graphics window

7.3.1 Graphics window: Set up for the ventilation cockpit (layout and setting trend timing)

The operator can configure the lay out of the Ventilation Cockpit panels to display real-time patient data, such as:

- Waveforms
- Loops
- Trend waveforms
- Dynamic Heart/Lung
- Vent Status
- ASV target graphics window
- ASV monitored data window
- Ventilation Horizon, Map, Guide
- Oxygenation Horizon, Map, Guide

For each patient group there is a separate default graphics layout. This can be predefined in the configuration window. (Section J.2)

This operator-configured default graphics layout is always used for **`New Patient`**. You can always choose the default graphics layout using the **`Restore`** button in the **`Graphics`** window (Figure 7-5).

To set the trend timing and lay out of the Cockpit:

1. Touch the **`Graphics`** window button (Figure 7-5).

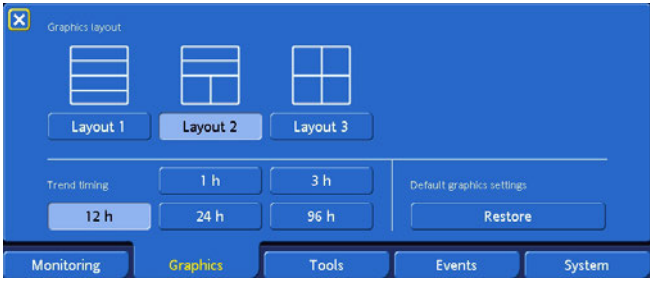


Figure 7-5. Graphics window

2. Select a **Trend timing** value of **1 h, 3 h, 12 h, 24 h,** or **96 h** to be applied to any trends in your layout.

3. As a **Graphics layout**, select **Layout 1, Layout 2, Layout 3**. The types of graphic available for the three layouts are shown below. The window closes automatically.

<table>
<tr><td>Waveform</td><td colspan="2">Waveform</td><td rowspan="2">Waveform, Loop, Trend or Intelligent panel[1]</td><td rowspan="2">Waveform, Loop, Trend or Intelligent panel[1]</td></tr>
<tr><td>Waveform</td><td colspan="2">Waveform</td></tr>
<tr><td>Waveform</td><td rowspan="2">Waveform, Loop, Trend or Intelligent panel[1]</td><td rowspan="2">Waveform, Loop, Trend or Intelligent panel[1]</td><td rowspan="2">Waveform, Loop, Trend or Intelligent panel[1]</td><td rowspan="2">Waveform, Loop, Trend or Intelligent panel[1]</td></tr>
<tr><td>Waveform</td></tr>
<tr><td>Layout 1</td><td colspan="2">Layout 2</td><td colspan="2">Layout 3</td></tr>
</table>

1. Intelligent panel can be ASV graphics window, ASV monitored data window, Dynamic lung, Vent Status, or Ventilation/Oxygenation Horizon, Map or Guide window.

4. Continue setting up each individual panel (Figure 7-6).

7.3.2 Setting up individual panels

To set up the panel (in this example, change the type of waveform, loop, trend, or Intelligent Panel), touch the panel area of the screen to select it. A pop-up window opens. (Figure 7-6 shows the waveform setup window). Select a parameter. If you selected a loop or trend, additional pop-up windows will open.

Figure 7-6. Panel setup window (waveform window shown)

7.3.3 About graphic types

NOTE:

- The device uses an autoscaling function, so that the scales of individual waveforms and loops may differ, based on the range of values to be displayed. For example, the pressure scale can vary from one pressure/time waveform to another.
- If TRC is activated, an additional waveform, (Ptrach), the calculated pressure at the end of the tracheal tube, is displayed in orange (see Section 5.6.2)

7.3.3.1 Waveforms

The device can plot pressure (Paw or Paux), volume, flow, CO_2 (FCO_2 or PCO_2) or plethysmographic waves versus time. Figure 7-7 shows a pressure waveform. In ASV, INTELLiVENT®-ASV and APV a blue band is displayed. The blue band is the "safe" pressure zone (10 cmH_2O below the high Pressure alarm limit). The high Pressure limit is shown as a blue dashed line.

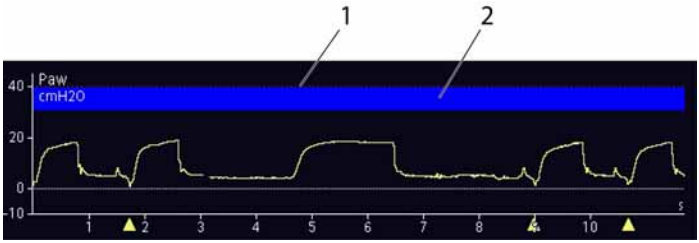


Figure 7-7. Pressure waveform display

1 High pressure alarm limit line

2 Blue pressure band (in ASV, INTELLiVENT®-ASV and APV)

7.3.4 Loops

NOTE:

When Paw/Paux is selected, both values are displayed together, plotted versus the second parameter.

The device can display a dynamic loop based on two of the following parameters: pressure (Paw and/or Paux), volume, flow, or CO_2 (FCO_2 or PCO_2). There are "pre-defined loops" for paw/V, paw-paux/V, paw/flow and V/CO_2. Figure 7-8 shows a paw/volume loop.

1. Press the **Loop Reference** button to store the loop curve with the current date and time. The past and actual values are shown (Figure 7-8).

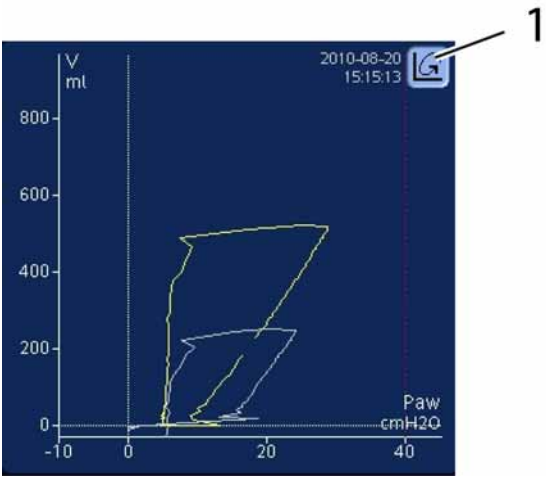


Figure 7-8. Dynamic pressure/volume loop display

1 Loop reference button

If the parameter combination is changed and the **Loop Reference** button is once again pressed, the present curve is stored. The previous one is not retained.

7.3.4.1 Trends

NOTE:

In setting up trends, you can choose among the parameters shown in the two monitored parameter windows, with these additions:

- To trend Ppeak, Pmean, and PEEP/CPAP, select Pcombi; this causes all these pressure values to be trended together.
- To trend fTotal and fControl, select fcombi; this causes both rate values to be trended together.
- You can also trend the Pinsp parameter.
- An additional trending for Oxygenation is available in INTELLiVENT®-ASV.
- With the Masimo Rainbow SpHb monitoring option, the Trend graph varies depending on the selected mode. See Appendix F, Pulse oximetry.

To show monitored parameters, select 1 hr, 3 hrs, 12 hrs, 24 hrs, or 96 hrs trends. After you select the time value, you will see the trend displays (Figure 7-9), including all data since you switched on the ventilator or for the past time value you entered.

From the time start ventilation, the device continually stores the monitored parameters in memory, so you have access to any of this data, even after standby. The data disappears from the device's memory when power is switched OFF or **New Patient** is selected.

Alternatively, the freeze and cursor measurement function can be used to examine points on trend waveforms. When trends are frozen, the time axis displays elapsed time relative to the present.

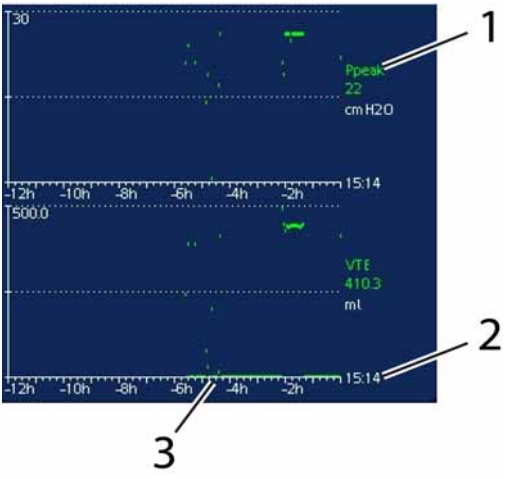


Figure 7-9. Trend display

1 Mean or median value (shown in green on the monitor)

2 Current time

3 Elapsed time relative to present

7.3.4.2 Dynamic lung

The Dynamic Heart and Lung panel displays tidal volume, lung compliance, interaction with heart, patient triggering, and resistance in real-time. For more information, see Section 8.2 of this manual and also the INTELLiVENT®-ASV manual.

7.3.4.3 Vent status

The Vent Status panel displays six parameters related to oxygenation, CO_2 elimination, and patient activity, plus indicates the patient's level of ventilator dependency and when discontinuing ventilation could be considered. For more information, see Section 8.4.

7.3.4.4 INTELLiVENT®-specific intelligent panels

For detailed information, see the INTELLiVENT®-ASV manual.

7.3.4.5 ASV graphics window

The ASV target graphics window (Figure C-4) displays the adaptive lung controller moving toward its targets. This window displays the target and actual parameters together for tidal volume, frequency, pressure, and minute ventilation.

See Appendix C, ASV, for detailed information on ASV, including how to interpret the data in the target graphics window.

7.3.4.6 ASV data window

The ASV monitored data window (Figure C-5) provides numeric target and actual parameters for tidal volume, frequency, pressure, and minute ventilation.

See Appendix C, ASV, for detailed information on ASV, including how to interpret the data in the monitored data window.

7.3.5 Freeze and cursor measurement

This function lets you freeze the display of a graphic and then determine the numeric values for points on the graphic using a cursor.

The freeze function is particularly useful when you perform a breath hold maneuver. The screen automatically freezes after a successful inspiratory or expiratory hold maneuver.

To freeze the graphic:

1. Select the **Freeze** button. The graphic image will freeze (Figure 7-10).

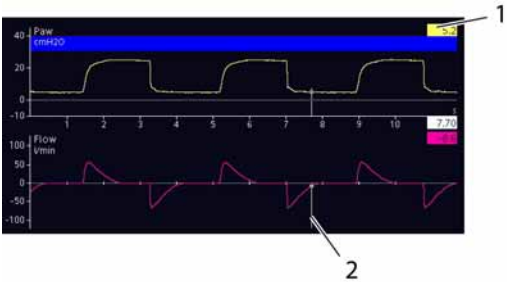


Figure 7-10. Freeze and cursor function

1 Cursor value

2 Cursor

2. To read the numeric value at a point on the graphic, turn the knob to the desired point. Read the value to the right of the graphic.
3. Repeat for additional points.
4. Unfreeze with the freeze button or by pressing the knob.

7.4 Tools window

This section describes how to perform respiratory maneuvers from the **`Tools`** window.

7.4.1 Hold: Performing inspiratory/expiratory hold maneuvers

WARNING

The HAMILTON-G5 does not provide ventilation during breath hold maneuvers.

NOTE:

- To terminate a pending hold, **Close** the window. You can terminate an active hold by pressing the knob during the hold cycle.
- To display the entire hold maneuver, wait to start the maneuver until the first inspiration is shown to the far left of the curve display.

The inspiratory and expiratory hold maneuvers let you stop the ventilator's breathing cycle at the end of inspiration or exhalation, for a maximum of 10 s (adult and pediatric patients) or 3 s (infant patients). The primary application of the breath hold is to measure lung mechanics by the occlusion technique.

To perform a hold maneuver:

1. Open the **Tools -> Hold** window (Figure 7-11).
2. Select **Insp hold** or **Exp hold** to perform an inspiratory or expiratory hold maneuver. When the pressure waveform flattens, deactivate the hold maneuver by selecting **Insp hold** or **Exp hold** again. After the maneuver, the **Hold** window closes, and the freeze function is activated automatically.

Figure 7-11. Hold window

For example: Performing a manual AutoPEEP assessment maneuver:

1. Ensure the Paw waveform is displayed.
2. Open the **Hold** window.
3. Wait until the Paw waveform plot restarts from the left-hand side.
4. Wait for the next inspiration.
5. Then select **Exp hold**. Close the window without activating. Do not touch the screen or press the button.
6. Observe the patient's Paw during the subsequent obstructed exhalation phase.
7. Measure AutoPEEP by examining points on the curve with the cursor (for details about the freeze and cursor measurement, see the previous section).

7.4.2 Performing a static P/V maneuver

Refer to Chapter 9, P/V tool maneuver option, for details.

7.5 Monitored parameters

NOTE:

- The HAMILTON-G5 automatically measures inspiratory and expiratory resistance (Rinsp and Rexp), compliance (Cstat), and AutoPEEP breath by breath, during mandatory and spontaneous breathing in all modes, without interruption in ventilation. To obtain these measurements, the device uses a statistical technique called the least squares fitting (LSF) method. This method is applied on a breath-by-breath basis, without the need for special inspiratory flow patterns and occlusion maneuvers, when the patient is relaxed or nearly relaxed.
- Actively breathing patients can create artifact or noise, which can affect the accuracy of these measurements. The more active the patient, the less accurate the measurements. To minimize patient activity during these measurements, you can choose increased Psupport by 10 cmH2O. After completion, return this control to its former setting.

Table 7-1 is an alphabetical list of the device's monitored parameters. The display of monitored parameters is updated every breath.

For detailed information about parameters derived from CO_2 sensor measurements, refer to Appendix E, or consult the HAMILTON MEDICAL Volumetric Capnography User's Guide. For detailed information about parameters derived from SpO_2 sensor measurements, refer to Appendix F. For details about parameters used in Quick Wean, refer to the INTELLiVENT®-ASV manual.

Table 7-1. Monitored parameters

Parameter (unit)	Monitoring Window	Definition
AutoPEEP (cmH2O)	Monitoring 1	**WARNING** **The HAMILTON-G5's automatic measurement of AutoPEEP is accurate only in patients without small airway collapse. DO NOT use this measurement to quantify hyperinflation in COPD patients. Refer to manual for AutoPEEP measurement.** The difference between the measured and set PEEP. AutoPEEP is the abnormal pressure generated by air "trapped" in the alveoli due to inadequate lung deflation. Ideally, it would be zero. AutoPEEP is calculated using the LSF method applied to the entire breath. When AutoPEEP is present, volutrauma or barotrauma can occur. In active patients, AutoPEEP can cause an extra workload to the patient. AutoPEEP or air trapping can result from a too short expiratory maneuver, which may be observed under following circumstances: • 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

Table 7-1. Monitored parameters

Parameter (unit)	Monitoring Window	Definition
Cstat (ml/ cmH2O)	Monitoring 1	**NOTE:** Actively breathing patients can create artifact or noise, which can affect the accuracy of these measurements. The more active the patient, the less accurate the measurements. To minimize patient activity during these measurements, you can choose increased Psupport by 10 cmH2O. After completion, return this control to its former setting. Static compliance of the respiratory system, including lung and chest wall compliances. It is calculated using the LSF method applied to the entire breath. With Cstat changes of the elastic characteristics of the patient's lungs can be detected.
Delay Time	SBT Controls	Quick Wean parameter. The minimum length of time each parameter in the **`To start`** list must be in range before the countdown to start an automated spontaneous breathing trial (SBT) may begin. For details, see the Quick Wean chapter in the INTELLiVENT®-ASV manual.
Duration max	SBT Controls	Quick Wean parameter. The total time that an automated spontaneous breathing trial (SBT) can run. For details, see the Quick Wean chapter in the INTELLiVENT®-ASV manual.
Exp Flow (l/min)	Monitoring 1	Peak expiratory flow.

Table 7-1. Monitored parameters

Parameter (unit)	Monitoring Window	Definition
ExpMinVol (l/min)	Monitoring 1, 2	Expiratory minute volume. The moving average of the monitored expiratory volume per minute, over the last 8 breaths. In Noninvasive modes (NIV, NIV-ST, nCPAP-PS), ExpMinVol is replaced by MinVol NIV.
$FetCO_2$ (%)	Monitoring 2	Fractional end-tidal CO_2 concentration. $PetCO_2$/(Pambient – PH_2O), whereupon PH_2O = 47 mmHg. Permits assessment of arterial CO_2. (Note that $FetCO_2$ is inaccurate in pulmonary embolism.) Only available if CO_2 sensor is installed.
fSpont (b/min)	Monitoring 1	Spontaneous breath frequency. The moving average of spontaneous breaths per minute, over the last 8 spontaneous breaths. An increased fSpont may indicate that the patient is compensating increased compliance. This may indicate ventilatory fatigue due to imposed work of breathing.
fTotal (b/min)	Monitoring 1	**NOTE:** INTELLiVENT®-ASV manualRespiratory rate monitoring on the HAMILTON-G5 requires breath delivery followed by detection of expiratory flow at the proximal flow sensor. Total breathing frequency. The actual average of the patient's total breathing frequency over the last 8 breaths, including both mandatory and spontaneous breaths. When the patient triggers or the user initiates a breath, fTotal may be higher than the rate setting.

Table 7-1. Monitored parameters

Parameter (unit)	Monitoring Window	Definition
I:E	Monitoring 1	Inspiratory:expiratory ratio. Ratio of the patient's inspiratory to expiratory time. This includes both mandatory and spontaneous breaths. I:E may differ from the set I:E ratio if the patient breathes spontaneously.
Insp Flow (l/min)	Monitoring 1	Peak inspiratory flow, spontaneous or mechanical.
HLI	Monitoring 2	Heart-Lung Interaction Index is a value for the variation of the plethysmogram amplitude which reflects how much ventilation interacts with hemodynamics. High variation means high interaction. For details, see the INTELLiVENT®-ASV manual.
MinVol NIV (l/min)	Monitoring 1	Expiratory minute volume. The moving average of the monitored expiratory volume per minute, over the last 8 breaths. Used only in Noninvasive modes (NIV, NIV-ST, nCPAP-PS), this parameter replaces ExpMinVol, as it is leak compensated.
MVLeak	Monitoring 1	Total minute volume leakage. MVLeak shows VLeak x frequency (breath rate).
MV Spont (ml)	Monitoring 1	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 modes (NIV, NIV-ST, nCPAP-PS), MV Spont is replaced by MV Spont NIV.

Table 7-1. Monitored parameters

Parameter (unit)	Monitoring Window	Definition
MV Spont NIV (ml)	Monitoring 1	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. Used only in Noninvasive modes (NIV, NIV-ST, nCPAP-PS), this parameter replaces MV Spont, as it is leak compensated.
Oxygen	Monitoring 1	Oxygen concentration of the delivered gas. It is measured by the oxygen cell in the inspiratory pneumatics. This parameter does not display when: a) the oxygen supply is not connected, b) the oxygen cell is not installed or is defective, or c) if oxygen measurement is disabled.

Table 7-1. Monitored parameters

Parameter (unit)	Monitoring Window	Definition
P0.1 (cmH2O	Monitoring 1	**NOTE:** Due to changes in pneumatic impedance, P0.1 values can vary with different settings of the Trigger function. Airway occlusion pressure. The maximal slope of the airway pressure drop during the first 100 ms when the airway is occluded. P0.1 indicates the patient's respiratory drive and efforts. It applies to patient-triggered breaths with pressure trigger only. A P0.1 value of -3 cmH2O indicates a strong inspiratory effort, and a value of -5 cmH2O, 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 if in manual mode • Shorten P-ramp time
PEEP/CPAP (cmH2O)	Monitoring 1	Monitored PEEP/CPAP. The airway pressure at the end of exhalation. Measured PEEP/CPAP can differ slightly from set PEEP/CPAP, especially in actively breathing patients.

Table 7-1. Monitored parameters

Parameter (unit)	Monitoring Window	Definition
$PetCO_2$ (mmHg/ Torr/kPa)	Monitoring 2	End-tidal CO_2 pressure. The maximum partial pressure of CO_2 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. Under certain conditions, it represents a reliable index of CO_2 partial pressure in the arterial blood. Note: Inaccurate in pulmonary embolism Available if CO_2 sensor is installed.
Pcuff (cmH_2O)	Monitoring 2	Pressure measured in the cuff at the end of exhalation.
PI (%)	Monitoring 2	Perfusion index. Indicates pulse strength at the sensor location.
Pinsp (cmH_2O)	Vent Status panel	Only inspiratory pressure, the target pressure (additional to PEEP/CPAP) applied during the inspiratory phase. Available in ASV, Trends, and in the Vent Status panel. Pinsp is: ASV and APV modes: Automatically calculated target pressure Pressure-controlled modes (P-CMV, P-SIMV): Pcontrol (setting) Pressure-supported modes (SPONT, DuoPAP, APRV, NIV): Psupport (setting) Volume-controlled modes (CMV, SIMV): Pplateau (monitored parameter) – PEEP. When Pplateau is not available, Pinsp = Ppeak (monitored parameter) – PEEP
Pmean (cmH_2O)	Monitoring 1	Mean airway pressure (Ppeak – PEEP/CPAP) over 8 breath cycles. Pmean is an important indicator of the possible impact of applied positive pressure on hemodynamics and surrounding organs.

Table 7-1. Monitored parameters

Parameter (unit)	Monitoring Window	Definition
Pminimum (cmH_2O)	Monitoring 1	Minimum airway pressure of the previous breath cycle. Pminimum can be lower than the PEEP/CPAP if TRC is active, or if the patient is making strong inspiratory efforts.
Ppeak (cmH_2O)	Monitoring 1	Peak airway pressure. The highest pressure of the previous breath cycle. It is influenced by airway resistance and compliance. It can be higher than expected due to the device's breathing circuit compensation. It can differ noticeably from alveolar pressure if airway flow is high.
Pplateau (cmH_2O)	Monitoring 1	Plateau or end-inspiratory pressure. The pressure measured at the end of inspiration when flow is or is close to zero. • In volume modes when the set **Pause** is greater than zero. • In non-volume modes when the end-inspiratory pressure is very stable (pressure change < 1 cmH_2O over 100 ms). Pplateau is a rough representation of alveolar pressure.

Table 7-1. Monitored parameters

Parameter (unit)	Monitoring Window	Definition
PTP (cmH_2O*s)	Monitoring 1	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. Both PTP and WOBimp (see below) indicate work by the patient to trigger the breath. The work depends on • the intensity of the patient's effort, • the trigger type and sensitivity, and • the volume and resistance of the breathing circuit. PTP and WOBimp are valid for patient-initiated breaths only. Neither PTP nor WOBimp indicates total patient work. But both indicates of how well the ventilator is adapted to the patient. If PTP and WOBimp values increase: • Check and remove water in tubes. • Switch to flow trigger. • Increase trigger sensitivity.
Pulse (1/min)	Monitoring 2	Pulse rate of the patient measured by the SpO_2 sensor.
Pulse inc (%)	Monitoring 2	Quick Wean parameter. Percentage increase in heart rate. This is calculated during a spontaneous breathing trial (SBT). For details, see the Quick Wean chapter in the INTELLiVENT®-ASV manual.
QI-HLI	Monitoring 2	Quality Index of the HLI reflects the reliability of the HLI value expressed in percentage. The greater the QI value the greater reliability of the HLI value.

Table 7-1. Monitored parameters

Parameter (unit)	Monitoring Window	Definition
QI-SpO_2	Monitoring 2	Quality Index of the SpO_2 reflects the reliability of the SpO_2 value expressed in percentage. The greater the QI value, the greater reliability of the SpO_2 value.
Rate inc (%)	Monitoring 2	Quick Wean parameter. Percentage increase in breathing rate. This is calculated during a spontaneous breathing trial (SBT). For details, see the Quick Wean chapter in the INTELLiVENT®-ASV manual.
RCexp (s)	Monitoring 1	Expiratory time constant. The time the lung is fully deflated: 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. For adults, an RCexp value above 1.2 s indicates airway obstruction, and a value below 0.5 s indicates a severe restrictive disease.

Table 7-1. Monitored parameters

Parameter (unit)	Monitoring Window	Definition
RCinsp (s)	Monitoring 1	Inspiratory time constant. It is calculated from the product of Rinsp and Cstat and defines the inflation time. RCinsp is calculated using the LSF method. **NOTE:** Actively breathing patients can create artifact or noise, which can affect the accuracy of these measurements. The more active the patient, the less accurate the measurements. To minimize patient activity during these measurements, you can choose increased Psupport by 10 cmH2O. After completion, return this control to its former setting. An inspiratory time shorter than 2 x RCinsp indicates disequilibrium between ventilator pressure and alveolar pressure and can result in inadequate inspiration.
Rexp (cmH_2O/(l/s))	Monitoring 1	**NOTE:** Actively breathing patients can create artifact or noise, which can affect the accuracy of these measurements. The more active the patient, the less accurate the measurements. To minimize patient activity during these measurements, you can choose increased Psupport by 10 cmH_2O. After completion, return this control to its former setting. Resistance to expiratory flow caused by the endotracheal tube and major airways during exhalation. It is calculated using the LSF method applied to the expiratory phase.

Table 7-1. Monitored parameters

Parameter (unit)	Monitoring Window	Definition
Rinsp (cmH_2O/(l/s))	Monitoring 1	**NOTE:** Actively breathing patients can create artifact or noise, which can affect the accuracy of these measurements. The more active the patient, the less accurate the measurements. To minimize patient activity during these measurements, you can choose increased Psupport by 10 cmH_2O. After completion, return this control to its former setting. 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.
RSB (1/(l*min))	Monitoring 2	Rapid shallow breathing index. The total breathing frequency (fTotal) divided by the exhaled tidal volume (VTE). It has significance for spontaneously breathing patients only. Patients with dyspnea typically takes faster, shallower breaths than nondyspneic patients, RSB is high in the dyspneic patient and low in the nondyspneic patient. RSB is often used clinically as an indicator to judge whether a ventilated patient is ready for weaning.
SBT Time range	SBT Controls	Quick Wean parameter. Defines the hours between which an automated spontaneous breathing trial (SBT) can be started. For details, see the Quick Wean chapter in the INTELLiVENT®-ASV manual.
slopeCO_2 (%CO_2/l)	Monitoring 2	Slope of the alveolar plateau. Volume/flow status of the lungs. Permits assessment of COPD, asthma and inefficient ventilation. Available if CO_2 sensor is installed.

Table 7-1. Monitored parameters

Parameter (unit)	Monitoring Window	Definition
SpCO (%)[1]	Monitoring 2	With Masimo pulse oximeter. Carbon monoxide concentration in arterial blood. For details, see Appendix F, Pulse oximetry. Available in Continuous or Spot check mode. See Section F.2.1.1.
SpHb (g/dL)[3]	Monitoring 2	With Masimo pulse oximeter. Total haemoglobin in arterial blood. For details, see Appendix F, Pulse oximetry. Available in Continuous or Spot check mode. See Section F.2.1.1.
SpHb (mmol/L)[3]	Monitoring 2	With Masimo pulse oximeter. Total haemoglobin in arterial blood. For details, see Appendix F, Pulse oximetry. Available in Continuous or Spot check mode. See Section F.2.1.1.
SpMet (%)[3]	Monitoring 2	With Masimo pulse oximeter. Methaemoglobin concentration in arterial blood. For details, see Appendix F, Pulse oximetry.
SpO_2 (%)	Monitoring 2	SpO_2 is an indirect measurement of oxygen saturation in the blood. It is measured by the SPO_2 sensor and is expressed in a percentage format.
SpO_2/FiO_2	Monitoring 2	100*SpO_2 (%)/FiO_2 (%); If SpO_2 > 94% the value of SpO_2/FiO_2 becomes OFF value. For further information see Appendix F, Pulse oximetry.
SpOC (mL/dL)[3]	Monitoring 2	With Masimo pulse oximeter. Calculated measurement of amount of oxygen in arterial blood. For details, see Appendix F, Pulse oximetry.

Table 7-1. Monitored parameters

Parameter (unit)	Monitoring Window	Definition
TE (s)	Monitoring 1	Expiratory time. In mandatory breaths, TE is measured from the start of exhalation until the set time has elapsed for the switchover to inspiration. In spontaneous breaths, TE is measured from the start of exhalation, as dictated by the ETS setting, until the patient triggers the next inspiration. TE may differ from the set expiratory time if the patient breathes spontaneously.
TI (s)	Monitoring 1	Inspiratory time. In mandatory breaths, TI is measured from the start of breath delivery until the set time has elapsed for the switchover to exhalation. In spontaneous breaths, TI is measured from the patient trigger until the flow falls to the ETS setting, for the switchover to exhalation. TI may differ from the set inspiratory time if the patient breathes spontaneously.
Time before starting SBT	SBT Controls	Quick Wean parameter. Defines the length of time that patient conditions must meet the **To start** criteria, while %MinVol is reduced to a minimum of 70%, before an automated spontaneous breathing trial (SBT) will start. For details, see the Quick Wean chapter in the INTELLiVENT®-ASV manual.
Time between 2 SBTs	SBT Controls	Quick Wean parameter. Defines the minimum length of time that must pass between two automated spontaneous breathing trials (SBT). For details, see the Quick Wean chapter in the INTELLiVENT®-ASV manual.
Tolerance Time	Quick Wean Configuration, To abort screen	Quick Wean parameter. Defines the length of time a parameter can be out of range during weaning activity before a spontaneous breathing trial (SBT) is aborted. For details, see the Quick Wean chapter in the INTELLiVENT®-ASV manual.

Table 7-1. Monitored parameters

Parameter (unit)	Monitoring Window	Definition
V'alv (ml/min)	Monitoring 2	Alveolar minute ventilation. Valv * f (normalized to 1 min). Permits assessment of actual alveolar ventilation (as opposed to minute ventilation). Available if CO_2 sensor is installed.
V'CO_2 (ml/min)	Monitoring 2	CO_2 elimination. Net exhaled volume of CO_2 per minute. Permits assessment of metabolic rate (e.g., it is high with sepsis, tetanus, etc.) and treatment progress. Available if CO_2 sensor is installed.
VDaw (ml)	Monitoring 2	Airway dead space. Effective volume lost in the conducting airways. A relative increase in dead space indicates increased respiratory insufficiency and can be seen as an indicator of the current patient situation. Patients with high dead space in combination with muscles deficiency are at particular risk. Available if CO_2 sensor is installed.
VDaw/VTE (%)	Monitoring 2	Physiological dead space fraction at the upper airways. Available if CO_2 sensor is installed.
VeCO_2 (ml)	Monitoring 2	Exhaled CO_2 volume. Updated breath by breath. Available if CO_2 sensor is installed.
ViCO_2 (ml)	Monitoring 2	Inspired CO_2 volume. Updated breath by breath. Available if CO_2 sensor is installed.

Table 7-1. Monitored parameters

Parameter (unit)	Monitoring Window	Definition
VLeak (ml)	Monitoring 1	Leakage volume. The difference between the inspiratory tidal volume (VTI) and the expiratory tidal volume (VTE) measured by the flow sensor and averaged over the past 8 breaths. VLeak can indicate leaks on the patient side of the flow sensor (endotracheal tube, chest tube, mask). It does not include leakage between the ventilator and flow sensor. Displayed in NIV mode.
VLeak (%)	Monitoring 2	Leakage percent. The percentage of the delivered inspiratory volume (VTI) that is not returned during exhalation. Averaged flow measurements over 8 breaths (with flow sensor) allow to calculate leakage. Leak can indicate leaks on the patient side of the flow sensor (endotracheal tube, chest tube). It does not include leakage between the ventilator and flow sensor. Displayed in NIV mode.
Vtalv (ml)	Monitoring 2	Alveolar tidal ventilation. VTE – VDaw. Available if CO_2 sensor is installed.
VTE (ml)	Monitoring 1	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 at patient side, the displayed VTE may be less than the tidal volume the patient actually receives. In Noninvasive modes (NIV, NIV-ST, nCPAP-PS), VTE is replaced by VTE NIV.

Table 7-1. Monitored parameters

Parameter (unit)	Monitoring Window	Definition
VTE NIV (ml)	Monitoring 1	Expiratory tidal volume. The volume exhaled by the patient. Used only in Noninvasive modes (NIV, NIV-ST, nCPAP-PS), this parameter replaces VTE, as it is leak compensated.
VTE Spont (ml)	Monitoring 1	Spontaneous expiratory tidal volume. The volume exhaled by the patient. if there is a gas leak at patient side, the displayed VTEspont may be less than the tidal volume the patient actually receives. Only displayed for spontaneous breaths.
VTI (ml)	Monitoring 1	Inspiratory tidal volume. The volume by the ventilator. It is determined from proximal Flow sensor measurement.
VT/IBW (ml/kg)	Monitoring 1	Tidal volume/ ideal body weight ratio to avoid excessive tidal volumes and apply lung-protective strategies.
WOBimp (J/l)	Monitoring 2	Work of breathing imposed by the inspiratory valve, tubing, and humidifier. It is airway pressure integrated over inspiratory volume until pressure exceeds the PEEP/CPAP level. In the dynamic pressure/volume loop, WOBimp is the area below PEEP/CPAP. This is created exclusively by the patient; thus WOBimp is valid for patient-initiated breaths only. If based on Paw, WOBimp indicates the work required of the patient to be on a ventilator. It does not include work resulting from the endotracheal tube and the total respiratory system. If based on endotracheal pressure using Paux, WOBimp includes work resulting from the endotracheal tube. The significance of WOBimp is similar to that of PTP. For more information, see the description of the PTP parameter in this table.

1. Available only with the Masimo Rainbow SET option. Not compatible with Nihon-Kohden.

8 Intelligent panels

8.1 Introduction

NOTE:

A heart in the dynamic lung panel will only be displayed if the SpO_2 sensor is connected.

Configure the Ventilation Cockpit to display and select any of the types of panels available on the default touch screen by touching them.

8.2 Dynamic lung panel

The Dynamic Heart/Lung panel (Figure 8-1) visualizes tidal volume, lung compliance, hemodynamic status, pulse, patient triggering, and resistance in real-time. The lungs expand and contract in synchrony with actual breaths. Numeric values for resistance (Rinsp), compliance (Cstat), SpO_2, Pulse, HLI, patient conditions and $PetCO_2$ are also displayed. If all values are in a normal range, the panel is framed in green.

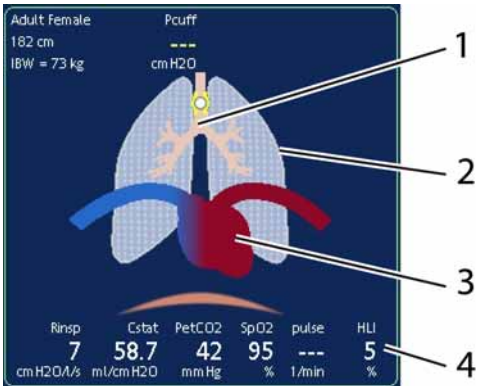


Figure 8-1. Dynamic Heart/Lung panel

1 Bronchial tree

2 "Normal" lungs (see text for details)

3 Beating heart

4 Treatment parameters

8.2.1 Tidal volume (Vt)

The Dynamic Lung expands and contracts to show tidal volume (Vt) in real-time. The movements shown in this window depict actual breaths occurring, based on the proximal flow sensor signal. The lung size shown is relative to "normal" size for the patient's height (IBW), based on a "normal" value of 10 ml/kg.

A **`Disconnection vent. side`** or **`Disconnection pat. side`** alarm is depicted by a deflated lung. An **`Exhalation obstructed`** alarm is depicted by an inflated lung.

8.2.2 Compliance (Cstat)

The Dynamic Lung shows compliance (Cstat) breath by breath relative to "normal" values for the patient's height (Figure 8-2). As the figure shows, the shape of the lungs changes with compliance (low compliance, normal compliance and high compliance). The numeric value is also displayed.

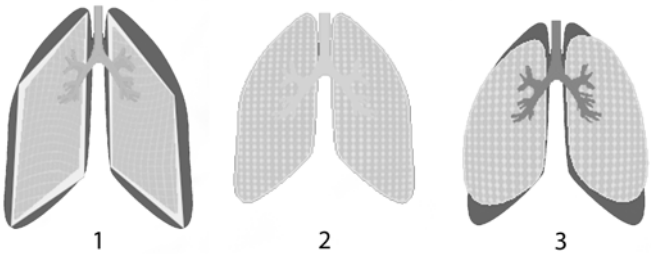


Figure 8-2. Compliance shown by the dynamic lung

1 Low compliance

2 Normal compliance

3 High compliance

8.2.3 Patient triggering: Muscle

The muscle in the Dynamic Lung shows patient triggering (Figure 8-3).

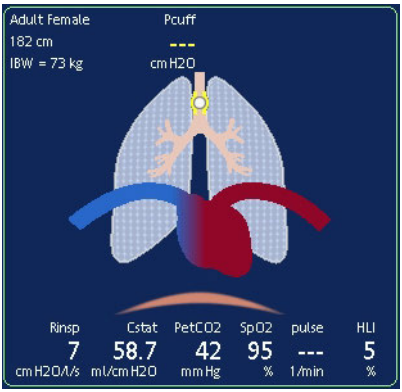


Figure 8-3. Patient triggering shown by the dynamic lung muscle

8.2.4 Resistance: Bronchial tree

The bronchial tree in the Dynamic Lung shows resistance (Rinsp) breath by breath relative to "normal" values for the patient's height (Figure 8-4).

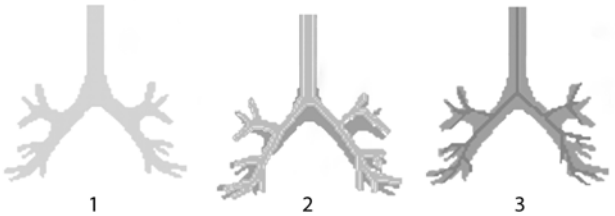


Figure 8-4. Rinsp shown by the bronchial tree of the dynamic lung

1 Normal resistance

2 Moderately high resistance

3 High resistance

Table 8-1. Dynamic lung normal values

Parameter	Definition of normal values
Tidal volume (Vt)	10 ml/kg IBW (calculated from Patient height)
Compliance (Cstat)	For Patient height between 30 and 135 cm: 0.000395 * Patient height $^{2.38}$ For Patient height > 135 cm: -0.0028 * Patient height + 1.3493 * Patient height – 84.268
Resistance (Rinsp)	For Patient height < 210 cm: (1.993 – 0.0092 * Patient height) * 10.2 + 5 For Patient height > 210 cm: 0.5 + 5

8.2.5 Heart circulation

In the heart-lung panel, the circulation of blood through the heart is displayed superimposed on the breathing of the lungs.

The heart and vessels are shown to be pulsating only if HLI becomes a higher value (indicating hemodynamic instability). The higher the HLI the larger the pulsation (the smaller the heart and the vessel diameter).

If there is no pulsation and the diameter is large, this means that hemodynamics are acceptable. If no HLI is available, there is no pulsation and the diameter is medium. A small white heart pulsates with the patient's pulse. If no pulse is detected, no white heart is displayed.

If there is no SpO_2, only the contour of the big colored heart is displayed.

Figure 8-5. Heart circulation (left: no SpO_2, hemodynamic status unclear; middle: haemodynamically unstable, showing pronounced pulsation; right: haemodynamically stable, with pulse)

8.3 Heart-Lung Interaction

For detailed information, see the INTELLiVENT®-ASV manual.

8.3.1 Graphic Display

Heart-Lung Interaction (HLI) is displayed graphically on the Cockpit screen of an intelligent panel.

1. Select one of the panels touch it and select "Dynamic lung" (Figure 8-6).

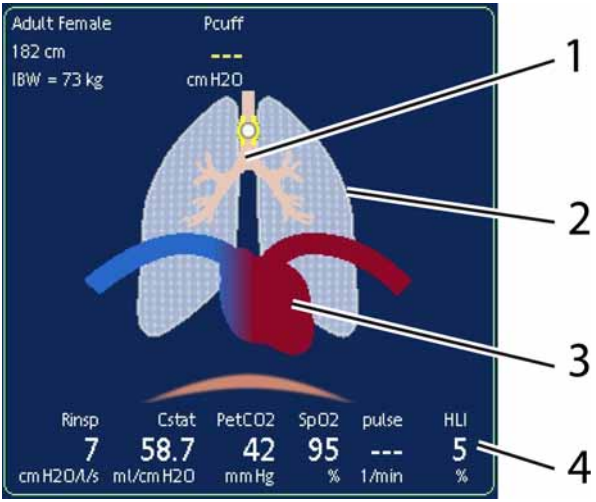


Figure 8-6. Dynamic Heart-Lung Interaction panel

1 Bronchial tree

2 Normal lung (refer to Dynamic Lung Panel for details)

3 Heart

4 Treatment parameters

The size of the heart and blood vessels in the graphic above would be considered normal. If the animation shows the heart and blood vessels contracting to a smaller size, this is an indication of a hemodynamic instability in the patient and requires you to adjust the ventilation.

8.4 Vent status

The Vent Status panel (Figure 8-7) depicts six separate parameters related to the patient's ventilator dependency, including oxygenation, CO_2 elimination, and patient activity.

A floating indicator moving up and down within the column shows the value for a specific 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 frame around the Vent Status panel changes to green. This color change indicates the patient could be ready for discontinuation of ventilation. The panel is updated breath by breath.

This section describes the parameters shown in the Vent Status panel. Oxygen, PEEP, ExpMinVol, and Pinsp values are always shown, but in Configuration mode you can configure the remaining two parameters from these choices: RSB, VariIndex[1] (variability index), P0.1, and %fSpont.

When Quick Wean is enabled, the Vent Status panel changes to show **`Time to Start SBT`**, and SBT running information when a spontaneous breathing trial is underway. For details on Quick Wean, SBTs, and the Vent Status panel in this mode, see the Quick Wean chapter in the INTELLiVENT®-ASV manual.

1. The variability index (VariIndex) parameter is not available in the USA

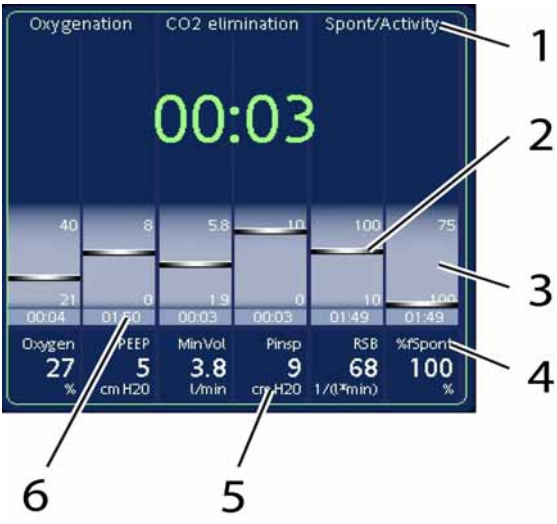


Figure 8-7. Vent status panel

1 Group title

2 Monitored graphic value (floater)

3 Light blue weaning zone with user-configurable limits

4 Choice of parameters for display is user configurable

5 Numeric monitored value

6 Elapsed time value has been in weaning zone

Table 8-2. Vent status parameter

Parameter (unit)	Definition
Oxygen (%)	Oxygen setting. See Table 5-2.
PEEP (cmH2O)	PEEP/CPAP setting. See Table 5-2.
ExpMinVol (%)	Monitored ExpMinVol as a percentage of normal minute ventilation. For details, see the INTELLiVENT®-ASV manual.

Table 8-2. Vent status parameter

Parameter (unit)	Definition
Pinsp (cmH2O)	Inspiratory pressure, the target pressure (additional to PEEP/CPAP) applied during the inspiratory phase (see Table 7-1).
RSB (1/(l*min))	RSB measurement. Shown only if 80% of the last 25 breaths are spontaneous (see Table 7-1). Can be configured on or off.
VariIndex (%)[1],[2]	Variability index. Indicates variability of volume and timing. The coefficient of variation (standard deviation/ mean) of the Vt/TI index. Calculated from the last 100 breaths. Updated breath by breath. Can be configured on or off.
P0.1 (cmH2O)[3]	P0.1 measurement. Shown only if pressure trigger is active (see Table 7-1). Can be configured on or off.
%fSpont (%)	Spontaneous breath percentage. The moving average of the percentage of spontaneous breaths over the last 8 total breaths. Can be configured ON or OFF.

1. Defined by the coefficient of variation (CV = standard deviation/mean) of Vtinsp/Ti over consecutive valid breaths. For adults, a CV > 19% for the VtI/TI has been associated with successful weaning in 100% of cases. (Wysocki M. Crit Care Med 2006.)
2. The variability index (VariIndex) parameter is not available in the USA.
3. A P0.1 < the default value is likely associated with high respiratory drive and unsuccessful separation from the ventilator.

8.5 ASV monitored data window

The ASV monitored data window (Figure C-5) provides numeric target and actual parameters for tidal volume, frequency, pressure, and minute ventilation.

See Appendix C, ASV, for detailed information on ASV, including how to interpret the data in the monitored data window.

8.6 ASV target graphics window

The ASV target graphics window (Figure C-4) shows how the adaptive lung controller moves toward its targets. And it shows both the target and actual parameters for tidal volume, frequency, pressure, and minute ventilation.

See Appendix C, ASV, for detailed information on ASV, including how to interpret the data in the target graphics window.

8.7 INTELLiVENT®-specific intelligent panels

For detailed information, see the INTELLiVENT®-ASV manual.

8.8 Quick Wean-specific intelligent panels

For detailed information, see the INTELLiVENT®-ASV manual.

9 P/V tool maneuver option

9.1 Introduction

NOTE:

The P/V Tool is a monitoring maneuver that provides information that may be used to optimize PEEP and other ventilator settings. This is just one piece of information that must be considered, however, along with hemodynamics and other clinical conditions. It is the clinician's responsibility to appropriately interpret and apply this information in patient treatment.

9.1.1 Overview

The P/V Tool is a respiratory mechanics maneuver that records a quasi-static P/V (pressure/volume) curve at the bedside.

The P/V Tool records both the inflation and deflation limbs. The P/V Tool can be used for diagnostic purposes plus for applying controlled recruitment maneuvers.

This curve, generated with very low flow, can provide the physician with valuable and objective information about the respiratory system mechanics. The information can be useful for clinical diagnosis as well as for optimization of ventilator settings.

A cursor function permits graphical analysis of the curve, including identification of inflection points, and a “visual curve fitting” that determines the linear compliance.

The maneuvers employ an adjustable pressure ramp in which airway pressure is slowly increased to an upper level and then decreased to a lower level.

The P/V Tool maneuvers do not require disconnection of the breathing circuit, and no patient setting changes. You can resume normal ventilation at any time.

9.1.2 Required conditions for use

Make sure the following conditions are met before attempting a P/V Tool maneuver.

- The patient must be intubated and ventilated but not breathing spontaneously. Some patients can require heavy sedation or neuromuscular blockade to prevent spontaneous breathing efforts.
- There must be no gas leak throughout the entire system composed of the ventilator, the breathing circuit, and the ventilated patient.
- Nebulization must be deactivated.
- The flow sensor must perform optimally.
- Total respiratory system compliance must be a minimum of 5 ml/cmH2O. (The P/V Tool maneuver does not function correctly with the IngMar infant lung model.)
- The P/V Tool is inactive in SPONT, NIV, NIV-ST, nCPAP-PS and in Backup modes.
- The P/V Tool is inactive **`Flow sensor calibration needed`** Alarm is active.

9.1.3 Indication for use

As long as the required conditions are met and no contraindications exist, the P/V Tool maneuver may be performed on any patient.

The P/V Tool maneuver is particularly valuable for use with restrictive lung "stiff lung" diseases (for example, ALI or ARDS patients).

Be careful when performing the P/V Tool maneuver on patients with obstructive "soft lung" diseases (for example, COPD). Set **`Ptop`** low to prevent generation of excessive volumes.

9.1.4 Contraindications for use

- Patients who are breathing spontaneously
- Patients with unstable cardiovascular dynamics
- Patients with confirmed or suspected intracranial hypertension
- Patients who cannot tolerate high intrapulmonary pressure for other reasons
- Patients vulnerable to baro- or volutrauma
- Leaks in the system (patient and/or breathing circuit)

9.1.5 How the P/V Tool works

The P/V Tool records the pressure-volume relation of the lungs at close to zero flow. Perform these tasks as presented:

1. **Maneuver initiation.** The operator initiates the maneuver by pressing **Start/Stop**.
2. **Prolonged exhalation.** The exhalation phase of the current control breath is prolonged, and pressure is reduced to the operator-set **Pstart** level. The exhalation lasts 10 x RCexp, or a minimum of 6 s and a maximum of 15 s.
3. **Linear pressure increase (inflation limb).** The breathing circuit is pressurized linearly to the operator-set **Ptop** pressure at the operator-set **Ramp speed**. Resultant volume changes are recorded.
4. **Pause at Ptop.** When the pressure reaches **Ptop**, any operator-set **Tpause** is performed. The inspiratory and expiratory valves are closed during the pause.
5. **Linear pressure decrease (deflation limb).** Pressure is released linearly to the operator-set **End PEEP** level. The **Ramp speed** defines the rate of pressure decrease.
6. **Ventilation resumes at new PEEP (End PEEP).** Ventilation resumes when **End PEEP** is reached. The P/V Tool window remains open with the curve frozen for analysis.

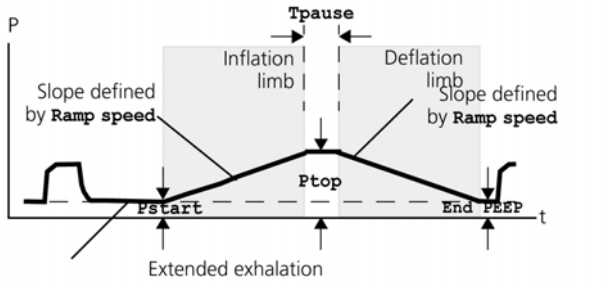


Figure 9-1. How the P/V Tool works

9.2 Procedure

WARNING

- **The P/V Tool can apply high pressures for extended periods of time.**
- **Use caution when performing the P/V Tool maneuver on patients with severe chronic obstructive pulmonary disease, this can generate excessive volumes.**
- **DO NOT attempt to use this tool on an active patient otherwise it can cause possible patient discomfort and erroneous readings.**

NOTE:

- Meaningful data from the P/V Tool maneuver requires that there be no gas leak on the patient side of the flow sensor, and that the flow sensor perform well at very low flows. HAMILTON MEDICAL recommends you to perform the tightness test and the flow sensor calibration before using the P/V Tool. However, if you have doubts about the validity of the resulting data, also perform the breathing circuit and flow sensor test described in Section 9.2.6.

- If the **Ptop** setting is greater than the high **Pressure** alarm setting, the high pressure alarm threshold becomes **Ptop** + 5 cmH2O. It overrides the operator-set alarm threshold.
- Patient alarms are suppressed during the P/V Tool maneuver.
- After completion of the P/V Tool maneuver, there can be transitional alarms caused by the interruption of ventilation by the maneuver.
- P/V Tool Pro: LIP, UIP, PDR and cursor start position are provided only if the curve fits shape shown in Figure 9-2 well.
- During the maneuver and 30 seconds after finishing the maneuver all patient alarms are suppressed. Apnea time restarts at conclusion of the maneuver.

9.2.1 Performing the maneuver

NOTE:

- For passive patients only
- Inactive in SPONT, NIV, NIV-ST, nCPAP-PS and apnea backup
- Breathing circuit must be gas tight
- Inactive for 5 breaths after a maneuver
- Inactive during, and for 5 breaths after, nebulization
- Inactive while **Flow Sensor cal. needed** is displayed
- Reconfirm if the setting exceeds critical limits
- The quality of information obtained depends on condition of flow sensor.
- If the compliance is normal to higher than normal, use a lower **Ramp speed** setting. If the compliance is lower, you can select a higher **Ramp speed** setting.

- For COPD patients it is suggested you set **Ptop** to 30 cmH2O and the **Ramp speed** to 2 cmH2O/s.
- To display Vpeep, set **Pstart** to 0 cmH2O.
- After you initiate a P/V Tool maneuver, you can terminate it any time by pressing the M-knob or **Start/ Stop** a second time.
- DO NOT begin a P/V Tool maneuver when automatically calibration is shown.

1. Touch the **Tools button and then** select the **P/V Tool** tab. The P/V Tool information window opens. Read this information carefully.

Figure 9-2. P/V Tool information window

2. Touch **OK** to continue. The P/V Tool or P/V Tool Pro window opens.

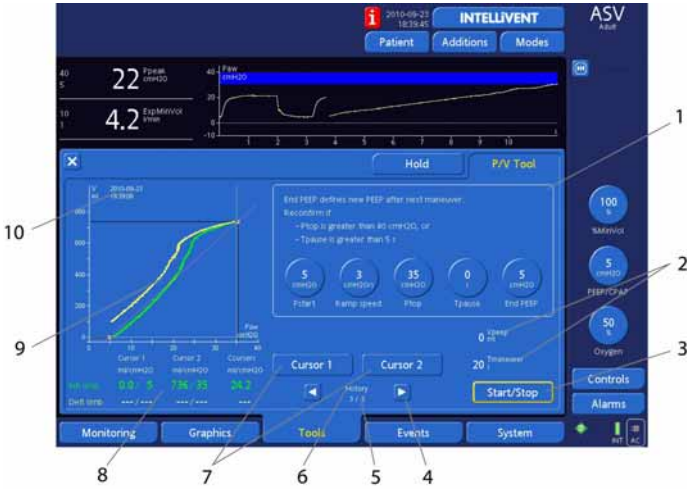


Figure 9-3. P/V Tool window

1 Settings[1]. Shows the currently active P/V Tool control settings. These settings are:

- **`Pstart.`** PEEP to be applied at start of maneuver.
- **`Ptop.`** Maximum pressure to be applied.
- **`End PEEP.`** PEEP to be applied at end of deflation limb. If Pstart and End PEEP are different. A window for confirmation displays asking whether you want to change PEEP/CPAP setting after maneuver.
- **`Ramp speed.`** Rate of change of pressure.
- **`Tpause.`** Length of pause between inflation and deflation limbs.

2

- **`Tmaneuver.`** Total maneuver time, calculated.
- **`Vpeep.`** Released volume at the start of a ZEEP maneuver.

3 **Start/Stop.** Begins maneuver (or ends it at any time).

4 Lets you scroll through the previous stored PV Tool curves.

5 Plot number/Total number of stored plots

6 **History.** Lets you scroll through the previous 5 stored P/V Tool curves.

7 **Cursor 1** and **Cursor 2.** Each cursor simultaneously selects two points, one for the inflation and one for the deflation limb. The points are vertically aligned. Using both cursors you can determine the linear compliance by obtaining a "best visual fit." Data about these points is also displayed.

8 Cursor data. The **Cursor** column shows the values for the points on the inflation limb (**Infl limb**) and deflation limb (**Defl limb**) of the curve. The **Cursors** column shows the calculated compliance in ml/cmH2O for a straight line that connects the cursor points.

9 Curve, for this example, a pressure/volume curve that includes both inflation and deflation limbs.

10 Time/date. Maneuver date and start time

1. See Table A-5 for a list of setting ranges, standard settings, and resolutions.

Figure 9-4. P/V Tool Pro window

1 **`Reference.`** Pushing the reference button overlays up to 3 curves starting at the current displayed PV Tool curve. The most recent curve is displayed on the top.

2 Plot number/Total number of stored plots

3 Lets you scroll through the previous stored PV Tool curves. If **`History`** is active, lets you move the cursor between the overlaid curves.

4 Settings[1]. Shows the currently active P/V Tool Pro control settings. These settings are:

- **`Pstart.`** PEEP to be applied at start of maneuver.
- **`Ptop.`** Maximum pressure to be applied.
- **`End PEEP.`** PEEP to be applied at end of deflation limb. If Pstart and End PEEP are different. A window for confirmation displays asking whether you want to change PEEP/CPAP setting after maneuver.
- **`Ramp speed.`** Rate of change of pressure.
- **`Tpause.`** Length of pause between inflation and deflation limbs.
- Push the **`Settings`** button to open a window which allows to change the settings.

5 **Cursor 1** and **Cursor 2.** Each cursor simultaneously selects two points, one for the inflation and one for the deflation limb. The points are vertically aligned. Using both cursors you can determine the linear compliance by obtaining a "best visual fit." Data about these points is also displayed.

6 **Tmaneuver.** Total maneuver time, calculated.

7 **Start/Stop.** Begins maneuver (or ends it at any time).

8 Cursor data. The **Cursor** column shows the values for the points on the inflation limb (**Infl limb**) and deflation limb (**Defl limb**) of the curve. The **Cursors** column shows the calculated compliance in ml/cmH2O for a straight line that connects the cursor points.

9 Curve, for this example, a pressure/volume curve that includes both inflation and deflation limbs.

10 **Vpeep.** Released volume at the start of a ZEEP maneuver.

11 Time/date. Maneuver date and start time.

1. See for a list of setting ranges, standard settings, and resolutions.

3. Adjust settings as desired by selecting and activating a parameter, followed by adjustments and activation. Repeat for each parameters you require. The calculated inflation time is displayed as **Tmaneuver**.
   If you attempt to set **Ptop** to greater than 40 cmH2O, **Tpause** greater than 5 seconds, or **End PEEP** to a value different from the current PEEP/CPAP, you must reconfirm your intention through the **Yes** button.
4. When necessary you can change the plot type, see Changing the Plot type in this section.
5. Select **Start/Stop** to begin the maneuver. When the maneuver is completed, the window remains open with the curve displayed for approximately 1 minute, waiting for possible input before closing.
   If the **Start/Stop** button is pushed during a running P/V maneuver, the maneuver will be terminated immediately and pressure will be reduced to End PEEP, and the controlled ventilation restarts.

9.2.2 Using the cursor feature to graphically analyze the plot

NOTE:

The cursor selects two points simultaneously: one on the inflation limb and one on the deflation limb.

You can use the P/V Tool cursors to determine numeric values for points on the curve. Using both cursors, you can also perform a "visual curve fitting" to determine the linear compliance, which is then displayed.

Regardless of the type of curves, the cursor remains available and adjustable. The actual value at cursor positions is displayed as temporary information on the screen.

To determine the numeric value at a point on the curve, turn the P&T knob. You can read the values at the bottom of the window (Figure 9-5).

P/V Tool Pro:

LIP, UIP and PDR are automatically calculated during the PV maneuver. After calculation each reading is displayed as numerical values and the cursor will automatically jump to LIP and PDR.

To perform a "visual curve fitting" to determine the compliance, complete these instructions:

1. Select **`Cursor 1`**; then select a point on the curve where you suspect the low inflection point is located (Figure 9-5 and Figure 9-5). Deselect **`Cursor 1`**.
2. Select **`Cursor 2`**; then find a point on the curve where you suspect the upper inflection point is located. Deselect **`Cursor 2`**.
3. Two straight lines (linear compliance) are automatically drawn, each connecting the cursors on the inflation or deflation limb. Adjust the cursors for the "best visual fit".

That is, where the straight lines lie on the longest and steepest linear segment of the curve. Pressure and volume/ flow values are displayed at the bottom of the window along with the calculated compliances (Figure 9-7 and Figure 9-5).

4. Close the window to return to the basic screen. This returns P/V Tool settings to their defaults.
5. Reopen the P/V Tool window at any time to re-examine the curve. The curve remains available for later observation until the maneuver is repeated. You can change the plot type (see Section 9.2.4). Also use the History feature to review stored curves.

Figure 9-5. Using the cursor function in the P/V Tool window: Creating the linear compliance curve

1 Cursor 1

2 Cursor 2

Figure 9-6. Using the cursor function in the P/V Tool Pro window: Creating the linear compliance curve

1 dv curve

2 Cursor 1

3 Cursor 2

9.2.3 Analyzing the curve

NOTE:

The P/V Tool is a monitoring maneuver providing information that can be used to optimize PEEP and other ventilator settings. The P/V Tool is just one piece of information that must be considered, along with hemodynamics and other clinical conditions. The clinician's remains responsible to appropriately interpret and apply this information in course of patient treatment.

A pressure/volume (P/V) curve depicts data that can be used to optimize ventilator settings, among others uses. Figure 9-7 shows some information that you can obtain from a P/V curve.

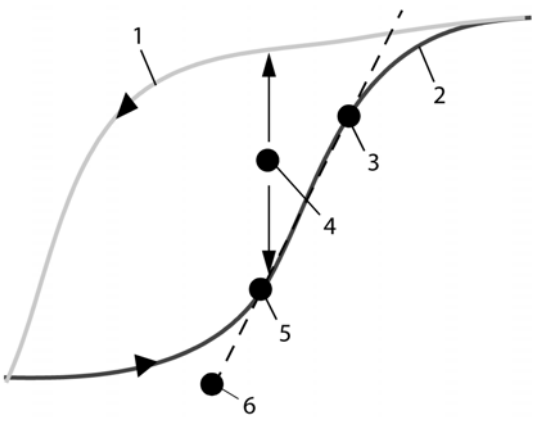


Figure 9-7. Interpreting the P/V curve

1 Deflation limb

2 Inflation limb

3 Upper inflection point of inflation limb (UIP)

4 Difference in volume between two curves (dv)

5 Lower inflection point of inflation limb (LIP)

6 Linear compliance (Clin)

The P/V Tool maneuver generates two curves: 1) the inflation P/V curve (in green), and 2) the deflation P/V curve (in yellow and usually shifted to the left). Obtain the information from the curve as listed above (see legend number 3 to 6).

In addition, you can obtain several pieces of information from the deflation limb, such as the PEEP level required to avoid alveoli collapse after a special maneuver to open alveoli (recruitment maneuver). For comprehensive physiological explanations, refer to recent publications[1].

1. Maggiore SM, Richard JC, Brochard L. What has been learnt from P/V curves in patients with acute lung injury/acute respiratory distress syndrome. Eur Respir J Suppl. 2003;42:22s-6s.

The lower inflection point of the inflation pressure/ volume curve (LIP)

The LIP is the point of maximal curvature below the linear portion of the inflation P/V curve, or the point where the rate of increase in respiratory system compliance is maximal. This point is where alveoli start to open as airway pressure increases. The recommendation is to set positive end expiratory pressure (PEEP) at that level or slightly above[1].

The difference in volume between the two curves (dv)

The difference between the inflation and the deflation limb, also called hysteresis, can have several meanings. Recent publications suggest that in patients with acute lung injury or acute respiratory distress syndrome hysteresis could indicate the volume that might be gained by increasing PEEP or by using a special maneuver to open alveoli (recruitment maneuver)[2].

The linear compliance of the inflation pressure/volume curve (Clin)

This part of the curve is where the maximal compliance is obtained. In that zone, a change in volume requires a minimal increase in pressure. The recommendation is to set PEEP and tidal volume to obtain tidal ventilation in that zone2.

The upper inflection point of the inflation pressure/volume curve (UIP)

The UIP is the point of maximal curvature at the end of the linear portion of the inflation PV curve, or the point where the rate of decrease in respiratory system compliance is maximal. This point is where all recruitable alveoli are open and start to overinflate. The recommendation is to set the tidal volume to obtain a plateau pressure below that point2.

1. Tobin MJ. Advances in mechanical ventilation. N Engl J Med. 2001;344:1986-96.

2. Hickling KG. The pressure-volume curve is greatly modified by recruitment. A mathematical model of ARDS lungs. Am J Respir Crit Care Med. 1998;158:194-202.

9.2.4 Selecting plot type

The P/V Tool lets you display your maneuver data in various forms for flexibility in patient assessment. You can change the plot type before, or after the maneuver; and you can change the representation of stored curves while using the **`History`** feature.

Touch the P/V Tool graphics area to open the **`P/V Tool plot`** pop-up window (Figure 9-8). Select a plot type:

- **Paw/V** (airway pressure/volume)
- P/V Tool Pro: **Paw/V+Paw/dv** (airway pressure/volume+airway pressure/volume difference (expiration - insufflation). Can be used to find the point of derecruitment.
- **Paw/Flow.** This curve can be used to check the quality of the maneuver. If flow at any point is outside the range ±10 l/min, consider reducing the **`Ramp speed`**.
- **Paux/V**
- **Paw-Paux/V.** If you use esophageal pressure as the Paux input, a transpulmonary pressure curve is displayed. This curve shows the compliance of the lungs alone, eliminating the chest wall compliance.

P/V tool: Cursors can be used on Paw/V, Paux/V curve.
P/V Tool Pro: Cursors can be used in all curves (Paw/flow, Paw/V+Paw/dv).

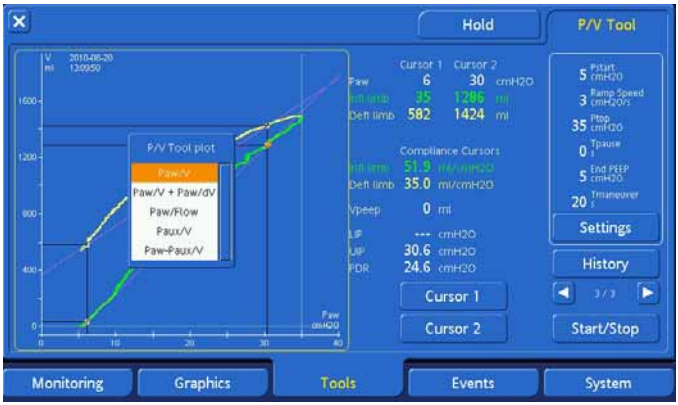


Figure 9-8. P/V Tool plot window

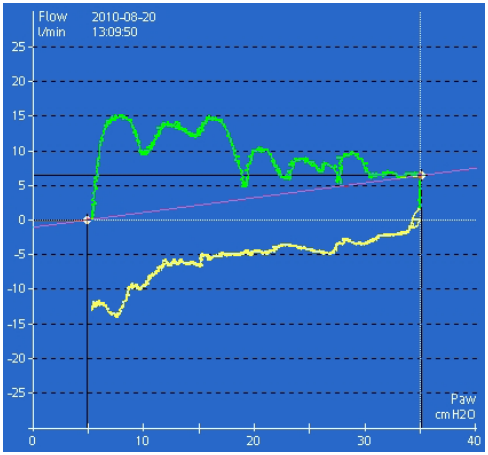


Figure 9-9. Paw/Flow plot

9.2.5 Using the Reference feature to review stored curves

The reference feature monitors patient change and treatment effectiveness over time. To have a trace of recruitment maneuvers, one previous loop is displayed in different color with time stamp displayed in the same color as the curve. The Cursor is active on the last curve in the stack of 2 loops. With forth and back (triangle) the active cursor can be selected. Functionality can be activated with an additionally **Reference** button.

9.2.6 Flow sensor and breathing circuit check

NOTE:

- Perform this check only when you require a much higher quality of measurement.
- Ensure another source of ventilatory support is available during this test. The patient must be disconnected from the ventilator during it.
- To ensure the validity of this test, you must use the actual parts to be used when performing the P/V Tool maneuver, including the flow sensor.

Reason to perform: If you have doubts about the validity of P/V Tool maneuver data.

Required materials:

- Set up a breathing circuit to be used for P/V Tool, including breathing circuit, flow sensor, expiratory membrane and cover
- An adult (2 l) demonstration lung assembly with ET tube.

Figure 9-10. Demonstration lung assembly

Description: Meaningful data from the P/V Tool maneuver requires there be no gas leak on the patient side (that is, between the flow sensor and the patient's respiratory system) and that the flow sensor perform well at low flows (that is, < 15 l/min in both directions).

For the purposes of normal ventilation, the tightness test and the flow sensor calibration assure these patient circuit parts will perform adequately. For the purposes of the P/V Tool maneuver, however, the tightness test and the flow sensor calibration could not be sufficient. This is because the P/V Tool maneuver involves very low flows. therefore could not tolerate small leaks, or less-than-optimal performance, which would be perfectly adequate during routine ventilation.

Preparation: Connect the ventilator to AC power, and air and oxygen supplies. Set up the ventilator for normal ventilation, complete with appropriate breathing circuit, appropriate flow sensor, appropriate demonstration lung or lung model, and expiratory membrane and cover. Switch power ON.

Procedure:

1. Run the tightness test and flow sensor calibration.
2. Open the P/V Tool window and make the following settings:

Pstart	0 cmH2O
Ptop	40 cmH2O
End PEEP	0 cmH2O
Ramp speed	2 cmH2O
Tpause	15 s

3. You will see the query **Confirm PEEP change**. Select **Yes**.
4. Select **Start/Stop** to perform a maneuver.
5. Verify there is no gas leakage on the patient side and confirm flow sensor performance at low ramp speed:

   A. Move **Cursor 2** to the left to 35 cmH2O.

   B. Examine the volume difference between the inflation and deflation limbs, which is where the pause occurred (Figure 9-11). Verify this is less than 150 ml.
   If the volume difference is greater than 150 ml, there is a gas leak between the flow sensor and the demonstration lung. Minimize the leak (inspect the lung, tubes, and connectors), and then repeat the maneuver until the volume difference is less than 150 ml.

   C. Examine the volume difference between the inflation and deflation limbs at Ptop. An unacceptable leak on the patient side appears as a volume difference > 150 ml when the pause is applied at **Ptop**.

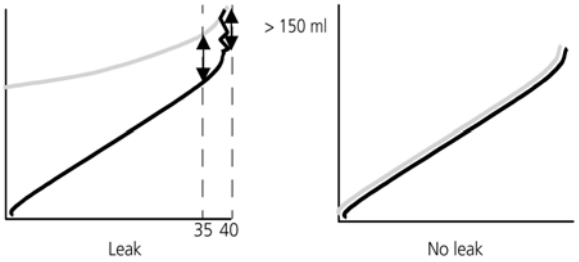


Figure 9-11. Checking for a gas leak between the Flow Sensor and the demonstration lung

6. Check flow sensor performance at high ramp speed:

   A. Change the **Ramp speed** setting from 2 cmH2O/s to 5 cmH2O/s.

   B. Begin another maneuver by selecting and activating **Start/Stop**.

   C. To use the History feature, compare the curves obtained at **Ramp speed**s of 2 and 5 cmH2O/s. Verify that the inflation and deflation limbs of the two curves are visually (more or less) parallel (Figure 9-12).
   If the curves are not parallel, the flow sensor performance is not sufficient to produce meaningful P/V Tool results. Consider using a new flow sensor.

Figure 9-12. Checking flow sensor performance

Compare curves obtained at different **Ramp speed**s. Nonparallel curves can indicate insufficient flow sensor performance.

9.2.7 P/V Tool against P/V Tool Pro

Table 9-1. P/V Tool against P/V Tool pro

P/V Tool	P/V Tool Pro
Curve small screen size	Increased screen size for curves
Cursors on pressure volume curve	Cursors on all curves
No reference overlay	Reference curve displayed with date and time stamp
--	Paw/V+Paw/dv curve
--	LIP, UIP, PDR calculation and cursor setting

9.3 References

- **Lu Q, Rouby J-J.** Measurement of pressure-volume curves in patients on mechanical ventilation: methods and significance. Crit Care 2000, 4:91-100.
- **Maggiore SM, Brochard L.** Pressure-volume curve in the critically ill. Current Opinion in Critical Care 2000, 6:1-10.
- **Maggiore SM, Brochard L.** Pressure-volume curve:methods and meaning. Minerva Anestesiol 2001, 67:228-37.
- **Ware LB, Matthay MA.** The acute respiratory distress syndrome. N Engl J Med. 2000 May 4;342(18):1334-49.
- **Ranieri VM, Giunta F, Suter PM, Slutsky AS.** Mechanical ventilation as a mediator of multisystem organ failure in acute respiratory distress syndrome. JAMA. 2000;284:43-44.
- **Ranieri VM, Suter PM, Tortorella C, De Tullio R, Dayer JM, Brienza A et al.** Effect of mechanical ventilation on inflammatory mediators in patients with acute respiratory distress syndrome: a randomized controlled trial. JAMA. 1999;282:54-61.

- **Amato MB, Barbas CS, Medeiros DM, Magaldi RB, Schettino GP, Lorenzi-Filho G et al.** Effect of a protective-ventilation strategy on mortality in the acute respiratory distress syndrome. N Engl J Med. 1998;338:347-54.
- **The Acute Respiratory Distress Syndrome Network.** Ventilation with Lower Tidal Volumes as Compared with Traditional Tidal Volumes for Acute Lung Injury and the Acute Respiratory Distress Syndrome. N Engl J Med. 2000;342:1301-8.
- **Tobin MJ.** Advances in mechanical ventilation. N Engl J Med. 2001;344:1986-96.
- **Hickling KG.** Best compliance during a decremental, but not incremental, positive end-expiratory pressure trial is related to open-lung positive end-expiratory pressure: a mathematical model of acute respiratory distress syndrome lungs. Am J Respir Crit Care Med. 2001;163:69-78.
- **Hickling KG.** The pressure-volume curve is greatly modified by recruitment. A mathematical model of ARDS lungs. Am J Respir Crit Care Med. 1998;158:194-202.

10 Responding to alarms

10.1 Introduction

The HAMILTON-G5's alarms notify the operator of problems. These alarms can be categorized as:

- High priority
- Medium priority
- Low priority

Additionally there are other alarms conditions associated with technical fault alarms and operator messages.

The main monitoring parameters (MMP) change their colors when a corresponding alarm activates. The color reflects the priority of the alarm.

Table 10-1 shows the audio and visual characteristics of these types of alarm and tells you how to respond. Figure 10-1 shows the ventilator's visual alarm indications. You can view active alarms in the active alarm buffer (Figure 10-2). Information about the alarm is also stored in an event log (see Section 10.4).

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

Table 10-1. Alarm indications in HAMILTON-G5

Status	Emergency LED on ventilation unit	Message bar[1]	Alarm lamp	Audio	Action required
High-priority alarm	ok	Red	Red	A sequence of five beeps, repeats until the alarm is reset. If the audible alarm is not silenced during the first minute, continuous tone buzzer also sounds.	The patient's safety is compromised. The problem needs immediate attention.
Medium-priority alarm	--	Yellow	Yellow	A sequence of three beeps, repeated periodically	The patient needs prompt attention.
Low-priority alarm	--	Yellow	Yellow	Two beeps. (This is not repeated.)	This can indicate a procedure is in progress, a control setting conflict, or the faulty results of a process.
Operator message	--	Yellow	--	--	Comply with instructions on the screen.
Technical fault	ok	Red	Red	A sequence of 5 beeps, repeats until the alarm is reset; or with a continuous buzzer tone. This buzzer cannot be silenced.	Provide alternative ventilation. Turn OFF the ventilator. The device requires service.

1. If more than one alarm is active, the associated alarm messages alternate in the message bar.

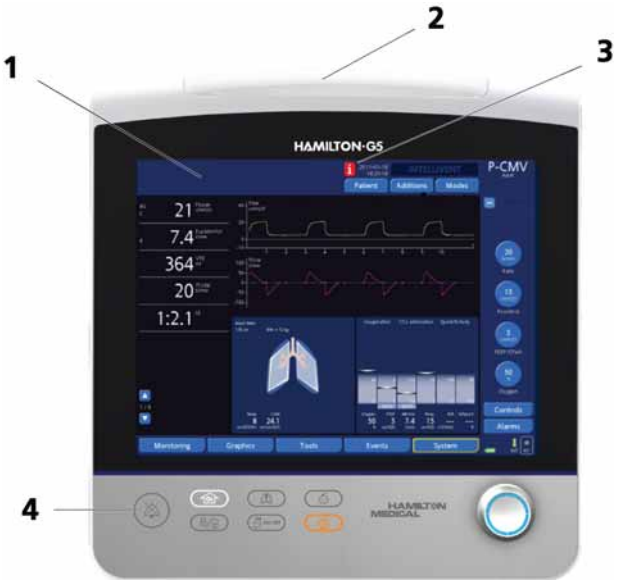


Figure 10-1. Visual alarm indications

1 Message bar area

2 Alarm lamp

3 i-icon

4 Alarm silence key

10.2 How to respond to an alarm

WARNING

- **Ensure the patient has adequate ventilation, this prevents possible patient injury when alarms are active. Identify and rectify the cause of the alarms. Re-adjust the alarm limits only when they are inappropriately set for the current conditions.**
- **When an equipment malfunction occurs, HAMILTON MEDICAL recommends that you immediately remove any ventilator with a technical fault from use, record the technical fault (TF) number, and have the device serviced.**

CAUTION

Setting alarm limits to extreme values can render the alarm system useless.

NOTE:

- Be aware that an alarm can result from either a clinical condition, or an equipment problem.
- Be aware that one alarm condition can induce multiple alarms. Normally only one or two indicate the root cause of the alarm; the rest occur as a result. Your search for the causes of the alarm condition could be assisted by, but not limited to, the alarm messages displayed.

Respond to an alarm as follows:

1. Approach the patient immediately. Secure sufficient and effective ventilation for the patient. Then take actions to silence the alarm.
2. Correct the alarm condition from the alarm messages, referring to the Alarm troubleshooting table later in this section. Search for other related alarm conditions in the active alarm buffer. When the condition causing an alarm is corrected, the device automatically resets the alarm. Later, you can see which alarms were reset in the **Alarms** event log.

10.3 Active alarm buffer

The active alarm buffer (Figure 10-2) displays active alarms. Corresponding alarm messages also alternate in the message bar. They are stored in the **Alarms** log (Section 10.4). The alarm information remains in the buffer as long as the conditions that caused each alarm persist.

Open the **Alarms** -> **Buffer** window with the **Buffer** tab. The latest occurring alarm is at the top; here the displays six active alarms. You can only view the previous six detected alarms. This way, the original alarm remains visible.

To view the latest inactive alarms, open the inactive alarms message bar with the i-icon. Confirm that you read and accept the inactive alarms by closing the i-icon window. Inactive alarms will be stored in the event log and the i-icon will disappear.

Figure 10-2. Active alarm buffer

1 Active alarms alternate in message bar. Touch to open active alarm buffer.

2 High-priority alarm (red background)

3 Low- or medium- priority alarm (yellow background).

10.4 Event logs: Reviewing events

NOTE:

A more extensive log including technical and configuration information is available to authorized service personnel.

Beginning with power ON, several event logs collect data about clinically relevant ventilator activities, including alarms, setting changes, calibrations, maneuvers, and special functions.

The date, time, and a unique identification reference (ID) for event classification is included. When there are new alarms the red Info button appears.

When you open the **Events** tab you can view these logs:

- **Settings**: Includes setting changes, calibrations, maneuvers, special functions, power ON/OFF
- **Alarms**: Includes all alarm messages
- **All events**: A compilation of all events

Figure 10-3. Events window (all events shown)

10.5 Alarm troubleshooting table

Table 10-2 is an alphabetical list of the alarms and important messages displayed by the HAMILTON-G5. Each description include the appropriate definitions and suggested corrective actions. The suggested corrective actions offer you the most probable malfunction, or present the most efficient corrective action first. The suggested actions are not always correct for the particular problem. Other actions can be required to respond to the alarm.

Table 10-2. Alarms and other messages

Alarm	Definition	Complete these actions
AERONEB disconnected	*Medium priority*. Aeroneb is active and the nebulizer cable is disconnected.	Connect the nebulizer cable. The alarm will be cleared.
AERONEB module disconnected	*Low priority*. Aeroneb is active and the module is removed or can not be identified.	Inspect the connection of the module.
All gas supplies failed	*High priority*. All three alarms appear at the same time	Inspect all gas supplies. Off set one of the three alarms.
Air+heliox supplies failed	*Medium priority.* Both alarms appear at the same time	Inspect gas supplies. Off set one of the alarms.
Air supply failed	*Medium priority.* The air supply pressure < 1.9 bar (190 kPa/28 psi) or the input flow dropped below 40 l/min. The device will ventilate the patient with 100% oxygen if the internal pressure can be maintained. (The alarm is not activated when the Oxygen setting is 100%.)	Inspect air supply. Increase air supply pressure. Consider changing source.
Apnea	*High priority*. No patient trigger after the operator-set apnea time in SPONT, SIMV, P-simv, APV-simv, DuoPAP, APRV, NIV or NIV-ST-mode. Additionally, Apnea Alarm can also be activated temporally, during a recruitment maneuver, if the apnea-time set is lower than the recruitment-maneuver.	Check the patient! Consider switching to a mandatory mode or consider increasing the mandatory rate or NIV-ST rate.
Apnea ventilation	*Low priority.* Apnea backup ventilation is active.	Search for reason why switch to apnea ventilation was made. Check patient.

Table 10-2. Alarms and other messages

Alarm	Definition	Complete these actions
Apnea ventilation ended	*Low priority*. Backup mode was reset, and device is again ventilating in its original support (pre-apnea) mode.	No action required.
APV: Check high pressure limit	*Low priority:* The operator-set high Pressure Alarm limit is too low, the ventilator cannot deliver vtarget.	Observe the patient. Verify the control settings. Consider to increasing the high Pressure limit to an appropriate level consider decreasing the vtarget to an appropriate value
ASV/APV: Initialization failed	*Medium priority.* ASV, APVsimv, or APVcmv cannot start, because the test breath results are not acceptable.	Consider increasing the high Pressure limit (the difference between PEEP/CPAP and the high Pressure limit must be > 25 cmH_2O). Calibrate the flow sensor. Check for leaks. Replace the flow sensor. Switch to a conventional pressure mode.

Table 10-2. Alarms and other messages

Alarm	Definition	Complete these actions
ASV: Cannot meet target	*Low priority.* The operator-set %MinVol cannot be delivered, possibly because of setting conflicts.	Observe the patient. Verify the control settings. Consider decreasing the %MinVol setting or increasing the high Pressure alarm limit to an appropriate level. Consider suctioning or other therapy. **NOTE:** Display the ASV target graphics screen to help troubleshoot this alarm.
ASV: Check high pressure limit	*Low priority.* The operator-set high pressure alarm limit is too low, and the ventilator cannot deliver the calculated target tidal volume.	Observe the patient. Consider suctioning or other therapy. Verify the control settings. Consider increasing the high Pressure limit to an appropriate level.

Table 10-2. Alarms and other messages

Alarm	Definition	Complete these actions
Automatic calibration	*Operator Message.* Autozero of pressure sensors is in progress. Curve display may be interrupted.	No action required.
	NOTE: During ventilation the device periodically performs an autocalibration (autozero) function to "zero" or adjust the device's pressure sensors to a zero value. This is controlled periodically by applying ambient pressure to the sensor, measuring the pressure, comparing it to the expected ambient pressure, and making an internal correction to remove pressure sensor drift due to temperature changes or other factors. Autocalibration is performed automatically at defined intervals.	
Breath detected within 20 s	*Operator message.* A CO_2 sensor/adapter calibration was attempted, but insufficient time has elapsed since last patient breathing effort.	Ensure the sensor and airway adapter are removed from the breathing circuit. Wait at least 20 seconds; then recalibrate.
Brightness test alarm	*Medium priority.* Alarm is shown while changing the alarm lamp brightness.	none
Calibration faulty	*Operator message* The flow sensor calibration could not be performed.	Repeat the calibration. If the message is displayed again, install a new flow sensor.
Calibration in progress	*Operator message.* An operator-initiated calibration is in progress.	Wait.

Table 10-2. Alarms and other messages

Alarm	Definition	Complete these actions
Check $CO_2$2 airway adapter[1]	*Low priority.* The airway adapter was disassembled from the CO_2 sensor; there is an optical blockage on the windows of the adapter; or the adapter type was changed, but the sensor/adapter calibration was not performed.	Clean the airway adapter and dry thoroughly, then re-attach it. If the problem persists or the adapter type was changed, calibrate the CO_2 sensor/adapter.
Check CO_2 sampling line	*Low priority*. Sampling line of CO_2 sidestream sensor kinked or disconnected.	Check sampling line.
Check Flow Pattern	*Low priority.* The desired setting cannot be obtained because of setting conflicts.	Confirm the proposed new setting. Adjust other settings as required.
Check Flow Sensor tubing	*High priority.* The flow sensor sensing lines are disconnected or occluded. If flow triggering is active, the device will switch to pressure triggering. The device automatically returns to flow triggering (if selected) when the alarm condition is eliminated.	Inspect the flow sensor and the sensing lines. Confirm the new setting for pressure triggering, if applicable. Replace the flow sensor.
Check Flow Sensor type	*High priority.* The flow sensor in use may not match the selected patient type. This is detected during ventilation.	Use and adult/pediatric flow sensor. Run the flow sensor calibration.
Check I:E	*Low priority.* The desired setting cannot be obtained because of setting conflicts.	Confirm the proposed new setting. Adjust other settings as required.
Check internal battery	High priority. The internal battery or cable is disconnected or faulty.	Suppress the alarm with the alarm silence key. Have the ventilator serviced.

Table 10-2. Alarms and other messages

Alarm	Definition	Complete these actions
Check %MinVol	*Low priority*. The desired setting cannot be obtained because of setting conflicts	Confirm the proposed new setting. Adjust other settings as required.
Check patient system	*Operator message.* The tightness test failed.	Inspect the circuit connections. Replace leaking parts and repeat the tightness test.
Check pause	*Low priority.* The Pause setting is too long in relation to other breath timing parameters.	Confirm the proposed new setting. Adjust other settings as required.
Check peak flow	*Low priority*. The desired setting cannot be obtained because of setting conflicts.	Confirm the proposed new setting. Adjust other settings as required.
Check PEEP/Pcontrol	*Low priority.* The PEEP/CPAP setting + the Pcontrol setting > 100 cmH2O.	Confirm the proposed new setting. Adjust other settings as required.
Check PEEP/high pressure limit	*Low priority.* The operator-set high Pressure alarm limit is too low to achieve sufficient ventilation in ASV or the APV modes. The difference between PEEP/CPAP and the high Pressure alarm limit < 10 cmH2O.	Observe patient. Verify monitored data for adequate ventilation. Verify control settings, including high Pressure limit.
Check PEEP/ Psupport	*Low priority.* The PEEP/CPAP setting + the Psupport setting > 100 cmH2O.	Confirm the proposed new setting. Adjust other settings as required.
Check P-ramp	*Low priority.* The chosen setting cannot be obtained because of setting conflicts.	Confirm the proposed new setting. Adjust other settings as required.

Table 10-2. Alarms and other messages

Alarm	Definition	Complete these actions
Check rate	*Low priority.* The chosen setting cannot be obtained because of setting conflicts.	Confirm the proposed new setting. Adjust other settings as required.
Check SpO_2 monitoring	*Medium priority*. SpO_2 monitoring not available	Inspect probe attachment, observe if probe site properly perfused
Check TI	*Low priority.* The chosen setting cannot be obtained because of setting conflicts.	Confirm the proposed new setting. Adjust other settings as required.
Check %TI	*Low priority.* The chosen setting cannot be obtained because of setting conflicts.	Confirm the proposed new setting. Adjust other settings as required.
Check trigger	*Low priority.* The trigger is OFF and the operator has attempted to activate a mode allowing spontaneous breathing. The ventilator switches to the selected mode and uses a pressure trigger of -3 cmH2O. It continues to alarm.	Verify the P-trigger setting or switch the Flowtrigger on.
Check Vt	*Low priority.* The chosen setting cannot be obtained because of setting conflicts.	Confirm the proposed new setting. Adjust other settings as required.
Check INTELLiVENT® PEEP limit setting	HLI ≤ 10% and VT/kg ≤ 6 ml or (Ppeak exp pressure ≤ 10 cmH2O) and PEEP ≥ 10 cmH2O	Verify if patient is haemodynamic stable. Alarm is reset when HLI limitation is deactivated
CO_2 sensor calibrated OK	*Operator Message*. The CO_2 sensor calibration was successful.	No action required.

Table 10-2. Alarms and other messages

Alarm	Definition	Complete these actions
CO_2 sensor calibration failed	*Operator Message.* The CO_2 sensor calibration did not complete successfully.	Ensure there is no source of CO_2 near the airway adapter. Inspect the adapter and clean if necessary. Recalibrate. Install new airway adapter. Install new CO_2 sensor.
CO_2 sensor calibration in progress	*Operator Message.* The CO_2 sensor is being calibrated.	Wait.
CO_2 sensor current unstable	*Operator Message.* The CO_2 sensor measurement is fluctuating. This is normal during startup.	If message is displayed during start up, no action is needed. If message is displayed during operation, recalibrate sensor.
CO_2 sensor disconnected	*Low priority.* The CO_2 module is not inserted or the CO_2 sensor is not connected to the module and CO_2 monitoring is enabled.	Ensure a CO_2 sensor is installed. Inspect CO_2 sensor connections (CO_2 sensor cable to module, CO_2 module to ventilator). Have the ventilator serviced.
CO_2 sensor faulty	*Low priority.* CO_2 sensor signal indicates a hardware error; or a third-party sensor is installed.	Disconnect the sensor from the CO_2 module. Wait 10 seconds, and reconnect. Then recalibrate the sensor. Install a new CO_2 sensor, if error persists. Ensure the sensor is a genuine HAMILTON MEDICAL sensor.

Table 10-2. Alarms and other messages

Alarm	Definition	Complete these actions
CO_2 sensor over temperature	*Low priority.* Temperature at CO_2 sensor too high.	Remove the sensor from the airway, and disconnect the sensor from the CO_2 module. Reconnect. Verify that system is running within the specified environmental conditions. Check for excessive airway temperature (examples: caused by defective humidifier, heater wire, or probe).
CO_2 sensor temperature unstable	*Operator Message.* CO_2 sensor measurement is fluctuating. This is normal during startup.	If message is displayed during startup, no action is needed. If message is displayed during operation, recalibrate sensor.
CO_2 sensor warming up	*Operator Message.* CO_2 sensor operating temperature not yet reached or unstable.	Wait for sensor to warm up.
CF disk full	*Operator Message.* Inadequate space on CompactFlash® device to complete requested file transfer.	Insert CompactFlash® device with adequate storage space.
Confirm mode change first	*Operator Message.* A mode change was begun, but not completed.	Confirm mode change in **Controls** window before proceeding.
Cuff disconnection	*Medium priority*. Cuff pressure cannot be built up.	Check cuff and cuff connection. Check cuff controller. Switch OFF cuff controller. Maintain cuff pressure manually.
Cuff leak	*Low priority.* Cuff leak is detected.	Check cuff and cuff connection. Check cuff controller. Switch OFF cuff controller. Maintain cuff pressure manually.

Table 10-2. Alarms and other messages

Alarm	Definition	Complete these actions
Cuff high pressure	*Medium priority.* Cuff pressure larger than set cuff pressure by more than 5 mbar for more than 10 seconds.	Check cuff and cuff connection. Check cuff controller. Switch OFF cuff controller. Maintain cuff pressure manually.
Demo key used up	*Operator Message.* The demo option (the demo key activates the option for 30 days) has already been activated once.	Contact your HAMILTON MEDICAL representative.
Disconnect patient	*Operator Message.* Instruction message during the flow sensor calibration and tightness test.	Disconnect the breathing circuit at the patient side of the flow sensor.
Disconnection	*High priority.* A disconnection was detected, but tidal volume is too low (< 200 ml) to determine whether it is on the patient or ventilator side.	Troubleshoot according to **`Disconnection on patient side`** or **`Disconnection on ventilator side`**.
Disconnection on patient side	*High priority*. VTE < than 1/8 delivered tidal volume for 2 consecutive breaths. Disabled in the NIV mode.	Observe the patient. Inspect the breathing circuit for a disconnection between the patient and the flow sensor, or for other large leaks (for example, ET tube, Bronchopleural Fistula).
Disconnection on ventilator side	*High priority.* Inspiratory tidal volume < 1/2 VTE for 2 consecutive breaths.	Inspect the breathing circuit for a disconnection between the ventilator and the flow sensor, or for other large leaks (for example, patient breathing circuit, humidifier). Reconnect and calibrate the flow sensor. Remove the CO_2 adapter if necessary.

Table 10-2. Alarms and other messages

Alarm	Definition	Complete these actions
Exhalation obstructed	*High priority.* Proximal airway pressure does not drop during exhalation.	Observe the patient. Inspect the expiratory limb for occlusion. Inspect the expiratory valve membrane and cover. Replace the expiratory valve membrane and cover. Inspect the flow sensor tubes for occlusion. Adjust breath timing controls to increase the expiratory time.
Low ExpMinVol alarm off	*Low priority.* The operator-adjustable low ExpMinVol alarm is set to off.	For information only.
Expiratory valve calibration needed	*Low priority*. The ventilator does not have correct expiratory valve calibration data	Have the ventilator serviced.
External battery empty	*Low priority.* The extended battery pack is depleted. The device is running on its internal battery.	If desired, replace depleted battery pack with a spare, charged battery pack. Otherwise, wait for extended battery pack to charge. If extended battery pack is not fully charged after 7 hours, install new extended battery pack.
FiO_2 oscillation	*Medium priority*. Large up and down changes of FiO_2 in a short period of time.	Check patient. Set PEEP and oxygen to manual control.
Flow Sensor calibration canceled	*Operator Message.* The user canceled the flow sensor calibration.	No action required.

Table 10-2. Alarms and other messages

Alarm	Definition	Complete these actions
Flow Sensor calibration needed	*Low priority.* The ventilator does not have correct calibration data or automatic recalibration of the flow sensor is impossible. The flow trigger is disabled, and the pressure trigger is enabled.	Try calibrating the flow sensor up to two times. Replace the flow sensor.
Flow Sensor calibrated OK	*Operator Message.* The Flow Sensor calibration was successful.	No action required.
Heliox supply failed	*Medium priority.* The air supply Pressure<1.9bar (190kPa/28psi)or the input Flow< 40l/min.	Inspect Heliox supply. Increase Heliox supply Pressure. Consider changing source
High frequency	*Medium priority.* The measured fTotal > the set alarm limit.	Confirm the patient for adequate ventilation (VTE). Check the alarm limits. If the ventilator is in ASV, refer to Appendix C, ASV.
High HLI	*Medium priority.* Measured HLI> alarm limit.	Verify the hemodynamic status of the patient and adjust the alarm limits if needed.
High leak	*Medium priority.* The percentage of delivered inspiratory volume that is not returned during exhalation > the set the Leak alarm limit.	Check for leaks at patient interface (on patient side of flow sensor).
High minute volume	*High priority.* The measured ExpMinVol > the set alarm limit.	Observe the patient. Confirm and adjust the ventilator settings, including alarms.

Table 10-2. Alarms and other messages

Alarm	Definition	Complete these actions
High oxygen	*High priority*. Measured Oxygen concentration > (the operator-set Oxygen + 5%); maximum 105%, display corrected to 100%. This alarm is disabled if there is an **O_2 cell missing** or **O_2 cell defective** alarm, or if oxygen measurement is disabled.	Calibrate the oxygen cell. Install a new oxygen cell. Troubleshoot the **Air supply failed** alarm, if present.
High $PetCO_2$	*Medium priority*. $PetCO_2$ > the set alarm limit.	Observe the patient. Verify and adjust the ventilator settings, including alarms.
High pressure	*High priority*. The measured inspiratory pressure > the set alarm limit. The device immediately stops gas flow to the patient and relieves pressure to the PEEP/CPAP level. If the pressure continues to rise, the mechanical relief valve opens at 120 cmH_2O. The ventilator enters the ambient state. This alarm cannot be silenced.	Observe the patient. Adjust the high Pressure alarm limit. Inspect the breathing circuit and flow sensor tubes for kinks and occlusions. Provide alternative ventilation once the device enters the ambient state.
High pressure during sigh	*High priority.* Ppeak during a sigh > the high Pressure limit. The sigh will only be partly delivered.	Observe the patient. Inspect the breathing circuit. Adjust the high Pressure alarm limit. Consider disabling the sigh function.
High tidal volume	*Medium priority.* The measured Vt > the set limit for 2 consecutive breaths.	Reduce the Psupport setting. Adjust the high Vt alarm limit.

Table 10-2. Alarms and other messages

Alarm	Definition	Complete these actions
Insert O_2 cell	*Operator Message.* You have enabled oxygen monitoring and/ or tried to perform an oxygen cell calibration, but the oxygen cell is missing.	Install oxygen cell and perform the calibration.
IntelliCuff® not found	*Low priority.* Cuff controller disconnected or damaged.	Connect (or switch OFF) Cuff controller.
Internal battery empty	*High priority.* The ventilator is running on its internal battery, and the battery can support < 10 min ventilator operation.	Connect the device to AC power.
Internal battery low	*Medium priority.* The ventilator is running on its internal battery, and the battery can support < 30 min ventilator operation.	Connect the device to AC power.
IRV	*Low priority.* If insufflation takes longer then expiration (I:E > 1)	Adjust the control settings.
Loss of mains power	*Medium priority.* The device is running on battery power due to AC power loss.	Silence the alarm; this also resets the alarm. Check integrity of connection to AC power. Check battery status. If you have spare extended batteries, prepare to swap if necessary. Prepare for possible power loss. Obtain alternative ventilation.

Table 10-2. Alarms and other messages

Alarm	Definition	Complete these actions
Loss of PEEP	*Medium priority.* Pressure < (PEEP/CPAP – 3 cmH2O) for more than 10 s.	Observe the patient. Inspect the breathing circuit for leaks. Replace the breathing circuit, if necessary.
Low frequency	*Medium priority.* Measured fTotal < the set limit.	Check the patient. Adjust the fTotal alarm limit. If the ventilator is in ASV, check the %MinVol, Patient height and actual body weight settings. Consider suctioning, check for a kinked ET tube, or consider the possibility of acute asthma.
Low internal pressure	*High priority.* The internal reservoir pressure < 150 cmH_2O for more than 3 s and one gas supply registers no pressure. The usual cause is loss of supply pressure. The ventilator enters the ambient state. This alarm cannot be silenced.	Inspect the gas supply for adequate pressure. Consider using an alternative source of compressed air (for example, VENTILAIR[II] medical air compressor) or oxygen. Have the ventilator serviced.

Table 10-2. Alarms and other messages

Alarm	Definition	Complete these actions
Low minute volume	*High priority.* Measured ExpMinVol < the set limit.	Observe the patient. Inspect the breathing circuit. Confirm and adjust the ventilator settings, including alarms. If the ventilator is in ASV, check the %MinVol, Patient height and actual body weight settings. Consider suctioning, check for a kinked ET tube, or consider the possibility of acute asthma.
Low oxygen	*High priority.* Measured Oxygen is < (the operator-set Oxygen – 5%). This alarm is disabled if there is an **O_2 cell missing** or **O_2 cell defective** alarm, or if oxygen measurement is disabled.	Observe the patient. Inspect the oxygen supply. Provide an alternative source of oxygen, if necessary. Calibrate the oxygen cell. Install a new oxygen cell.
Low $PetCO_2$	*Medium priority*. $PetCO_2$ < the set alarm limit.	Observe the patient. Verify ventilator settings, including alarm settings.
Low pressure	*High priority.* Measured Ppeak < the set limit for 2 consecutive breaths.	Observe the patient. Confirm and adjust the ventilator settings, including alarm limits.

Table 10-2. Alarms and other messages

Alarm	Definition	Complete these actions
Low tidal volume	*Medium priority.* Measured VTE < the set limit for 2 consecutive breaths.	Observe the patient. Confirm and adjust the ventilator settings, including alarm limits. Inspect for leaks and disconnects. If the ventilator is in ASV, consider suctioning, check for a kinked ET tube, or consider the possibility of acute asthma.
MV oscillation	*Medium priority*. Large up and down changes of %MinVol over a short period of time.	Switch %MinVol to manual control.
Maneuver in progress	*Operator Message*. P/V Tool maneuver is in progress.	Wait.
Maximum leak compensation	*Low priority.* VLeak is greater than half of the set VTarget, and the APV controller is compensating the leak at its maximum compensation level. VTE will be lower than VTarget. Applies to the APV modes.	Inspect for leaks. Suction patient. Check high Pressure limit. Switch to another mode.
No hemodynamic status available	*Medium priority.* HLI for > 6 minutes invalid, SpO_2 measurement ON, and HLI used by the controller.	Inspect the pulse oximeter attachment location on the patient. Verify the pulse oximeter plethysmogram
No hemodynamic status available	*Low priority.* HLI for > 6 minutes invalid, SpO_2 measurement ON, High HLI alarm limits on and HLI not used by the controller.	Inspect the pulse oximeter attachment location on the patient. Verify the pulse oximeter plethysmogram.

Table 10-2. Alarms and other messages

Alarm	Definition	Complete these actions
O_2 alarms off	*Message in alarm limits window*. O_2 monitoring is disabled.	If desired, enable O_2 monitoring through the **System** -> **Sensors on/off** window.
O_2 cell calibration needed	*Low priority.* The ventilator does not have correct calibration data, measured Oxygen < 18%, or measured Oxygen > 105%.	Calibrate the oxygen cell. If you are attempting to calibrate the cell, make sure oxygen is connected.
O_2 cell calibrated OK	*Operator Message.* The oxygen cell calibration was successful.	No action required.
O_2 cell calibration in progress	*Operator Message.*	No action required.
O_2 cell defective	*High priority.* The oxygen cell is depleted (monitored Oxygen < approximately 10%), or calibration is not possible).	Install a new oxygen cell.
	WARNING **To ensure that oxygen monitoring is always fully functional, replace an exhausted or missing oxygen cell as soon as possible or use an external monitor that complies with EN ISO 21647.**	
O_2 cell misconnected	*Operator Message.* Oxygen cell connector reversed.	Reverse oxygen cell connection.
O_2 cell missing	*Low priority.* There is no signal from the oxygen cell. This is not shown if oxygen monitoring is disabled.	Install an oxygen cell or use an external monitor, according to ISO 21647. Enable O_2 monitoring through the **System** -> **Sensors on/off** window.

Table 10-2. Alarms and other messages

Alarm	Definition	Complete these actions
O_2 monitoring cannot be disabled	*Operator message.* You attempt to disable O_2 monitoring during Heliox administration, this is not allowed.	No actions required
Oxygenation adjustment OFF (no SpO_2)	*Medium priority*. PEEP or oxygen automatic, SpO_2 invalid and needed since at least 60 seconds	Set PEEP and oxygen to manual control
Oxygenation adjustment OFF (no SpO_2)	*Low priority*. PEEP or oxygen automatic, SpO_2 invalid and needed since at least 30 seconds	Set PEEP and oxygen to manual control
Oxygenation Controller on Limit	*Low priority*. SpO_2 too low and PEEP and/or oxygen can not be further increased.	Observe patient. Set oxygen and/or PEEP to manual control or resolve problem.
Oxygen set to 100% due to low saturation	*Medium priority.* The INTELLiVENT®-ASV has increased oxygen to 100%.	Observe the patient. Silence the alarm. Reset the alarm by touching the i-icon and/or alarm buffer.
Option key already in use	*Operator Message.* This option has already been activated once using this option activating code (key).	Contact your HAMILTON MEDICAL representative
Option key invalid	*Operator message.* The option code (key) you entered is not recognized.	Retry entry of valid option code.
Option unknown	*Operator message.* The option you tried to activate is not available for your ventilator's software version.	Retry entry of valid option code.

Table 10-2. Alarms and other messages

Alarm	Definition	Complete these actions
Oxygen + air supplies failed	*High priority.* Input pressures of both oxygen and air < 1.9 bar (190 kPa/27 psi), or the input flow dropped below 40 l/min. The device continues to ventilate as long as there is sufficient reservoir pressure to maintain gas flow. If the reservoir pressure drops below 150 cmH_2O, the ventilator enters the ambient state. This alarm cannot be silenced.	Provide alternative ventilation. Check air and oxygen supplies, or provide alternative compressed air or oxygen sources to the ventilator (VENTILAIR^{II} medical air compressor or oxygen cylinder).
Oxygen + heliox supplies failed	*High priority.* Input pressures of both oxygen and heliox < 1.9 bar (190 kPa/ 27 psi), or the input flow dropped below 40 l/min. The device continues to ventilate as long as there is sufficient reservoir pressure to maintain gas flow. If the reservoir pressure drops below 150 cmH2O, the ventilator enters the ambient state. This alarm cannot be silenced.	Provide alternative ventilation. Check heliox and oxygen supplies, or provide alternative compressed air or oxygen sources to the ventilator (VENTILAIRII medical air compressor or oxygen cylinder).
Oxygen supply failed	*High priority.* Input pressure of oxygen < 1.9 bar (190 kPa/28 psi), or the input flow dropped below 40 l/ min. The ventilator continues to function at an oxygen concentration of 21% if the internal pressure can be maintained. Under these conditions, the low Oxygen concentration alarm is disabled.	Observe the patient. Inspect the oxygen supply. Provide an alternative source of oxygen, if necessary.

Table 10-2. Alarms and other messages

Alarm	Definition	Complete these actions
Panel connection lost	*High priority.* The ventilation cockpit cannot communicate with the ventilation unit.	Make sure that the Ventilation cockpit cable is securely seated in the ventilation unit receptacle. Have the ventilator serviced.
Patient system tight	*Operator Message.* The tightness test was successful.	No action required.
Press Manual breath to resume	*Operator Message.* Instruction message during suctioning.	Resume ventilation when desired by first reconnecting the patient, then pressing Manual breath.
%MinVol automation off	*Operator Message.* Patient weight is set below 7 kg and %MinVol is in automatic mode.	none
PEEP automation off	*Operator Message.* Patient weight is set below 7 kg and PEEP is in automatic mode	none
PEEP manual	*Operator Message.* Chronic Hypercapnia only (but no ARDS) and/or brain injury selected	none
PEEP oscillation	*Medium priority*. Large up and down changes in PEEP over a short period of time.	Check patient. PEEP set to manual control
Perfusion index (PI) too low	*Low priority.* The peripheral perfusion measured by the sensor is below the set limit.	Observe the patient. Verify ventilator settings, including alarm settings.
Perfusion index (PI) too high	*Low priority.* The peripheral perfusion measured by the sensor exceeds the set limit.	Observe the patient. Verify ventilator settings, including alarm settings.

Table 10-2. Alarms and other messages

Alarm	Definition	Complete these actions
Pressure limit changed	*Operator Message.* User has changed the Pasv control, which modifies the high Pressure alarm limit.	No action required.
Pressure low limit reached	*Low priority.* The operator-set Vtarget limit is too low, the ventilator cannot further reduce the inspiratory pressure (minimum Pcontrol above PEEP[1]). The delivered tidal volume is higher than the set Vtarget.	Observe the patient. Confirm the control settings.
Pressure not released	*High priority.* Airway pressure has exceeded the high Pressure limit, and the pressure was not released after 5 s. The ventilator enters the ambient state.	Provide alternative ventilation. Have the ventilator serviced.
Print screen failed	*Operator Message.* The requested print screen operation could not be performed.	Check the insertion of a proper CompactFlash® and USB storage device.
Recruitment in Progress	*Low priority*. Recruitment maneuver in progress.	Wait. Observe patient.
Required number of breaths not reached	*Operator Message.* Requested P/V Tool maneuver could not be performed, because fewer than five breaths have been delivered since the last maneuver.	Wait, and retry maneuver.
SBT aborted	*Medium priority*. The SBT was aborted because one or more parameters were out of range for longer than Tolerance Time or the test was manually stopped.	The device returns to monitoring mode. When conditions are met, another SBT will be conducted. Touch the **`I-icon`** or the alarm message to dismiss the alarm.

Table 10-2. Alarms and other messages

Alarm	Definition	Complete these actions
SBT successfully fulfilled	*Medium priority*. The SBT was ended because Duration max was reached.	None. Touch the **`I-icon`** or the alarm message to dismiss the alarm.
Screen lock active!	*Operator message.* Screen lock key is pressed.	Unlock screen if user entry is desired.
Serial number doesn't match!	*Operator message*. Entered option key is for a device with a different serial number.	Contact HAMILTON MEDICAL representative:
SpCO high	*Low priority.* SpCO value measured by the sensor exceeds the set limit.	Observe the patient. Verify ventilator settings, including alarm settings.
SpCO low	*Low priority.* SpCO value measured by the sensor is below the set limit.	Observe the patient. Verify ventilator settings, including alarm settings.
SpHb high	*Low priority.* SpHb value measured by the sensor exceeds the set limit.	Observe the patient. Verify ventilator settings, including alarm settings.
SbHb low	*Low priority.* SpHb value measured by the sensor is below the set limit.	Observe the patient. Verify ventilator settings, including alarm settings.
SpMet high	*Low priority.* SpMet value measured by the sensor exceeds the set limit.	Observe the patient. Verify ventilator settings, including alarm settings.
SpMet low	*Low priority.* SpMet value measured by the sensor is below the set limit.	Observe the patient. Verify ventilator settings, including alarm settings.
SpO_2: sensor error (left slot)	*Medium priority*. Hardware problem with sensor adapter	Replace left sensor adapter.

Table 10-2. Alarms and other messages

Alarm	Definition	Complete these actions
SpO_2: patient disconnected (left slot)	*Medium priority.* Probe is detached from patient or not properly attached to patient. Probe malfunction.	Check if left probe is attached properly to patient. Replace left probe.
SpO_2: no sensor (left slot)	*Medium priority.* Probe is disconnected from adapter. Adapter is disconnected from ventilator. Cable defective.	Connect left probe to adapter. Connect left sensor adapter to ventilator. Replace left adapter and/or left probe.
SpO_2: light interference (left slot)	*Medium priority.* Light interference in sensor probe	Cover left probe with blanket or change attachment site on patient. Replace left probe
SpO_2: poor signal (left slot)	*Medium priority.* Pulse from left SpO_2 sensor not found	Verify left probe attachment, check if left probe site is properly perfused
SpO_2 left sensor adapter faulty	*Operator Message.* Hardware problem with left sensor adapter. Second SpO_2 sensor still working normally.	Replace left sensor adapter.
SpO_2 left sensor disconnected	*Operator Message.* Left probe is disconnected from adapter. Adapter is disconnected from ventilator. Cable defective. Second SpO_2 sensor still working normally.	Connect left probe to adapter. Connect left sensor adapter to the ventilator. Replace left adapter and/or probe.
SpO_2 left sensor probe faulty	*Operator Message.* Left probe is detached from patient or properly attached to patient. Probe malfunction. Second SpO_2 sensor still working normally.	Check left probe is attached properly to patient. Replace left probe.

Table 10-2. Alarms and other messages

Alarm	Definition	Complete these actions
SpO_2 left sensor light interference	*Operator Message.* Light interference in left sensor probe. Second SpO_2 sensor still working normally.	Cover left probe with blanket or change attachment site on patient. Replace left probe.
SpO_2: poor signal (left slot)	*Operator Message.* Pulse from left SpO_2 sensor not found. Second SpO_2 sensor still working normally.	Verify left probe attachment, check if left probe site is properly perfused.
SpO_2: sensor error (right slot)	*Medium priority.* Hardware problem with sensor adapter.	Replace right sensor adapter.
SpO_2: patient disconnected (right slot)	*Medium priority.* Probe malfunction. Probe is detached from patient or not properly attached to patient.	Verify if right probe is attached properly to patient. Replace right probe.
SpO_2: no sensor (right slot)	*Medium priority.* Probe is disconnected from adapter. Adapter is disconnected from ventilator. Cable defective.	Connect right probe to adapter. Connect right sensor adapter to ventilator. Replace right adapter and/or probe.
SpO_2: light interference (right slot)	*Medium priority.* Light interference in sensor probe	Cover right probe with blanket or change attachment site on patient. Replace right probe.
SpO_2: poor signal (right slot)	*Medium priority.* Pulse from right SpO_2 sensor not found.	Verify right probe attachment, check if right probe site is properly perfused
SpO_2 right sensor adapter faulty	*Operator Message.* Hardware problem with right sensor adapter. Second SpO_2 sensor still working normally.	Replace right sensor adapter.

Table 10-2. Alarms and other messages

Alarm	Definition	Complete these actions
SpO_2 right sensor disconnected	*Operator Message.* Right probe is disconnected from adapter. Adapter is disconnected from ventilator. Cable defective. Second SpO_2 sensor still working normally.	Connect right probe to adapter. Connect right sensor adapter to the ventilator. Replace right adapter and/or probe.
SpO_2 right sensor probe faulty	*Operator Message.* Right probe is detached from patient or properly attached to patient. Probe malfunction. Second SpO_2 sensor still working normally.	Check right probe is attached properly to patient. Replace right probe.
SpO_2 right sensor light interference	*Operator Message.* Light interference in right sensor probe. Second SpO_2 sensor still working normally.	Cover right probe with blanket or change attachment site on patient. Replace right probe.
SpO_2: poor signal (right slot)	*Operator Message.* Pulse from right SpO_2 sensor not found. Second SpO_2 sensor still working normally.	Verify right probe attachment, check if right probe site is properly perfused.
SpO_2 too high	*Low priority.* Measured SpO_2> alarm limit	Observe the patient. Verify ventilator settings, including alarm settings.
SpO_2 too low	*High priority.* Monitored SpO_2 is below 88% and alarm limit.	Observe the patient. Verify ventilator settings, including alarm settings.
SpO_2 too low	*Medium priority*. Monitored SpO_2 is below alarm limit.	Observe the patient. Verify ventilator settings, including alarm settings.
Suctioning tool	*Operator Message.* Ventilation suppression is active, and ventilator settings are being maintained, although the HAMILTON-G5 is not delivering breaths.	Resume ventilation when desired by first reconnecting the patient, then pressing Manual breath.

Table 10-2. Alarms and other messages

Alarm	Definition	Complete these actions
TF: xxxx	*Technical fault.* A hardware or software malfunction was detected. The ventilator may switch to the ambient state, and the patient will breathe room air unassisted. You will hear the high-priority alarm tone, or the continuous-tone buzzer will sound as long as possible.	Provide alternative ventilation. Have the ventilator serviced.
	WARNING **To prevent possible patient injury arising from an equipment malfunction, HAMILTON MEDICAL recommends that you immediately remove any ventilator with a technical fault from use, record the number of the fault, and have the ventilator serviced.**	
Tighten patient system	*Operator Message.* Instruction message during tightness test.	Block the patient side of the patient end of the flow sensor (a finger covered with an alcohol pad may be used).
Turn Flow Sensor	*Operator Message.* Instruction message during flow sensor calibration.	Reverse the ends of the flow sensor so that the blue tube is closest to the Y-piece.
Turn the Flow Sensor	*Medium priority.* The flow sensor connections are reversed. The flow trigger is turned OFF and the device switches to a pressure trigger.	Rotate the flow sensor. The blue sensing line is close to the patient and must be attached to the blue connector. The colorless sensing line is close to the ventilator and must be attached to the white connector.

Table 10-2. Alarms and other messages

Alarm	Definition	Complete these actions
Ventilator unit connection lost	*High priority*. The Ventilation Cockpit cannot communicate with the ventilation unit. This message cannot be displayed as an active alarm but it is logged as an event.	Make sure the Ventilation Cockpit cable is securely seated in the ventilation unit receptacle. Have the ventilator serviced.
Ventilation adjustment OFF (no $PetCO_2$)	*Low priority*. %MinVol automatic and 2. highest value of $PetCO_2$ during last 8 breaths invalid and $PetCO_2$ needed by controller since > 30 seconds and < 60 seconds.	Set %MinVol to manual control, or resolve problem causing CO_2 measurement error
Ventilation adjustment OFF (no $PetCO_2$)	*Medium priority.* %MinVol automatic and 2. highest value of $PetCO_2$ during last 8 breaths invalid and $PetCO_2$ needed by controller since at least 60 seconds.	Set %MinVol to manual control or resolve problem causing CO_2 measurement error.
Ventilation Controller on Limit	*Low priority*. %MinVol can not be further increased.	Observe patient. Set %MinVol to manual control or resolve problem.
Volume too low for nebulizer	*Low priority.* The pneumatic nebulizer was turned ON, but it cannot operate because the ventilator settings would require > 50% of the tidal volume to be delivered by the nebulizer.	Check and adjust ventilator settings to increase inspiratory peak flow.
Wrong Flow Sensor type	*High priority.* The type of flow sensor installed (pediatric/adult or infant) does not match the patient type setting. This is detected during calibration.	Use an adult/pediatric flow sensor.

1. Pcontrol: 3 cmH2O (only for Japan, Pcontrol: 5 cmH2O)

11 Maintenance

11.1 Introduction

The operator must comply these maintenance procedures to ensure the safety and reliability of the HAMILTON-G5. All the procedures in this manual are intended to be performed by the operator. For additional maintenance requirements, contact your HAMILTON MEDICAL service representative.

11.2 Cleaning, disinfection, and sterilization

WARNING

- **Always disconnect the device from electrical power before cleaning. This step reduces the risk of electrical shock.**
- **DO NOT reuse single-use bacteria filters, flow sensors, and other accessories. They must be discarded after single use. Reusing, disassembling, cleaning, disinfecting, or sterilizing a single-use part may compromise its functionality and system performance, leading to a possible operator or patient hazard. Performance is not guaranteed if an item labeled as single-use is reused.**
- **Always use caution when handling bacteria filters. This care minimizes the risk of bacterial contamination or physical damage.**
- **To prevent patient exposure to sterilizing agents and to prevent premature deterioriation of parts, sterilize parts using the techniques recommended in this section only.**

CAUTION

- **DO NOT attempt to sterilize the interior of the ventilator. DO NOT attempt to sterilize the entire device with ETO gas.**
- **Exposure to sterilizing agents may reduce the useful life of certain parts. Using more than one sterilization technique on a single part may damage a part.**

NOTE:

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 manual only gives general guidelines for cleaning, disinfecting, and sterilizing. It is the operator's responsibility to ensure the validity and effectiveness of the actual methods used.

The following subsections provide general guidelines for cleaning and decontaminating parts. Table 11-1 tells you the specific methods that are applicable to each device part. For parts not supplied by HAMILTON MEDICAL, comply with the manufacturers' guidelines. DO NOT attempt cleaning procedures unless specified by HAMILTON MEDICAL or the original manufacturer.

After cleaning and decontaminating parts, perform any required tests and calibrations described in Chapter 4, Tests, calibrations, and utilities.

Table 11-1. Decontamination methods for HAMILTON-G5 parts

Part (material)	How to decontaminate	Remarks
Ventilator exterior, including housing, basket, tray, gas supply hoses, power cord, modules	Wipe with an appropriate bactericidal agent after each patient use	DO NOT use alcohol as a disinfectant. It does not harm the ventilator but it has not been proven to be an effective bactericidal or bacteriostatic. DO NOT clean the ventilator interior. This can damage internal parts.
Touch screen	Dampen a soft cloth with isopropyl alcohol or a nonabrasive glass cleaner and wipe the screen.	Avoid using cleaners other than glass cleaners. DO NOT use any vinegar-based solutions. Avoid using gritty cloths. Handle the touch screen with care. To permit cleaning press **Screen lock**.
Breathing tubes (silicone rubber)	Steam autoclave, chemically disinfect, or ETO sterilize	Roll tubes into large coils. DO NOT twist, kink, or cross tubes when sterilizing them. The tubing lumen must not have vapor or moisture before wrapping for autoclaving. Avoid exposing silicone rubber breathing tubes to grease, oil, silicone-based lubricants, organic solvents (benzene, ether, ketone, and chlorinated hydrocarbons), acids, concentrated alkaline cleaning products, and phenols and derivatives.

Table 11-1. Decontamination methods for HAMILTON-G5 parts

Part (material)	How to decontaminate	Remarks
Mask (silicone rubber)	Steam autoclave, chemically disinfect, or ETO sterilize	Avoid exposing silicone rubber masks to grease, oil, silicone-based lubricants, organic solvents (benzene, ether, ketone, and chlorinated hydrocarbons), acids, concentrated alkaline cleaning products, and phenols and derivatives. Deflate air cushion before steam autoclaving to prevent possibility of explosion.
Flow sensor, single-use	Chemically disinfect (only if this single-use Sensor requires decontamination before use)	The flow sensor is designed for single-patient use. It is delivered clean and ready for patient use. If the sensor must be decontaminated, DO NOT use hard brushes, pointed instruments, or rough materials. These can damage the flow sensor's membrane.
Flow sensor, reusable	Chemically disinfect or ETO sterilize	DO NOT use hard brushes, pointed instruments, or rough materials. These can damage the flow sensor's membrane.
Inspiratory filter, reusable autoclavable	Steam autoclave	Always inspect the filter media for cracks or foreign matter; replace if necessary. Replace after 20 autoclave cycles. NEVER chemically disinfect or expose to ETO gas.

Table 11-1. Decontamination methods for HAMILTON-G5 parts

Part (material)	How to decontaminate	Remarks
Expiratory valve membrane (silicone rubber)	Steam autoclave, chemically disinfect, or ETO sterilize	**NOTE:** Inspect the membrane for damage; replace if necessary. Replace after 30 autoclave cycles.
Nebulizer jar, reusable (polysulfone)	Steam autoclave or chemically disinfect	
Expiratory valve cover (polysulfone) Y-piece Water traps Adapters Connectors (polysulfone) Temperature probe housing (polysulfone and silicone rubber)	Steam autoclave, chemically disinfect, or ETO sterilize	Solutions such as Medizyme, Pyroneg, Control 3, Solution 2, and CIDEX® have been tested according to the manufacturers' guidelines. Other brand names with similar active ingredients may also be suitable. DO NOT autoclave if medications containing chlorinated or aromatic hydrocarbons are used.
Humidifier and chamber Temperature probe Other accessories	Comply with the manufacturer's guidelines	
Small-bore tubing for Paux measurement		Discard every 48 hours or when changing breathing circuit.

Table 11-1. Decontamination methods for HAMILTON-G5 parts

Part (material)	How to decontaminate	Remarks
CO_2 sensor	Clean and disinfect the outside by wiping with a cloth dampened with 70% isopropyl alcohol, a 10% aqueous solution of sodium hypochlorite (bleach), disinfectant spray cleaner such as Steris Coverage® Spray HB, ammonia, or mild soap. Wipe down with a clean water-dampened cloth to rinse, and dry before use. Make sure the sensor windows are clean and dry before reuse.	Always disconnect the CO_2 sensor before cleaning. DO NOT immerse or attempt to sterilize the sensor. Before reusing the sensor, ensure the windows are dry and residue-free, and that the sensor has not been damaged during handling or by the cleaning process. Replace if damaged or if excessive secretions are observed.
	WARNING **Reusing, disassembling, cleaning, disinfecting, or sterilizing the single-use CO_2 airway adapter can compromise its functionality and system performance, leading to a possible user or patient hazard. Performance is not guaranteed if an item labeled as single-use is reused.**	

Table 11-1. Decontamination methods for HAMILTON-G5 parts

Part (material)	How to decontaminate	Remarks
CO_2 sensor airway adapter, reusable (polyetherimide), aluminum, black oxide finish, Al2O3-sapphire)	Steam autoclave (adult adapters only) at 121 °C (250 °F) for 20 min, unwrapped; pasteurize;	Acceptable chemical disinfectants include 70% isopropyl alcohol, a 10% aqueous solution of sodium hypochlorite (bleach), a 2% glutaraldehyde solution such as CIDEX, Steris System 1®, or ammonia (refer to the disinfectant manufacturer's instructions for use). Rinse with sterile water and dry. With proper care and if not otherwise damaged, adapters can be disinfected/sterilized according to the stated validated methods at least 100 times. Before reusing the adapter, make sure the windows are dry and residue-free, and that the adapter has not been damaged during handling or by the cleaning/sterilizing process. Replace if damaged or if excessive secretions are observed.

Table 11-1. Decontamination methods for HAMILTON-G5 parts

Part (material)	How to decontaminate	Remarks
SpO_2 Adapter	Periodically clean the SpO_2 adapter. Wipe with a soft cloth moistened with ethanol (15°C (59°F), 76.9 to 81.4% by vol). Dry the SpO_2 adapter completely after cleaning. After cleaning before use, wipe liquid off with a dry cloth and thoroughly dry the SpO_2 adapter.	DO NOT immerse the SpO_2 adapter in chemical solution or water. If the SpO_2 adapter is immersed, wipe off liquid with a dry cloth and thoroughly dry the SpO_2 adapter before use. DO NOT disinfect and sterilize the SpO_2 adapter. It will damage the SpO_2 adapter.
SpO_2 probe	Refer to the operator's manual of the probe you use.	
Aeroneb adapter	Autoclave wrapped parts using steam sterilization pre-vacuum cycle, a minimum of 134°C (270°F – 275°F) for 20 minutes with drying cycle (sometimes referred to as a "Prion cycle").	DO NOT reassemble parts prior to autoclaving.
Aeroneb control module, control module cable and AC/DC adapter	Wipe clean with a damp cloth. DO NOT autoclave. Check for exposed wiring, damaged connectors, or other defects and replace if any are visible.	
Aeroneb mounting brackets	Wipe clean with a damp cloth and mild liquid detergent. DO NOT use abrasive or sharp tools.	

11.2.1 General guidelines for cleaning

CAUTION

- **To prevent damage to breathing circuit parts, DO NOT clean with hard brushes, pointed instruments, or rough materials.**
- **To prevent damage to breathing circuit parts, follow the soap manufacturer's guidelines. Exposure to soap solution that is stronger than recommended can shorten the useful life of some products. Soap residue can cause blemishes or fine cracks, especially on parts exposed to elevated temperatures during sterilization.**

Clean the device parts as follows:

1. Disassemble parts. Breathing circuits must be disassembled completely.
2. Wash parts in warm water and soap or mild detergent solution.
3. Rinse parts thoroughly with clean, warm water.
4. Air dry.
5. Inspect all parts, and replace if damaged.
6. If you will sterilize or disinfect the part, continue with the appropriate sterilization/disinfection procedure. If you will not sterilize or disinfect the part, reassemble and reinstall parts, and perform any required tests.

11.2.2 General guidelines for chemical disinfection

CAUTION

The Specifications chapter of this manual lists materials of construction for the HAMILTON-G5 parts. To prevent premature deterioration of parts, make sure the disinfecting chemical is compatible with the part material.

To disinfect the device parts:

1. Clean, but DO NOT re-assemble.
2. Disinfect with a mild bactericidal chemical solution. Acceptable chemicals include: Schülke & Mayr Lysetola AF and Gigasepta FF, Henkel-Ecolab Incidura, Sekusepta PLUS, and CIDEX. Solutions such as these have been tested according to the manufacturers' guidelines. Other brand names with similar active ingredients may also be suitable.
3. Reassemble and reinstall parts, and perform any required tests.

11.2.3 General guidelines for autoclave sterilization

To Autoclave the device's parts:

1. Clean.
2. Reassemble.
3. Inspect.
4. Autoclave.
5. Perform any required tests.

11.3 Preventive maintenance

NOTE:

- HAMILTON MEDICAL recommends that you document all maintenance procedures.
- Dispose of all parts removed from the device according to your institution's protocol. 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, oxygen cell, batteries).
- HAMILTON MEDICAL recommends you to perform preventive maintenance. No maintenance causes loss of warranty.

Perform preventive maintenance on your HAMILTON-G5 according to the schedule shown in Table 11-2. You can view the hours of ventilator operation in the **System -> Info** window. The following subsections provide details for some of these preventive maintenance procedures.

Table 11-2. Preventive maintenance schedule

Interval	Part/accessory	Procedure
Between patients and according to hospital policy	Breathing circuit (including mask, inspiratory filter, flow sensor, nebulizer jar, exhalation valve cover and membrane)	Replace with sterilized or new single-patient use parts. Run the tightness test and the flow sensor calibration (Section 4.3.2).
	Entire ventilator	Run the preoperational check (Section 4.2).
Every day or as required	Gas inlet water trap	Empty any water by pressing on drain valve.
Every 2 days or according to hospital policy	Breathing circuit	Empty any water from breathing tubes or water traps. Inspect parts for damage. Replace as necessary.
Every month (or more often, if required)	**WARNING** **To reduce the risk of patient cross-contamination through the fan filter, always perform maintenance at the prescribed interval.**	
	Fan filter (rear panel)	Check for dust and lint. If needed, clean or replace.
Every 3 months (1250 hours)	Batteries	Verify that batteries can hold their charge by unplugging ventilator power cord and verifying that after 10 min battery symbol (INT or EXT) is still green.

Table 11-2. Preventive maintenance schedule

Interval	Part/accessory	Procedure
Yearly or every 5000 hours, whichever comes first, or as necessary	**NOTE:** Oxygen cell life specifications are approximate. The actual cell life depends on operating environment. Operation at higher temperatures or higher oxygen concentrations shortens cell life.	
	• Oxygen cell • Gas supply filter 1 • Cuff controller filter 1	Replace if depleted.
	Ventilator	Perform service-related preventive maintenance.[1]
	CO_2 sensor	Have a CO_2 accuracy check performed.1
Every 2 years or as necessary	**NOTE:** Battery life specifiations 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.	
	Internal (lead acid) and extended (lithium ion) batteries	Replace[1]
Every 5 years	Backlight LCD display	Replace[1]

1. This must be done by a HAMILTON MEDICAL authorized service personnel according to instructions in the service manual.

11.3.1 Cleaning or replacing the fan filter

Pull off the filter cover. Either install a new filter; or wash the existing filter in a mild soap solution, rinse, and dry.

11.3.2 Removing a gas supply filter housing

NOTE:

Refer the gas supply microfilters for servicing by a HAMILTON MEDICAL authorized service personnel. Never attempt to clean a microfilter.

Disconnect the ventilator from the gas supply. Unscrew the filter housing. Clean the housing if desired and replace it.

11.3.3 Replacing the oxygen cell

WARNING

To reduce the risk of explosion, DO NOT burn the oxygen cell or force the cell open.

NOTE:

- Observe the orientation of the connector when installing the oxygen cell.
- Dispose of the oxygen cell according to your institution's protocol. Comply with all local, state, and federal regulations with respect to environmental protection.

Remove the oxygen cell cover by pushing lightly downward; then disconnect the cell connector and remove the cell. Install the new cell; then replace the oxygen cell cover. Run the oxygen cell calibration.

11.4 Calibration of the extended battery

If after a full charging cycle of the extended battery, the battery indicator does not display the maximal charging level, consider calibrating the extended battery packs.

For such calibration, only use the specific HAMILTON MEDICAL external Li-ion battery charger and calibrator for this device.

11.5 Storage

To maintain the battery charge and to prolong the life of the batteries, keep the ventilator connected to AC power. Have the batteries recharged every 3 to 9 months, depending on storage conditions (see Appendix A, Specifications).

11.6 Repacking and shipping

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.

12 Special functions

12.1 Standby

WARNING

- **To prevent possible patient injury due to lack of ventilatory support, secure alternative ventilation for the patient before entering the standby mode. You must confirm that no patient is attached before entering the stand-by mode.**
- **To prevent possible patient injury or damage to breathing circuit from overheated gas after reconnection from standby, turn OFF the humidifier when entering the standby mode.**

CAUTION

When in Standby, the HAMILTON-G5 does not automatically resume ventilation when the patient is reconnected. Instead you must close Standby *mode manually.*

NOTE:

- To keep the batteries fully charged, make sure the ventilator is connected to AC power while in standby mode.
- Alarms are suppressed during Standby.

Standby is a waiting mode that lets you maintain ventilator settings while the device is not performing any ventilatory functions. For very short interruptions in ventilation, you can use the ventilation suppression function (see Section 12.3).

To begin Standby mode, press the Standby key (Figure 12-1). The **Standby** window (Figure 12-2) opens. Select **Activate Standby**.

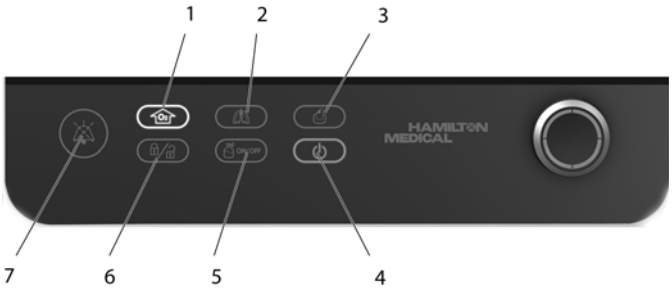


Figure 12-1. Special function keys

1 O_2 enrichment
2 Manual breath
3 Print screen
4 Standby
5 Nebulizer on/off
6 Screen lock
7 Alarm silence

Figure 12-2. Activate standby window

The **Standby** window (Figure 12-3) opens. During Standby, the window shows the elapsed time since you began this mode. Automatic controls resume their default settings (see Appendices describing automatic adjustments).

Figure 12-3. Standby activated window

To stop standby and resume ventilation, change the patient set up if desired, then select **Start**. Ventilation will then resume with the current settings.

12.2 O_2 enrichment

NOTE:

- Oxygen alarms are suppressed when the 100% O_2 function is active.
- Recruitment maneuver is aborted when O_2 enrichment is activated.

The O_2 enrichment function delivers for adults and pediatrics 100% oxygen for 2 minutes. For neonates the applied oxygen concentration during the enrichment maneuver is increased by 25% of the last oxygen setting (example: last oxygen setting 40%, resulting oxygen concentration during O_2 enrichment maneuver 50%).[1] This function is useful for pre-oxygenation before tracheal suctioning, or for other clinical applications.

To start oxygen enrichment, press the **O_2 enrichment** key. After a short time, which is required for the oxygen concentration to rise, the device starts delivering 100% oxygen (adult and pediatric) or the current oxygen setting increased by 25% of the setting (neonate). Afterward the device resets the concentration to the previous operator-set value.

The currently applied oxygen concentration is displayed on the oxygen control knob (green).

To stop delivery of O_2 enrichment before the 2-minute period finishes, press the key again, or manually activate the oxygen control. This control displays the last value set, which can now be adjusted. The device resumes ventilation at the set oxygen concentration.

12.3 Suctioning tool

NOTE:

- The suctioning tool is inactive during NIV, NIV-ST and nCPAP-PS.
- The pre- and post oxygenation is displayed with a green O_2 control and timer (maximum 120 seconds).

During suctioning, the patient's secretions can escape from the tubing. When using the suctioning tool, the ventilation stops and prevents secretions from escaping.

The suctioning tool is directly accessible using the **O_2 enrichment** key.

1. Not available in Japan and USA. in these markets 100% O_2 is applied during maneuver.

1. To perform the suctioning maneuver, press the **O_2 enrichment** key for pre-oxygenation.

   Disconnection terminates the ventilation and starts the maneuver. For 60 seconds, all alarms are completely suppressed.

   After reconnection the post-oxygenation starts and again for 60 seconds all acoustic alarms are suppressed. The alarm message and lamp is still active.

2. To terminate the pre- and post oxygenation maneuver, press the **O_2 enrichment** key.

12.4 Manual breath

The **Manual breath** key lets the device deliver a manually triggered breath. The manual breath uses the same settings of a mandatory breath (standard or operator-set). You can activate this function in all modes of ventilation.

To deliver a manual breath, press and release the key. DO NOT quickly or repeatedly press the key.

If you try to start a manual breath during the early stage of inspiration or the early stage of exhalation, the breath will not be delivered.

12.5 Pneumatic and Aeroneb® nebulizer

WARNING

- **DO NOT use an expiratory filter or HME in the patient's breathing circuit during nebulization. Nebulization can cause an expiratory side filter to clog, substantially increasing flow resistance and impairing ventilation.**
- **To prevent the expiratory valve from sticking due to nebulized medications, use only medications approved for nebulization and regularly check and clean the expiratory valve.**

NOTE:

- To determine whether nebulization is enabled, view **`System -> Info`** window. If it is not enabled, enable it in **`System -> Nebulization`**.
- Pneumatic nebulization is inactive if the nebulizer volume is greater than 50% of the total delivered volume.
- For infant/neonatal ventilation pneumatic nebulization is inactive.
- Delivered ventilation is compensated for the contribution of the internal nebulizer so that the expected volume and pressure are delivered.

For more information, see Section 3.4.

The device's pneumatic nebulization function provides nebulization during the breath phases and for the duration defined during configuration. To start nebulization, press the **`Nebulizer ON/OFF`** key. This function can be activated in all modes of ventilation. To terminate nebulization before the set time, press the key a second time.

For effective nebulization, use a pneumatic nebulizer jar tested by HAMILTON MEDICAL (see Table 1-1). Sections 2.5 and 3.3 describe how to install the nebulizer. The Aeroneb® nebulizer is integrated (see Section 3.4).

12.6 Print screen

NOTE:

The use of HAMILTON MEDICAL CompactFlash® or USB is recommended.

The print screen function saves a JPG file of the current ventilator screen to a CompactFlash® or USB storage device. To create a screen shot, insert one of these storage devices into the CompactFlash® connector, or insert an USB memory stick into the USB connector; then press the **`Print screen`** key while the desired screen is shown.

The filename takes this format:

screenshot_yyyymmdd_hhmmss.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

12.7 Screen Lock/Unlock

The Screen Lock/Unlock function prevents inadvertent touch screen entries. When touching the locked screen, an acoustic BEEP sounds and the message, "screenlock active", appears.

To lock or unlock the screen, press the **Lock/Unlock** key (Figure 12-1).

APPENDIX

A Specifications

A.1 Physical characteristics

Table A-1. Physical characteristics

Weight	With trolley: 57 kg (126 lb) Shelf-mount version: 42 kg (93 lb)
Dimensions	See Figure A-1

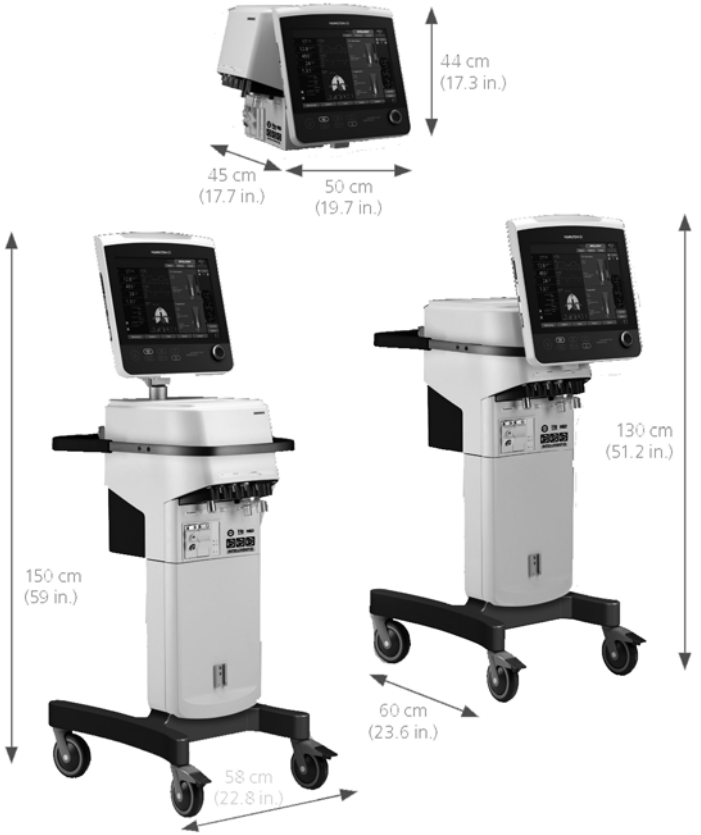


Figure A-1. HAMILTON-G5 dimensions

A.2 Environmental requirements

Table A-2. Environmental requirements

Temperature	Operating: 10 to 40 °C (50 to 104 °F) Storage: -10 to 60 °C (14 to 140 °F); -40 to 70 °C (-40 to 158 °F) for CO_2 sensor only
Relative humidity	Operating: 30 to 75%, noncondensing Storage: 5 to 85%, noncondensing; <90%, non-condensing for CO_2 sensor only
Altitude	Up to 3000 m (9843 ft) above sea level
Water/Dust resistance	IPX 1

A.3 Pneumatic specifications

Table A-3. Pneumatic specifications

Oxygen and air inlet supplies	Pressure: • Oxygen: 2 to 6 bar (200 to 600 kPa/29 to 86 psi) • Air: 2 to 6 bar (200 to 600 kPa/29 to 86 psi) Flow: Maximum of 120 l/min STPD, minimum of 40 l/min STPD
Oxygen, Air and Heliox inlet supplies (if Heliox option is installed)	Pressure: • Oxygen: 2 to 6 bar (200 to 600 kPa/29 to 86 psi) • Air: 2,8 to 6 bar (280 to 600 kPa/41 to 86 psi) • Heliox: 2,8 to 6 bar (280 to 600 kPa/41 to 86 psi) Flow: Maximum of 120 l/min STPD, minimum of 40 l/min STPD

Table A-3. Pneumatic specifications

Gas mixing system	Delivered flow: 180 l/min peak flow, 120 l/min continuous flow, 4 to 30 l/min continuous base flow Delivered pressure: 0 to 100 cmH_2O Operating pressure range: 2 to 6 bar (200 to 600 kPa/29 to 86 psi)
Connectors	Inspiratory limb connector per ISO 5356-1: 22 mm male/15 mm female conical Expiratory limb connector (on exhalation valve): ISO 15 mm female/22 mm conical male High-pressure gas inlets: DISS (standard) (air CGA 1160-A, oxygen CGA 1240, heliox CGA 1180-A), NIST (optional), or NF (optional)

A.4 Electrical specifications

Table A-4. Electrical specifications

Input power	100 to 240 V ac ±10%; 50/60 Hz; 2.7 A maximum (at 100 V), 1.2 A maximum (at 240 V)

Table A-4. Electrical specifications

Mains fuses (2)	T 5.0 AH 250 V
Batteries	Electrical specifications: 12 V dc, 15 Ah (internal battery) 14.4 V dc, 6.6 Ah (extended battery pack) Type: Sealed lead-acid (internal battery) and lithium ion (extended battery pack), supplied by HAMILTON MEDICAL only Operating time per internal battery or extended battery pack (at standard settings and with nebulizer and communications interface option enabled): 1 hour minimum. These operating times apply to new, fully charged batteries not exposed to extreme temperatures. The actual operating time depends on battery age and on how the batteries are used and recharged. Recharge time: 15 hours minimum (internal battery) and 7 hours minimum (extended battery pack) while ventilator is connected to ac power Storage: Remove extended battery pack from ventilator for long-term storage. Store at -20 to 40 °C (-4 to 104 °F), but preferably below 30 °C (86 °F), with relative humidity of 25 to 85%. Storage place must be free from vibration, dust, direct sunlight, and moisture. Avoid storing battery packs for more than 12 months. To maintain battery integrity, recharge the batteries at these intervals: **Storage temperature** < 20 °C (68 °F) 20 to 30 °C (68 to 86 °F) 30 to 40 °C (86 to 104 °F) **Recharge interval** Every 9 months Every 6 months Every 3 months **NOTE:** Battery life specifiations 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.

A.5 Control settings

Table A-5 is an alphabetical list of the HAMILTON-G5's control settings, their ranges, standard settings, and resolutions.

Table A-6 lists the control settings that apply to the various ventilation modes.

Table A-7 lists the P/V Tool setting ranges, standard settings, and resolutions.

Table A-5. Control setting ranges and resolutions

Setting	Range	Standard setting[1]	Resolution
Backup	Enabled, disabled	Enabled	--
ETS (expiratory trigger sensitivity)			
Adult	5 to 70% (of inspiratory peak flow)	25%	5%
Pediatric/infant/ neonatal	5 to 70% (of inspiratory peak flow)	15%	5%
Flow Pattern			
Adult/pediatric	Sine, square, 100% decelerating, 50% decelerating	50% decelerating	--
Infant/neonatal	--	--	--

Table A-5. Control setting ranges and resolutions

Setting	Range	Standard setting[1]	Resolution
IntelliCuff®	Minimum pressure 0-50 cm H2O		--
Manual mode	5-50 cm H2O	20 cmH2O	--
Automatic mode			
Rel. pressure	-15 to 5 cmH2O	0 cmH2O	--
Min. pressure	-15 to 50 cmH2O	20 cmH2O	--
Max. pressure	5 to 50 cmH2O	30 cmH2O	--
Flowtrigger			
Adult	0.5 to 15 l/min	5 l/min	0.5 l/min
Pediatric	0.5 to 15 l/min	3 l/min	0.5 l/min
Infant/neonatal	0.1 to 5 l/min	1.5 l/min	0.1 l/min for < 2.0 l/min 0.5 l/min for ≥ 2.0 l/min
Gender	Male, female	Male	--
I:E[1]			
Adult	1:9 to 4:1	1:2	1 for 1:9 to 1:4 0.1 for 1:4 to 4:1
Pediatric/infant/ neonatal	--	--	--
Loudness (alarm)	1 to 10	5	1
%MinVol (% minute volume)			
Adult/pediatric	25 to 350%	100%	5%
Infant/neonatal	--	--	--

Table A-5. Control setting ranges and resolutions

Setting	Range	Standard setting[1]	Resolution
Max Duration (Quick Wean)	no limit	60 m	1
Mode			
Adult	(S)CMV, P-CMV, SIMV, P-SIMV, SPONT, APVcmv, APVsimv, ASV, DuoPAP, APRV, NIV, NIV-ST	ASV	--
Pediatric	(S)CMV, P-CMV, SIMV, P-SIMV, SPONT, APVcmv, APVsimv, ASV, DuoPAP, APRV, NIV, NIV-ST	ASV	--
Infant/neonatal	P-CMV, P-SIMV, SPONT, APVcmv, APVsimv, Duo-PAP, APRV, nCPAP-PS	P-CMV	--
Oxygen	21 to 100%	50%	1%
Patient	Infant/neonatal, pediatric, adult	Adult	--
Patient height			
Adult	130 to 250 cm (50 to 100 in.)	176 cm (69 in.)	2 cm (1 in.)
Pediatric	30 to 150 cm (12 to 60 in.)	100 cm (39 in.)	2 cm (1 in.)
Infant/neonatal	--	--	--

Table A-5. Control setting ranges and resolutions

Setting	Range	Standard setting[1]	Resolution
Pause[1]			
Adult/pediatric	0 to 70% (of cycle time)	0%	5%
Infant/neonatal	--	--	--
Pcontrol (pressure control, added to PEEP/CPAP)			
Adult/pediatric	5 to 100 cmH_2O	15 cmH_2O	1 cmH_2O
Infant/neonatal	3 to 50 cmH_2O[2]	15 cmH_2O	1 cmH_2O
Peak Flow[1]			
Adult	1 to 180 l/min	54 l/min	1 l/min
Pediatric/infant/neonatal	--	--	--
PEEP/CPAP			
Adult/pediatric	0 to 50 cmH_2O	5 cmH_2O	1 cmH_2O
Infant/neonatal	0 to 25 cmH_2O	5 cmH_2O	0.5 cmH_2O for 0.1 cmH2O < 8 and 0.5 cmH2O > 8
P high	0 to 50 cmH_2O	20 cmH_2O	1 cmH_2O
P low			
Adult/pediatric	0 to 50 cmH_2O	5 cmH_2O	1 cmH_2O
Infant/neonatal	0 to 25 cmH_2O	5 cmH_2O	0.5 cmH_2O for 0.1 cmH2O < 8 and 0.5 cmH2O > 8

Table A-5. Control setting ranges and resolutions

Setting	Range	Standard setting[1]	Resolution
P-ramp (pressure ramp)			
Adult: P-CMV and APVcmv Other modes	 50 to 200 ms 25 to 200 ms	 50 ms 50 ms	25 ms
Pediatric/infant/ neonatal: P-CMV and APVcmv (as applicable) Other modes	 50 to 200 ms 25 to 200 ms	 100 ms 100 ms	25 ms
Psupport (pressure support, added to PEEP/CPAP or P low)			
Adult/pediatric	0 to 100 cmH_2O	15 cmH_2O	1 cmH_2O
Infant/neonatal	0 to 50 cmH_2O	15 cmH_2O	1 cmH_2O
P-trigger (pressure trigger)			
Adult/pediatric	-0.5 to 10 cmH2O (below PEEP/ CPAP)	-2 cmH2O	0.5 cmH2O
Infant/neonatal	-0.1 to 5 cmH2O (below PEEP/ CPAP)[2]	-1 cmH2O	0.1 cmH2O for < 2.0 cmH2O 0.5 cmH2O for > 2.0 cmH2O

Table A-5. Control setting ranges and resolutions

Setting	Range	Standard setting[1]	Resolution
Rate			
Adult: (S)CMV, P-CMV, APVcmv	5 to 120 b/min	15 b/min	1 b/min
SIMV, P-SIMV, APVsimv, Duo-PAP	1 to 60 b/min	15 b/min	1 b/min
Pediatric: (S)CMV, P-CMV, APVcmv	5 to 120 b/min	25 b/min	1 b/min
SIMV, P-SIMV, APVsimv, Duo-PAP	1 to 60 b/min	25 b/min	1 b/min
Infant/neonatal: PCMV, APVcmv	5 to 150 b/min	30 b/min	1 b/min
P-SIMV, APVsimv, DuoPAP	1 to 80 b/min[2]	30 b/min	1 b/min
Sigh	Enabled, disabled	Disabled	--
T high			
Adult	0.1 to 30.0 s	1.3 s	0.05 < 1.5 s 0.1 s > 1.5 s
Pediatric	0.1 to 30.0 s	0.8 s	0.05 < 1.5 s 0.1 s > 1.5 s
Infant/neonatal	0.1 to 30.0 s	0.6 s	0.05 < 1.5 s 0.1 s > 1.5 s

Table A-5. Control setting ranges and resolutions

Setting	Range	Standard setting[1]	Resolution
%TI (% inspiratory time)[3]	Maximum 10 seconds		
Adult	10 to 80% (of cycle time)	33%	1%
Pediatric/infant/ neonatal	--	--	--
TI (inspiratory time)[1]			
Adult	0.1 to 10.0 s	1.3 s	0.1 s
Pediatric	0.1 to 3.0 s	0.8 s	0.1 s
Infant/neonatal	0.1 to 3.0 s	0.6 s	0.05 s
Ti max (maximum inspiratory time, spontaneous breaths)			
Adult	1.0 to 3.0 s	2.0 s	0.1 s
Pediatric	0.5 to 3.0 s	1.5 s	0.1 s
Infant/neonatal	0.25 to 3.0 s	1.0 s	0.05 s
Time before starting SBT (Quick Wean)	10 min to 120 min, OFF	OFF	1
Time between 2 SBTs (Quick Wean)	30 min to 240 min, OFF	30 m	1
Tip (inspiratory pause time)[1]			
Adult	0 to 8 s	0.0 s	0.1 s
Pediatric/infant/ neonatal	--	--	--

Table A-5. Control setting ranges and resolutions

Setting	Range	Standard setting[1]	Resolution
T low			
Adult	0.1 to 30.0 s	2.7 s	0.05 < 1.5 s 0.1 s > 1.5 s
Pediatric	0.1 to 30.0 s	1.6 s	0.05 < 1.5 s 0.1 s > 1.5 s
Infant/neonatal	0.1 to 30.0 s	1.3 s	0.05 < 1.5 s 0.1 s > 1.5 s
Tolerance Time (Quick Wean)	Adult: 10 to 600 s Pediatric: 10 to 300 s	Adult: 180 s Pediatric: 30 s	1
TRC (tube resistance compensation)			
Adult: Tube type Tube size Compensate	 ET tube, Trach tube, or TRC off 5.0 to 10.0 mm 10 to 100%	 TRC off 7.0 mm 80%	 Not applicable 0.5 mm 10%
Pediatric: Tube type Tube size Compensate	 ET tube, Trach tube, or TRC off 3.0 to 7.0 mm 10 to 100%	 TRC off 4.0 mm 80%	 Not applicable 0.5 mm 10%
Trigger			
Adult	P-trigger, Flowtrigger, Trigger off	P-trigger	--
Infant/neonatal	P-trigger, Flowtrigger, Trigger off	Flowtrigger	--

Table A-5. Control setting ranges and resolutions

Setting	Range	Standard setting[1]	Resolution
Vt (tidal volume)			
Adult	100 to 2000 ml	500 ml	10 ml for < 1000 ml 50 ml for > 1000 ml
Pediatric	20 to 300 ml	100 ml	1 ml for < 100 ml 10 ml for > 100 ml
Infant/neonatal	--	--	--
Vtarget (target tidal volume)			
Adult	100 to 2000 ml	500 ml	10 ml for < 1000 ml 50 ml for ≥ 1000 ml
Pediatric	20 to 300 ml	100 ml	1 ml for < 100 ml 10 ml for ≥ 100 ml
Infant/neonatal	2 to 200 ml	20 ml	0.1 ml for < 10 ml 1 ml for ≥ 10 ml

1. The standard setting is the default for a new patient for the first application of that specific control. If the control setting is later changed, the new setting overrides the standard setting.
2. With 2 ml option
3. Depending on how the ventilator is configured, you can see different time-related control settings. See Appendix J for details.

Table A-6. Control settings applicable to HAMILTON-G5 ventilation modes

Mode	Control settings		
	Adult	**Pediatric**	**Infant/neonatal**
(S)CMV	FlowPattern I:E and Pause, Peak Flow and Tip, or %TI and Pause Rate Vt P-trigger, Flowtrigger, or Trigger off PEEP/CPAP Oxygen	FlowPattern TI and Pause Rate Vt P-trigger, Flowtrigger, or Trigger off PEEP/CPAP Oxygen	--
P-CMV	I:E or %TI Rate P-ramp P-trigger, Flowtrigger, or Trigger off Pcontrol PEEP/CPAP Oxygen	TI Rate P-ramp P-trigger, Flowtrigger, or Trigger off Pcontrol PEEP/CPAP Oxygen	TI Rate P-ramp P-trigger, Flowtrigger, or Trigger off Pcontrol PEEP/CPAP Oxygen
APVcmv	I:E or %TI Rate P-ramp Vtarget P-trigger, Flowtrigger, or Trigger off PEEP/CPAP Oxygen	TI Rate P-ramp Vtarget P-trigger, Flowtrigger, or Trigger off PEEP/CPAP Oxygen	TI Rate P-ramp Vtarget P-trigger, Flowtrigger, or Trigger off PEEP/CPAP Oxygen

Table A-6. Control settings applicable to HAMILTON-G5 ventilation modes

Mode	Control settings		
	Adult	**Pediatric**	**Infant/neonatal**
SIMV	FlowPattern TI and Pause, Tip and Peak Flow, or %TI and Pause Rate P-ramp Vt ETS P-trigger or Flowtrigger Psupport PEEP/CPAP Oxygen	FlowPattern TI and Pause Rate P-ramp Vt ETS Ti max P-trigger or Flowtrigger Psupport PEEP/CPAP Oxygen	--
P-SIMV	TI or %TI Rate P-ramp ETS P-trigger or Flowtrigger Pcontrol Psupport PEEP/CPAP Oxygen	TI Rate P-ramp ETS Ti max P-trigger or Flowtrigger Pcontrol Psupport PEEP/CPAP Oxygen	TI Rate P-ramp ETS Ti max P-trigger or Flowtrigger Pcontrol Psupport PEEP/CPAP Oxygen

Table A-6. Control settings applicable to HAMILTON-G5 ventilation modes

Mode	Control settings		
	Adult	**Pediatric**	**Infant/neonatal**
APVsimv	TI or %TI Rate P-ramp Vtarget ETS P-trigger or Flowtrigger Psupport PEEP/CPAP Oxygen	TI Rate P-ramp Vtarget ETS Ti max P-trigger or Flowtrigger Psupport PEEP/CPAP Oxygen	TI Rate P-ramp Vtarget ETS Ti max P-trigger or Flowtrigger Psupport PEEP/CPAP Oxygen
SPONT	P-ramp Psupport ETS P-trigger or Flowtrigger PEEP/CPAP Oxygen	P-ramp Psupport ETS Ti max P-trigger or Flowtrigger PEEP/CPAP Oxygen	P-ramp Psupport ETS Ti max P-trigger or Flowtrigger PEEP/CPAP Oxygen
ASV	%MinVol P-ramp ETS P-trigger or Flowtrigger PEEP/CPAP Oxygen	%MinVol P-ramp ETS P-trigger or Flowtrigger PEEP/CPAP Oxygen	--

Table A-6. Control settings applicable to HAMILTON-G5 ventilation modes

Mode	Control settings		
	Adult	**Pediatric**	**Infant/neonatal**
DuoPAP	T high Rate P-ramp P high ETS P-trigger or Flowtrigger PEEP/CPAP Psupport Oxygen	T high Rate P-ramp P high ETS P-trigger or Flowtrigger PEEP/CPAP Psupport Oxygen	T high Rate P-ramp P high ETS P-trigger or Flowtrigger PEEP/CPAP Psupport Oxygen
APRV	T high T low P-ramp P high ETS P-trigger or Flowtrigger P low Psupport Oxygen	T high T low P-ramp P high ETS P-trigger or Flowtrigger P low Psupport Oxygen	T high T low P-ramp P high ETS P-trigger or Flowtrigger P low Psupport Oxygen
NIV	P-ramp Psupport ETS Ti max P-trigger or Flowtrigger PEEP/CPAP Oxygen	P-ramp Psupport ETS Ti max P-trigger or Flowtrigger PEEP/CPAP Oxygen	--

Table A-6. Control settings applicable to HAMILTON-G5 ventilation modes

Mode	Control settings		
	Adult	**Pediatric**	**Infant/neonatal**
NIV-ST	Rate TI Psupport ETS TImax PEEP/CPAP Flowtrigger/ Ptrigger P-ramp Oxygen	Rate TI Psupport ETS TImax PEEP/CPAP Flowtrigger/ Ptrigger P-ramp Oxygen	
nCPAP-PS	--	--	Rate TI Psupport ETS PEEP/CPAP Flow trigger/ Ptrigger P-ramp Oxygen TImax

Table A-7. P/V Tool setting ranges and resolutions

Setting	Range	Standard setting	Resolution
Pstart	0 to 20 cmH_2O	Current PEEP/CPAP setting	1 cmH_2O
Ptop	25 to 60 cmH_2O	35 cmH_2O	1 cmH_2O
End PEEP	0 to 20 cmH_2O	Current PEEP/CPAP setting	1 cmH_2O
Tpause	0 to 30 s	0 s	1 s
Ramp speed	2 to 5 cmH_2O/s	3 cmH_2O/s	1 cmH_2O/s

A.6 Monitored parameters

Table A-8 is an alphabetical list of monitored parameter ranges and resolutions, including the Vent Status panel.

Table A-9 lists the ranges of the real-time curves. Pressure, flow, and volume measurements are based on readings from the Flow Sensor. Optionally, you can select an auxiliary pressure sensing site via the Paux connector. Directly measured (non-calculated) parameters have these tolerances:

- Volume-related parameters: ±10% or 2 ml, whichever is greater (ATPD) for calibrated infant/neonatal flow sensor; ±15% or 20 ml, whichever is greater (ATPD) for calibrated adult/pediatric flow sensor.
- Pressure-related parameters: ±5% of reading or 1 cmH_2O, whichever is greater
- Oxygen: ±3% absolute FiO_2, including stability of measurement
- CO_2(BTPS):
  0 to 40 mmHg (0 to 5.3 kPa): ±2 mmHg (0.3 kPa)
  41 to 70 mmHg (5.4 to 9.3 kPa): ±5% of reading
  71 to 100 mmHg (9.4 to 13.3 kPa): ±8% of reading
  101 to 150 mmHg (13.4 to 20.0 kPa): ±10% of reading

  SpO_2 Range:70 – 80% ±3%
  80 – 100% ±2%

  Pulse: 30 – 300 b/min ±3%, ±1 b/min

Table A-8. Monitored parameter ranges and resolutions

Parameter	Range	Resolution
Pressure		
Ppeak	0 to 120 cmH2O	0.1 cmH_2O for < 10 cmH_2O 1 cmH_2O for ≥ 10 cmH_2O
Pmean	0 to 99 cmH2O	0.1 cmH_2O for < 10 cmH_2O 1 cmH_2O for ≥ 10 cmH_2O
Pminimum	-99 to 99 cmH2O	1 cmH_2O for ≤ -10 cmH_2O 0.1 cmH_2O for -9.9 to 9.9 cmH_2O 1 cmH_2O for ≥ 10 cmH_2O
Pplateau	0 to 99 cmH2O	0.1 cmH_2O for < 10 cmH_2O 1 cmH_2O for ≥ 10 cmH_2O
Pcuff	-250 to 250 cmH2O	1 cmH_2O
AutoPEEP	0 to 99 cmH2O	0.1 cmH_2O for < 10 cmH_2O 1 cmH_2O for ≥ 10 cmH_2O
Flow		
Insp Flow	0 to 999 l/min	0.1 l/min for < 100 l/min 1 l/min for ≥ 100 l/min
Exp Flow	0 to 999 l/min	0.1 l/min for < 100 l/min 1 l/min for ≥ 100 l/min
Volume		
VTE	0 to 9999 ml	0.1 ml for < 10 ml 1 ml for ≥ 10 ml

Table A-8. Monitored parameter ranges and resolutions

Parameter	Range	Resolution
VTE NIV	0 to 9000 ml	0.1 l/min for < 10 l/min 1 l/min for ≥ 10 l/min
VTI	0 to 9999 ml	0.1 ml for < 10 ml 1 ml for > 10 ml
VTEspont	0 to 9999 ml	0.1 ml for < 10 ml 1 ml for ≥ 10 ml
VTE Leak	0 to 9999 ml	0.1 ml for < 10 ml 1 ml for > 10 ml
%VTE Leak	0 to 100%	--
ExpMinVol	0.0 to 99.9 l/min	0.01 l/min for < 3.0 l/min 0.1 l/min for ≥ 3.0 l/min
MinVolNIV	0.0 to 99.9 l/min	0.01 l/min for < 3.0 l/min 0.1 l/min for ≥ 3.0 l/min
MVleak	0.0 to 99.9 l/min	0.01 l/min for < 3.0 l/min 0.1 l/min for ≥ 3.0 l/min
MVspont MVspoNIV	0.0 to 99.9 l/min	0.01 l/min for < 3.0 l/min 0.1 l/min for ≥ 3.0 l/min
VLeak%	0 to 100%	1%
VLeak ml	0 to 9999 ml	1 ml
VT/kg	0.0-99.9	0.1 ml/kg
VT/IBW		

Table A-8. Monitored parameter ranges and resolutions

Parameter	Range	Resolution
Time		
I:E	1:99 to 99:1	1 for 1:10 to 1:99 0.1 for 1:9.9 to 9.9:1 1 for 99:1 to 10:1
fTotal	0 to 999 b/min	1 b/min
fSpont	0 to 999 b/min	1 b/min
TI	0.00 to 99.9 s	0.01 s for < 10.0 s 0.1 s for ≥ 10.0 s
TE	0.00 to 99.9 s	0.01 s for < 10.0 s 0.1 s for ≥ 10.0 s
Other calculated parameters		
Cstat	0 to 200 ml/cmH2O	0.1 ml/cmH2O for < 100 ml/cmH_2O 1 ml/cmH2O for ≥ 100 ml/cmH_2O
P0.1	-99 to 0.0 cmH2O	1 cmH_2O for ≤ -10 cmH_2O 0.1 cmH_2O for > -10 cmH_2O
PTP	0 to 99.9 cmH2O*s	0.1 cmH2O*s
RCexp	0.0 to 99.9 s	0.01 s for < 10.0 s 0.1 s for ≥ 10.0 s
RCinsp	0.0 to 99.9 s	0.01 s for < 10.0 s 0.1 s for ≥ 10.0 s
Rexp	0 to 999 cmH2O/l/s	1 cmH2O/l/s
Rinsp	0 to 999 cmH2O/l/s	1 cmH2O/l/s
RSB	0 to 999 1/(l*min)	1 1/(l*min)
SpO_2/FiO_2	0 to 500	1
VariIndex[1]	0 to 50%	1
WOBimp	0.00 to 9.99 J/l	0.01 J/l
Oxygen		
O_2	18 to 100%	1%

Table A-8. Monitored parameter ranges and resolutions

Parameter	Range	Resolution
Carbon dioxide		
$FetCO_2$	0 to 19.7%	0.1%
$PetCO_2$	0 to 150 mmHg 0 to 20 kPa	1 mmHg 0.1 kPa
$slopeCO_2$	0 to 9.99%CO_2/l	0.01%CO_2/l
Vtalv	0 to 9999 ml	1 ml
V'alv	0 to 20 l/min	0.01 l/min for < 1 l/min 0.1 l/min for ≥ 1 l/min
$V'CO_2$	0 to 9999 ml/min	1 ml/min
VDaw	0 to 999 ml	1 ml
VDaw/VTE	0 to 100%	1%
$VeCO_2$	0 to 999 ml	1 ml
$ViCO_2$	0 to 999 ml	1 ml
SpO_2		
HLI	- 200 to 200	1
HR (pulse rate)	0 to 240	1
PI (perfusion index)	0.00 to 20.0	.01 for < 10% .1 for >= 10%
SpCO	0 to 100	1
SpHb (g/dL)	0.0 to 25.0	Configurable: 0.1 (default) 0.5 1
SpHb (mmol/L)	0.0 to 16.0	Configurable: 0.1 (default) 0.5 1
SpMet	0.0 to 100.0	0.1

Table A-8. Monitored parameter ranges and resolutions

Parameter	Range	Resolution
SpO_2	0 to 100 (Masimo) 70 to 100 (Nihon-Kohden)	1
SpOC	0 to 40	1
SpO_2 (quality index)	0 to 100	1
HLI quality index)	0 to 100	1
Vent Status panel		
Oxygen	21 to 100%	1%
PEEP	0 to 30 cmH_2O	1 cmH_2O
MinVol	0 to 350% (normal minute ventilation)	5%
Pinsp	0 to 50 cmH_2O	1 cmH_2O
RSB	Adult: 10 to 400 1/(l*min) Pediatric/infant/neonatal: 10 to 60 1/(l*min)	1 1/(l*min)
VariIndex[1]	50 to 0%	1%
P0.1	0 to -15 cmH_2O	1 cmH_2O
%fSpont	100 to 0%	1%
Other calculated and displayed parameters		
IBW	5 to 100 kg	1 kg

1. The variability index (VariIndex) parameter is not available in all markets.

Table A-9. Real-time curves

Parameter	Range
Volume (V)	0 to 3200 ml
Flow	-200 to 200 l/min
Airway pressure (Paw)	-10 to 120 cmH2O
Auxiliary pressure (Paux)	-10 to 120 cmH2O
Time	5 to 60 s
FCO_2	0 to 10%
PCO_2	0 to 100 mmHg 0 to 14 kPa

A.7 Alarms

Table A-10 is an alphabetical list of the ventilator alarm settings, their ranges, plus the automatic and standard alarm settings.

Table A-10. Adjustable alarms with automatic and standard settings

Parameter	Unit	Range	Standard setting	Automatic setting	Resolution
ADULT					
ExpMinVol high	l/min	Off, 2-50	10	- ASV: (IBW*0.1+ 40%)*%MinVol, if >100% - All other modes: ExpMinVol + 40%	1

Table A-10. Adjustable alarms with automatic and standard settings

Parameter	Unit	Range	Standard setting	Automatic setting	Resolution
ExpMinVol low	l/min	Off[1] 0.1-49	4	- ASV: (IBW*0.1-40%)*%MinVol, if >100% - NIV, NIV-ST, nCPAP-PS: ExpMinVol - 70% - All other modes: ExpMinVol - 40%	1
Pulse rate high	bpm	5 - 235 in increments of 5	140	Same as standard settings	1
Pulse rate low	bpm	30 - 230 in increments of 5	50	Same as standard settings	1
Pressure high	cmH2O	10-120	40	- Volume modes/ASV: Ppeak+ 10 cmH2O or minimum of 40 cmH2O - APV: Ppeak+ 10 cmH2O - Pressure modes: Pcontrol+PEEP+ 10 mbar - SPONT: Psupp+ PEEP+10 mbar - NIV, NIV-ST, nCPAP-PS: 2*Psupp+PEEP +10 mbar	1
Pressure low	cmH2O	2-119	5	PEEP+5 mbar	1

Table A-10. Adjustable alarms with automatic and standard settings

Parameter	Unit	Range	Standard setting	Automatic setting	Resolution
Vt high	ml	Off, 100-3000	750	Vt+50%	<1000: 10 >1000: 50
Vt low	ml	Off, 50-2950	250	Vt-50%	<1000: 10 >1000: 50
Rate high	b/min	2-130	23	- Volume modes/ASV: Rate/fControl+40% - All other modes: fTotal+40%	
Rate low	b/min	0-128	8	- Volume modes/ASV: Rate/fControl-40% - All other modes: fTotal-40%	
Apnea time	s	15-60	20	Same as standard settings	5
VLeak high	%	Off, 5-80%	Off	--	5%
$EtCO_2$ high	mmHg Torr	Off, 1-100	60	$EtCO_2$+25%	1
$EtCO_2$ high	kPa	Off, 0-13.3	8	$EtCO_2$+25%	0.1
$EtCO_2$ low	mmHg Torr	Off, 1-99	30	$EtCO_2$-25%	1
$EtCO_2$ low	kPa	Off, 0-13.2	4	$EtCO_2$-25%	0.1

Table A-10. Adjustable alarms with automatic and standard settings

Parameter	Unit	Range	Standard setting	Automatic setting	Resolution
Oxygen high	%			Oxygen +5% (permanently, not with "Auto" Button	
Oxygen low	%			Oxygen -5% (permanently, not with "Auto" Button	
PI high	%	0.04 - 0.10, in increments of 0.01 0.10 - 1.0, in increments of 0.10 1.0 - 19, in increments of 1	off	Same as standard settings	0.01 0.1 1
PI low	%	0.03 - 0.10, in increments of 0.01 0.10 - 1.0, in increments of 0.10 1.0 - 18, in increments of 1	off	Same as standard settings	0.01 0.1 1
SpCO high	%	2 - 98, in increments of 1	10	Same as standard settings	1
SpCO low	%	1 - 97, in increments of 1	off	Same as standard settings	1
SpO_2 high	%	Off 71-100 (Nihon Koden) 2-99 (Masimo)	99	Same as standard settings	1
SpO_2 low	%	85-99 (Nihon-Kohden)	90	Same as standard settings	1

Table A-10. Adjustable alarms with automatic and standard settings

Parameter	Unit	Range	Standard setting	Automatic setting	Resolution
SpO_2 low	%	70-85 (Nihon-Kohden)	90	Same as standard settings	1
SpO_2 low	%	1-98 (Masimo)	90	Same as standard settings	1
SpOC	ml/dl	0-40		Same as standard settings	1
SpMet high	%	0.1 - 2.0, in increments of 0.1 2.0 - 99, in increments of 0.5	3.0	Same as standard settings	0.1 0.5 1.0
SpMet low	%	1.0 - 2.0, in increments of 0.1 2.0 - 99.5, in increments of 0.5	off	Same as standard settings	0.1 0.5 1.0
HLI high	%	Off, 0-40	30	Same as standard settings	1

Table A-10. Adjustable alarms with automatic and standard settings

Parameter	Unit	Range	Standard setting	Automatic setting	Resolution
PEDIATRIC (only where differing from ADULT values)					
ExpMinVol high	l/min	Off, 0.3-10	3.5	- ASV: (IBW*0.2+ 40%)*%MinVol, if >100% - All other modes: ExpMinVol + 40%	1
ExpMinVol low	l/min	Off[2] 0.1-9.8	1.5	- ASV: (IBW*0.2- 40%)*%MinVol, if >100% - NIV, NIV-ST, nCPAP-PS: ExpMinVol - 60% - All other modes: ExpMinVol - 40%	1
Vt high	ml	Off, 10-500	150	Vt+50%	< 100:10 > 100:10
Vt low	ml	Off, 0-300	50	Vt-50%	< 100:10 > 100:10
Rate high	b/min	2-130	38	- Volume modes/ASV: Rate/fControl+40% - All other modes: fTotal+40%	

Table A-10. Adjustable alarms with automatic and standard settings

Parameter	Unit	Range	Standard setting	Automatic setting	Resolution
Rate low	b/min	0-128	12	- Volume modes/ASV: Rate/fControl-40% - All other modes: fTotal-40%	
Apnea time	s	15-60	20	--	5
NEONATAL (only where differing from ADULT values)					
ExpMinVol high	l/min	Off, 0.03-10	2	ExpMinVol +40%	1
ExpMinVol low	l/min	Off, 0.1-9.8	0.5	- NIV, NIV-ST, nCPAP-PS: ExpMinVol -70% - All other modes: ExpMinVol -40%	1
Vt high	ml	Off, 0-250	40	Vt+50%	< 100:10 > 100:10
Vt low	ml	Off, 0-240	3	Vt-50%	< 100:10 > 100:10
Rate high	b/min	2-160	45	- Volume modes/ASV: Rate/fControl+40% - All other modes: fTotal+40%	

Table A-10. Adjustable alarms with automatic and standard settings

Parameter	Unit	Range	Standard setting	Automatic setting	Resolution
Rate low	b/min	0-158	12	- Volume modes/ASV: Rate/fControl-40% - All other modes: fTotal-40%	
Apnea time	s	15-60	15	--	5
SpO_2 high	%	Off, 71-100	95	Same as standard settings	1

1. "Off" only for NIV and NIV-ST, low priority alarm "Low ExpMinVol alarm off" is appearing when set to "Off"
2. "Off" only for NIV and NIV-ST, low priority alarm "Low ExpMinVol alarm off" is appearing when set to "Off"

A.8 Configuration specifications

Table A-11 lists the configurable parameters, ranges, and default or standard (factory) settings.

Table A-11. Configuration specifications

Parameter	Range	Standard setting	Resolution
Customize			
Breath timing philosophy (Controls)	I:E/Pause, Peak Flow/Tip, %Ti/Pause	I:E/Pause	--
Active alarms (Alarms)	ExpMinVol high, Pressure low, Vt high, Vt low, Rate high, Rate low, Apnea time, VLeak[1]	ExpMinVol high, Pressure low, Vt high, Vt low, Rate high, Rate low, Apnea time	--

Table A-11. Configuration specifications

Parameter	Range	Standard setting	Resolution
Interface – I:E Outlet (relay position)			
Insufflation	Open, Closed	Closed	--
Pause	Open, Closed	Closed	--
Expiration	Open, Closed	Closed	--
Language	English, Bulgarian, Chinese, Czech, Danish, Dutch, Finish, French, German, Greek, Hungarian, Indonesian, Italian, Japanese, Korean, Norwegian, Polish, Portuguese, Russian, Serbian, Slovakian, Spanish, Swedish, Turkish	English	--
Main Monitoring Parameter selection (most parameters can be activated as MMP)			
Pressure	Ppeak, Pmean, PEEP/CPAP, Pplateau, Pminimum, Auto-PEEP, Pcuff	Ppeak	--
Volume	ExpMinVol, VTE, VLeak, Vleak%, VT/IBW, MVSpont, VTI, VTESpont	ExpMinVol, VTE	--
Peak flow	Exp Flow, Insp Flow	--	--
Rate	fTotal, fSpont	fTotal	--
Time	TI, TE, I:E,	I:E	--
R&C	RCinsp, RCexp, Cstat, Rinsp, Rexp, RSB	--	--
CO_2	$FetCO_2$, $PetCO_2$, $slopeCO_2$, Vtalv, V'alv, $V'CO_2$, VDaw, VDaw/VTE, $ViCO_2$, $VeCO_2$	--	--

Table A-11. Configuration specifications

Parameter	Range	Standard setting	Resolution
Pulse oximetry	SpO_2, HLI (Nihon-Kohden only), Pulse, SpO_2/FiO_2, QI-SpO_2, QI-HLI, PI. Masimo Rainbow SET options: SpHb, SpMet, SpOC, SpCO	--	--
Others	P0.1, WOBimp, PTP, Oxygen	--	--
Nebulizer			
Type	Internal, External	Internal	--
Breath phase	Inspiration, Expiration, Continuous	Inspiration	--
Aeroneb®	Inspiration, Continuous	Inspiration	--
Time-limited operation	Duration (limited), Unlimited	Duration	--
Length of time if Duration selected	5 to 40 min	30 min	1 min
Quick Wean settings			
To start PEEP, Oxygen, VT/IBW, Delay Time, RSBi (Adults only)	-- See Quick Wean chapter in INTELLiVENT-ASV manual.	Note these differences: RSBi only for adults PEEP (Adult): 8 cmH20 PEEP (Pediatric): 6 cmH20	--

Table A-11. Configuration specifications

Parameter	Range	Standard setting	Resolution
SBT Settings PEEP, %MinVol	-- See Quick Wean chapter in INTELLiVENT-ASV manual.		--
To abort Rate inc, Oxygen, $PetCO_2$ inc, Tolerance Time, Max Duration	-- See Quick Wean chapter in INTELLiVENT-ASV manual.	Note these differences: Tolerance Time (Adult): 180 s Tolerance Time (Pediatric): 30 s	--

1. The high Pressure and low ExpMinVol alarms are always enabled.

A.9 Breathing circuit specifications

Table A-12 lists specifications for HAMILTON MEDICAL breathing circuits.

Table A-12. Breathing circuit specifications

Parameter	Specification
Resistance[1]	Adult circuit (19 mm ID, flow of 60 l/min): Inspiratory limb: 6.0 cmH_2O/60 l/min Expiratory limb: 4.2 cmH_2O/60 l/min Pediatric circuit (15 mm ID, flow of 30 l/min): Inspiratory limb: 4.0 cmH_2O/30 l/min Expiratory limb: 4.8 cmH_2O/30 l/min Infant/neonatal circuit (10 mm ID, flow of 5 l/min): Inspiratory limb: 3.0 cmH_2O/5 l/min Expiratory limb: 3.3 cmH_2O/5 l/min
Compliance[1]	Adult circuit (19 mm ID): 2.1 ml/cmH_2O Pediatric circuit (15 mm ID): 1.9 ml/cmH_2O Infant/neonatal circuit (10 mm ID): 1 ml/cmH_2O
Volume[1]	Adult circuit (19 mm ID): 2.4 l Pediatric circuit (15 mm ID): 1.8 l Infant/neonatal circuit (10 mm ID): 0.9 l
Bacteria filter	Particle size: Captures particles of 0.3 mm (micron) with > 99.99% efficiency Resistance: < 4 cmH_2O at 60 l/min
CO_2 airway adapter	Dead space: < 5 ml (adult/pediatric), < 1 ml (infant/pediatric)
Flow Sensor	Dead space: < 1.3 ml (infant), < 9 ml (pediatric/adult)

1. 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.

A.10 Other technical data

Table A-13 lists other ventilator technical data.

Table A-13. Other technical data

Parameter	Specification
Inspiratory time (SPONT breaths)	0.2 to 3 s 0.2 to 10 s (ASV)
Minimum expiratory time	20% of cycle time
Automatic expiratory base flow	Pressuretrigger = 1l/min Flowtrigger setting ≤ 1l/min: 2l/min Flowtrigger setting > 1l/min: 2*Flowtrigger
Maximum limited pressure	120 cmH_2O, ensured by overpressure valve
Maximum working pressure	120 cmH_2O, ensured by high Pressure limit
Measuring and display devices	Pressure and volume measurements: Type: Differential pressure transducer, variable orifice Sensing position: Patient Y-piece Measurements: See Table A-8
	Time measurements: Type: Microprocessor Sensing position: Inside ventilator Measurements: See Table A-8

Table A-13. Other technical data

Parameter	Specification
Measuring and display devices	Oxygen measurement: Type: Galvanic cell sensing position: Inspiratory pneumatics Measurement: Delivered oxygen concentration, range: 18 to 105% Response time: 20 s Initialization time (time from switching on until operating performance): < 40 s
	CO_2 measurement: Type: Nondispersive infrared (NDIR) technology Sensing position: Mainstream Measurements: See Table A-8 Rise time: < 60 ms Initialization time: Capnogram displayed in < 15 s at an ambient temperature of 25 °C, full specifications within 2 min Sampling frequency: 100 Hz CO_2 calculation method: BTPS CO_2 stability: Short-term drift: ≤0.8 mmHg (0.10 kPa) over 4 h. Long-term drift: Accuracy specification maintained over 120 h CO_2 noise (rms): ≤ 0.25 mmHg (0.03 kPa) at 7.5% CO_2
	Display of settings, alarms, and monitored data: Type: LCD (liquid crystal display) Size: 1024 x 768 pixels, 15 in./381 mm (diagonal)
Tidal volume/target tidal volume	2 to 2000 ml
Minute volume capability	Up to 60 l/min
Inspiratory valve response time	< 13 ms

Table A-13. Other technical data

Parameter	Specification
Oxygen cell life	1 year or 5000 hours nominal. Actual cell life depends on operating environment. Operation at higher temperatures or higher oxygen concentrations shortens cell life.
Alarm loudness	50 to 85 dB(A) at 1 m
Tests and special functions	Tightness test, oxygen cell calibration, Flow Sensor calibration, manual breath, inspiratory/expiratory hold maneuver, P/V Tool maneuver, Paux measurement, internal pneumatic nebulization (30 min, 6 l/min at 1 bar/100 kPa/14.5 psi), communications interface (optional), internal battery, extended battery pack (optional)
Ventilator	IPX1 classification (Degree of protection provided by enclosure)
Optional CO_2 sensor related specifications	
Water resistance (sensor head but not the connector)	IPX4 classification (splash-proof)
Cable length	3 m (10 ft)
Optional **SpO_2 sensor related specifications**	
Water resistance (SpO_2 probe head but not the connector)	IPX4 classification (splash-proof) • SpO_2 probe (all reusable types) IPX1 classification • SpO_2 sensor • SpO_2 sensor module
Cable length	1.6 m (5.25 ft)

A.11 Standards and approvals

The HAMILTON-G5 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 1 certified quality management system.

The ventilator meets the Essential Requirements of Council Directive 93/42/EEC. It is a class IIb device.

The ventilator meets relevant parts of the following standards:

- **IEC 60601-1:** Medical electrical equipment, Part 1: General requirements for safety. The device classification is: Class I, Type B applied part (ventilator breathing system, VBS), type BF applied part (CO_2 sensor including CO_2 module connector and SpO_2 sensor including SpO_2 adapter), ordinary enclosed equipment without protection against ingress of liquids, continuous operation
- **IEC 60601-1-2:** Medical electrical equipment: General requirements for safety – Collateral standard: Electromagnetic compatibility. Requirements and tests
- **IEC 60601-2-12:** Medical electrical equipment: Particular requirements for the safety of lung ventilators – Critical care ventilators
- **EN 794-1:** Lung ventilators. Particular requirements for critical care ventilators

A.12 EMC declarations (IEC 60601-1-2)

The HAMILTON-G5 ventilator is intended for use in the electromagnetic environment specified in Table A-14, Table A-15, and Table A-16. The customer (or the operator) of the HAMILTON-G5 ventilator should ensure that it is used in such an environment.

The HAMILTON-G5 is intended for use in an electromagnetic environment in which radiated RF disturbances are controlled. The customer or the user of the HAMILTON-G5 can help prevent electromagnetic interference by maintaining a minimum distance between portable and mobile RF communications equipment (transmitters) and the HAMILTON-G5 as recommended in Table A-16, according to the maximum output power of the communications equipment.

Table A-14. Guidance and manufacturer's declaration – electromagnetic emissions

Emissions test	Compliance	Electromagnetic environment – guidance
RF emissions CISPR 11	Group 1	The HAMILTON-G5 ventilator uses RF energy only for its internal function. Therefore, its RF emissions are very low and are not likely to cause any interference in nearby electronic equipment.
RF emissions CISPR 11	Class A	The HAMILTON-G5 ventilator is suitable for use in all establishments other than domestic and those directly connected to the public low-voltage power supply network that supplies buildings for domestic purposes.
Harmonic emissions IEC 61000-3-2	Class A	
Voltage fluctuations/ flicker emissions IEC 61000-3-3	Complies	

Table A-15. Guidance and manufacturer's declaration – electromagnetic immunity[1]

Immunity test	IEC 60601 test level	Compliance level	Electromagnetic environment – guidance
Electrostatic discharge (ESD) IEC 61000-4-2	±6 kV contact ±8 kV air	±6 kV contact ±8 kV air	Floors should be wood, concrete, or ceramic tile. If floors are covered with synthetic material, the relative humidity should be at least 30%.
Electrical fast transient/ burst IEC 61000-4-4	±2 kV for power supply lines ±1 kV for input/output lines	±2 kV for power supply lines ±1 kV for input/output lines	Mains power quality should be that of a typical commercial or hospital environment.
Surge IEC 61000-4-5	±1 kV line(s) to line(s) ±2 kV line(s) to earth	±1 kV line(s) to line(s) ±2 kV line(s) to earth	Mains power quality should be that of a typical commercial or hospital environment.
Voltage dips, short interruptions, and voltage variations on power supply input lines IEC 61000-4-11	< 5% UT (>95% dip in UT) for 0.5 cycle 40% UT (60% dip in UT) for 5 cycles 70% UT (30% dip in UT) for 25% UT (>95% dip in UT) for 5 s	<5% UT (>95% dip in UT) for 0.5 cycle 40% UT (60% dip in UT) for 5 cycles 70% UT (30% dip in UT) for 25 cycles <5% U(>95% dip in UT) for 5 s	Mains power quality should be that of a typical commercial or hospital environment.

Table A-15. Guidance and manufacturer's declaration – electromagnetic immunity[1]

Immunity test	IEC 60601 test level	Compliance level	Electromagnetic environment – guidance
Power frequency (50/60 Hz) magnetic field IEC 61000-4-8	3 A/m	30 A/m	The power frequency magnetic field should be at levels consistent of a typical location in a typical commercial or hospital environment.
			Portable and mobile RF communications equipment should be used no closer to any part of the HAMILTON-G5 ventilator, including cables, than the recommended separation distance calculated from the equation applicable to the frequency of the transmitter. Recommended separation distance:
Conducted RF IEC 61 000-4-6	3 Vrms 150 kHz to 80 MHz outside ISM bands[2] 10 Vrms 150 kHz to 80 MHz in ISM bands4	10 Vrms 10 Vrms	**d = 0.35 √ P** **d = 1.2 √ =P**

Table A-15. Guidance and manufacturer's declaration – electromagnetic immunity[1]

Immunity test	IEC 60601 test level	Compliance level	Electromagnetic environment – guidance
Radiated RF IEC 61000-4-3	10 V/m 80 MHz to 2.5 GHz	10 V/m	80 MHz to 800 MHz **$d = 1.2 \sqrt{P}$** 800 MHz to 2.5 GHz **$d = 2.3 \sqrt{P}$**
			where P is the maximum output power rating of the transmitter in watts (W) according to the transmitter manufacturer and d is the recommended separation distance in meters (m).[3] Field strengths from fixed RF transmitters, as determined by an electromagnetic site survey[4], should be less than the compliance level in each frequency range[5]. Interference may occur in the vicinity of equipment marked with the symbol 

1. UT is the AC mains voltage before application of the test level.
2. The ISM (industrial, scientific and medical) bands between 150 kHz and 80 MHz are 6.765 MHz to 6.795 MHz; 13.553 MHz to 13.567 MHz; 26.957 MHz to 27.283 MHz; and 40.66 MHz to 40.70 MHz.
3. The compliance levels in the ISM frequency bands between 150 kHz and 80 MHz and in the frequency range 80 MHz to 2.5 GHz are intended to decrease the likelihood that mobile/portable communications equipment could cause interference if it is inadvertently brought into patient areas. For this reason, an additional factor of 10/3 is used in calculating the recommended separation distance for transmitters in these frequency ranges.
4. Field strengths from fixed transmitters, such as base stations for radio (cellular/cordless) telephones and land mobile radios, amateur radio, AM and FM radio broadcast and TV broadcast cannot be predicted theoretically with accuracy. To assess the electromagnetic environment due to fixed RF transmitters, an electromagnetic site survey should be considered. If the measured field strength in the location in which the HAMILTON-G5 ventilator is used exceeds the applicable RF compliance level above, the HAMILTON-G5 ventilator should be observed to verify normal operation. If abnormal performance is observed, additional measures may be necessary, such as re-orienting or relocating the HAMILTON-G5 ventilator.
5. Over the frequency range 150 kHz to 80 MHz, field strengths should be less than 10 Vrms.

Table A-16. Recommended separation distances between portable and mobile RF communications equipment and the HAMILTON-G5 ventilator[1]

Rated maximum output power of transmitter (W)	Separation distance according to frequency of transmitter (m)[2345]			
	Conducted		Radiated	
	150 kHz to 80 MHz outside ISM bands **d = 0.35 √ P**	150 kHz to 80 MHz in ISM bands **d = 1.2 √ P**	80 MHz to 800 MHz **d = 1.2 √ P**	800 MHz to 2.5 GHz **d = 2.3 √ P**
0.01	0.035	0.12	0.12	0.23
0.1	0.11	0.38	0.38	0.73
1	0.35	1.2	1.2	2.3
10	1.1	3.8	3.8	7.3
100	3.5	12	12	23

1. These guidelines may not apply in all situations. Electromagnetic propagation is affected by absorption and reflection from structures, objects, and people.
2. For transmitters rated at a maximum output power not listed above, the recommended separation distance d in meters (m) can be determined using the equation applicable to the frequency of the transmitter, where P is the maximum output power rating of the transmitter in watts (W) according to the transmitter manufacturer.
3. At 80 MHz and 800 MHz, the separation distance for the higher frequency range applies.
4. The ISM (industrial, scientific and medical) bands between 150 kHz and 80 MHz are 6.765 MHz to 6.795 MHz; 13.553 MHz to 13.567 MHz; 26.957 MHz to 27.283 MHz; and 40.66 MHz to 40.70 MHz.
5. An additional factor of 10/3 is used in calculating the recommended separation distance for transmitters in the ISM frequency bands between 150 kHz and 80 MHz and in the frequency range 80 MHz to 2.5 GHz to decrease the likelihood that mobile/portable communications equipment could cause interference if it is inadvertently brought into patient areas.

A.13 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.

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.

A.14 Miscellaneous

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.

APPENDIX

B Modes of ventilation

B.1 Introduction

The HAMILTON-G5 has a full range of ventilation modes that provide full and partial ventilatory support. This section summarizes the characteristics of these modes. The accompanying tables list the controls active in all modes.

The subsections provide details specific to the modes. In general, PEEP/CPAP, oxygen, and patient trigger sensitivity (flow or pressure) are set in all modes, although you can lock out trigger sensitivity in the mandatory modes.

A positive baseline pressure can be set for all breaths in all modes. There are no negative pressures generated during exhalation.

Table B-1. Ventilation mode summary

Mode	Pressure-controlled	Volume-controlled	Time-cycled	Flow-cycled	Pressure-triggered	Flow-triggered
(S)CMV		X	X		X	X
P-CMV	X		X		X	X
SIMV	X	X	X	X	X	X
P-SIMV	X		X	X	X	X
SPONT	X			X	X	X
APVcmv	X	X	X		X	X
APVsimv	X	X	X		X	X
ASV	X		X	X	X	X
DuoPAP	X		X	X	X	X
APRV	X		X	X	X	X
NIV	X		X	X	X	X
NIV-ST	X	X	X	X	X	X
nCPAP-PS	X		X	X	X	X

Table B-2. Controls active in HAMILTON-G5 ventilation modes

	Closed-loop mode	Mandatory modes		SIMV modes				Dual-control (APV) modes		DuoPAP/APRV		Pressure support	
Mode	**ASV**	**(S)CMV**	**P-CMV**	**SIMV**	**P-SIMV**	**NIV-ST**	**nCPAP-PS**	**APVcmv**	**APVsimv**	**DuoPAP**	**APRV**	**SPONT**	**NIV**
Timing	--	Rate									T low	--	
		I:E and Pause[1]	I:E[1]	TI and Pause[1]	TI[1]			I:E[1]	TI[1]	T high			
Mandatory breath control	--	Vt	Pcontrol	Vt	Pcontrol	Pinsp		Vtarget		P high		--	
Spontaneous breaths	--			Psupport				--	Psupport				
	ETS	--		ETS					ETS				
	--			Ti max[2]					Ti max[2]	--		Ti max[2]	TI max
Baseline	PEEP/CPAP										P low	PEEP/CPAP	
General	P-trigger or Flow-trigger	P-trigger, Flowtrigger, or Trigger off		P-trigger or Flowtrigger				P-trigger, Flowtrigger, or Trigger off	P-trigger or Flowtrigger				
	P-ramp	--	P-ramp										
	--	Flow-Pattern	--	Flow-Pattern	--								
	Oxygen												
ASV-specific	%MinVol	--											

1. Depending on how the ventilator was configured and the patient type, you may see different time-related control settings. See Appendix J, Configuration, for details.
2. Only in pediatric.

B.2 Mandatory modes

The mandatory ventilation modes ((S)CMV and P-CMV) deliver time-cycled mandatory breaths, volume-controlled or pressure-controlled, respectively.

When the patient triggers, or the operator initiates a breath, the respiratory rate increases, while both the inspiratory time and the tidal volume (for (S)CMV), or the inspiratory pressure (for P-CMV) remains constant. The minute volume increases as a result.

B.2.1 Synchronised controlled mandatory ventilation ((S)CMV) mode

The (S)CMV mode provides volume-controlled mandatory breaths only. The controls active in the (S)CMV mode are shown in Figure B-1. The tidal volume (Vt) setting defines the delivered volume. The Rate and breath timing settings (see Appendix J.4.1) define the breath cycle timing. Breaths can be triggered by the ventilator, patient, or operator.

In this mode, the operator sets the Vt, the Rate and other breath timing controls, and the FlowPattern. As in all other modes, the operator also sets the PEEP/CPAP and Oxygen, and the pressure or flow trigger when required.

Figure B-1. (S)CMV control window

B.2.2 Pressure-controlled CMV (P-CMV) mode

The P-CMV mode provides pressure-controlled mandatory breaths only. The control settings active in the P-CMV mode are shown in Figure B-2. The pressure control (Pcontrol) setting defines the applied pressure. The rate and breath timing settings (see Appendix J.4.1) define the breath cycle timing. Breaths can be triggered by the ventilator, patient, or operator.

In this mode, the operator sets the Pcontrol and the Rate and other breath timing controls, and the pressure rise time (P-ramp). As in all other modes, the operator also sets the PEEP/CPAP and Oxygen controls, and the pressure or flow trigger when required.

The P-CMV mode, while delivering a preset pressure, does not guarantee delivery of a fixed tidal volume, especially during changes in respiratory system compliance, airway resistance, AutoPEEP, or the patient's respiratory activity.

Figure B-2. P-CMV control window

B.3 SIMV (synchronized intermittent mandatory ventilation) modes

The HAMILTON-G5's SIMV modes (SIMV and P-SIMV) guarantee one or more breaths are delivered within an interval determined by the operator-set Rate. A combination of mandatory and spontaneous breaths can be delivered.

Each SIMV breath interval includes mandatory time (Tmand) and spontaneous time (Tspont) portions (Figure B-3). During Tmand, the ventilator waits for the patient to trigger a breath. If the patient does trigger a breath, the ventilator immediately delivers a mandatory breath. If the patient does not trigger a breath, then the ventilator automatically delivers a mandatory breath at the end of Tmand. 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.

Apnea backup ventilation can be activated in the SIMV modes.

Because the SIMV modes are mixed modes, with attributes of both a mandatory and a spontaneous pressure support mode, the operator must set the parameters specific to the applicable mandatory mode and to the SPONT mode. For example, when the P-SIMV mode is selected, the operator must set the parameters used in the P-CMV mode as well as in the SPONT mode. As in all other modes, the operator also sets PEEP/CPAP, Oxygen, and the pressure or flow trigger.

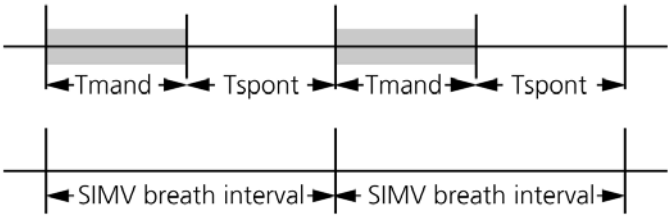


Figure B-3. Breath delivery in SIMV modes

B.3.1 SIMV mode

In the SIMV mode, the mandatory breaths are (S)CMV breaths (Figure B-4). These can be alternated with SPONT breaths. The control settings active in the SIMV mode are shown in Figure B-5.

The SIMV mode guarantees volume delivery. Minute Volume, a function of tidal volume and breath frequency, is managed by the mandatory breaths. Simultaneously, this mode helps the patient gain full control of their breathing pattern allowing spontaneous breaths and synchronizing those with the mandatory breaths.

Because of these characteristics of the SIMV mode, it is chosen both as a ventilatory support and as a weaning modality.

Figure B-4. SIMV control window

B.3.2 P-SIMV mode

In the P-SIMV mode, the mandatory breaths are P-CMV breaths (Section B). These can be alternated with SPONT breaths. The settings active in the P-SIMV mode are shown in Figure B-5.

The P-SIMV mode does not guarantee the delivery of an adequate tidal volume at all times. When using this mode, carefully monitor changes in the patient's status.

Figure B-5. PSIMV+ control window

B.4 Pressure support mode (SPONT)

In the pressure support (SPONT) mode, spontaneous and operator-initiated manual (mandatory) breaths are delivered. As such, the HAMILTON-G5 functions as a demand flow system while supporting the patient's spontaneous breathing efforts with a set pressure support. When pressure support is set to zero, the device functions like a conventional CPAP system. It is recommended that apnea backup ventilation be enabled in the SPONT mode. The control settings active in the SPONT mode are shown in Figure B-6.

The pressure support (Psupport) setting defines the applied pressure. The patient determines the breath timing. Breaths can be triggered by the patient or operator.

In this configuration, the operator sets the Psupport, the pressure rise time (P-ramp), and the expiratory trigger sensitivity (ETS) in percentage of peak flow. Consistent with all other modes, the operator also sets the PEEP/CPAP, Oxygen, and the pressure or flow trigger.

Figure B-6. SPONT control window

B.5 Advanced ventilation modes

B.5.1 Adaptive pressure ventilation (APV)

The APV modes, APVcmv and APVsimv, function similar to the conventional pressure-controlled modes of ventilation (P-CMV and P-SIMV) with this exception: these conventional modes do not ensure a tidal volume. The APV modes ensure that the set target volume will be delivered. The control settings active in the APVcmv and APVsimv modes are shown in Figure B-7 and Figure B-8.

In the APV versions of these pressure-controlled modes, the operator sets the target tidal volume (Vtarget) instead of Pcontrol. Otherwise, the settings are the same as for the pressure-controlled mode.

Figure B-7. APVcmv control window

Figure B-8. APVsimv control window

B.5.1.1 Advantages

Working in the APV modes offer these benefits:

- Through the automatic regulation of the inspiratory pressure and flow, the set target volume is achieved with the lowest pressure possible depending on the lung characteristics.
- During short-term post-operative ventilation, the delivered volume remains constant despite rapid changes in breathing activity.

B.5.1.2 Principles of operation

The APV modes operate in this order:

1. **Assessing the breathing pattern.** The APV modes start by determining the patient's volume/pressure response (V/P). This is achieved based on the previous ventilation or on a sequence of three (3) test breaths. V/P is defined as:

   Vt / (Ppeak – PEEP/CPAP)

2. **Achieving the target volume.** The device uses V/P to calculate the lowest inspiratory pressure applied to achieve the VTarget. The minimal pressure delivered is 3 cmH_2O above PEEP.

   The operator sets the VTarget, rate, PEEP/CPAP, and the high Pressure alarm limit. The adaptive controller compares the monitored Vt to the VTarget. If the patient's actual tidal volume is equal to the VTarget, APV maintains the inspiratory pressure. If the monitored tidal volume is higher or lower than the target volume, the inspiratory pressure is gradually adjusted by up to 2 cmH2O per breath to attain the target level.

   The inspiratory pressure is adjusted within this range: (PEEP + 3 cmH2O) to (high Pressure alarm limit – 10 cmH2O). In this case, HAMILTON MEDICAL recommends a high Pressure alarm limit setting at least 10 cmH2O above peak pressure. On its pressure curve display, the device displays a blue band 10 cmH2O below the set high Pressure alarm limit.

3. **Maintaining the target volume with the lowest inspiratory pressure.** The parameters needed for APV are measured breath by breath. When required, the operator recalculates the minimal inspiratory pressure to achieve the target volume based on the current lung characteristics. The minimal inspiratory pressure is limited to minimum 3 cmH2O above PEEP.

   The continuous reassessment of the patient's dynamic lung status is designed to guarantee the required ventilation while preventing hypoventilation or barotrauma.

B.5.2 Adaptive support ventilation (ASV)

See Appendix C, ASV, for detailed information on this mode.

B.5.3 DuoPAP (Duo positive airway pressure) and APRV (Airway pressure release ventilation)

B.5.3.1 Introduction

DuoPAP and APRV are two related forms of pressure ventilation designed to support spontaneous breathing on two alternating levels of CPAP. In these modes, the ventilator switches automatically and regularly between two operator-selected levels of positive airway pressure or CPAP (P high and low). Either mode permits a combination of mandatory and spontaneous breaths. The patient can breathe freely at either level, and pressure support can be added to these spontaneous breaths. Cycling between the levels is triggered by DuoPAP/APRV timing settings or by patient effort. Pressure/time curves for these modes are shown in Figure B-11 and Figure B-12.

The control settings active in the DuoPAP mode are shown in Figure B-9. The control settings active in the APRV mode are shown in Figure B-10.

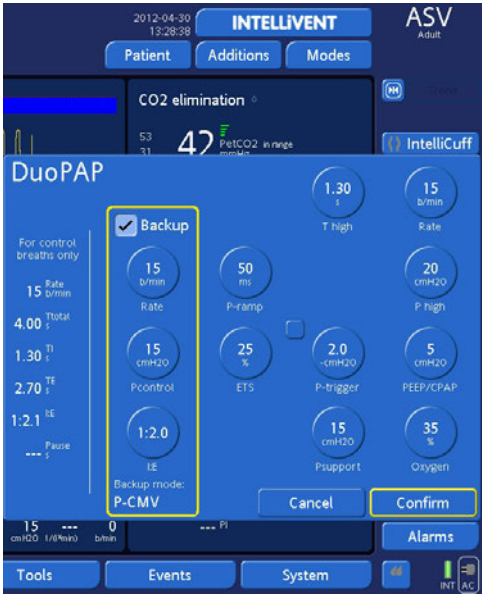


Figure B-9. DuoPAP control window

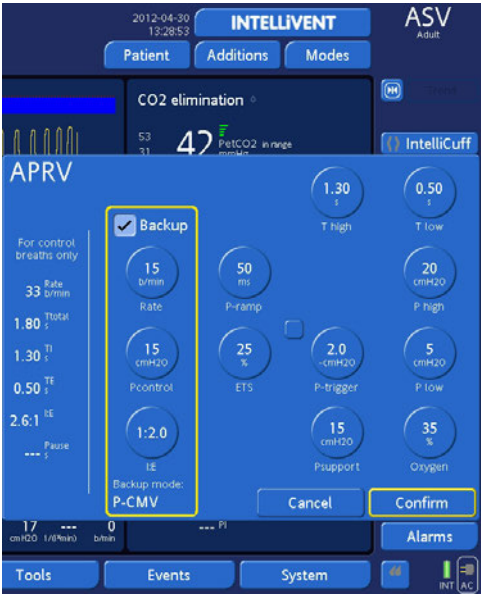


Figure B-10. APRV control window

In DuoPAP (Figure B-11), the switchover between the two levels is defined by pressure settings P high and PEEP/CPAP and time settings T high and Rate. Like PEEP/CPAP, P high is relative to *atmospheric pressure*. In APRV (Figure B-12), the switchover is defined by pressure settings P high and P low and time settings T high and T low. In DuoPAP, PEEP/CPAP is the baseline for Psupport, while in APRV, P low is the baseline for Psupport – Psupport is relative to *PEEP/CPAP* or P *low*.

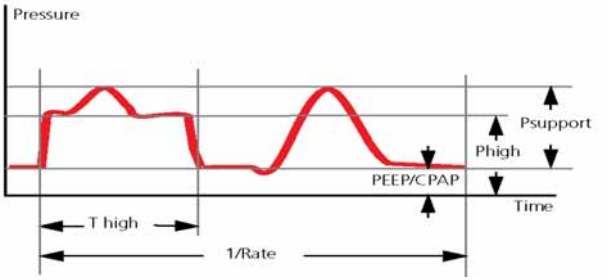


Figure B-11. DuoPAP pressure curve

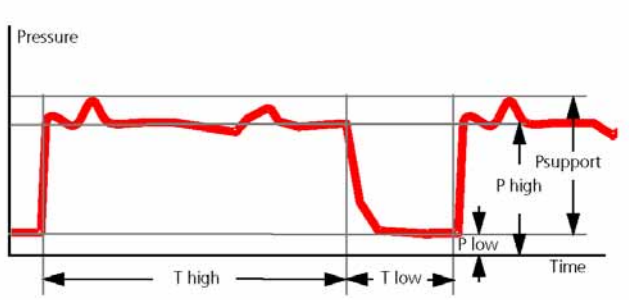


Figure B-12. APRV pressure curve

B.5.3.2 Differences between DuoPAP and APRV

As shown, the two modes differ in the operator settings required to determine the breath pattern. In DuoPAP, you set Rate and T high to establish the breath timing. In APRV, you set T high and T low to establish the time at each level. In DuoPAP you set P high and PEEP/CPAP to establish the two pressure levels, while in APRV you set P high and P low.

For clinical use, these two ventilation modes typically differ in the time allowed at the lower pressure level. When using DuoPAP, operators tend to prefer relatively long times at both the high and low pressure levels to allow spontaneous breathing at both. When using APRV, operators tend to prefer relatively long T high and shorter T low settings, this action results with the spontaneous breathing mostly done at the upper pressure level. The pressure is then "released" to the lower pressure level just long enough for the lung volume to decrease, then is immediately returned to the upper pressure level.

B.5.3.3 The many faces of DuoPAP and APRV

With different patients and with different combinations of control settings, DuoPAP and APRV can be made to resemble a variety of conventional ventilation modes. At conventional settings and in the absence of spontaneous breathing, DuoPAP and APRV resemble P-CMV. As you decrease the rate, keeping

T high short relative to the time at the lower pressure level, the modes look more like P-SIMV, with spontaneous breaths following mandatory breaths. If you set the breath cycle time to a total of 7.5 to 15 seconds with just enough time at the low level to allow full or near-full exhalation, these modes look like classical APRV. By setting PEEP/CPAP / P low and P high equal to one another and adjusting other parameters, the modes can be made to resemble SPONT.

B.5.3.4 Pressure support in DuoPAP/APRV breaths

Pressure support can be set to assist spontaneous breaths in DuoPAP/APRV, whether they occur at the PEEP/CPAP / P low or P high level. Psupport is set relative to PEEP/CPAP / P low – the target pressure becomes PEEP/CPAP / P low + Psupport.

This means spontaneous breaths at the P high level are supported only when this target pressure is greater than P high. Figure B-13 (a) shows the situation where breaths at both the P low and P high level are pressure-supported. Figure B-13 (b) shows the situation where only breaths at the PEEP/CPAP/ P low level are pressure-supported.

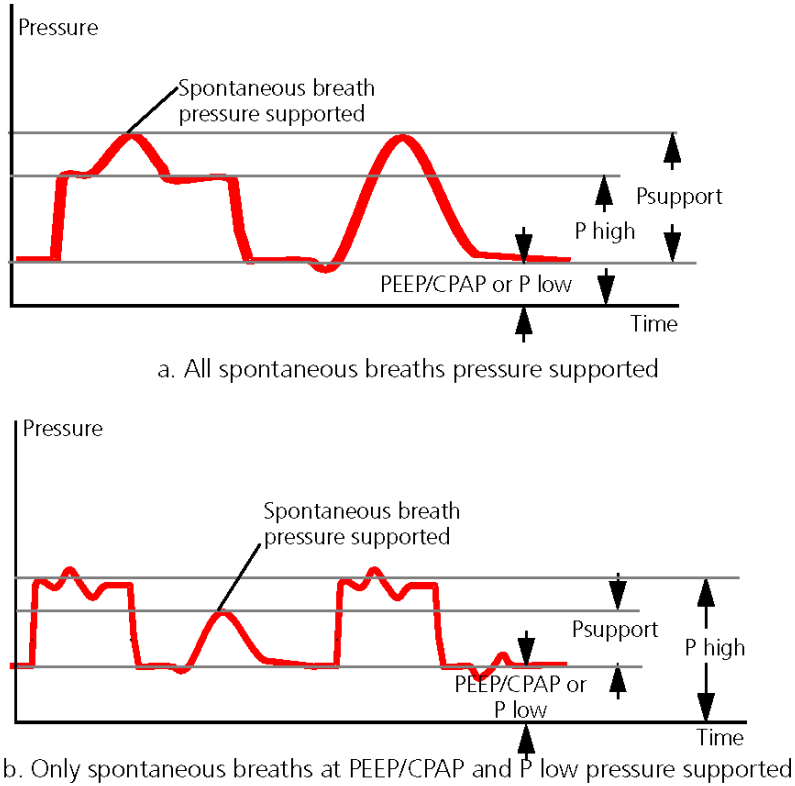


Figure B-13. Pressure support in DuoPAP/APRV

B.5.3.5 Synchronization

To easily adapt to the patient's spontaneous breathing pattern, the change-overs from low to high pressure level and vice versa are synchronized with the patient's spontaneous breathing.

The frequency of the change-over is kept constant, even with patient synchronization, by defining a trigger time window with a fixed time constant. In APRV Tlow is not prolonged if the patient breathes active.

B.5.3.6 References

- **Rasanen J et al.** Airway pressure release ventilation during acute lung injury: a prospective multicenter trial. Crit Care Med 1991 Oct;19(10):1234-41.
- **Stock MC, Downs JB et al.** Airway pressure release ventilation. Crit Care Med 1987 May;15(5):462-6.
- **Antonsen K et al.** Invasive ventilation. Classification, technique and clinical experiences with BIPAP/APRV (Biphasic Positive Airway Pressure/Airway Pressure Release Ventilation. Ugeskr Laeger 1996 Jan 22;158(4):413-9.
- **Rathgeber J.** Ventilation modes and strategies in intensive care medicine. Anaesthesiol Reanim 1997;22(1):4-14.
- **De Carvalho WB et al.** Airway Pressure release in postoperative cardiac surgery in pediatric patients. Rev Assoc Med Bras 2000 Apr-Jun;46(2):166-73.

B.5.4 Noninvasive ventilation (NIV and NIV-ST)

The NIV (noninvasive ventilation), deliver spontaneous breaths and operator-initiated manual (mandatory) breaths. In NIV the ventilator functions as a demand flow system. The patient's spontaneous breathing efforts can also be supported with the set pressure support. When pressure support is set to zero, the ventilator functions like a conventional CPAP system.

The NIV-ST (spontaneous/timed noninvasive ventilation) mode delivers pressure-controlled, time-cycled mandatory breaths and pressure-supported, flow-cycled spontaneous breaths. NIV-ST, like NIV, is designed for use with a mask or other noninvasive patient interface.

The control settings active in the NIV mode are shown in Figure B-14 and the NIV-ST mode in Figure B-15.

See Appendix D, Noninvasive ventilation, for clinical application information on the noninvasive modes.

Figure B-14. NIV control window

Figure B-15. NIV-ST control window

B.5.5 nCPAP-PS mode

B.5.5.1 Introduction

NOTE:

For nCPAP-PS the position of the flow sensor is at the expiratory valve. The correct set-up is shown in Figure 2-13.

The nasal Continuous Positive Airway Pressure – Pressure Support (nCPAP-PS) mode is designed to apply CPAP and intermittent positive pressure support over a nasal interface (mask or prongs). The pressure support Psupport can alternatively be set to zero. When set to zero, the patient's oxygenation is fostered over the PEEP and the FiO_2. Ventilation is performed by the patient by inhalation and exhalation from the base flow.

As with the PSIMV mode, nCPAP-PS delivers a preset Psupport pressure, but does not guarantee a fixed tidal volume, especially during changes in respiratory system compliance, airway resistance, AutoPEEP, or the patient's respiratory activity.

If the patient triggers a breath during a portion of the breath interval, the ventilator immediately delivers a spontaneous breath (Figure B-16). If the patient does not trigger an inspiration during this time, the ventilator initiates a mandatory breath at the end of t_{imv}.

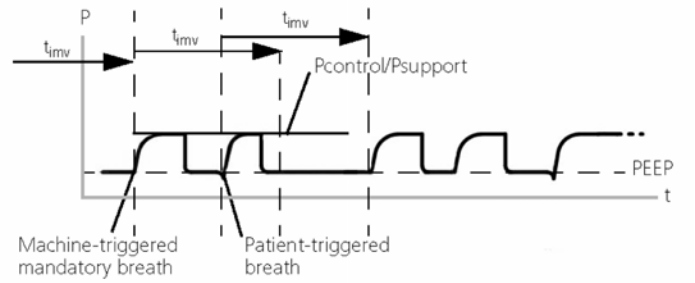


Figure B-16. Breath timing in nCPAP-PS

The control settings active in the nCPAP-PS mode are shown in Figure B-17. This mode requires that you set the parameters needed for both mandatory and spontaneous breath types. The inspiratory pressure (Psupport) setting 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. Breaths can be triggered by the ventilator, patient, or operator.

The nCPAP-PS system is integrated with a nasal cannula with interchangeable silicone prongs (size marked), a Delivery Circuit (heated wire) and Cap (see separate instruction leaflet).

B.5.5.2 Controls of nCPAP-PS

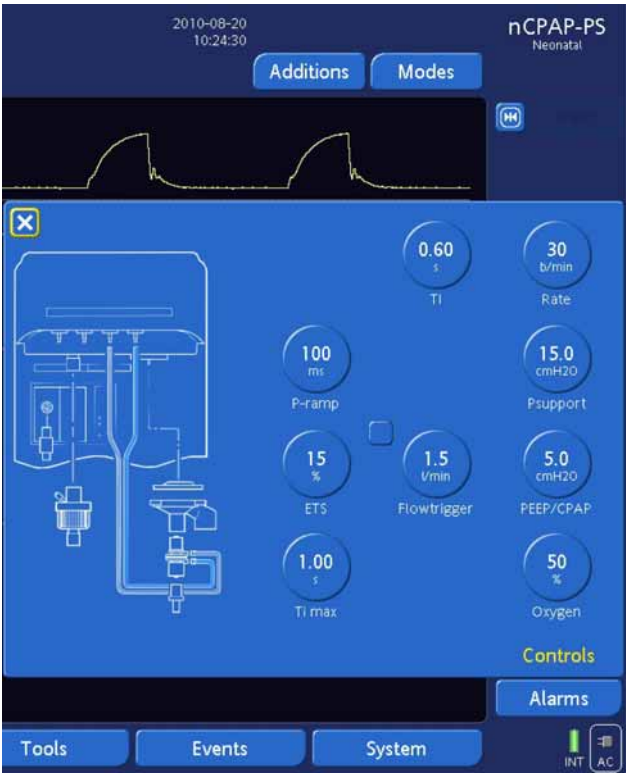


Figure B-17. nCPAP-PS basic controls

B.6 Leak compensation

For an invasive ventilator to function properly, no significant leaks can be present anywhere in the entire system, including ventilator, breathing circuit, and patient respiratory system. For optimal ventilator performance, leakage must be stopped or minimized rather than compensated.

The difference between the inspiratory flow delivered to the patient, and the patient's expiratory flow, as measured by the proximal flow sensor, is a way of measuring the amount of leakage in the circuit.

Early recognition is the key to stopping leakage. Using the proximal flow sensor, this device can distinguish between leakage at the breathing circuit from leaks on the patient side.

The benefits are:

- Detection and notification of the presence of leakage plus its location (that is, tubing or patient side).
- Display of the actual exhaled tidal volume (VTE) so the clinician can easily note any discrepancy between set and exhaled tidal volumes.
- Display of the leak volume (VLeak) breath by breath. VLeak is determined as the difference between delivered (inspiratory) tidal volume and exhaled tidal volume. It is displayed in mL and also as a percentage of total tidal volume. Note that VLeak indicates the leak at the patient side only.

In all pressure modes, the device automatically compensates for leakage by adjusting gas delivery to achieve and maintain the set pressure profile.

With its **IntelliTrig** function, the ventilator can automatically adapt to changing breath patterns and system leaks to achieve optimum synchronization between patient and device.

To synchronize, IntelliTrig compensates any leaks and resistances between the ventilator and the patient, and with each breath it measures the leakage at the patient interface (mask). With this information IntelliTrig adapts the trigger mechanism so leakage and the changing breath pattern do not influence the operator-set trigger sensitivity (flow trigger).

The modes that permit spontaneous breathing use flow (the ETS setting) to cycle into exhalation. As a backup for pediatric and for all patients in NIV mode, time (the Ti max setting), serves as a backup. This backup mechanism can prevent the possibility of endless inspiration resulting from a large leak, and is critically important in the NIV mode.

An automatic adjustment mechanism maintains PEEP stability even with a moderate breathing circuit leak.

APPENDIX C

ASV® (Adaptive Support Ventilation)

C.1 Introduction

WARNING

This appendix describes ASV as it is implemented in the HAMILTON-G5 device. It does not replace the clinical judgment of a physician and is not to be used for clinical decision making.

In 1977, Hewlett et al. introduced mandatory minute volume (MMV). "The basic concept is that the system is supplied with a metered, preselected minute volume of fresh gas, from which the patient breathes as much as he is able, the remainder being delivered to him via a ventilator. Thus the patient is obliged to breathe, one way or the other, a Mandatory Minute Volume MMV" (Hewlett 1977).

Since then, many ventilators have included versions of MMV under different names. However, all commercially available MMV algorithms have clear limitations, which lead to certain risks for the patient (Quan 1990). These include rapid shallow breathing, inadvertent PEEP creation, excessive dead space ventilation, and inadvertent wrong operator settings due to very complicated use.

Adaptive Support Ventilation (ASV®) was designed to minimize those risks and limitations. ASV maintains an operator-preset, minimum minute ventilation independent of the patient's activity. The target breathing pattern (tidal volume and rate) is calculated using Otis' equation, based on the assumption that if the optimal breath pattern results in the least work of breathing, it also results in the least amount of ventilator-applied inspiratory pressure when the patient is passive. Inspiratory pressure and machine rate are then adjusted to meet the targets. A lung protection strategy ensures ASV's safety. In contrast to MMV, ASV attempts to guide the patient using a favorable breathing pattern and avoids potentially detrimental patterns like rapid shallow breathing, excessive dead space ventilation, breath stacking (inadvertent PEEP), and excessively large breaths.

Contrary to some opinions, ASV does not eliminate the need for a physician or clinician. However, ASV alleviates the need for tedious tasks and laborious readjustments of the ventilator; thus, it is a modern tool for the clinician. As such, ASV does not make clinical decisions. ASV executes a general command from the clinician and the clinician can modify it. This command can be summarized, where the modifiable parts are in bold:

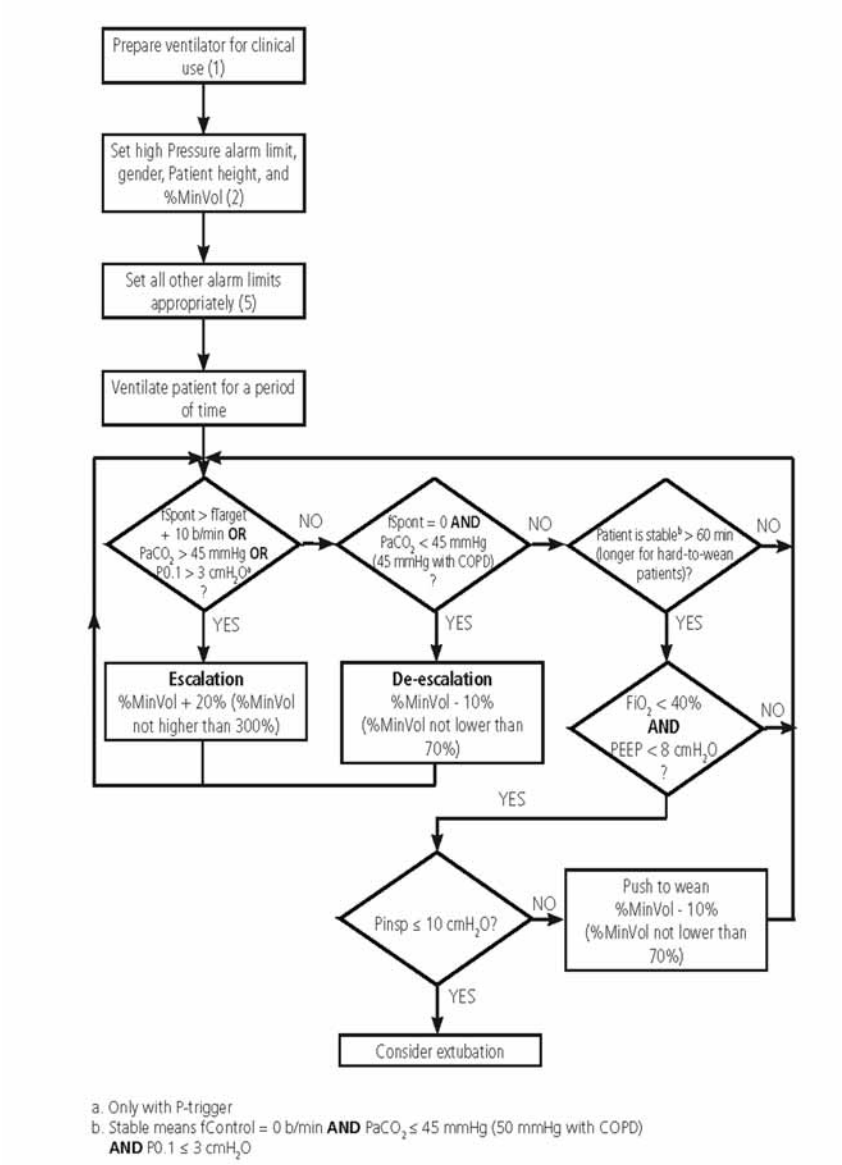
Maintain a **present minimum minute ventilation**,

- Take spontaneous breathing into account
- Prevent tachypnea
- Prevent AutoPEEP
- Prevent excessive dead space ventilation
- Fully ventilate in apnea or low respiratory drive
- Give control to the patient if breathing activity is okay
- All this without exceeding a plateau pressure of 10 cmH_2O below the **upper pressure limit**

This appendix explains in practical terms how to use ASV at the patient's bedside and provides a detailed functional description. Since Otis' equation (Otis 1950) is the cornerstone of the optimal-breath pattern calculation, this equation is included and described. A table of detailed technical specifications and pertinent references is also given.

C.2 ASV use in clinical practice

ASV does not require a special sequence of actions. You use it in much the same way as are older modes of ventilation. This appendix summarizes how to use ASV, while the subsequent subsections explain it in detail and shows the control settings active in the ASV mode.



a. Only with P-trigger
b. Stable means fControl = 0 b/min **AND** $PaCO_2 \leq 45$ mmHg (50 mmHg with COPD) **AND** $P0.1 \leq 3$ cmH_2O

Figure C-1. Clinical use of ASV. The numbers in parentheses are step numbers, which are explained in the next subsections.

Figure C-2. ASV control window

Step 1: Before connecting the patient to the HAMILTON-G5

It is important to prepare the device for clinical use according instructions in Chapter 2. This includes, but is not limited to, performing the pre-operational procedures and testing indicated.

Step 2: Preparing the device for ASV before ventilation

NOTE:

The high limit must be at least 25 cmH_2O above PEEP/CPAP.

ASV requires you to set these basic parameters:

Pressure	High Pressure alarm limit, in cmH_2O
Patient height	Patient height, in cm or in.
Gender	Sex of patient
%MinVol	Desired minute ventilation, in % of normal values

HAMILTON MEDICAL suggests you complete these steps before connecting the patient to the ventilator:

1. Remove the demonstration lung (when a demonstration lung is used) and silence the alarm.
2. Set the high Pressure alarm limit to an appropriate value (example 45 cmH_2O or 50 cmH_2O for COPD patients). The maximum inspiratory pressure delivered in ASV (Pasv) will be **10 cmH2O below the preset high pressure limit**, indicated by a blue band on the pressure curve display. The maximal inspiratory pressure for ASV can be also set using the Pasv control in the **Controls** window. Changing the Pasv value will also change high Pressure limit.
3. Activate ASV in the **Modes** window and then **Confirm** the mode change. The **Controls** window automatically opens.
4. Complete these control settings:
   - **Patient height**
   - **Gender**
   - **%MinVol.** A logical starting point is a %MinVol that will result in the same minute volume as a previous mode, when required. The %MinVol for a normal patient might be 100%; for a COPD patient, 90%; for an ARDS patient, 120%; and for other patients, 110%. Add 20% if body temperature > 38.5 °C (101.3 °F) and 5% per 500 m (1640 ft) above sea level.
   - **Trigger.** Recommended settings are: a Flowtrigger of 2 l/min; or you can leave the previous patient trigger method and sensitivity, when required.

- **ETS.** The recommended setting is 25% (40% for a COPD patient); or you can you can leave this unchanged, when required.
- **TRC.** It is recommended that TRC be enabled, with Compensate set to 100%.
- **Other settings.** Set PEEP/CPAP and Oxygen values according to clinical requirements. You can leave the P-ramp setting at its standard value unless clinical judgment calls for adjustment. To set it, see Table 5-2.

5. **Confirm** the settings.
6. Connect the patient to the ventilator if applicable. This will initiate three test breaths.

Step 3: Compensation for changes in apparatus dead space

NOTE:

Changes in alveolar dead space due to ventilation/perfusion mismatch must be compensated via the %MinVol control.

The device calculates the (anatomical or "series") dead space based on the IBW calculated from the patient height input. Dead space is calculated as 2.2 ml per kg (1 ml per lb). 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. If this dead space is altered by an artificial airway configuration such as a the use of a heat and moisture exchange filter (HME), or nonstandard tubing, modify the Patient height setting accordingly to take into account the added or removed dead space.

Consider this information when compensating dead space:

- A shorter-than-standard endotracheal or tracheostomy tube probably does not require compensation.
- Different sizes of endotracheal tube probably do not require compensation.
- A much longer-than-normal catheter mount can require compensation.

- A bacterial filter or an HME can require compensation. The volume of these devices, for an adult, is on average 50 to 60 ml, but may be as high as 95 ml (Mallinckrodt Hygroster). For an HME, a simple rule of thumb is to add 10% to the IBW (by adjusting the Patient height control).

Step 4: Adjusting ventilation: Maintaining adequate ventilation

WARNING

It is inappropriate to adjust the IBW (through the Patient height control) to change minute volume. Always use the %MinVol control to adjust minute volume.

After ASV is started, the device calculates an optimal breath pattern and associated target values for tidal volume and rate according to the rules in Section C.4. ASV then adjusts the inspiratory pressure (Pinsp) and machine rate (fControl) to achieve the targets.

After the calculated targets are reached, the result of the ventilation needs to be assessed. All the device's 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 C-1 provides examples of how to adjust the %MinVol setting.

Table C-1. Blood gas and patient conditions and possible adjustments for ASV

Condition	%MinVol change	Remarks
Normal arterial blood gases	None	--
High $PaCO_2$	Increase %MinVol	Pay careful attention to inspiratory pressures
Low $PaCO_2$	Decrease %MinVol	Pay careful attention to mean pressures and oxygenation status
High respiratory drive	Consider increase in %MinVol	Consider sedation, analgesia, or other treatments
Low O_2 saturation	None	Consider increase in PEEP/CPAP and/ or Oxygen

Step 5: Alarm settings review and special ASV alarms

When monitoring the breathing pattern, you must review the alarm settings periodically and set them according to clinically acceptable values. As described below, ASV changes the breathing pattern according to the respiratory system mechanics and within the boundaries resulting from the operator's settings for ASV. However, you can closely monitor ASV®'s actions through the alarm system, since the alarm settings work totally independent of ASV.

It is possible to select a %MinVol that is incompatible with the lung-protective rules that govern ASV (for a detailed description, see Section C). For example, the operator could want a high ventilation for a COPD patient in spite of severe pulmonary obstruction. In such a case, ASV tries to achieve the maximum possible ventilation and alarms **`ASV: Cannot meet target`**. Such a case is shown in Figure C-3, where a high ventilation (300% at 70 kg) was set by the operator for a patient with severely obstructed lungs (Raw = 40 $cmH_2O/(l/s)$.

The high ventilation moves the minimum minute volume curve to the right while the obstructive disease causes the safety limit of rate to shift to the left. These two effects cause the minute volume curve to lie outside the safety limits as determined by the lung-protective rules strategy (see functional description below). ASV thus chooses the safest point closest to the operator-set minute volume.

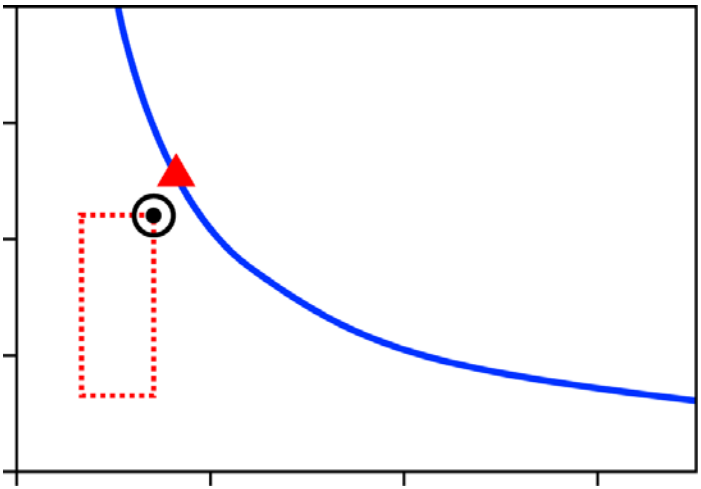


Figure C-3. Hypothetical example of high %MinVol setting incompatible with the lung-protective rules strategy. The open circle denotes the actual target, the closed triangle (never shown on the ventilator) denotes the (energetically) optimal target according to Otis' equation. The device will alarm and inform the operator that the ASV target cannot be achieved.

Step 6: Monitoring ASV

ASV interacts continuously with the patient. Whenever the patient's respiratory mechanics change, ASV adapts to this change. Whenever the patient's breathing activity changes, ASV adapts. To view the current status, the device provides the ASV target graphics window (Figure C-4) and the ASV monitored data window (Figure C-5).

To monitor progress over time, it is recommended you plot trends for Pinsp, fTotal, and fSpont. Interpret these trends, together with the %MinVol setting. Table C-2 through Table C-4 provide interpretation of typical ventilatory patterns. Figure C-4 shows the ASV adjustment/weaning process.

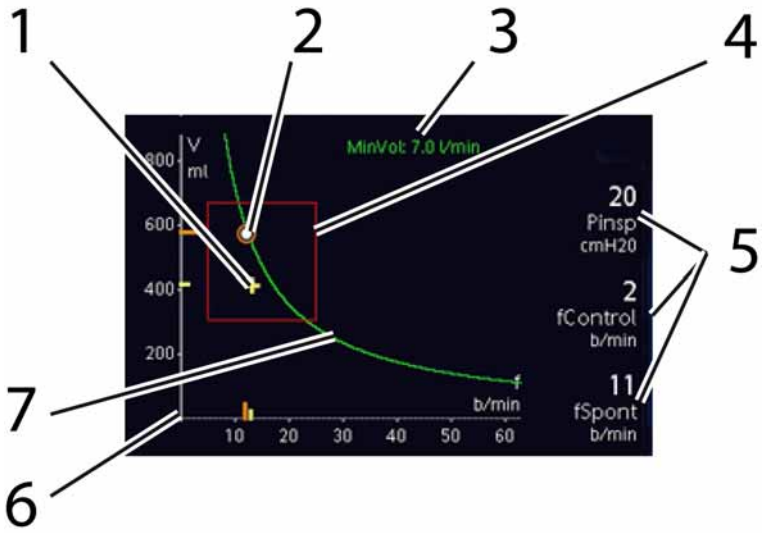


Figure C-4. ASV target graphics window

1 Current measured point, formed by intersection of measured tidal volume and rate.

2 Target point, formed by intersection of target tidal volume and target rate.

3 Numerical value of target minute volume

4 Safety frame in which target point may move.

5 FSpont = spontaneous breath rate, fControl = machine rate, Pinsp = inspiratory pressure set by ventilator

6 Horizontal axis for rate (f). Vertical axis for tidal volume (Vt).

7 Minute volume curve.

Figure C-5. ASV monitored data window

Table C-2. Interpretation of breathing pattern at 100% MinVol setting

Pinsp	fControl	fSpont	Interpretation
> 10	> 10	0	Fully controlled, mechanical ventilation. To start weaning, consider reducing %MinVol.
> 10	0	Acceptable	Supported spontaneous breathing. Consider reducing %MinVol.
< 8	0	Acceptable	**Unsupported breathing**. Consider extubation.
> 10	0	High	Dyspnea. Consider increasing %MinVol and other clinical treatments. Check for autotriggering.

Table C-3. Interpretation of breathing pattern at much higher than 100% MinVol setting

Pinsp	fControl	fSpont	Interpretation
> 10	> 10	0	Fully controlled mechanical ventilation. Check arterial blood gases. To start weaning, consider reducing %MinVol.
> 10	0	Acceptable	Supported spontaneous breathing. Check reason for increased ventilation requirement. Consider reducing %MinVol.
< 8	0	Acceptable	**Unsupported breathing.** Check reason for increased ventilation requirement. Consider reducing %MinVol and extubation.
> 10	0	High	Dyspnea. Check reason for increased ventilation requirement. Consider other mode of ventilation and clinical treatment. Check for autotriggering.

Table C-4. Interpretation of breathing pattern at much 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. Monitor 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. Observe for autotriggering.

Step 7: Weaning

Weaning patients from the ventilator is a clinical task that requires significant experience, and involves more than just ventilation issues. Important: This appendix does not intend to provide clinical information other than what is 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. Actually, weaning can begin with ASV at an early point that it could go unrecognized clinically. Therefore it is 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. If the patient tolerates minimum respiratory support after a period of time with

Pinsp < 8 cmH2O, fControl = 0

weaning can be considered achieved, if minimum

fSpont is acceptable and ExpMinVol is acceptable

What is "acceptable" must be defined by the clinician.

It can 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, this does not mean 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 minimal values can weaning be assumed to be complete.

C.3 Detailed functional description of ASV

C.3.1 Normal minute ventilation

ASV defines normal minute ventilation according to the graph in Figure C-6.

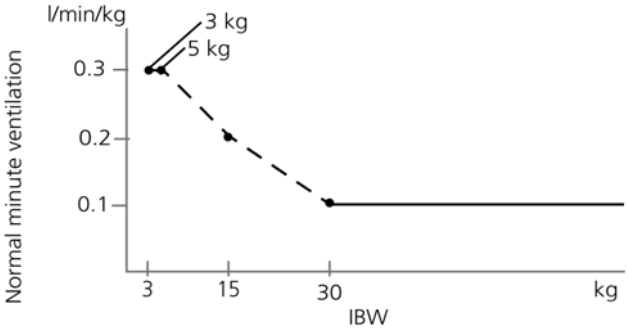


Figure C-6. Normal minute ventilation as a function of ideal body weight (IBW)

For adult patients, minute ventilation is calculated as 0.1 l/kg * IBW (solid line). For pediatric patients, the value indicated by the dotted line is used. Minute ventilation for a 15 kg patient thus 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.

C.3.2 Targeted minute ventilation

When you chose 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, as discussed above. A setting less than 100% or higher than 100% corresponds to a minute ventilation lower or higher than normal.

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

Body weight (in kg) x NormMinVent (in l/kg/min) x (%Min Vol/100)

where NormMinVent is the normal minute ventilation from Figure C-6.

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

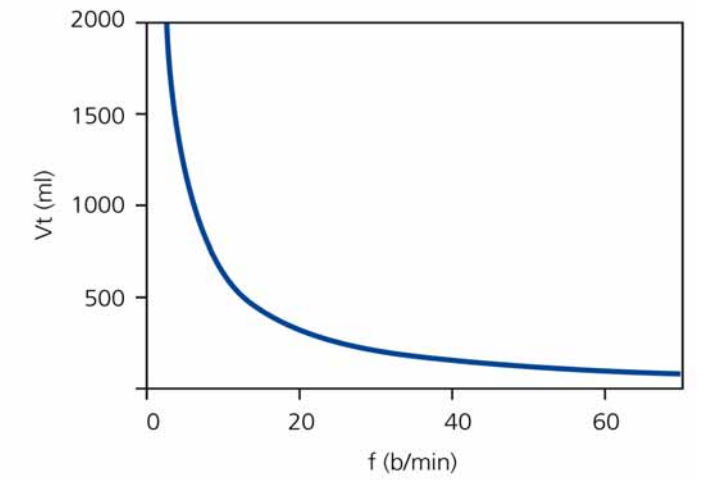


Figure C-7. MinVol = 7 l/min. All possible combinations of Vt and f which result in a minute ventilation of 7 l/min lie on the bold line.

C.3.3 Lung-protective rules strategy

Not all combinations of Vt and f shown in Figure C-7 are safe for the patient. The high tidal volumes will over distend 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 necessary to limit the number of possible combinations of Vt and f. When limits are imposed on the possible combinations of Vt and f, then 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 C-8 and explained in the subsequent subsections.

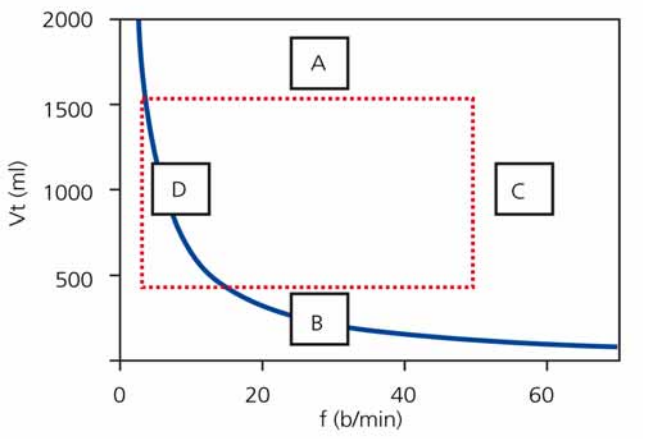


Figure C-8. Lung-protective rules strategy to avoid high tidal volumes and pressures (A), low alveolar ventilation (B), dynamic hyperinflation or breath stacking (C), and apnea (D)

A: High tidal volume limit

WARNING

Check Vt high setting to make sure the target minute ventilation can be reached in passive patients.

The tidal volume applied by ASV is limited (see A in Figure C-8) by three operator settings: high Pressure alarm limit, Vt high alarm limit, and Patient height.

The operator must set the high Pressure limit before connecting a patient to the ventilator. It was recommended by a group of physicians (Slutsky 1994) that the plateau pressure not exceed 35 cmH_2O. To achieve this with ASV, the high Pressure limit must be set to 45 cmH_2O. The maximum pressure to be applied in the ASV mode is 10 cmH_2O below the high Pressure limit.

For example, a normal 70 kg normal (post-operative) patient would have a compliance of about 50 ml/cmH_2O. A high Pressure limit of 45 cmH_2O will result in a maximum applied pressure of 35 cmH_2O. With a PEEP level of 5 cmH_2O, the effective pressure swing will be 30 cmH_2O. This in turn leads to an effective Vt of equal to, or less than 1500 ml. If the patient's lungs stiffen, to a compliance of 30 ml/cmH_2O, the maximum tidal volume becomes 900 ml.

If the operator sets the Pressure limit to a very high pressure, say 60 cmH_2O, the target volume is limited by the second criterion: 22 x IBW. For the 70 kg sample patient, a maximum target volume of 1540 ml results.

Additionally the target volume is limited to 1.5 * VT high limit, and pressure support actually is limited in a way that the inspired volume does not exceed Vt high limit in mechanical breaths for more than a few breaths.

B: Low tidal volume limit

To determine the minimum target Vt in ASV (see B in Figure C-8) use the IBW calculated from the Patient height, which corresponds to 4.4 ml/kg. In this example for a 70 kg patient, the minimum target Vt is 308 ml.

The operator 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):

The lower limit for tidal volume is based on this equation and calculated to be at least twice the dead space. Or, the minimum Vt is 4.4 x IBW.

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

C: High rate limit

You derive the maximum rate (see C in Figure C-8) 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**)

For example, the 70 kg patient described above will have a maximum rate of 22 b/min, when %MinVol is set to 100%.

However, as an example, 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) (Marini 1989, Brunner 1995). 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 x 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 x RCexp and a minimum expiratory time equal to 2 x RCexp, which results in these equations:

fmax = 60 / (3 x RCexp) = 20 / RCexp
fmax ≤ 60 b/min (**3**)

For example, the 70 kg patient with a respiratory system compliance of 50 ml/cmH_2O (equal to 0.05 l/cmH_2O), an airway resistance including endotracheal tube of 5 cmH_2O/l/s, and a resistance of the expiratory hose and valve of another 5 cmH_2O/l/s, would have an RCexp of

0.05 l/cmH_2O x (5+5) cmH_2O/l/s = 0.5 s

and thus a maximum rate of 40 b/min. Since this value is higher than the one calculated above, the lower of the two values is in effect, that is, 22 b/min.

This limit applies to the respiratory rate of the ventilator only, *not* to the respiratory rate of the patient.

D. Low rate limit

The lowest target rate (see D in Figure C-8) is fixed at 5 b/min. This low rate in turn limits the maximum tidal volume to 1400 ml in the example of the 70 kg patient above, when %MinVol is set to 100%.

C.3.4 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 C-8, 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 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 uses the original equation by Otis (Otis 1950) and calculates the optimal rate based on operator entries of %MinVol and the IBW (based on the Patient height setting) as well as on the measurement of RCexp (see Section C.4).

For example, with the 70 kg patient, a setting of 100 %MinVol, and a measured RCexp of 0.5 s, the optimal rate is 15 b/min according to Otis' equation.

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

Vt = target MinVol / optimal rate (**4**)

In the example of the 70 kg patient, the target Vt becomes 467 ml (see Section C.4 for details).

Figure C-9 shows the position of the target breathing pattern as well as the safety limits imposed by the lung-protective rules strategy.

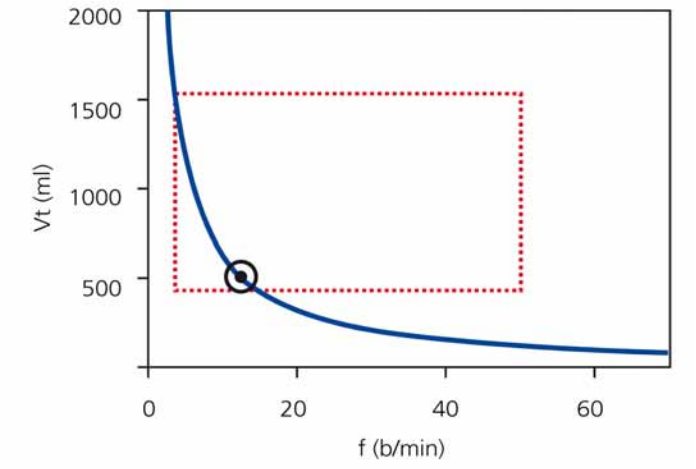


Figure C-9. Anatomy of the ASV target graphics window. The rectangle shows the safety limits; the circle shows the target breath pattern.

C.3.4.1 Initial breaths: How ASV starts

How does the operator make this determination: how to achieve the target values in a given patient if it is not known whether or not the patient can breathe spontaneously? For this purpose, ASV uses a synchronized intermittent mandatory pressure ventilation mode.

Each breath triggered by the patient is pressure-supported and flow-cycled, or, the transition to exhalation is made based on flow. In contrast, if the patient does not trigger the breath, the delivery of the breath is pressure-preset and time-cycled.

The operator-set controls (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:

- SIMV 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, the operator inputs the Patient height setting, which is used to calculate the IBW.

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 actual and target Vt as well as the actual and target rates.

C.3.4.2 Approaching the target

Figure C-10 shows a possible scenario after the three initial test breaths. The actual breath pattern, which is plotted as the patient symbol, shows clear deviation from the target. The task of ASV is now to move the patient symbol as close to the circle as possible.

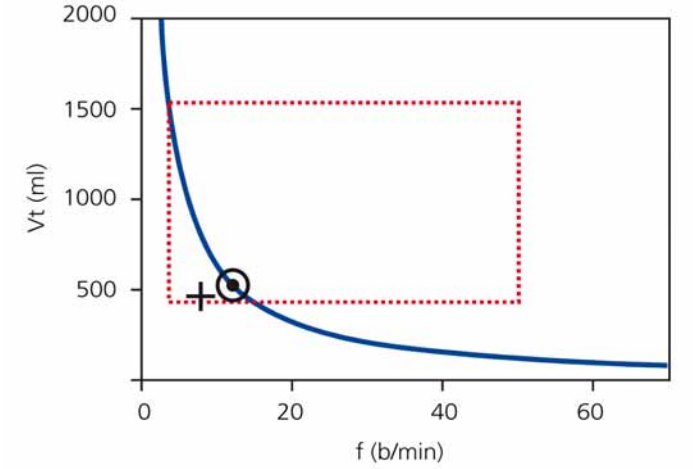


Figure C-10. Example of a situation after the three initial breaths. The patient symbol marks the actual measured values for Vt and rate.

To achieve the target, use this 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 SIMV rate is increased.
- If actual rate > target rate, the SIMV rate is decreased.
- If actual rate = target rate, the SIMV rate is left unchanged.

As a result, the patient symbol in Figure C-10 moves toward the circle. The actual 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.

C.3.5 Dynamic adjustment of lung protection

The operator preset values are not changed by ASV, and the corresponding safety limits remain as defined above. However, if the respiratory system mechanics change, the safety limits change accordingly and as defined in Section C.3.3. 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 according to Equation 5.

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 C-11.

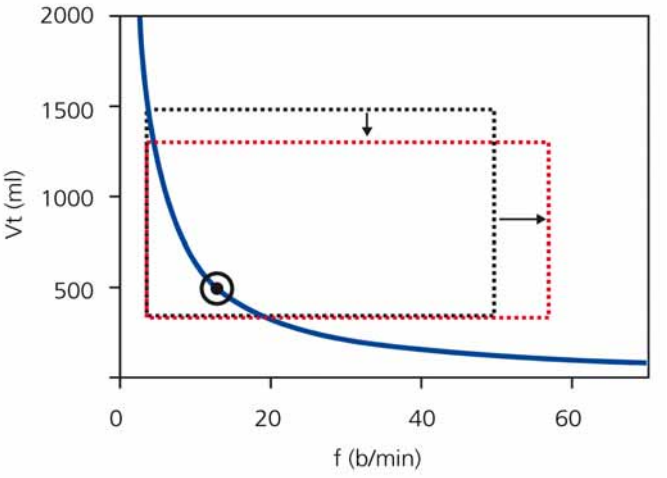


Figure C-11. Lung-protective limits are changed dynamically and according to the respiratory system mechanics. However, the limits derived from the operator input are never violated.

C.3.6 Dynamic adjustment of optimal breath pattern

After calculated, the optimal breath pattern is revised with each breath according to the measurements of RCexp. Apply Otis' equation and a new target breathing pattern is calculated. The targets do not change under steady-state conditions. However, if the patient's respiratory system mechanics change, the target values also change.

In this example: the bronchi of our normal 70 kg sample patient (being ventilated at 15 b/min and with a Vt of 467 ml) constrict due to asthma, and the expiratory resistance increases to values higher than 5 $cmH_2O/l/s$. For this reason, more time is needed during exhalation for the lungs to reach the end-expiratory equilibrium position. In technical terms, the RCexp has increased and this increase requires a longer expiratory time.

For a given minute ventilation, this calls for an increase in Vt and a decrease in rate (longer expiratory time). Otis' equation yields new targets:

f = 11 b/min and Vt = 636 ml.

Figure C-12 shows the change. Notice also that the increase in resistance results in a decrease in the volume/pressure ratio (V/P). The changes in RCexp and dynamic compliance affect the safety limits accordingly and with each breath (see previous subsection).

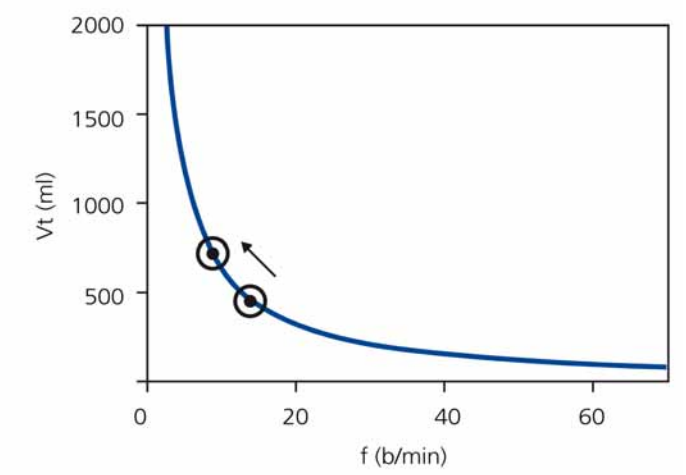


Figure C-12. Changes of target values in broncho-constriction. For clarity, the safety limits are omitted. For clinical examples, see Belliato 2000.

C.4 Minimum work of breathing (Otis' equation)

Otis' basic question was: how do mammals choose their breathing pattern and on what parameters does it depend (Otis 1950)? The same question was investigated years before by Rohrer and a very similar result was obtained (Rohrer 1925). The hypothesis was that the breath pattern with the least work of breathing (WOB) is chosen by mammals. Figure C-13 shows the relationship between rate and WOB graphically, for resistive load, elastic load, and total load to breathing.

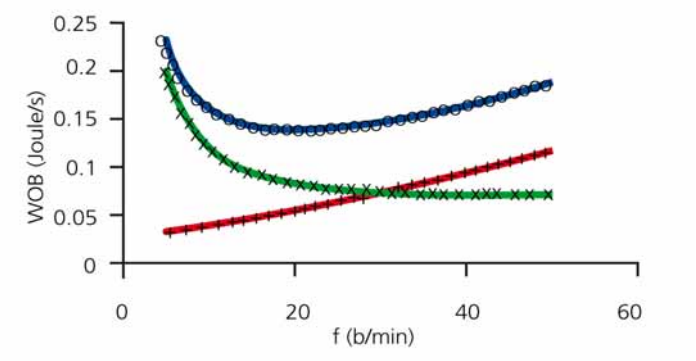


Figure C-13. Three different relationships between rate and WOB are plotted for a hypothetical lung: (+) purely resistive load causes WOB to rise with rate, (x) purely elastic load creates highest load at low rates, (o) the total lung shows a clear minimum which can be calculated according to the equation below.

The following equation was found to represent the rate where WOB is minimum:

$$\mathbf{f = (1 + 2a*RCe*(MinVol-f*Vd)/(Vd))^{-0.5}} \text{ -1/a*RCe}$$

where *a* is a factor that depends on the flow waveform. For sinusoidal flows, *a* is $2\pi^2/60$.

The corresponding tidal volume is calculated as:

Vt = MinVol/f

Example: A 70 kg male patient with normal lungs (Rtotal = 5 $cmH_2O/l/s$, expiratory resistance hose and valve = 5 $cmH_2O/l/s$, Crs = 50 ml/cmH_2O) may have a measured RCexp of 0.5 s, an estimated VDaw of 154 ml, and an operator-set %MinVol of 100%. With these values, the target MinVol becomes

MinVol = 100% x 70 kg x 0.1 l/min/kg = 7 l/min

Next, Otis' equation is applied with the following parameters:

MinVol = 7 l/min

VDaw = 154 ml

RCexp = 0.5s

$a = 2\pi^2/60$

f = 10 b/min (this is always used as a starting value)

The result is a new rate f(1)

f(1) = 15 b/min

This rate is again inserted into Otis' equation, the calculation is performed again, and the next estimate for rate f(2) is obtained. This procedure is repeated until the difference between subsequent results for rate (f) becomes lower than 0.5 b/min. In the present example, one iteration step is sufficient, i.e.,

ftarget = 15 b/min

Finally, the target tidal volume is obtained by dividing MinVol by f:

Vtarget = 7000 ml/min / 15 b/min = 467 ml

C.5 ASV technical data

Table C-5 lists technical data related to ASV. *Underlined* parameters are operator-set in the ASV mode.

Table C-5. ASV technical data

ASV-related operator settings	
%MinVol	25 to 350%
Patient height	130 to 250 cm / 50 to 100 in. (adult) 30 to 150 cm / 12 to 60 in. (pediatric)

Table C-5. ASV technical data

Internal calculations	
IBW	In kg, calculated based on Patient height and Gender (see Section 5.2)
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. For details, see the INTELLiVENT-ASV manual.
fTotal	In b/min, calculated on the basis of Otis' equation
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
Status of patient (numerical)	fSpont, fControl, Pinsp
Graphics display (curve)	f versus Vt, target value, actual value, safety boundaries
Alarms	
All alarms are functional except apnea alarms	See Section Alarms
Special	ASV: Check hi press limit, ASV: Cannot meet target

Table C-5. ASV technical data

Performance specifications	
Response time (90% of steady state)	< 1 min (typical)
Overshoot/undershoot	< 20%
Maximum pressure change per breath	2 cmH_2O
Lung-protective rules	
Maximum Vt	Depends on high *Pressure* alarm limit, Vt alarm limit and volume/ pressure ratio (V/P) always < 22 x IBW. Inspiration is aborted in mechanical breaths as soon as volume is exceeding 1.5*Vt high alarm limit.
Minimum Vt	4.4 x IBW
Maximum machine rate	The maximum rate in ASV is the smallest value of the following condition: - 60 b/min - 23 b/min*%MV/100 / (Weight ≥ 30 kg) - 20/RCexp
Minimum target rate	5 to 15 b/min
Maximum Pinsp	High *Pressure* alarm limit – 10 cmH_2O – PEEP
Minimum Pinsp	5 cmH_2O above *PEEP/CPAP*
Minimum inspiratory time (TI)	0.5 s or RCexp, whichever is longer
Maximum inspiratory time (TI)	2 s
Minimum expiratory time (Te)	2 x RCexp
Maximum expiratory time (Te)	12 s
I:E range	1:4 to 1:1

C.6 ASV Start up

When ASV is started, the device delivers 3 (three) test breaths in the synchronized intermittent mandatory pressure ventilation mode. The device automatically selects the values for SIMV rate, inspiratory time (TI), and inspiratory pressure (Pinsp) based on the calculated IBW, which is determined from the operator-set Patient height and Gender settings, and according to information described in Table C-6 and Table C-7.

Table C-6. Initial breath pattern for Adult settings

IBW (kg)	P insp (cmH2O)	TI (s)	SIMV rate (b/min)	Minimum target rate (b/min)
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

Table C-7. Initial breath pattern for Pediatric settings

IBW (kg)	P insp (cmH2O)	TI (s)	SIMV rate (b/min)	Minimum target rate (b/min)
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

C.7 References

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- **...more** and updated references on www.hamilton-medical.com

D NIV (Noninvasive ventilation)

D.1 Introduction

CAUTION

When using a mask for noninvasive ventilation, pay special attention to how the mask is attached to prevent patient skin irritation.

NOTE:

- Noninvasive ventilation in critically ill patients should only be used by properly trained and experienced personnel.
- 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 noninvasive ventilation mode (NIV) and the spontaneous/timed noninvasive ventilation mode (NIV-ST) are implementations of noninvasive positive pressure ventilation (NPPV). NPPV can use as its patient interface a mask, mouthpiece, or helmet-type interface, rather than an invasive conduit such as an endotracheal tube.

Used for years in home care and subacute care settings, NPPV can also benefit intensive care ventilation patients by decreasing the need for intubation and promoting early extubation. Benefits such as reduced mortality (COPD patients), reduced ventilation time (COPD and ARF patients), and reduced complication rates (of ventilator-associated pneumonias) have been clearly demonstrated[1,2].

1. Mehta S et al. Noninvasive ventilation. Am J Respir Crit Care Med 2001 Feb;163(2):540-77.

Intended for actively breathing patients, noninvasive ventilation is provided through a nonvented or nonported mask interface. Because this open breathing circuit permits air to leak around the mask or through the mouth, the ventilator achieves and maintains the prescribed pressure by adjusting the inspiratory flow. If the leak is large, the ventilator's inspiratory flow can be large, thus compensating at least in part for most leaks. The NIV modes were also designed to minimize nuisance leak-related alarms.

NIV is an adaptation of the SPONT mode, while NIV-ST is an adaptation of the PSIMV+ mode. The primary difference between SPONT and NIV or PSIMV+ and NIV-ST is that SPONT and PSIMV+ are designed for an intubated patient, while the NIV modes are designed for use with a mask or other noninvasive patient interface. See Appendix A for technical details about the ventilator's noninvasive modes.

D.2 Benefits of noninvasive ventilation[1,2]

Noninvasive ventilation offers these short-term benefits:

- Relieves respiratory symptoms
- Optimizes patient comfort
- Reduces work of breathing (WOB)
- Improves or stabilizes gas exchange
- Improves patient-ventilator synchrony
- Minimizes risks associated with aspiration, intubation, injury to the mucus membranes and teeth, and circulatory reactions

2. Hess DR. The evidence for noninvasive positive-pressure ventilation in the care of patients in acute respiratory failure: a systematic review of the literature. Respiratory Care 2004 Jul;49(7):810-25.

1. Mehta S et al. Noninvasive ventilation. Am J Respir Crit Care Med 2001 Feb;163(2):540-77.

2. Hess DR. The evidence for noninvasive positive-pressure ventilation in the care of patients in acute respiratory failure: a systematic review of the literature. Respiratory Care 2004 Jul;49(7):810-25.

Noninvasive ventilation offers these long-term benefits:

- Improves sleep duration and quality
- Maximizes quality of life
- Enhances functional status
- Prolongs survival

D.3 Required conditions for use

CAUTION

- **To prevent possible patient injury, DO NOT use noninvasive ventilation on patients with no or irregular spontaneous breaths. Noninvasive ventilation was 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.**
- **When using a mask for noninvasive ventilation, pay special attention to how the mask is attached to prevent patient skin irritation.**

Ensure these requirements are met to use noninvasive ventilation:

- The clinician's instructions must be strictly followed.
- The patient must not be intubated.
- The patient must be able to trigger the ventilator and must have regular spontaneous breaths.
- The patient must be conscious.
- The patient must be able to maintain an adequate airway.
- The patient must be monitored by external monitors.
- Intubation must be possible at any time.
- The mask should fit face structures well.

D.4 Contraindications

- Intolerance of interface
- Inability to trigger breath
- Facial or brain injury
- Recent upper airway or esophageal surgery
- haemodynamic instability
- Gastric distension
- Inability to protect airway

D.5 Potential adverse reactions

- Skin breakdown from interface (pressures sores)
- Aspiration
- Conjunctivitis
- Gastric insufflation
- Claustrophobic reaction
- Potential haemodynamic instability

D.6 Selecting a patient interface

The quality and performance of the patient interface largely determine the effectiveness of noninvasive ventilation. Either a face (oronasal) mask which covers the mouth and nose, a nasal mask which covers the nose only, a mouthpiece, or a helmet-type interface can be used with noninvasive ventilation. In general, a face mask is more efficient than a nasal mask, but a nasal mask is better tolerated. Consider these additional advantages and disadvantages when selecting a patient interface shown in Table D-1.

Table D-1. Patient interfaces

Type	Advantage	Disadvantage
Face mask	• Little patient cooperation required • Little leakage • Ability to sleep	• Verbal communication not possible • Gastric distension • Greater dead space
Nasal mask	• Comfort • Verbal communication possible • Little dead space	• Patient cooperation required • Oral leakage
Mouthpiece	• Simple to use • Inexpensive	• Nasal air leakage • Greater dead space

In general, a mask used with the noninvasive modes can meet these requirements:

- It must be of the non-vented/non-ported design
- Gas leakage should be controllable at low mask application pressures
- The material in contact with the face should be soft, biocompatible, and nonallergenic
- It should be easy to install and remove
- It should remain properly positioned when the patient moves their head

If you try using a nasal mask, but there is significant gas leakage through the open mouth, switch to a face mask.

D.7 Control settings

CAUTION

- **When ventilating with a mask, avoid high airway pressures. High pressures may cause gastric distension.**
- **Peak pressures exceeding 33 cmH2O may increase the risk of aspiration due to gastric insufflation[1]. 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. For this reason, the TI max setting was added, providing an alternative way to cycle into exhalation. When inspiration lasts longer than TI max, the ventilator cycles into exhalation.

When the ventilator cycles are based on the ETS setting rather than TI max, it is the most comfortable for the patient. 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. The leakage in this mode reduces the actual applied PEEP/CPAP and give rise to autotriggering. Adjust Psupport or Pinsp to obtain appropriate tidal volumes. Adjust PEEP/CPAP further, considering oxygenation and AutoPEEP.

1. Bach JR, Alba AS, Saporito LR. Intermittent positive pressure ventilation via the mouth as an alternative to tracheostomy for 257 ventilator users. Chest 1993;103:174-182.

D.8 Alarms

Volume alarms are less meaningful in noninvasive than in other modes, because of the unpredictable gas leakage in these 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.

D.9 Monitored parameters

NOTE:

- Due to the changing and unpredictable amount of leakage, the following numeric monitoring parameters cannot be used for reliable analysis of patient conditions: RCexp, Rinsp, Insp Flow, AutoPEEP, and Cstat. Continuous monitoring of the clinical parameters and patient comfort is of critical importance.
- The parameters VTE NIV, ExpMinNIV, MVSpoNIV 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 (a bidirectional device proximal to the patient) measures the delivered volume and the exhaled tidal volume.

In order to estimate the exhaled tidal volume, the expiratory minute volume, the spontaneous expiratory minute volume and the minute volume lost over the leakage the monitoring parameters VTE, ExpMinVol, MVSpont and Leak are exchanged with VTE NIV, ExpMinVol NIV, MVSpont NIV and MVLeak. These NIV parameters take into account the measured leak during non-invasive ventilation.

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 all the other clinical parameters, TI, Ppeak, PEEP/CPAP, I:E, fTotal, Pmean, and fSpont can be used to assess the patient's ventilatory status, as usual.

D.10 Additional notes about using noninvasive ventilation

NOTE:

If the mask fit cannot be improved, select an alternative treatment method.

Due to some unique characteristics of noninvasive ventilation, consider the following points when using it. Consistent with best practices, monitor the patient closely to evaluate the adequacy of the prescribed therapy.

IntelliTrig (intelligent trigger) function. With its IntelliTrig function, the ventilator can automatically adapt to changing breath patterns and system leaks to achieve optimum synchronization between patient and device.

To synchronize, IntelliTrig compensates any leaks and resistances between the ventilator and the patient, and with each breath it measures the leakage at the patient interface (mask). With this information IntelliTrig adapts the trigger mechanism so leakage and the changing breath pattern do not influence the operator-set trigger sensitivity (flow trigger).

For information on leak compensation, see Section B.6.

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 ventilator maintains PEEP with the expiratory valve in combination with a compensating base flow delivered by the inspiratory valve through the breathing circuit.

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. For noninvasive ventilation to function as intended, the mask must fit well and remain in place. It is desirable to maintain a good seal and minimize leakage.

Inspect the mask position regularly and adjust as necessary. If the mask slides away from the mouth and nose (patient disconnection), reinstall and secure it. React promptly and appropriately to any alarms.

The ventilator's Leak parameter provides one indicator of mask fit. To check the proper fit of the mask, verify that the patient can trigger and flow-cycle inspiration. Verify that:

Ppeak = (PEEP/CPAP + Psupport/Pinsp) ±3 cmH2O.

CO_2 rebreathing in noninvasive ventilation.
CO_2 rebreathing per breath can increase in noninvasive ventilation. Typically this is not critical, because there is also generally significant leakage in noninvasive ventilation. CO_2 rebreathing can occur because there is not the usual dead space reduction from an endotracheal tube or tracheostomy, and the mask or other noninvasive interface creates additional dead space.

Consider this additional dead space when prescribing a specific type of noninvasive patient interface. Despite the use of a noninvasive interface, the dead space ventilation per minute can decrease when the therapy results in an increase in tidal volume and decrease in respiratory rate.

D.11 References

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APPENDIX

E CO_2 sensor option: Volumetric Capnography

E.1 Introduction

Capnography has become an important tool to evaluate the adequacy of ventilation, as the obvious goal of ventilation is to remove the CO_2 produced by the body's metabolic processes. But conventional, time-based capnography allows only qualitative and semi-quantitative, and sometimes misleading, measurements, so volumetric capnography has emerged as the preferred method to assess the quality and quantity of ventilation.

To this end, the ventilator's volumetric capnography measurements provide the following information:

- The **CO_2 elimination (V'CO_2)** measurement permits assessment of metabolic rate (example., it is high with sepsis, tetanus, and so on) and treatment progress.
- The **end-tidal CO_2 ($PetCO_2$ and $FetCO_2$)** measurements permit assessment of arterial CO_2 (Notice that they are inaccurate in pulmonary embolism.).
- The **airway dead space (VDaw)** and alveolar minute ventilation (V'alv) measurements permit assessment of actual alveolar ventilation (as opposed to minute ventilation).
- The **capnogram shape (slopeCO_2)** permits assessment of COPD, asthma, and inefficient ventilation.
- The **physiological dead space fraction (VD/Vt)** permits assessment of risk (Nuckton 2002).

E.2 CO_2 elimination ($V'CO_2$)

To convert a time-based capnogram into a volumetric capnogram, CO_2 must be combined with flow. Figure E-3 shows the volume of CO_2 exhaled in one breath, combining a typical $FetCO_2$ versus time curve (Figure E-1) with the flow curve (Figure E-2) for a mechanically ventilated patient. The area under the expiratory curve (B) minus the area under the inspiratory curve (A) is the net transfer of CO_2 out of the lungs per breath, or VCO_2.

CO_2 elimination ($V'CO_2$) is obtained by adding VCO_2 over several breaths and dividing the sum by the total time in minutes (Noe 1963). Steady-state conditions are essential to interpret the $V'CO_2$ values (Brandi 1999). $V'CO_2$ thus represents CO_2 elimination but not necessarily CO_2 production. Normal values for $V'CO_2$ can be found in the reference literature or in Table E-1.

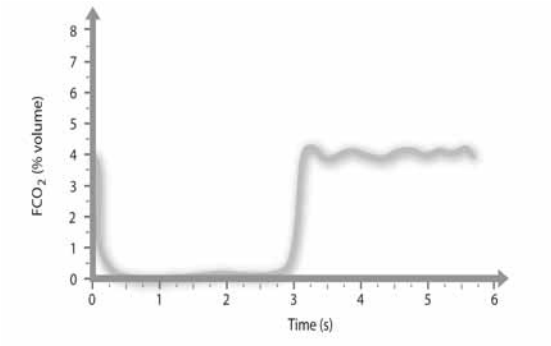

Figure E-1. Typical capnogram of patient on pressure-controlled ventilation, showing fractional concentration of CO_2 plotted against time[1]

1. Inspiration starts at time 0; exhalation, at approximately 2.75 sec. Notice that inspiratory gas initially contains CO_2 (rebreathing) that is washed out of the Y-piece.

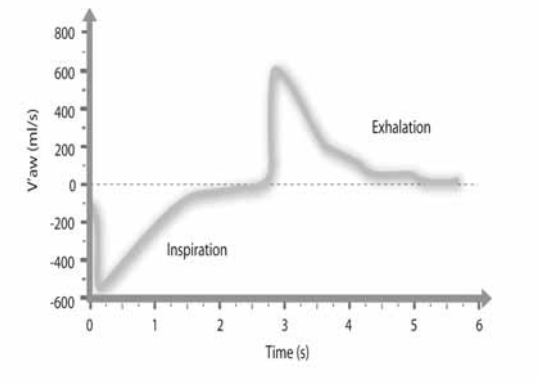

Figure E-2. Typical spirogram of a patient on pressure-controlled ventilation (same breath as shown in Figure E-1)[1]

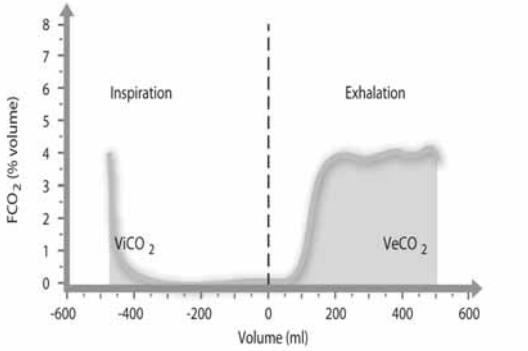

Figure E-3. Combination of capnogram and spirogram (that is, fractional end-tidal CO_2 concentration plotted against volume)[2]

1. The flow into the patient (inspiration) is negative, while the flow out of the patient (exhalation) is positive. The expiratory flow curve is an exponential decay curve. Notice that in spontaneously breathing subjects, the flow curves may be of different shapes.

E.3 End-tidal CO_2 ($PetCO_2$ and $FetCO_2$)

The maximum value of CO_2 measured during exhalation is normally considered the end-tidal CO_2 value, and is either given as a partial pressure ($PetCO_2$), or as a fractional concentration of CO_2 in dry gas ($FetCO_2$).

Normal values for $PetCO_2$ and $FetCO_2$ can be found in the literature or in Table E-1.

E.4 Airway dead space (VDaw)

NOTE:

The Airway dead space (VDaw) is in approximation to the anatomical dead space.

Airway dead space measurement using a volumetric capnogram gives an effective, in-vivo measure of volume lost in the conducting airways. By dividing the capnogram into phases[1] (Figure E-4), VDaw can be calculated as the smallest measurable dead space, essentially the volume exhaled up until phase II. The calculation, described in literature (Wolff 1989 and Aström 2000), consists of a number of computational steps, which take the slope of the alveolar plateau into account.

Normal values for VDaw can be found in the literature or in Table E-1.

2. $ViCO_2$ is the volume of inspired CO_2, while $VeCO_2$ is the volume of exhaled CO_2. The net elimination of CO_2 is $VeCO_2$ - $ViCO_2$. $ViCO_2$, which is a negative volume indicating rebreathed CO_2, is normally omitted.

1. In an early detailed description (Folkow 1955), the capnogram can be thought of as being divided into phases: phase I (no CO_2 present), phase II (rapid rise in CO_2), and phase III (alveolar plateau).

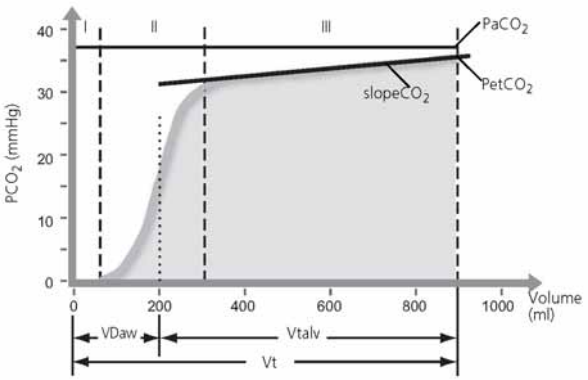

Figure E-4. Interpretation of volumetric capnogram[1]

E.5 Alveolar minute ventilation (V'alv)

Minute ventilation includes not only ventilation of the lungs, but also ventilation that is wasted in the airways. Thus, high minute ventilation does not conclusively indicate the actual alveolar reach. For example, a tidal volume of 100 ml at 80 b/min yields the same minute ventilation as a tidal volume of 500 ml at 16 b/min, yet it has no real benefit to the patient since only dead space ventilation occurs. Alveolar ventilation is defined as

V'alv = MinVol-V'Daw

where

MinVol = f*Vt

and

V'Daw = f*VDaw

1. Phase I: pure airway dead space, from point of measurement of CO_2 toward the lungs. Phase II: weighted average of alveolar gas from different lung spaces, at the sensor location; measurement is VDaw. Phase III: alveolar plateau; measurement is slopeCO_2 together with end-tidal CO_2, PetCO_2, or FetCO_2.

or

V'alv = f*(Vt-VDaw)

Therefore, V'alv is the pertinent parameter to measure ventilation.

Not all gas that enters the alveoli participates in gas exchange. Some gas ends up in non- or under-perfused lung spaces. To measure the efficiency of alveolar ventilation, $PaCO_2$ must be determined from an arterial blood gas sample. The ratio of mixed to ideal alveolar partial pressure is a measure of alveolar efficiency (Severinghaus 1957).

Normal values for V'alv can be found in the literature or in Table E-1.

E.6 Capnogram shape (slope of the alveolar plateau, slopeCO_2)

The slope of the alveolar plateau (slopeCO_2) is a characteristic of the volumetric capnogram shape. This slope is measured in the geometric center of the curve, which is defined as the middle two quarters lying between VDaw and the end of exhalation (Wolff 1989, Aström 2000). A steep slope is seen in COPD patients, while a flat plateau is seen in postoperative patients. A steep slope in normal patients may indicate a technical problem.

Normal values for slopeCO_2 can be found in the literature or in Table E-1.

Table E-1. Examples of "normal" or expected values in mechanically ventilated patients[1]

Description	Unit[2]	Normal	Reference
VDaw	ml BTPS	2.2 ml/kg IBW	Radford 1954
slopeCO_2	%CO_2/l	31324*Vt-1.535	Aström 2000
V'CO_2[3]	ml/min STPD	2.6 to 2.9 ml/min/kg	Weissmann 1986Wolff 1986
FetCO_2[4]	%	5.1 to 6.1%	Wolff 1986
V'alv	mmHg (kPa)	36 mmHg (4.8 kPa)	Kiiski, Takala 1994
VD/Vt	ml/min BTPS	52 to 70 ml/min/kg actual body weight	[5]
VD/Vtbohr	--	Normal: 0.36 to 0.42High: > 0.63 ±0.1	Kiiski, Takala 1994 Wolff 1986 Nuckton 2002[6]

1. These values are for illustration purposes and do not replace physician-directed treatment.
2. Bulk gas volumes such as minute ventilation and tidal volumes are usually measured in BTPS. Specific gas volumes are expressed in STPD. Conversion factors can be found in physics textbooks.
3. V'CO_2 = V'alv * FetCO_2
4. FetCO_2 = PetCO_2/(Pb-PH_2O)
5. V'alv = V'CO_2/FetCO_2 STPD
   Lower value of normal range:
   V'alv = 2.6/0.061 = 43*ml*kg/min*STPD = 52*ml*kg/min*BTPS
   Upper value of normal range:
   V'alv = 2.9/0.051 = 57*ml*kg/min*STPD = 70*ml*kg/min*BTPS
6. VD/Vtbohr is equivalent to VD/Vt if PetCO_2 is identical to PaCO_2. In normal lungs, this is the case. In diseased lungs, however, PetCO_2 and PaCO_2 are not identical. The classic example is pulmonary embolism.

E.7 Formulas

Alveolar tidal ventilation (Vtalv)

Vtalv = Vt-VDaw

Alveolar minute ventilation (V'alv)

V'alv =f*Vtalv

Volume of CO_2 eliminated in one breath (VCO_2)

$VCO_2 = VeCO_2\text{-}ViCO_2$

Fractional concentration of CO_2 in exhaled gas ($FeCO_2$)

$FeCO_2 = V'CO_2/MinVol$

Partial pressure of CO_2 in exhaled gas ($PeCO_2$)

$PeCO_2 = FeCO_2*(Pb\text{-}PH_2O)$

Bohr dead space fraction (VDbohr/Vt) (Note: Vt in this formula needs to be in ml STPD)

$VDbohr/Vt = 1\text{-}(VeCO_2/(Vt*FeCO_2))$

Physiological dead space fraction (VD/Vt)

$VD/Vt = 1\text{-}((VeCO_2/Vt)/(paCO_2/Pb\text{-}PH_2O))$

E.8 References

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APPENDIX

F Pulse oximetry

F.1 Introduction

WARNING

- **A pulse CO-oximeter should be considered an early warning device. As a trend towards patient hypoxemia is indicated, blood samples should be analyzed by laboratory instruments to completely understand the patient's condition.**
- **SpO_2 is empirically calibrated to functional arterial oxygen saturation in healthy adult volunteers with normal levels of carboxyhaemoglobin (COHb) and methaemoglobin (MetHb). A pulse oximeter can not measure elevated levels of COHb or MetHb. Increases in either COHb or MetHb will affect the accuracy of the SpO_2 measurement.**
  - **For increased COHb: COHb levels above normal tend to increase the level of SpO_2. The level of increase is approximately equal to the amount of COHb that is present.**

NOTE:

High levels of COHb may occur with a seemingly normal SpO_2. When elevated levels of COHb are suspected, laboratory analysis (CO-oximetry) of a blood sample should be performed.

  - **For increased MetHb: The SpO_2 may be decreased by levels of MetHb of up to approximately 10% to 15%. At higher levels of MetHb, the SpO_2 may tend to read in the low- to mid-80s. When elevated levels of MetHb are suspected, laboratory analysis (CO-oximetry) of a blood sample should be performed.**

- **The pulsations from intra-aortic balloon support can be additive to the pulse rate on the oximeter pulse rate display. Verify patient's pulse rate against the ECG heart rate.**
- **Misapplied sensors or sensors that become partially dislodged may cause either over or under reading of actual arterial oxygen saturation.**
- **For measurements of high or low SpHb readings, blood samples should be analyzed by laboratory instruments to completely understand the patient's condition.**
- **Elevated levels of total Bilirubin may lead to inaccurate SpO_2, SpMet, SpCO, SpHb, and SpOC measurements.**
- **Motion artifact may lead to inaccurate SpMet, SpCO, SpHb, and SpOC measurements.**
- **Haemoglobin synthesis disorders may cause erroneous SpHb readings.**
- **Loss of pulse signal can occur when**
  - **The sensor is too tight**
  - **The patient has hypotension, severe vasoconstriction, severe anemia, or hypothermia**
  - **There is arterial occlusion proximal to the sensor**
  - **The patient is in cardiac arrest or is in shock**
- **In case of anemia and blood loss, the SpO_2 sensor is unable to detect tissue hypoxia.**
- **Severe anemia may cause erroneous SpO_2 readings.**
- **Very low arterial oxygen saturation (SpO_2) levels may cause inaccurate SpCO and SpMet measurements.**

- **Use disposable sensors only once. They cannot be sterilized and can cause cross infection.**
- **SpO_2 measurement can be incorrect if**
  - **The patient's carboxyhaemoglobin or methaemoglobin increases abnormally**
  - **Dye is injected into the blood**
  - **An electrosurgical unit is used**
  - **Measuring at a site with venous pulse**
  - **There is body movement**
  - **The pulse wave is small (insufficient peripheral circulation)**
- **Skin pigmentation can affect the SpO_2 value. Verify SpO_2 by checking the plethysmographic waveform and the quality index of the measured SpO_2 value.**
- **To avoid cross contamination, only use Masimo single-use sensors on the same patient.**
- **Unless otherwise specified, do not sterilize sensors or patient cables by irradiation, steam, autoclave or ethylene oxide. See the cleaning instructions in the directions for use with the Masimo reusable sensors.**
- **Never use the SpO_2 adapter in the presence of any flammable anesthetic gas or high concentration oxygen atmosphere. Failure to comply with this warning can cause explosion or fire.**
- **Never use the SpO_2 adapter in a hyperbaric oxygen chamber. Failure to comply with this warning may cause explosion or fire.**
- **When not measuring SpO_2, disconnect the SpO_2 adapter from the instrument. Otherwise, noise from the sensor can interfere, and incorrect data is displayed on the screen.**

- **Before monitoring SpO_2 through the SpO_2 adapter, confirm that the operator's manual of the instrument to which the SpO_2 adapter is connected allows the use of the SpO_2 adapter. The safety of the attachment section (including the SpO_2 adapter and the sensor) depends on the specifications of the connected instrument. If the SpO_2 adapter is used with an instrument or SpO_2 sensor other than those specified, the patient and operator can get an electrical shock and the SpO_2 adapter can become hot.**
- **If the attachment site is unclean, clean the attachment site before attaching the sensor. If there is nail polish on the attachment site, remove the polish. Otherwise, the amount of transmitted light decreases, and measured value can be incorrect or measurement unable to be performed.**
- **DO NOT permit the operation of mobile phones, small wireless devices and other devices that produce strong electromagnetic interference around a patient, except for devices allowed by the hospital administrator. Radio waves from devices such as mobile phones or small wireless devices can cause the display of incorrect data.**
- **Keep the patient away from the cable as much as possible. If the cable coils around the patient by their body movement, the patient can get injured. If this happens, remove the cable promptly.**
- **DO NOT use SpO_2 measurement and PEEP/ Oxygen adjustment with patients suffering from carbon monoxide intoxication**

- **Attach the pulse oximetry sensor carefully, and check the position periodically. Do not diagnose patients based solely on the data from the pulse oximeter. Overall judgment must be made by a physician who understands the limitations and characteristics of the pulse oximeter and can read the biomedical signals acquired by other instruments.**
- **The sensor cable must face away from the patient. Safely secure the sensor cable out of the way, to do so, attach the sensor cable holding clips to the airway tubing, and then connect the sensor cable to the clips.**
- **SpO_2 measurement in case of patients with carbon monoxide poisoning can be incorrect.**
- **Interfering Substances: Dyes, or any substance containing dyes, that change usual blood pigmentation may cause erroneous readings.**
- **When there is abnormally high methaemoglobin and carboxyhaemoglobin, the SpO_2 reading is incorrect.**
- **Pulse rate measurement is based on the optical detection of a peripheral flow pulse and therefore may not detect certain arrhythmias. The pulse oximeter should not be used as a replacement or substitute for ECG-based arrhythmia analysis.**
- **HLI cannot be used in patients with significant cardiac arrhythmias (for example, arterial fibrillation, frequent premature beats, ventricular fibrillation). In these patients, due to irregular time between heart beats, HLI does not reflect the effect of mechanical ventilation on the stroke volume of the heart.**
- **High intensity extreme lights (including pulsating strobe lights) directed on the sensor may not allow the pulse CO-oximeter to obtain readings.**

- **If there is low transthorasic pressure, the intensity of HLI is decreased.**
- **HLI can be incorrect when**
  - **Tidal volume is < 8 ml/kg**
  - **Patient's breath activity is spontaneous**
  - **Driving pressure is < 10 cmH_2O**
- **If PEEP changes often and too many recruitment maneuvers occur, the HLI will fluctuate.**
- **When there are cardiac dysfunctions, HLI will read too high or too low.**
- **When HR/RR<3-4, HLI sensitivity is low.**
- **Regularly check the plethysmographic curve (patient motion), as well as SpO_2 and HLI QI.**
- **Before maintenance or cleaning, disconnect the SpO_2 adapter from the device. Failure to comply with this instruction can result in electrical shock and SpO_2 malfunction or both.**
- **With very low perfusion at the monitored site, the readings may read lower than core arterial oxygen saturation.**
- **Avoid permanent contact of the SpO_2 adapter and the body.**
- **Regularly change the measurement site of the sensors according to the skin of the patient. Take extreme care with the following patients: patient with fever, patient with peripheral circulation insufficiency.**

- **The site must be checked at least every four (4) hours to ensure adequate adhesion, circulation, skin integrity and correct optical alignment. If the circulatory condition or skin integrity has deteriorated, the sensor should be applied to a different site.**
- **Change the SpO_2 sensor measurement site regularly, every eight hours for disposable and every four hours for reusable sensors. The skin temperature may increase at the attached site by 2 °C or 3 °C degrees and cause a burn or pressure necrosis.**
- **Avoid placing the sensor on any extremity with an arterial catheter or blood pressure cuff.**
- **Do not use tape to secure the sensor to the site; this can restrict blood flow and cause inaccurate readings. Use of additional tape can cause skin damage or damage the sensor.**
- **If the sensor is wrapped too tightly or supplemental tape is used, venous congestion/pulsations may occur, causing erroneous readings.**
- **Venous congestion may cause under-reading of actual arterial oxygen saturation. Therefore, assure proper venous outflow from monitored site. The sensor should not be below heart level (for example, sensor on hand of a patient in a bed with arm dangling to the floor).**
- **Venous pulsations may cause erroneous low readings (for example, tricuspid valve regurgitation).**
- **The pulse CO-oximeter can be used during defibrillation, but the readings may be inaccurate for up to 20 seconds.**
- **The pulse CO-oximeter is NOT intended for use as an apnea monitor.**

CAUTION

- **Do not use the pulse CO-oximeter or oximetry sensors during magnetic resonance imaging (MRI) scanning. Induced current could potentially cause burns. The pulse CO-oximeter may affect the MRI image, and the MRI unit may affect the accuracy of the oximetry measurements.**
- **If using pulse CO-oximetry during full body irradiation, keep the sensor out of the irradiation field. If the sensor is exposed to the irradiation, the reading might be inaccurate or the unit might read zero for the duration of the active irradiation period.**
- **Exercise caution when applying a sensor to a site with compromised skin integrity. Applying tape or pressure to such a site may reduce circulation and/or cause further skin deterioration.**
- **Circulation distal to the sensor site should be checked routinely.**
- **A functional tester cannot be utilized to assess the accuracy of the pulse CO-oximeter or any sensors.**
- **Do not modify or alter the sensor in any way. Alterations or modification may affect performance and/or accuracy.**
- **Verify SpO_2 periodically by observing the plethysmographic wave form and the quality index (QI-SpO_2) of the measured SpO_2 value.**
- **Verify SpO_2 periodically by comparing measured SpO_2 against patients' SaO_2 with an ABG (Arterial Blood Gas) measurement.**
- **Detach SpO_2 sensor before defibrillation, unless collecting CO measurements.**
- **Use of the second SpO_2 sensor can increase the reliability and the quality of the measured SpO_2 value.**

- **SpO_2 measurement of a patient with insufficient peripheral circulation can be incorrect.**
- **All devices are not protected against the effect of the discharge of a cardiac defibrillator.**
- **When two sensors are attached beside each other, the light from each sensor interferes with the other sensor and SpO_2 cannot be monitored properly. Make sure that there is no light interference when attaching more than one sensor.**
- **Normal external light does not affect measurement, but strong light such as a surgical light or sunlight can affect measurement. If the measuring site is affected, cover it with a blanket.**
- **If the sensor is attached to same limb that is used for NIBP measurement or an IPB catheter, the blood circulation at the attachment site is affected and the measurement might not be correct. Attach the sensor to a limb where the blood circulation is not affected.**
- **Do not pull or bend the sensor cable, and do not let caster feet run over the sensor cable. Failure to follow these cautions may cause cable discontinuity, short circuit, skin burn on the patient and incorrect measurement date. Replace any broken sensor with a new one.**
- **Redness or skin irritation may appear on the attachment site. Take extreme care of patients with weak skin. In case of redness or skin irritation, change the attachment site or stop using the sensor.**

NOTE:

- Use components specified by HAMILTON MEDICAL only.
- DO NOT use or store outside of specified environmental conditions.
- HLI is not available with the Masimo pulse oximeters.

The SpO_2 sensor (probe) is connected to an adapter to measure patient's SpO_2 and pulse rate and send measured data (SpO_2 real time value, plethysmograph, pulse rate and status) to the device. Figure F-1 shows the Masimo pulse oximeter parts.

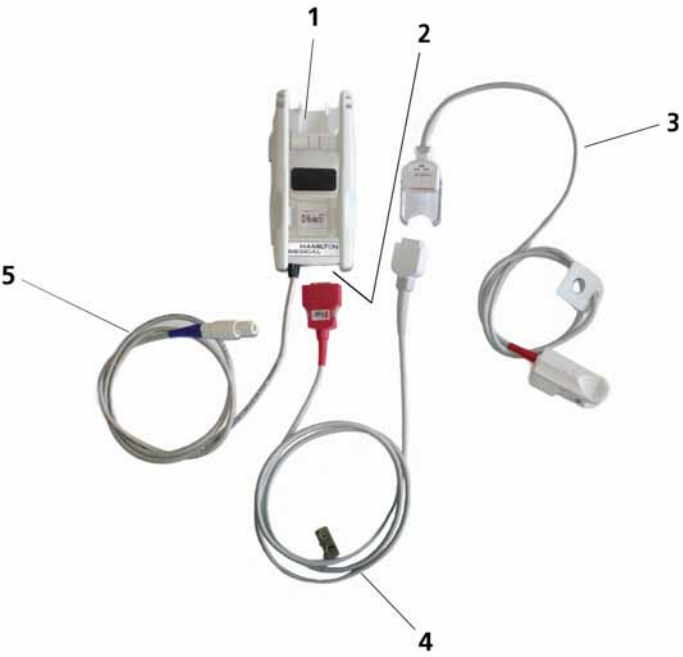


Figure F-1. Masimo SpO_2 pulse oximeter components

1 Masimo adapter, which contains the oximeter hardware

2 Cable connection ports

3 SpO_2 sensor (probe) and cable

4 Patient cable (connects to adapter and probe (sensor))

5 Adapter cable (connects the adapter to SpO_2 module on ventilator)

For information on enabling, configuring, and connecting the oximeters, see Sections F.8 to F.9.

F.2 SpO_2 monitoring options

The HAMILTON-G5 supports SpO_2 pulse oximeters from two manufacturers: Masimo® and Nihon-Kohden®. The system comes standard with a pulse oximeter, from whichever manufacturer is chosen when ordering.

Table F-1 describes the options available with each oximeter. Details on each option are provided in this chapter.

Table F-1. SpO_2 pulse oximeter options

Options, Measurements	Nihon-Kohden	Masimo SET SpO_2[1]	Masimo Rainbow[2] SET
SpO_2	X	X	
Pulse rate	X	X	
Plethysmogram	X	X	
Perfusion Index (PI)		X	
SpCO (carboxyhaemoglobin)			X
SpMet (Methaemoglobin)			X
SpHb (total haemoglobin)[3]			X

Table F-1. SpO_2 pulse oximeter options

Options, Measurements	Nihon-Kohden	Masimo SET SpO_2[1]	Masimo Rainbow[2] SET
SpOC (oxygen content)			X
Alarm delay		X	X

1. The system supports the use of two Masimo oximeters at the same time.
2. Masimo Rainbow SET measurements are purchasable options to the Masimo pulse oximeter. They require the use of the Masimo SpO2 pulse oximeter.
3. SpHb offers two modes of use: continuous monitoring or individual spot checks. See Section F.2.1.1.

This operator's manual includes several descriptions, warnings and specifications for both the Nihon Kohden® and Masimo SET® SpO_2 adapters and pulse oximeters, and for the Masimo Rainbow® SET option. Not all the information is included in this manual. For detailed information, see the product inserts. Additional information may also be available at the manufacturer's website:

http://www.masimo.com
http://www.nihonkohden.com/products/type/mon/#pl-spo2

F.2.1 About Masimo SET and Masimo Rainbow SET

The Masimo SET SpO_2 pulse oximeter takes a reading every second to provide accurate, reliable data for SpO_2, heart rate (pulse), and perfusion index, including a plethysmograph waveform and quality index, even in conditions where the patient is moving.

In addition to the standard parameters, the Masimo device gives you the opportunity to add one or more monitored parameters with the Masimo Rainbow SET option.

With the Rainbow SET option, you can monitor one or more of the following parameters, depending on what is purchased and configured:

- SpCO (carboxyhaemoglobin)
- SpMet (methaemoglobin)
- SpHb (total haemoglobin, in g/dl or mmol/L)
- SpOC (oxygen content)

  Note that the SpOC value is calculated using the measurement recorded for SpHb as one of the inputs.

The values of these parameters are integrated into the ventilator's MMP display, they support trend graphics, and are subject to applicable alarms, all of which are controlled at the ventilator.

With the Masimo pulse oximeter, you can also configure an alarm delay, which allows you to specify a short waiting period after an alarm condition occurs before the system sounds an audible alarm. For details, see Section F.6.1.

For information on Masimo patents, see *www.masimo.com/patents.htm.*

F.2.1.1 Masimo SpHb sensor modes of operation

The Masimo Rainbow SET **SpHb** sensor has a finite lifespan. Several options are available, including 33 hours and 66 hours. The sensors have two modes of operation, Continuous and Spot Check, described in Table F-2.

Table F-2. Masimo SpHb sensor modes

Mode	Description	Lifespan
Continuous	The sensor updates the SpHb value every minute for the total number of hours allowed for the purchased option. For example, a total of 66 hours of monitoring. When the time is expired, the sensor stops recording measurements. To continue SpHb monitoring, you must replace the sensor. **NOTE:** The timer is only in effect when the sensor is connected. To lengthen the lifespan of the sensor, disconnect it from the patient cable when it is not in active use.	Check with your HAMILTON MEDICAL representative for available options
Spot Check (the default)	SpHb measurements are only recorded when manually requested. Note that if the sensor cannot capture a valid measurement, the time is not counted. For each spot check requested, you have an additional period of time, the Free Retry period, during which you can request repeat measurements. In this mode: • SpHb and SpOC[1] values are only displayed in the Monitoring window, SMP, and MMP for 1 minute, as this data is variable. After 1 minute, the last measurement value is visible in the **Tools -> Spot Check** window. See Figure F-4. • Trend graphs show a single point. • When a measurement is out of range, an alarm is activated for 1 minute.	~400 measurements

1. The SpOC value is calculated using the measurement recorded for SpHb as one of the inputs.

For information on where the SpHb and SpOC data is displayed, see Section F.4. For details on performing spot check updates, see Section F.5.

F.2.2 About Nihon-Kohden

The Nihon-Kohden SpO_2 pulse oximeter takes a reading every second to provide accurate, reliable data for SpO_2 and heart rate (pulse).

The values of these parameters are integrated into the ventilator's MMP display, support trend graphics, and are subject to applicable alarms, all of which are controlled at the ventilator.

F.3 Monitored parameters and settings

Table F-3 lists the pulse oximeter-related parameters that are recorded.

NOTE:

- When a parameter shows dashes or no value, it is not used in any calculations.
- When running the SpHb sensor in Spot Check mode, the SpHb and SpOC values are displayed on the screen only for 1 minute after obtaining the reading (SpHb) and making the calculation (SpOC).
- HLI is only available with the Nihon-Kohden pulse oximeter.

Table F-3. SpO_2 parameters and settings

Setting	Description	Display Range	Resolution
SpO_2 (%)[1] Nihon-Kohden	Arterial oxygen saturation in blood	70 to 100	1
SpO_2 (%)[2] Masimo	Arterial oxygen saturation in blood	0 to 100	1

Table F-3. SpO_2 parameters and settings

Setting	Description	Display Range	Resolution
HLI	Nihon-Kohden only. Heart-Lung Interaction Index. For details, see Appendix D.	-200 to 200	1
Pulse Rate (bpm)[1]	Heart rate	0 to 240	1
Perfusion index (%)[2]	Pulse strength	0.00 to 20.0	.01 if value < 10 .1 if value >= 10
SpCO (%)[3]	Carbon monoxide concentration in arterial blood. Available in Continuous or Spot check mode. See Section F.2.1.1.	0 to 100	1
SpHb (g/dL)[3]	Total haemoglobin in arterial blood Available in Continuous or Spot check mode. See Section F.2.1.1.	0.0 to 25.0	Configurable: 0.1 (default) 0.5 1
SpHb (mmol/L)[3]	Total haemoglobin in arterial blood Available in Continuous or Spot check mode. See Section F.2.1.1.	0.0 to 16.0	Configurable: 0.1 (default) 0.5 1
SpMet (%)[3]	Methaemoglobin concentration in arterial blood	0.0 to 100.0	0.1
SpOC (mL/dL)[3]	Calculated measurement of amount of oxygen in arterial blood	0 to 40	1

1. Both Nihon-Kohden and Masimo
2. Masimo only
3. Available only with the Masimo Rainbow SET option. Not compatible with Nihon-Kohden.

F.3.1 About the Masimo SpO_2 Raw parameter measurements

The raw data is primarily used when two sensors are in use, to evaluate the signal quality of each sensor. In **Mixed** mode (see Section F.8.1.3), INTELLiVENT®-ASV uses the raw data and quality index to determine which sensor to use as the master sensor. You can also use this data to help determine which sensor to use as the master, if not using **Mixed** mode. The raw SpO_2 data is displayed in the **Monitoring -> SpO2raw** tab.

Figure F-2. Monitoring window, SpO2raw

F.4 SpO_2 pulse oximeter data display

Pulse oximeter data is fully integrated with the ventilator monitoring system. The specific values displayed depend on the options available on the system. Sensor data can be presented in the main screen as MMP or SMP (Figure 7-1), as well as in the Monitoring window. Trend graphs are also supported for each parameter.

For details on selecting MMP parameters, see Appendix J, Configuration.

F.4.1 SpO_2 parameters in the Monitoring window

The following Monitoring window tabs show SpO_2-related parameters. Note that next to each parameter is a quality indicator. For a description of the indicators, see Section F.4.2.

NOTE:

- When a parameter shows dashes or no value, it is not used in any calculations.
- When running the SpHb sensor in Spot Check mode, the SpHb and SpOC values are displayed on the screen only for 1 minute after obtaining the reading (SpHb) and making the calculation (SpOC).

Table F-4. SpO_2 parameters in the Monitoring window

Monitoring window tabs	SpO_2 parameters
Window 2	Displays data for the SpO_2 parameters configured on your system. See Figure F-3.
SpO2raw	Displays the individual raw values for each parameter as recorded by each sensor. Primarily used by INTELLiVENT®-ASV with two sensors, to determine which sensor is master. See Figure F-2.

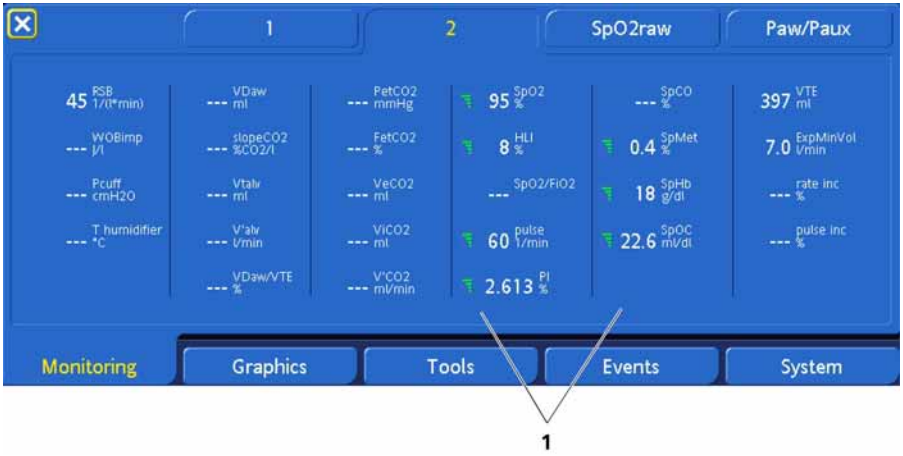


Figure F-3. Monitoring window, Window 2 tab[1]

1 SpO_2 sensor data with quality indicators

F.4.2 Quality index indicators

The quality index shows the pulse oximeter's evaluation of the signal quality. A low-quality index indicates a poor signal, due to interference from excessive motion or other cause. Table F-5 provides an overview of each indicator.

1. Some parameters are only available as Masimo Rainbow SET options. See Section F.2.1.

Table F-5. SpO_2 parameter quality index indicators

Quality index display in Monitoring window	Confidence value
NOTE: When the Confidence index for SpO_2 is <= 60%, the value is invalid for INTELLiVENT®-ASV running with the PEEP and/ or Oxygen controller active (closed-loop operation), and is not used.	
1 red bar 	0-30%. Note that this reading is also displayed when the parameter measurement is still initializing.
2 orange bars 	31-60%
3 green bars 	61-90%
4 green bars 	91-100%
4 grey bars 	OFF (no information)

F.5 Working in SpHb Spot Check mode

NOTE:

SpHb monitoring is a Masimo Rainbow SET option (Section F.2.1), and must be installed, enabled, and configured for Spot Check (Section F.8.1.1).

In Spot Check mode:

- SpHb and SpOC values are only displayed in the Monitoring window, SMP, and MMP for 1 minute, as this data is variable. After 1 minute, the last measurement value is visible in the **`Tools -> Spot Check`** window. See Figure F-4.
- Trend graphs show a single point.
- Any alarms related to SpHb or SpOC are only active for 1 minute. Alarm history is available in the Event log.

In this mode, SpHb measurements are only recorded when you manually initiate a measurement. The SpOC value is calculated using the SpHb measurement as one of its inputs.

As described in Table F-2, the SpHb sensor offers several options, including 66 hours (approx. 400 spot checks) of operation. For each spot check requested, you have an additional Free Retry period during which you can request repeat measurements. A progress bar shows you the remaining available time.

Each set of measurements takes approximately 1 minute to read. If the sensor cannot get a good reading in this time, it continues to attempt to measure these values until the Free Retry period is up. If the sensor cannot capture a valid measurement, the Spot Check attempt is not counted and the time is not subtracted from the total.

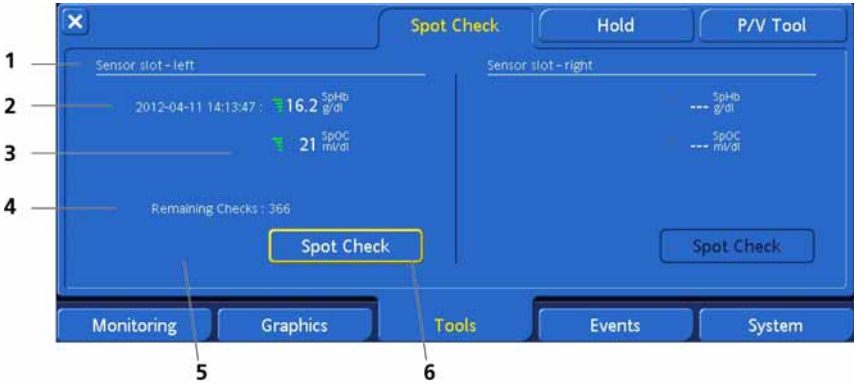


Figure F-4. Tools -> Spot Check window

1 Sensor location (left, right) (in this figure, left sensor is connected)

2 Date and time of last measurement

3 SpHb measurement, SpOC calculated value, and quality indicators

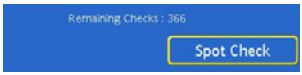
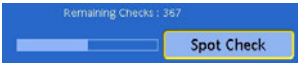
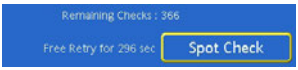
4 Number of remaining available spot checks

5 Status area (see Table F-6)

6 **`Spot Check`** button; click to get updated SpHb measurement and SpOC calculation

Table F-6 describes what is displayed in the Status area (item 5 above).

Table F-6. Spot Check window Status area options

Status area display	Description
Status area is clear 	The system is available for taking measurements.
Progress bar 	The system is in the process of measuring SpHb and calculating SpOC.
Free Retry countdown 	The system has updated the SpHb and SpOC values. You can select **Spot Check** again one or more times during the Free Retry period and not have it count against the total Remaining Checks.

F.5.1 Performing an SpHb spot check

To get an SpHb value measurement,

1. Open the **Tools -> Spot Check** window. See Figure F-4.
2. Select the **Spot Check** button.

   The sensor measures SpHb and the system calculates SpOC. When the values are updated, the Status area indicates your remaining Free Retry time available. The system also updates the Remaining Checks total.

   You can select **Spot Check** again one or more times during the Free Retry period and not have it count against the total remaining checks available.
3. Close the window when done.

F.6 Alarms

The SpO_2 pulse oximeter has several related alarms. You enable them in the **Configuration** window (Section F.8.1.4) and set limits in the **Alarms -> Limits 2** tab. You work with them in the same manner as other ventilator alarms. For alarm settings, see Table F-7. For troubleshooting, see Table F-12.

NOTE:

If you are running the SpHb sensor in Spot Check mode, the SpHb low or SpHb high alarms are only active for 1 minute.

F.6.1 Masimo SpO_2 alarm delay

Because SpO_2 can be relatively variable and potentially generate a high number of alarms, Masimo offers the possibility of setting an audible alarm delay. You can specify a short waiting period (0 to 15 s) after an alarm condition occurs before the system sounds an audible alarm, thereby potentially reducing the number of audible SpO_2 alarms.

A visual alarm is still generated anytime the parameter is above or below the limits set; the delay affects whether the system sounds an audible alarm for the condition.

When enabled, the SpO_2 value must be above or below the specified alarm limits for the selected amount of time before the audible alarm sounds.

An SpO2 alarm delay is set in the **System -> SpO_2** window. See Section F.8.1.4.

F.6.2 SpO_2 Alarm Limits window

The Pulse rate alarm and Masimo Rainbow SET parameters alarm limit controls are displayed in the **Alarms -> Limits 2** window. **Pulse rate**, is always displayed on the left side, regardless of which sensing options are installed.

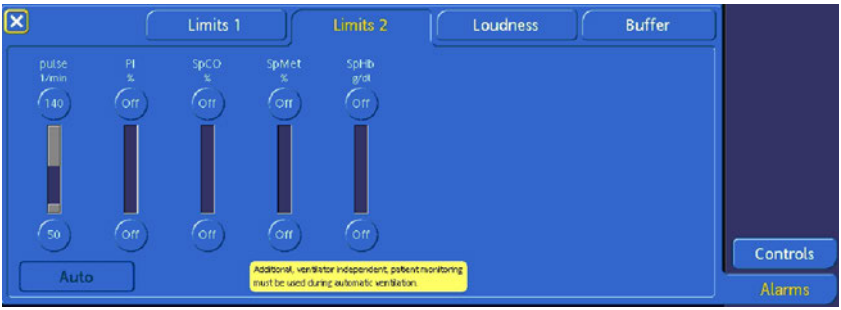


Figure F-5. SpO_2 Alarm Limits 2 window

For details on setting alarm limits, see Section 5.7.1.

F.6.3 Table of pulse oximeter-related alarm settings

Be sure all desired alarms are enabled (Section F.8.1.5) and correctly set. For troubleshooting, see Table F-12.

Table F-7. Adjustable alarms with automatic and standard settings

Parameter	Unit	Range
For all settings, -- indicates the alarm is off.		
Pulse rate	l/min	Low: 30 - 230 in increments of 5 (default: 50) High: 35 - 235 in increments of 5 (default: 140)
SpO_2 (Nihon-Kohden)	%	Low: 70 - 99 (default: 90) High: 71 - 100 (default: 99)

Table F-7. Adjustable alarms with automatic and standard settings

Parameter	Unit	Range
For all settings, -- indicates the alarm is off.		
SpO_2 (Masimo)	%	Low: 1- 98 (default: 90) High: 2 - 99 (default: 99)
SpMet	%	Low: .01 - 99 (default: off) • 1.0 - 2.0, in increments of 0.1 • 2.0 - 99.5, in increments of 0.5 High: 1 - 99.5 (default: 3.0) • 0.1 - 2.0, in increments of 0.1 • 2.0 - 99, in increments of 0.5
SpCO	%	Low: 1 - 97, in increments of 1 (default: off) High: 2 - 98, in increments of 1 (default: 10
SpHb	g/dL	Low: 1 - 24 (default: 7g/dL) • 1.0 - 20.0, in increments of 0.1 • 20.0 - 24, in increments of 0.5 High: 2 - 24.5 (default: 17g/dL) • 2.0 - 20.0, in increments of 0.1 • 20.0 - 24.5, in increments of 0.5

Table F-7. Adjustable alarms with automatic and standard settings

Parameter	Unit	Range
For all settings, -- indicates the alarm is off.		
SpOC	ml/dL	0 - 40
Perfusion Index (PI) high	%	Low: 0.03 - 18 (default: -- off) • 0.03 - 0.10, in increments of 0.01 • 0.10 - 1.0, in increments of 0.10 • 1.0 - 18, in increments of 1 High: 0.04 - 19 (default: -- off) • 0.04 - 0.10, in increments of 0.01 • 0.10 - 1.0, in increments of 0.10 • 1.0 - 19, in increments of 1

F.7 Masimo information codes and troubleshooting

The **`System -> Info 2`** tab shows detailed sensor information. This section describes what is displayed. For troubleshooting details, see Section F.10.

Be sure all desired alarms are enabled (Section F.8.1.5) and correctly set. For alarm settings, see Table F-7.

To display the window:

1. Open the **`System -> Info`** window.
2. Touch the right arrow in the top left corner to display page 2. See Figure F-6.

   Information is displayed for the attached sensor(s).

Figure F-6. System Info 2 window, pulse oximeter information

F.7.1 About the pulse oximeter information codes

The system displays four sets of information for each connected Masimo sensor. Table F-8 describes each component (using the example provided in Figure F-6).

For troubleshooting details, see Section F.10.

Table F-8. Masimo sensor information

Sensor Information	Description
NOTE: • In the Sensor Information column, the segment shown in **bold** text is described on the right, in the Description column. • In the Description column, information shown in **bold** text is described in Table F-12, Troubleshooting Masimo issues.	
Line 1: Masimo software and product information	
MASIMO DSP **V7.8.0.5**-1	Firmware version
MASIMO DSP V7.8.0.5-**1**	Product ID

Table F-8. Masimo sensor information

Sensor Information	Description
NOTE: • In the Sensor Information column, the segment shown in **bold** text is described on the right, in the Description column. • In the Description column, information shown in **bold** text is described in Table F-12, Troubleshooting Masimo issues.	
Line 2: Masimo adapter circuit board information	
MCU **V1.1.0.6**-**301**-1-c-205f-0	Adapter firmware version and board type
MCU V1.1.0.6-301-**1**-c-205f-0	Board mode (0=factory, 1=end user)
MCU V1.1.0.6-301-1-**c**-**205f**-0	Protocol revision and base board parameters
MCU V1.1.0.6-301-1-c-205f-**0**	**Board failure code**
Line 3: Masimo sensor and cable information	
Sensor **3-3-6**-581f-00000000	Sensor type, family member, algorithm type
Sensor 3-3-6-**581f**-00000000	Sensor available parameters
Sensor 3-3-6-581f-**00000000**	**Sensor status and errors**
Line 4: Masimo sensor remaining time/spot checks information	
60h/63h 363/376	**Time remaining on sensor**
60h/**63h** 363/376	**Total time on sensor**
60h/63h **363**/376	**Spot checks remaining on sensor**
60h/63h 363/**376**	**Total spot checks on sensor**

F.8 Configuring the oximeters

Configuration differs between the supported pulse oximeters.

F.8.1 Configuring the Masimo options

Setting up the pulse oximeter comprises the following steps, each of which is described in the following sections.

Configure:

Table F-9. Masimo option settings

Parameter	Parameters to configure	See Section ...
Data acquisition options	• Sensor type (Nihon-Kohden or Masimo) • Line frequency • SpHb averaging rate • SpHb mode • SpHb precision • SpHb unit • SpHb measurement (Continuous or Spot Check)	F.8.1.1
Monitoring options	• Alarm delay • SpO2 averaging interval • SpO2 sensitivity mode • FastSat	F.8.1.3
If using two SpO_2 sensors	Define a master SpO_2 sensor or Mixed mode	F.8.1.3
Enable specific alarms	Enable or disable alarms for any of your purchased measurement parameters	F.8.1.5

F.8.1.1 Configuring Masimo data acquisition options

NOTE:

If you are upgrading the system by adding another parameter measurement, select **Upgrade**. See the HAMILTON-G5 Service Manual for details on the upgrade process.

Configuration is performed in Standby.

To configure data acquisition options (see Figure F-7):

1. In the **Configuration -> SpO2** window, select **Masimo**. Masimo-specific settings are displayed.

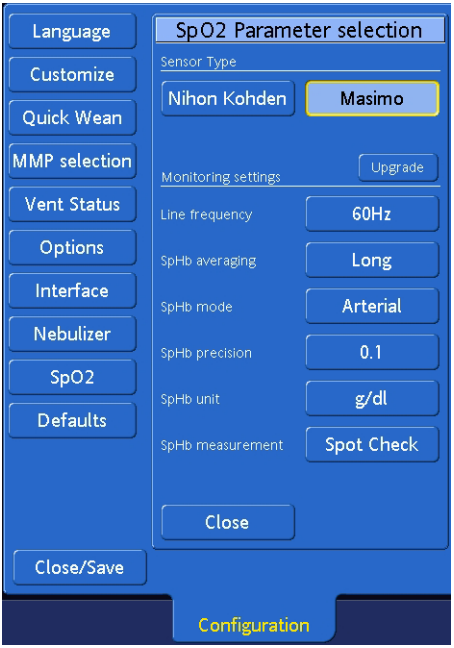


Figure F-7. Masimo data acquisition parameters

2. Select the appropriate settings. For definitions, see Table F-10.

3. Select **Close** and **Close/Save**.

F.8.1.2 Table of Masimo data acquisition settings

Table F-10 describes the SpO_2 data acquisition options and their settings.

Table F-10. Masimo data acquisition settings

Parameter	Description	Options
SpO_2 sensor type	Select the SpO_2 sensor manufacturer.	Nihon-Kohden (default) Masimo
Line frequency	Power line frequency.	50 Hz 60 Hz (default)
SpHb averaging	The length of time over which to collect data to include in the average calculation.	Long (default) Medium Short
SpHb mode	Haemoglobin measurement.	Arterial (default) Venous
SbHb precision	Precision level of the displayed data.	0.1 (default) 0.5 1
SpHb unit	Unit of measurement for the SpHb parameter.	g/dL (default) mmol/L
SpHb measurement	Monitoring method. For details on each method, see Section F.2.1.1.	Continuous Spot Check (default)

F.8.1.3 Enabling and configuring monitoring settings

To enable and configure monitoring settings:

1. Open the **`System -> Sensors on/off`** window.

Figure F-8. Selecting sensor options

2. Select the check box for the appropriate SpO_2 option(s) to enable. If two sensors are used, select a **`Master`** option.

   If you specify a sensor to use as the master, that device's data is used when the information between the two differs. By default, the left sensor is selected. If using two SpO_2 sensors, **`Mixed`** mode ensures INTELLiVENT®-ASV uses the raw data and quality index to determine which sensor to use as the master sensor.

3. Select the **`SpO2`** tab on the left.

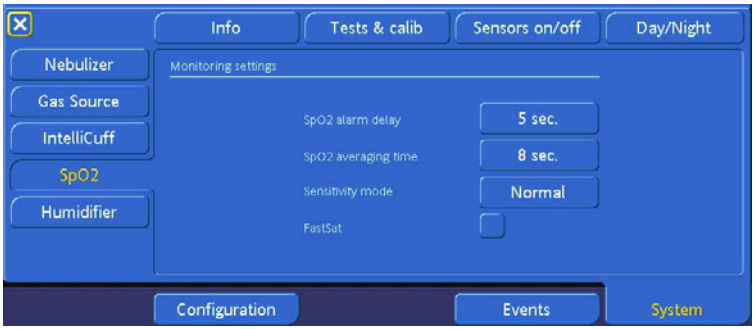


Figure F-9. Configuring Masimo monitoring settings

4. Select the appropriate settings. For definitions, see Table F-11.
5. Close the window.

F.8.1.4 Table of Masimo monitoring options

Table F-11 describes the SpO_2 monitoring options and their settings.

Table F-11. Masimo monitoring parameters

Parameter	Description	Options
SpO_2 alarm delay	Defines the length of time the SpO2 measurement must be outside the alarm limit before an audible alarm sounds. The SpO_2 value must be above or below the specified alarm limits for the selected amount of time before the audible alarm sounds. Use this setting to account for variations in readings and avoid unnecessary audible alarms.	In seconds. 0 5 (default) 10 15
SpO_2 averaging time	Defines how many SpO_2 readings will be used to calculate the final value to display. A higher averaging time provides a more accurate value, but takes longer. **NOTE:** When operating in a closed-loop (INTELLiVENT®-ASV, with active PEEP or Oxygen controller), this parameter is always set to 16 seconds.	In seconds. 2-4 4-6 8 (default) 10 12 14 16

Table F-11. Masimo monitoring parameters

Parameter	Description	Options
Sensitivity mode	Specifies the sensor sensitivity, which can be tailored to different patient conditions.	• **Maximum.** For patients with low perfusion. • **Normal** (default) • **APOD.** (Adaptive sensor off detection) For cases where it is likely that the sensor may be dislodged.
FastSat	Provides quick SpO_2 sampling and display. May show more changes in rate, as it is not an averaged value.	On Off (default)

F.8.1.5 Enabling and configuring Masimo alarms

The alarms you can configure depend on which options you have installed. Unavailable alarms are ghosted in the Configuration tab.

For a description of the alarms, see Section F.6. To specify an alarm delay for audible alarms, use the **`System -> SpO2`** tab as described in Section F.8.1.3.

To enable individual alarms:

1. Open **`Configuration -> Customize`**. See Figure F-10.
2. Select the alarms to enable, then select **`Close`** and **`Close/Save`**.

Figure F-10. Configuration SpO_2 alarms, using the Customize window

For more information about ventilator alarms, see Section J.4.

F.8.2 Configuring the Nihon-Kohden options

To configure the Nihon-Kohden oximeter:

1. In the **`Configuration -> SpO2`** window, select **`Nihon-Kohden`**. See FIgure F-7.
2. Select **`Close`** and **`Close/Save`**.

F.9 Connecting the equipment

SpO_2 measurement begins after the oximeter is configured, the SpO_2 adapter and the oximeter are connected to the HAMILTON-G5, the oximeter is attached to the patient, and the SpO_2 sensor is activated.

F.9.1 Connecting the Masimo oximeter

Before you begin:

- Ensure you have all the components: adapter, adapter cable, patient cable, sensor. See Figure F-1.
- Be sure the adapter is fully assembled; for details, refer to the Instruction Sheet provided with the adapter.
- Inspect connector pins to confirm they are straight and none of the pins are bent.
- The SpO_2 module(s) is already installed. See Section 2.5.

Connecting the oximeter is a simple 4-step process:

1. Attach the adapter to the rail on the trolley or other rail. See Section F.9.1.1.
2. Attach the adapter cable to the SpO_2 module on the ventilator. See Section F.9.1.2.
3. Attach the patient cable to the SpO_2 adapter. See Section F.9.1.3.
4. Attach the sensor to the patient cable. See Section F.9.1.4.

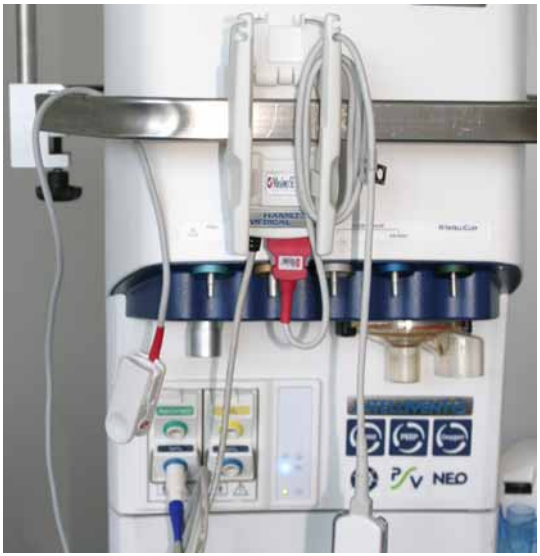


Figure F-11. Fully connected oximeter (Masimo)

F.9.1.1 Attaching the adapter to a rail

The adapter comprises two pieces that fit together and then attach to a standard rail. Both cables connect to the adapter.

Figure F-12. Adapter on rail, fully assembled (Masimo)

To attach the adapter to a rail:

1. Hold the adapter in one hand, and with the other, lift up the top part of the adapter by placing your fingers in the grooved indentations and gently squeezing the sides together while lifting.

Figure F-13. Adapter, open and closed views

2. Fit the adapter over the rail with the bottom part of the adapter behind the rail, and the top part in front. Be sure the rail fits snugly against the indentation in the adapter.

Figure F-14. Fit adapter over rail

3. Close the adapter over the rail, ensuring it clicks shut.

You can now attach the cables.

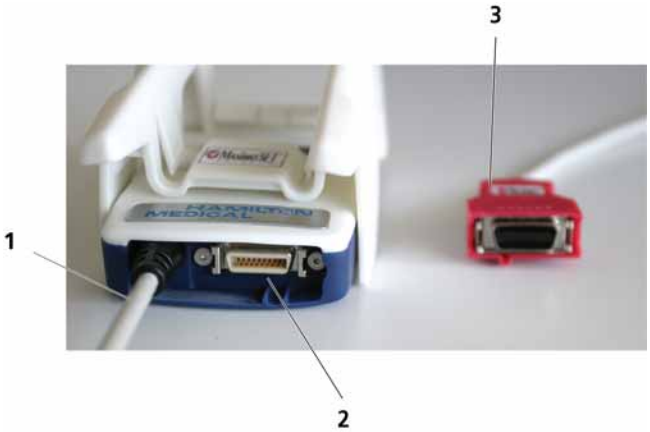


Figure F-15. Masimo adapter and patient cables, connection ports on adapter

1 Adapter cable (attached to adapter, connects to ventilator)

2 Patient cable port

3 Patient cable (connects to adapter and probe)

F.9.1.2 Attaching the adapter cable

One end of the adapter cable is permanently attached to the Masimo adapter.

Attach the connector of the adapter cable to the SpO_2 module on the ventilator. Ensure the cable "snaps" into place (Figure F-16).

Hold the connector (not the cable) to connect or disconnect the adapter cable to the module. If you hold the cable, this can cause cable discontinuity or break the cable.

Figure F-16. Connecting the ventilator SpO_2 cable to the ventilator (Masimo)

F.9.1.3 Attaching the patient cable to the SpO_2 adapter

Attach the connector of the patient cable to the SpO_2 adapter.

Figure F-17. Connecting the patient cable to the SpO_2 adapter (Masimo)

F.9.1.4 Attaching the sensor to the patient cable

1. Attach the connector of the sensor to the patient cable.
2. Close the locking cover.

Figure F-18. Connecting the patient cable to the sensor (Masimo)

Figure F-19. Locking cover between patient cable and sensor (Masimo)

F.9.2 Connecting the Nihon-Kohden oximeter

1. Attach the connector of the patient cable to the SpO_2 module on the ventilator. Ensure the cable "snaps" into place (Figure F-20).

Figure F-20. Connecting the patient cable to the ventilator

2. Connect the sensor to the patient cable adapter, and close the lock cover as shown in Figure F-21.

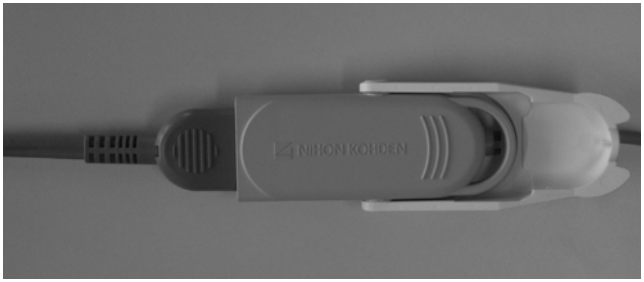


Figure F-21. Connecting sensor to the patient cable (Nihon-Kohden)

F.9.3 Confirming measurements

Once installed, you will verify the SpO_2 value is properly measured on the device. The first SpO_2 value is displayed after about 10 seconds. When SpO_2 is not monitored for 30 seconds, no pulse is detected and the **`Patient disconnected`** alarm is displayed.

Observe that the SpO_2 sensor is active, in the **`System -> Sensor on/off`** window. See Section 4.3.3.

F.9.4 Disconnecting the SpO_2 sensor

To remove the sensor cable, carefully pull back on the connector sheath at the ventilator module, and disengage from the connector.

F.10 Troubleshooting Masimo issues

Table F-12 describes how to address some potential pulse oximeter issues. The codes described here are displayed in the System -> Info 2 window.

Table F-12. Troubleshooting Masimo issues

Code or Issue	Description	Action
For details on Masimo information codes, see Section F.7.		
No sensor information in **System -> Info 2** window	The ventilator does not recognize the oximeter. This can occur for several reasons:	
	• Masimo is not properly enabled or configured.	• In **Configuration**, ensure Masimo is enabled. See Section F.8.1. • Ensure SpO_2 monitoring is enabled. See Section F.8.1.3.
No sensor information in **System -> Info 2** window	• The SpO2 module is not properly seated or installed.	• Reinstall the module per the installation instructions.
		• If the above solutions do not address the issue, contact a HAMILTON MEDICAL authorized service technician.
Line 2: MCU V1.1.0.6-301-1-c-205f-**0** where the last digit is any number from **1 to 10**	Codes 1 to 10 indicate a Masimo adapter board failure.	Contact a HAMILTON MEDICAL authorized service technician.
Line 2: Sensor 3-3-6-581f-**00000000** where the last code is any number other than **00000000**.	Codes other than **00000000** indicate a Masimo sensor or cable status or failure. The possible issues are described below.	

Table F-12. Troubleshooting Masimo issues

Code or Issue	Description	Action
For details on Masimo information codes, see Section F.7.		
0000 0001	No cable connected.	Connect cables. The time allotted for the cable is up. Replace the cable. The information in line 4 (Table F-8) always shows the remaining time or spot checks left.
0000 0002	Cable life expired.	The time allotted for the cable is up. Replace the cable. The information in line 4 (Table F-8) always shows the remaining time or spot checks left.
0000 0004	Incompatible cable.	Replace with a compatible Masimo cable.
0000 0008	Unrecognized cable.	Reconnect the cable. If this does not resolve the issue, replace the cable.
0000 0010	Defective cable.	Replace the cable.
0000 0080	No sensor connected.	Connect a Masimo sensor.
0000 0100	Sensor life expired.	The sensor has reached the end of its allotted hours or spot checks. Replace the sensor. The information in line 4 (Table F-8) always shows the remaining time or spot checks left.
0000 0200	Incompatible sensor.	Connect a compatible Masimo sensor.

Table F-12. Troubleshooting Masimo issues

Code or Issue	Description	Action
For details on Masimo information codes, see Section F.7.		
0000 0400	Unrecognized sensor.	Reconnect the sensor. If this does not resolve the issue, replace the sensor.
0000 0800	Defective sensor.	Replace the sensor.
0010 0000	Sensor initializing.	Wait. This is a normal process.
0020 0000	Sensor off patient.	Check the patient and adjust the sensor position.
0040 0000	Pulse search.	Wait. This is a normal process. If it takes too long, check the patient and adjust the sensor position.
0080 0000	Interference detected.	Check the patient and adjust the sensor position.
0100 0000	Low Perfusion Index.	Check the patient and adjust the sensor position.
1000 0000	Check sensor connection. The sensor is defective.	Replace the sensor.
2000 0000	SpO_2 only mode	Only SpO_2 measurements are enabled or available.

F.11 Masimo specifications

The specifications for the Masimo pulse oximeter with Rainbow SET technology are provided in Table F-13.

Table F-13. Masimo pulse oximeter specifications

Feature	Specifications
Display ranges	Oxygen saturation (SpO2): 0 - 100% Pulse rate (bpm): 25 - 240 bpm Carboxyhaemoglobin saturation (SpCO): 0 - 99% Methaemoglobin saturation (SpMet): 0 - 99.9% Total haemoglobin (SpHb): 0 - 25 g/dL Respiratory rate (RRa): 0 - 70 breaths per minute Total oxygen concentration (SpOC): 0 - 35 ml/dl Hematocrit (SpHct): 0 - 75% Perfusion Index (PI=): 0.02 - 20% Pleth Variability Index (PVI): 0 - 100%
Accuracy **See footnotes 1, 2, 3, 4, 5, 6, 7**	
SpO2, no motion	60 - 80 ± 3% adults/pediatrics/infants 70 - 100% ± 2% adults/pediatrics/infants; ± 3% neonates
SpO_2, motion	70 - 100% ± 3%, adults/pediatrics/infants/neonates
SpO_2, low perfusion	70 - 100% ± 2%, adults/pediatrics/infants/neonates
Pulse rate, no motion	25 - 240 ± 3 bpm, adults/pediatrics/infants/neonates
Pulse rate, motion	25 - 240 ± 5 bpm, adults/pediatrics/infants/neonates
Pulse rate, low perfusion	25 - 240 ± 5 bpm, adults/pediatrics/infants/neonates
SpCO	1 - 40 ± 3%, adults/pediatrics/infants
SpMet	1 - 15 ± 1%, adults/pediatrics/infants/neonates
SpHb	8 - 17 ± 1 g/dl (arterial or venous), adults/pediatrics

Table F-13. Masimo pulse oximeter specifications

Feature	Specifications
RRa	4 - 70 ± 1 breath per minute, adults (> 30 kg)
General	
Resolution	SpO_2: 1% Pulse rate: 1 bpm SpCO: 1% SpMet: 0.1% SpHb: 0.1 g/dl RRa: 1 breath per minute
Measurements	Low signal IQ Perfusion Index (PI) Total oxygen concentration (SpOC) Hematocrit (SpHct) Pleth Variability Index (PVI) Signal identification quality (SIQa)
Electrical	
Power (AC)	Voltage input range: 100 - 240 VAC, 47 - 63 Hz
Batteries	Rechargeable
Electrical	
Circuitry	Microprocessor controlled Automatic self-test of pulse CO-oximeter when powered on Automatic setting of default parameters Automatic alarm messages Trend data output
Firmware	Rainbow SET technology, MX board/circuitry
Mechanical	
Material	Polycarbonate/ABS blend

Table F-13. Masimo pulse oximeter specifications

Feature	Specifications
Environmental	
Operating temperature	0 to 50°C (32 to 122°F)
Storage temperature	-40 to 70°C (-40 to 158°F)
Relative storage humidity	10 to 95% noncondensing
Operating altitude	pressure: 500 to 1060 mbar Altitude: -304.5 to 486 m (-1000 to 18,000 ft)
Mode & sensitivity	
SpO_2 averaging mode	2, 4, 6, 8, 10, 12, and 16 seconds; FastSat
SpO_2 sensitivity	APOD, Normal, Maximum
Alarms	
Volume level adjustment: pulse/tone	OFF; 25 to 100% in four increments
Alarm silence	120 second delay; All mute: continuous silence
Out of Limit alarms: SpO_2, Pulse rate, SpCO, SpMet, SpHb, PI, PVI	High/low alarms
Sensor condition alarm	No Sensor; Sensor Off; Sensor Defect
Battery alarm	Low battery

Table F-13. Masimo pulse oximeter specifications

Feature	Specifications
Display & Indicators	
Data display	SpO_2 (%) Pulse rate (bpm) SpCO (%) SpMet (%) SpHb (g/dl) SpHbv (g/dl) RRa SpOC (ml/dl) SpHct (%) PI (%) PVI (%) Pleth waveform Signal IQ SIQa Sensor status Sensor time Status messages Alarm status Battery status
Output interface	
Satshare	Connection to multi-parameter monitors (SpO_2 only)
Serial port (RS-232 connector)	PC/printer connection Philips VueLink Spacelabs Universal Flexport RadNet Patient Safety Net Trends
Compliance	
EMC compliance	EN 60601-1-2, class B
Electrical safety	IEC 60601-1, 2nd edition; UL 60601-1
Type of protection (AC power)	Class 1

Table F-13. Masimo pulse oximeter specifications

Feature	Specifications
Compliance	
Type of protection (battery power)	Internally powered
Degree of protection (patient cable)	Type BF - applied part
Degree of protection (Satshare cable)	Type CF - applied part
Degree of protection (liquid ingress)	IPX1
Mode of operation	Continuous

Footnotes:

1. SpO_2, SpCO, and SpMet accuracy was determined by testing on healthy adult volunteers in the range of 60-100% SpO_2, 0-40% SpCO, and 0-15% SpMet against a laboratory CO-oximeter. SpO_2 and SpMet accuracy was determined on 16 neonatal NICU patients ranging in age from 7 - 135 days old and weighing between 0.5 - 4.25 kg. Seventy-nine (79) data samples were collected over a range of 70 - 100% SaO_2 and 0.5 - 2.5% MetHb with a resultant accuracy of 2.9% SpO_2 and 0.9% SpMet.
2. The Masimo sensors have been validated for no-motion accuracy in human blood studies on healthy adult male and female volunteers with light to dark skin pigmentation in induced hypoxia studies in the range of 70-100% SpO_2 against a laboratory CO-oximeter and ECG monitor. This variation equals plus or minus one standard deviation, which encompasses 68% of the population.
3. The Masimo sensors have been validated for motion accuracy in human blood studies on healthy adult male and female volunteers with light to dark skin pigmentation in induced hypoxia studies in the range of 70-100% SpO_2 against a laboratory CO-oximeter and ECG monitor. This variation equals plus or minus one standard deviation, which encompasses 68% of the population.
4. The Masimo SET technology has been validated for low-perfusion accuracy in bench-top testing against a Biotek Index 2 simulator and Masimo's simulator with signal strengths of greater than 0.02% and transmission of greater than 5% for saturations ranging from 70 to 100%. This variation equals plus or minus one standard deviation, which encompasses 68% of the population.
5. The Masimo sensors have been validated for pulse-rate accuracy for the range of 25-240 bpm in bench-top testing against a Biotek Index 2

simulator. This variation equals plus or minus one standard deviation, which encompasses 68% of the population.

6. SpHb accuracy has been validated on healthy adult male and female volunteers and on surgical patients with light to dark skin pigmentation in the range of 8-17 g/dl SpHb against a laboratory CO-oximeter. This variation equals plus or minus one standard deviation, which encompasses 68% of the population. The SpHb accuracy has not been validated with motion or low perfusion.
7. The following substances may interfere with pulse CO-oximetry measurements:
   - Elevated levels of methaemoglobin (MetHb) may lead to inaccurate SpO_2 and SpCO measurements.
   - Elevated levels of carboxyhaemoglobin (COHb) may lead to inaccurate SpO_2 and SpCO measurements.
   - Very low arterial oxygen saturation (SpO_2) levels may lead to inaccurate SpCO and SpMet measurements.
   - Severe anemia may cause erroneous SpO_2 measurements.
   - Dyes or any substance containing dyes that change usual blood pigmentation may cause erroneous readings.
   - Elevated levels of total bilirubin may lead to inaccurate SpO_2, SpMet, SpCO, and SpHb measurements.

F.12 Basics of pulse oximetry

Nearly the full amount of the oxygen transported from the lungs to the organs in the human body is present in a bound form in the arterial blood. An iron containing protein called haemoglobin is binding the oxygen molecules (4 binding sites per each haemoglobin molecule). This form of the haemoglobin is called oxyhaemoglobin, as opposed to deoxyhaemoglobin, the form not binding oxygen.

Oxygen saturation is defined as the percentage of oxygen binding sites occupied by oxygen. SpO_2 is an approximation of the oxygen saturation, and it can be measured by a pulse oximeter in the peripheral blood. It is defined as the ratio of oxyhaemoglobin to the total concentration of haemoglobin present in the blood.

$$\mathbf{SpO_2 = HbO_2/(HbO_2+Hb)}$$

The principle of pulse oximetry is based on the difference in red (R) and infrared (IR) light absorption characteristics of oxy- and deoxyhaemoglobin. Oxyhaemoglobin absorbs infrared light better than red light, whereas deoxyhaemoglobin absorbs red light more then infrared light (Figure F-22).

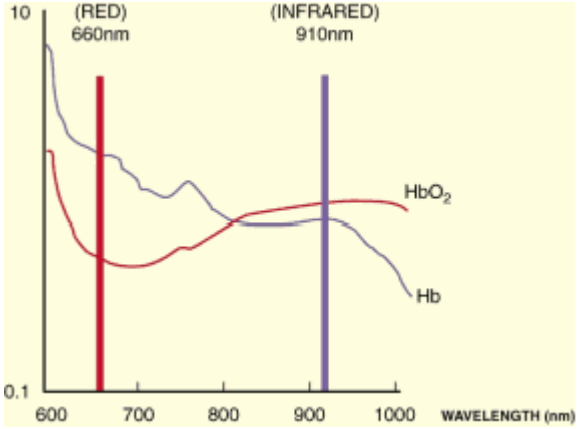


Figure F-22. Light absorption spectrum of oxy- (HbO_2) and deoxyhaemoglobin (Hb)

A pulse oximeter consists of a light emitter (with red and infrared LED light sources) and a light detector. The emitted light crosses a reasonably translucent and well perfused site (such as finger or earlobe in adults, palm or finger or foot in neonates) before it reaches the detector, which measures the light amount passing through the site (Figure F-23).

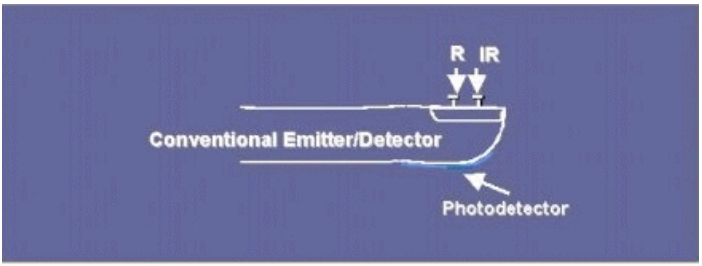


Figure F-23. Scheme of a pulse oximeter

Due to the difference in the absorption spectrum of the oxy- and deoxyhaemoglobin by measuring the amount of light passing through the measurement site at these two different light wavelength and calculating the R/IR ratio it is possible to asses an SpO_2 value using look-up tables (e.g. R/IR = 0.5 corresponds to approximately SpO_2 = 100% and R/IR = 1.0 to SpO_2 = 82%).

Light is absorbed by constant light absorbers such as skin, tissue and venous blood, as well as by pulsating arterial blood. For the calculation of SpO_2, which is an approximation of arterial oxygen saturation, the absorption caused by the constant non-pulsating parts has to be removed. A plethysmogram is the curve that visualizes the pulsating blood volume; it is delivered by the pulse oximeter (Figure F-24).

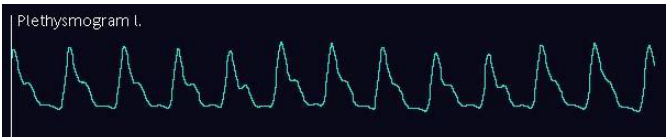


Figure F-24. Simultaneous pulse oximeter plethysmogram and airway pressure recording with POPmax and POPmin indicated on the plethysmogram

F.13 SpO_2/FiO_2

For the diagnosis of ARDS and ALI, the PaO_2/FiO_2 (P/F) ratio index is used, where PaO_2 is the partial pressure of oxygen in the arterial blood measured by arterial blood gas test, and FiO_2 is the fraction of inspired oxygen set on the ventilator. P/F is used as a measure of blood hypoxia.

SpO_2/FiO_2 (S/F) ratio is an approximation of the P/F, which in contrast to P/F can be calculated noninvasively and continuously. S/F ratio correlates well with the P/F ratio, in particular in adults S/F ratios of 235 and 315, in children 201 and 263 correspond to P/F ratios of 200 and 300. See the references in Section F.14.

Therefore, S/F ratio is a useful monitoring value for an easy bed side assessment of a patient's oxygenation status, and can be helpful relative to ALI and ARDS diagnosis and status follow up of these patients.

The S/F value is calculated on the HAMILTON-G5 if the measured SpO_2 is lower than 95%. With SpO_2 values greater than 94%, the oxygen-haemoglobin dissociation curve becomes "flat" and the SpO_2 correlation to PaO_2 is poor, making S/F ratio unreliable for P/F ratio approximation (Figure F-25).

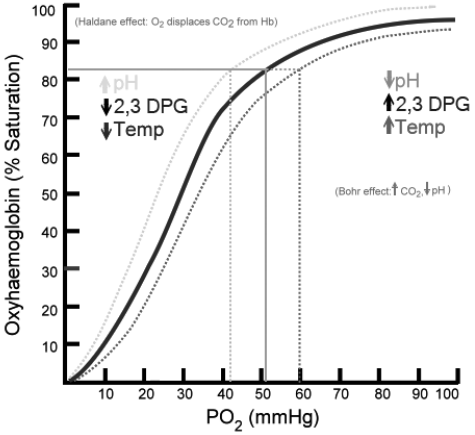


Figure F-25. Oxygen-haemoglobin dissociation curve

F.14 References

- **Rice TW, Wheeler AP, Bernard GR, Hayden DL, Schoenfeld DA, Ware LB.** Comparison on the SpO_2/FiO_2 ratio and the PaO_2/FiO_2 ratio in patients with acute lung injury or ARDS. Chest. 2007 Aug;132(2):410-7. Epub 2007 Jun 15.
- **Khemani RG, Patel NR, Bart RD 3rd, Newth CJ.** Comparison of the pulse oximetric saturation/fraction of inspired oxygen ratio and the PaO_2/fraction of inspired oxygenation in children. Chest. 2009 Mar;135(3):662-8. Epub 2008 Nov 24

APPENDIX

G Pneumatic diagram

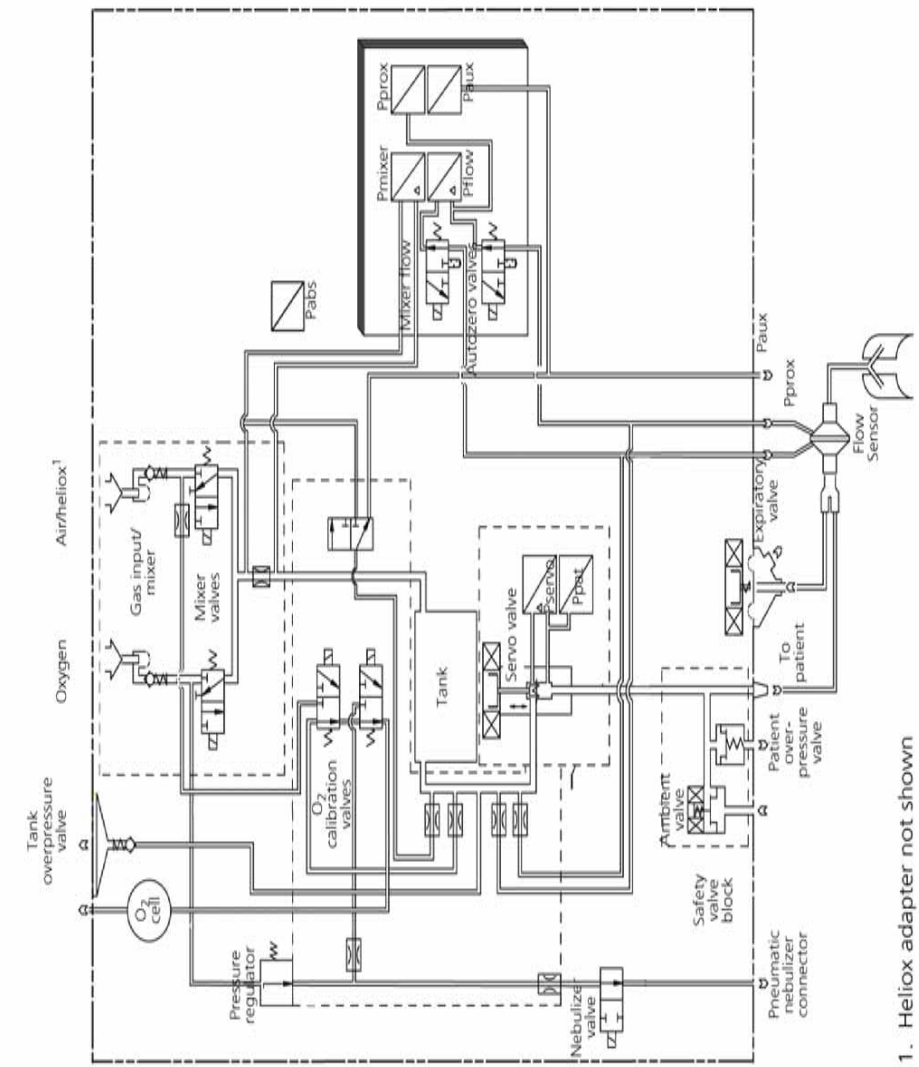


Figure G-1. Pneumatic diagram

APPENDIX

H Parts and accessories

Table H-1 and Figure H-1 show the user-orderable HAMILTON-G5 parts.

For additional parts and accessories, contact your HAMILTON MEDICAL representative.

NOTE:

Not all parts are available in all markets.

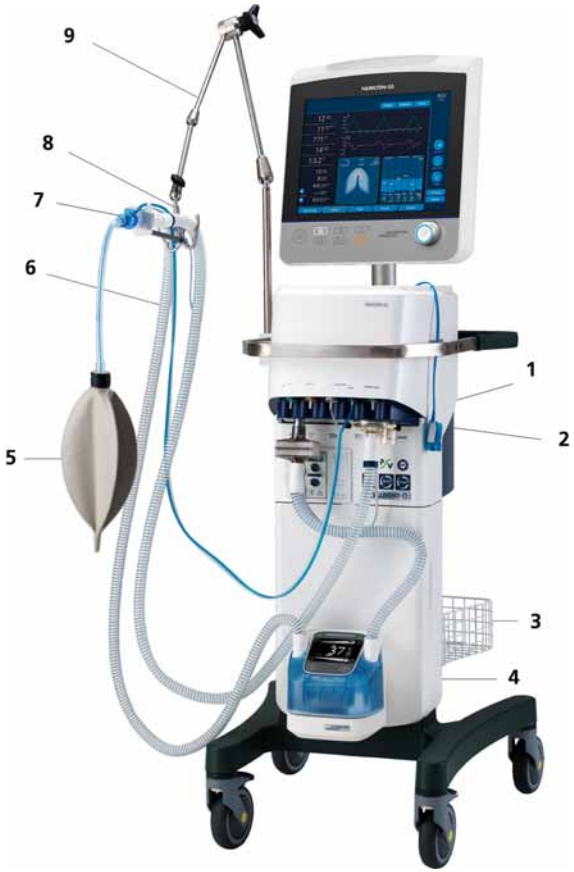


Figure H-1. Ventilator parts and accessories

Table H-1. Ventilator parts and accessories

Item No. (Figure H-1)	Description	REF-No.
1	Membrane, expiratory valve (package of 5) (Also included in all patient breathing circuits except PN 151965)	151233
2	Cover, expiratory valve (Also included in all patient breathing circuits except PN 151965)	151228
	Disposable expiratory valve including cover and membrane (box of six)	151972
3	Accessory basket, for trolley	159145
4	Humidifier (see your HAMILTON MEDICAL representative for ordering information)	--
	HAMILTON-H900 integrated humidifier See the HAMILTON-H900 Manual, pn 624431.	--
5	Demonstration lung assembly with endotracheal tube, 2 l, with 15 mm male x 22 mm male connector (adult)	151815
	Demonstration lung assembly with endotracheal tube, 0.5 l, with 15 mm male x 22 mm male connector (pediatric)[1]	151816
	Test lung model, IngMar neonatal[1]	R53353 (USA: 53353)
6	Patient breathing set (See your HAMILTON MEDICAL representative for ordering information)	--
7	Flow sensor, pediatric/adult, reusable (package of 10)	155362
	Flow sensor, pediatric/adult, single-use (package of 10)	281637
	Flow sensor, infant, single-use (package of 10)[1]	155500

Table H-1. Ventilator parts and accessories

Item No. (Figure H-1)	Description	REF-No.
8	Extension fork holder for quick-positioning support arm	281534
9	HAMILTON-G5 support arm, quick-positioning	281533
	Support arm, quick-positioning, basic[1]	281671
	Filter, fan[1]	391163
	HAMILTON-G Oxygen cell[1]	396008
	Oxygen cell, Teledyne[1]	396009
	Catalyst cell[1]	396018
	Standard trolley[1]	159121
	Universal trolley[1]	159120
	VENTILAIR II medical air compressor, 220 to 240 V ±10%, 50 Hz /230 V ±10%, 60 Hz[12] (together with universal trolley only)	155600
	VENTILAIR II medical air compressor, 100 to 115 V ±10%, 50/60 Hz[1] (together with universal trolley only)	155601
	Gas cylinder holder, for trolley[1] (together with universal trolley only)	159142
	Oxygen supply hose, white, 4 m[1]	281431
	Air supply hose, black/white, 4 m[1]	281432
	Power cord (See your HAMILTON MEDICAL representative for ordering information)[1]	--
	Operator's manual, SW V2.1x, English[1]	624302
	Operator's manual, SW V2.1x, French[1]	624305
	Operator's manual, SW V2.1x, German[1]	624303

Table H-1. Ventilator parts and accessories

Item No. (Figure H-1)	Description	REF-No.
	Operator's manual, SW V2.1x, Spanish[1]	624304
	Operator's manual, SW V2.1x, Russian[1]	624308
	Operator's manual, SW V2.1x, Portuguese[1]	624306
	Card, preoperational check, English[1]	624078
	Card, preoperational check, French[1]	624079
	Card, preoperational check, German[1]	624080
	Card, preoperational check, Spanish[1]	624081
	Cable, serial connector to computer, 2.5 m (8.2 ft). Shielded on male (ventilator) side only[1]	157354
	Extended battery pack[1]	369102
	Water bottle holder[1]	281575
	Nebulizer set, reusable[1] (see your HAMILTON MEDICAL representative for ordering information)[1]	151983
	CAPNOSTAT 5™ mainstream CO_2 sensor[1]	281718
	LoFlo CAPNOSTAT 5™ sidestream CO_2 sensor[1]	281928
	CO_2 preparation kit (module)[1]	159136
	Adapter, airway, CO_2 sensor, adult/pediatric, single-use, box of 10[1]	281719
	Adapter, airway, CO_2 sensor, infant/pediatric, single-use, box of 10[1]	281720
	Adapter, airway, CO_2 sensor, adult/pediatric, reusable[1]	281721
	Adapter, airway, CO_2 sensor, infant/pediatric, reusable[1]	281722

Table H-1. Ventilator parts and accessories

Item No. (Figure H-1)	Description	REF-No.
	Airway adapter set – ET > 4.0 mm[1]	281929
	Airway adapter set – ET ≤ 4.0 mm[1]	281930
	Airway adapter set H – ET > 4.0 mm[1]	281931
	Airway adapter set H – ET ≤ 4.0 mm[1]	281932
	nCPAP-PS Starter kit (20 sets incl. mask, prongs and bonnets)[1]	281975
	HAMILTON nCPAp-PS 20/box[1]	281976
	Prong nCPAP-PS xsmall 10/box	281977
	Prong nCPAP-PS small 10/box[1]	281978
	Prong nCPAP-PS medium10/box[1]	281979
	Prong nCPAP-PS large 10/box[1]	281980
	Prong nCPAP-PS xlarge 10/box[1]	281981
	Prong nCPAP-PS wide large 10/box[1]	281982
	Mask nCPAP-PS small 10/box[1]	281983
	Mask nCPAP-PS medium10/box[1]	281984
	Mask nCPAP-PS large10/box[1]	281985
	Bonnet nCPAP-PS xsmall 10/box[1]	281986
	Bonnet nCPAP-PS small 10/box1	281987
	Bonnet nCPAP-PS medium10/box[1]	281988
	Bonnet nCPAP-PS large 10/box[1]	281989
	Bonnet nCPAP-PS xlarge 10/box[1]	281990
	Bonnet nCPAP-PS xxlarge 10[1]	281991
	Bonnet nCPAP-PS xxxlarge 10[1]	281992

Table H-1. Ventilator parts and accessories

Item No. (Figure H-1)	Description	REF-No.
	Headbands 8 sizes reuse	281993
	nCPAP-PS measurement tape	281994
	Masimo SET SpO_2 pulse oximeter See the Masimo SET Accessories & Consumables list, pn 689484.	--
	Masimo Rainbow SET (SW option) See the Masimo Rainbow SET Accessories & Consumables list, pn 689485.	--
	Nihon-Kohden SpO_2 sensor adapter, USA/CAN (w/o probes)[1]	282009
	Nihon-Kohden S SpO_2 sensor adapter, INTER-NAT. (w/o probes)[1]	282010
	Finger probe[1]	281947
	Multi-site[1]	281948
	Finger-tip probe, regular[1]	281949
	Finger-tip probe, large[1]	281950
	Adult finger or toe probe, 24pcs/set[1]	281951
	Child finger or toe probe, 24pcs/set[1]	281952
	Neonate instep, 24pcs/set[1]	281953
	Infant finger or toe probe, 24pcs/set[1]	281954
	Multi-site Y probe, 5pcs/set[1]	281955
	Attachment tape S, 24pcs/set[1]	281956
	Attachment tape L, 24pcs/set[1]	281957
	Clip adapter[1]	281958

Table H-1. Ventilator parts and accessories

Item No. (Figure H-1)	Description	REF-No.
	Adapter, 15M x 15 F (Connects the CO_2 infant/ pediatric airway adapter and infant flow sensor)[1]	281803
	Heliox option kit (Includes option license, heliox adapter assembly, and mating fitting for heliox hose)[1]	159135
	Aerogen nebulizer cable[1]	159566
	Nebulizer unit with cap[1]	AGAP1000
	Silicone plug for tee[1]	AGAP1005
	Adult tee with plug (5P)[1]	AGAP1010
	Pediatric tee with plug (5P)[1]	AGAP1020
	Neonate adapter kit (5P)[1]	AGAP1025
	Filter cap (5P)[1]	AGAP1030
	Vented elbow (5P)[1]	AGAP1055
	Mask kit US (5P)[1]	AGAP1065
	Mask kit international (5P)[1]	AGAP1075
	Aeroneb solo conv. PKT5[1]	AGAS3300
	Aeroneb solo conv. PKT10[1]	AGAS3350
	Brochure ONQ aerosol generator[1]	AGMM0102

1. Not shown
2. Not available in the USA

APPENDIX

I Communication interface

I.1 Introduction

WARNING

To reduce the risk of excessive leakage current due to ground loops, and to prevent electromagnetic interference (EMI), ensure the connecting cable has a high-quality shield and is grounded properly *on one side only*, either at the ventilator or receiving device.

NOTE:

- Additional equipment connected to medical electrical equipment must comply with the respective IEC or ISO standards (e.g. IEC 60950 for data processing equipment). Furthermore all configurations shall comply with the requirements for medical electrical systems (see IEC 60601-1-1 or clause 16 of the 3Ed. of IEC 60601-1, respectively). Anybody connecting additional equipment to medical electrical equipment configures a medical system and is therefore responsible that the system complies with the requirements for medical electrical systems. Attention is drawn to the fact that local laws take priority over the above mentioned requirements. If in doubt, consult your local representative or the technical service department.
- This interface includes EMI-protective covers for the connectors. When the connectors are not in use, ensure the covers are installed.
- Ensure the option is enabled before you use the interface (see Section J.9).
- **Check ...** messages, which indicate a setting conflict, are not sent to the remote alarm outlet. To show all low-priority alarms, HAMILTON MEDICAL recommends you read them directly from the device's touch screen or consult the event log.

- The delay time from the onset of an alarm condition to the point that the representation of the alarm condition leaves the signal input/output port (of the communications interface) is typically 500 ms. The time it takes the message to appear on the connected monitor depends on the characteristics of the patient monitor.
- See Section J.8 for all production log information.

The communications interface option offers these capabilities:

- The RS-232 interface (2 ports) outputs monitored data, ventilator settings, and alarms to a monitoring device, a patient data management system (PDMS), or an other computer system.
- The I:E timing outlet outputs signals for time of insufflation, pause, and exhalation. These are used for special applications, such as an external nebulizer.
- The remote alarm outlet outputs alarm signals to a nurse call device.

A ventilator has three connectors at the back (Figure I-5). The patient monitor or computer connects to the Monitoring Interface connectors. The nurse call or other device connects to the Special Interface connector.

I.2 RS-232 interface

The RS-232 interface lets the HAMILTON-G5 send monitored data, waveforms, modes, control settings, and alarms to a patient monitor, a patient data management system (PDMS), or an other computer system through two Monitoring Interface connectors. Table I-3 lists the pin assignments for these connectors.

With the Humidifier option, you can connect the HAMILTON-H900 communication cable (see Figure 2-9) from the humidifier to the ventilator RS-232 port. This allows transfer of humidifier data to a connected PDMS. This connectivity is included with the option.

The interface uses two protocols: the Polling protocol, which sends the data only on request, and the block protocol, which sends data blocks continuously.

Hamilton Medical provides two communication protocols:

- **The Hamilton RS232 Polling Protocol (standard):**

  Standard Protocol for HAMILTON-G5/S1 to connect monitoring devices. It recognizes whether the Hamilton Protocol or the VueLink Open Protocol is used by the attached monitoring device. The protocol sends waves and parameter data only on request (polling).

  (The Galileo Polling Protocol is a compatibility mode that emulates the Galileo Polling Protocol).

- **The Hamilton RS232 Block Protocol on a G5/S1 (new):**

  The Hamilton Block Protocol sends all waves and parameter data once, every breath or continuously in blocks.

  Compared to the Hamilton Polling Protocol it is not limited by the amount of data possible to transmit.

You need to have a compatible monitoring device with the implemented protocol. For more information about the protocols contact HAMILTON MEDICAL.

I.3 Patient monitor

WARNING

To prevent possible patient injury when using a patient monitor, observe the patient and the ventilator whenever the monitor reports a ventilator alarm. Use caution as not all monitors provide detailed alarm message information.

NOTE:

- If your monitor does not recognize and report all modes and parameters (for example, ASV mode, peak pressure monitoring parameter). Additionally, some specific alarms could not be recognized, but reports them as general alarms. In such cases, HAMILTON MEDICAL recommends that you read the data directly from the HAMILTON-G5 screen.
- Silencing the device's audible alarm DOES NOT automatically silence the audible alarm of the remote patient monitor.
- To connect your HAMILTON-G5 to a monitor other than those described below, consult with the monitor manufacturer.

With the RS-232 interface, the device can send data to various patient monitors.

Using the device with a patient monitor requires the hardware shown in Figure I-1. Interfacing hardware specific to the manufacturer's monitors is listed in Table I-1.Order this interfacing hardware directly from the monitor manufacturer.

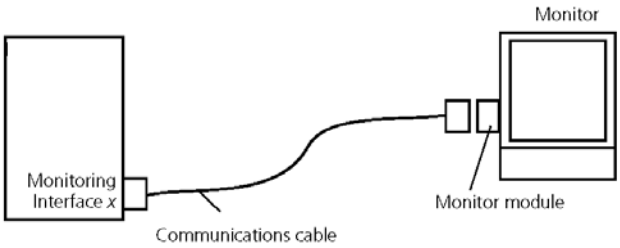


Figure I-1. HAMILTON-G5 connected to a patient monitor

Table I-1. Interfacing hardware for patient monitors

Manufacturer	Interfacing hardware required	Notes
Philips Medical Systems	VueLink Open interface cable with 25M connector, VueLink module with VueLink Open driver	--
Spacelabs Medical (GE Medical Systems)	Flexport converter and cable for HAMILTON MEDICAL ventilators	--
GE Marquette Medical Systems	Octanet and cable for HAMILTON MEDICAL ventilators	Tram-net is not compatible
Schiller	Cable for HAMILTON MEDICAL ventilators	--
Dräger Medical	MIB II Protocol Converter or MIB II Duo Protocol Converter and HAMILTON-G5 MIB interface cable	For use with Dräger/Siemens Infinity Modular Monitors. Contact HAMILTON MEDICAL Technical Support.
Nihon Kohden BSM-4100/5100 series bedside monitor	QI-407P interface	--

I.4 PDMS or other computer system

WARNING

The computer connected to the HAMILTON-G5 should be for medical use and meet the requirements of IEC 60601-1. Alternatively, a battery-powered laptop computer can be used. DO NOT connect other types of personal computer (PC), because such computers do not fulfill the requirements of the standard. Consult a technical specialist or safety inspector in your hospital for more information.

From the RS-232 interface, the device can transmit data from the ventilator to a patient data management system (PDMS), or other computer system. Data from the ventilator can be processed with software such as Microsoft® Excel. This is a useful tool for data management and clinical studies.

This application requires the hardware shown in Figure I-2. It also requires Data Logger software and manual; contact your HAMILTON MEDICAL representative.

For more information about the communications protocol, contact HAMILTON MEDICAL.

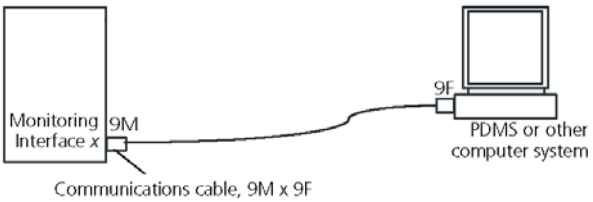


Figure I-2. HAMILTON-G5 connected to a computer system

Table I-2. Requirements for interfacing PDMS's

Manufacturer	Interfacing hardware required	Notes
Centricity® Critical Care Clinisoft care station	Centricity Ethernetbox and cables	Formerly known as Datex-Ohmeda S/S CCIMS
Capsule Technologie PDMS	DataCaptor Device Interfaces (DDIs)	RS-232 to XML, HL7
iMDsoft® MetaVision Clinical Information System	Consult iMDsoft representative	--

I.5 Inspiratory:Expiratory (I:E) timing outlet

The I:E timing outlet lets your HAMILTON-G5 send I:E timing signals through the 15-pin (Special Interface) connector. This is useful to administer nitric oxide (NO), or when using an external nebulizer.

This application requires the hardware shown in Figure I-3. The Connector Pin Assignment subsection below lists the pin assignments for this connector. Before using the outlet, make sure it is correctly configured (Figure I-3). The I:E timing capability is based on a relay inside the ventilator.

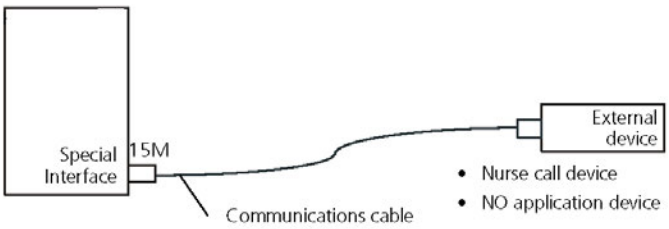


Figure I-3. HAMILTON-G5 connected to an external device through the Special Interface connector

I.6 Remote alarm outlet

NOTE:

- Before operating the remote alarm function (nurse call), ensure that the remote alarm function is operational.
- When the remote alarm function (nurse call) is used in an isolation ward, regularly verify the remote alarm function is operational.

The remote alarm (nurse call) capability allows alarm conditions to be activated at locations away from the ventilator (for example, when the ventilator is in an isolation room).

This application requires the hardware shown in Figure I-4. The device sends alarm signals to a nurse call device through the 15-pin (Special Interface) connector. The Connect Pin assignment subsection (see Table I-3) lists the pin assignments for this connector.

Press the alarm silence key located on the Ventilator Cockpit to silence the audible portions of both alarms on the ventilator and the remote alarm device.

The remote alarm capability is based on a relay inside the ventilator. Figure I-4 show the alarm and non-alarm circuit positions for the relay. Use either pins 7 and 14 or pins 7 and 6, depending on the logic of your nurse call system (normally open or normally closed).

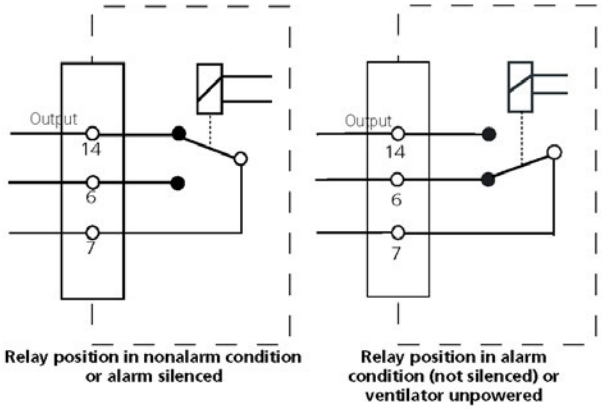


Figure I-4. Remote alarm relay positions

1 Relay position in nonalarm condition or alarm silenced

2 Relay position in alarm condition (not silenced) or ventilator unpowered

I.7 Connector pin assignments

Figure I-5 shows the locations of the interface connectors and pins. Table I-3 lists the pin assignments for these connectors.

The maximum allowable voltage and current between the relay contacts are 48 V, 0.5 A.

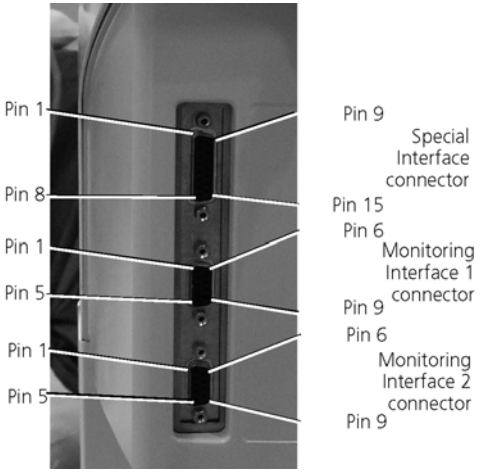


Figure I-5. Interface connectors

Table I-3. Interface connector pin assignments

Monitoring interface connectors	
Pin	**Signal**
1	GND
2	RXD
3	TXD
4	DTR
5	GND (signal ground)
6	DSR
7	RTS
8	CTS
9	--
Shield	Chassis ground

Special interface connectors	
Pin	**Signal**
1	--
2	--
3	--
4	--
5	--
6	Remote alarm return (see Figure I-4)
7	Remote alarm
8	I:E relay
9	--
10	--
11	--
12	--
13	--
14	Remote alarm return (see Figure I-4)
15	I:E relay return

APPENDIX

J Configuration

J.1 Introduction

During configuration, you set up the ventilator with a default language, breath timing control philosophy, main monitoring parameter display, and nebulization parameters.

Operator configuration also lets you enable and disable alarms and set up the I:E timing outlet. You typically configure the ventilator when you first acquire it, before you put it in service on a patient.

NOTE:

For details on INTELLiVENT®-ASV and Quick Wean configuration, see the INTELLiVENT®-ASV manual.

For details on SpO_2 configuration, see Appendix F, Pulse oximetry.

J.2 Begin configuration

1. To begin the Configuration process, put the ventilator into Standby.
2. Press the  and  buttons at the same time. The **Configuration** button is then displayed.
3. Touch the **Configuration button**. The Configuration window opens (Figure J-1).
4. Begin device configuration, identify your requirements, and then activate them.

   For more detail on specific instructions, read the next subsections to configure your ventilator.
5. Touch **Close** when done with each panel.
6. When you are done configuring the ventilator, touch **Close/Save** to save your selections.
7. Return to the Patient setup window.

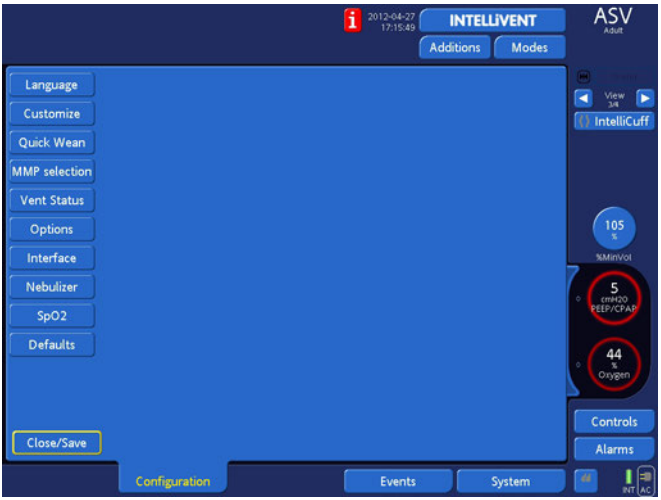


Figure J-1. Configuration window

J.3 Language: Choosing the default language

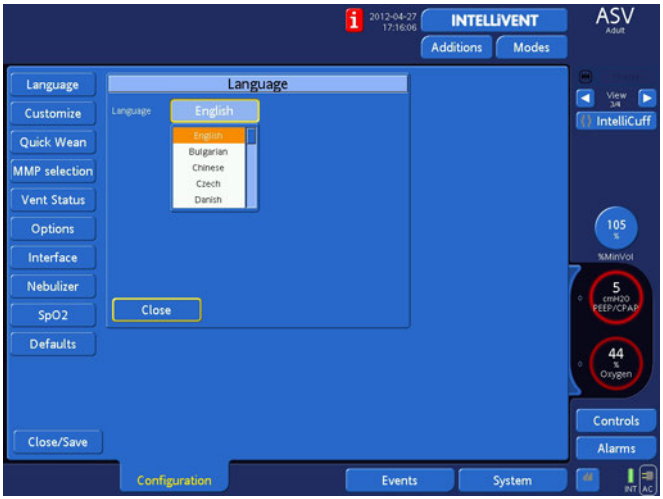


Figure J-2. Language window

The **Language** window lets you choose the language for the screen display.

To set the language:

1. Select the **Language -> English** button. A drop-down list opens.
2. Use the scroll arrows to display the desired language (highlighted). Select the language
3. Touch **Close**.
4. If you are done configuring the ventilator, touch **Close/ Save** to save your selections.

You return to the Configuration window.

J.4 Customize: Choosing the ventilation philosophy and alarms

The **Customize** window (Figure J-3) lets you choose what breath timing philosophy to use and what units of measure to use, and whether to enable/disable your operator-set alarms.

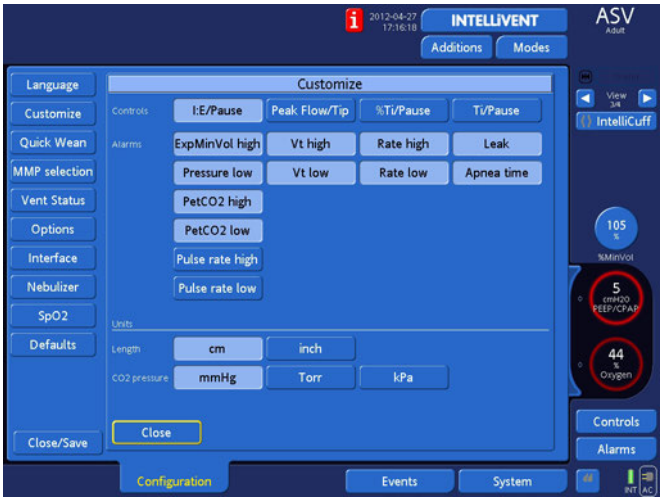


Figure J-3. Customize window

To enable alarms:

1. Click the alarm entries to enable.
2. Choose from the following parameters:

Parameter	Notes
Controls (ventilation philosophies)	Select a preferred way to define time profiles of breath cycles.
Alarms	Enable from 0 to 8 operator-set alarms. If an alarm is disabled, it will not be possible to set it from the **Alarms** window, and the device will not alarm for this condition. The high Pressure and low ExpMinVol alarms cannot be disabled. See Appendix A for details on the alarm settings.
Length	Select the unit of measure for patient height.
CO_2 pressure	Select the unit of measure for CO_2 pressure.

3. Touch **Close**.
4. If you are done configuring the ventilator, touch **Close/ Save** to save your selections.

J.4.1 Breath timing philosophies (adult patients)

The operator defines mandatory breath timing with settings that may include:

- Breath rate, in b/min (Rate)
- Inspiratory:expiratory ratio (I:E)
- Duration of inspiration phase not including pause, in seconds or % of total cycle time (TI or %TI)
- Duration of inspiratory pause/plateau, in seconds (Pause or Tip)
- Peak flow, in l/min (Peak Flow)

The relationships between these breath timing parameters are shown in Figure J-4.

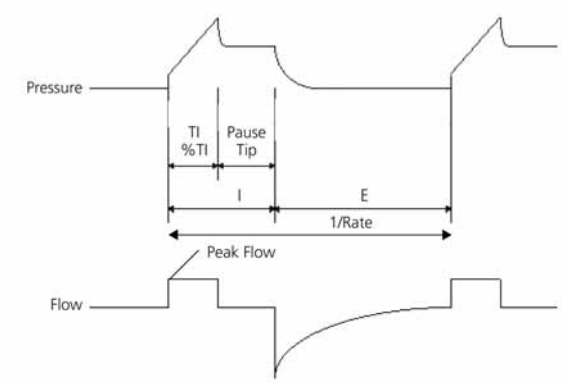


Figure J-4. Relationships between breath timing settings

Different hospitals are accustomed to specifying breath timing in different ways, however. The HAMILTON-G5 ventilator provides the flexibility to configure breath timing for adult patients in whichever way is most familiar and comfortable.

It offers four breath timing "philosophies" corresponding to four different ways of making these settings. You can choose from one of these four philosophies when you configure the device. Then, when you ventilate an adult patient on the device, your chosen philosophy is displayed.

The four philosophies are:

- I:E/Pause
- Peak Flow/Tip
- %TI/Pause
- TI/Pause

Table J-1 shows the active timing control settings corresponding to each philosophy.

Table J-1. Timing controls applicable to breath timing control philosophies[1]

Philosophy	Adult				Pediatric		Infant/ neonatal
	(S)CMV	P-CMV APV_{cmv}	SIMV	P-SIMV APV_{simv}	(S)CMV SIMV	P-CMV P-SIMV APV_{cmv} APV_{simv}	P-CMV P-SIMV APV_{cmv} APV_{simv}
I:E/ Pause	I:E, Pause	I:E	TI, Pause	TI	TI, Pause	TI	TI
Peak Flow/ Tip	Peak Flow, Tip	%TI	Peak Flow, Tip	%TI	TI, Pause	TI	TI
%TI/ Pause	%TI, Pause	%TI	%TI, Pause	%TI	TI, Pause	TI	TI
TI/ Pause	TI, Pause	TI	TI, Pause	TI	TI, Pause	TI	TI

1. SPONT, ASV, DuoPAP, NIV, DuoPAP, and APRV modes are not shown, because breath control timing philosophies do not apply to these modes.

J.5 Quick Wean: Choosing the default weaning activity criteria

Only available with the INTELLiVENT®-ASV option. The Quick Wean configuration screen gives you access to the settings to specify conditions for starting weaning activities, settings to be maintained during an SBT, and conditions for aborting ongoing weaning activities.

The factory default settings are evidence based (see references in the INTELLiVENT®-ASV manual). However, you can change the settings if you use a different protocol.

For detailed information about setting the parameters, recommended settings, and using Quick Wean, see the INTELLiVENT®-ASV manual.

Figure J-5. Quick Wean To start settings

Figure J-6. Quick Wean SBT settings

Figure J-7. Quick Wean To abort settings

To set the Quick Wean SBT settings:

1. In the **To start** window (Figure J-5), specify settings for the conditions to be met before weaning activity, including automated SBTs when enabled, is possible. Set the desired value for each parameter, for adult patients (top) and for pediatric patients (bottom).
2. Click the **SBT settings** tab (Figure J-6) and specify the desired settings for values to maintain during an SBT.
3. Click the **To abort** tab (Figure J-7) and specify the conditions that must be met for ongoing weaning activity, including an SBT, to be stopped.
4. Touch **Close**.
5. If you are done configuring the ventilator, touch **Close/Save** to save your selections.

J.6 MMP selection: Choosing the default main monitoring parameter display

From the **Main Monitoring Parameter selection** window (Figure J-5) you select the five main monitoring parameters to be displayed on the screen. These parameters will be displayed in the order selected.

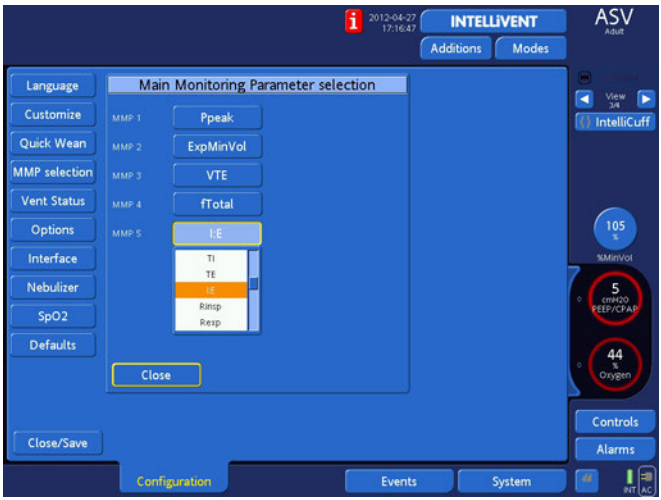


Figure J-8. Main Monitoring Parameter selection drop-down list

To set the main monitoring parameters:

1. Select a parameter position (MMP1 is the top position; MMP5 is the bottom position). A drop-down list opens.
2. Select the parameter for display.
3. Repeat step 1 and 2 for the other four parameter positions.
4. Touch **Close**.
5. If you are done configuring the ventilator, touch **Close/ Save** to save your selections.

J.7 Vent Status: Configuring the Vent Status intelligent panel

When the **Vent Status** window is open, (Figure J-9) you can configure the Vent Status intelligent panel (Figure J-10) according to your institution's protocol for weaning.

Oxygen, PEEP, MinVol, and Pinsp are always shown in the Vent Status panel, but you can configure the remaining two parameters from these choices: RSB or P0.1, and VariIndex[1] or %fSpont.

When Quick Wean is enabled, the Vent Status window monitors weaning settings. For details, see the Quick Wean chapter in the INTELLiVENT®-ASV manual.

Figure J-9. Vent status window

1. The variability index (VariIndex) parameter is not available in all markets.

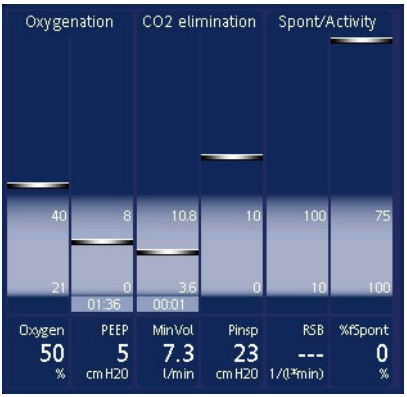


Figure J-10. Vent status intelligent panel

To select the Vent Status parameters:

1. Open the **`Vent Status`** window.
2. From the RSB, VariIndex[1], P0.1, and %fSpont parameters, select 2 (two) for display.
3. Select a parameter and adjust the value. Repeat the steps to select other required parameters.
4. Select **`Set factory default`** and revert the device to factory settings (see Section J.12).
5. Touch **`Close`**.
6. If you are done configuring the ventilator, touch **`Close/ Save`** to save your selections.

1. The variability index (VariIndex) parameter is not available in all markets

J.8 Options: Activating software and hardware options

NOTE:

In addition to activating CO_2 and/or SpO2, you must also enable the option(s) in the **System** window (Section 4.3.3).

To view the Options window (Figure J-11), touch the **Options** button. Select and activate software and hardware options.

Figure J-11. Options window

To configure options:

1. Enter the software option activating code from the accompanying license. Select **Enter**.
2. Repeat step 1 until all options are entered.
3. Select the desired hardware option. Press **Enter**.
4. Touch **Close**.
5. If you are done configuring the ventilator, touch **Close/Save** to save your selections.

J.9 Interface: Configuring the I:E timing outlet

The Interface window (Figure J-12) lets you configure the I:E outlet.

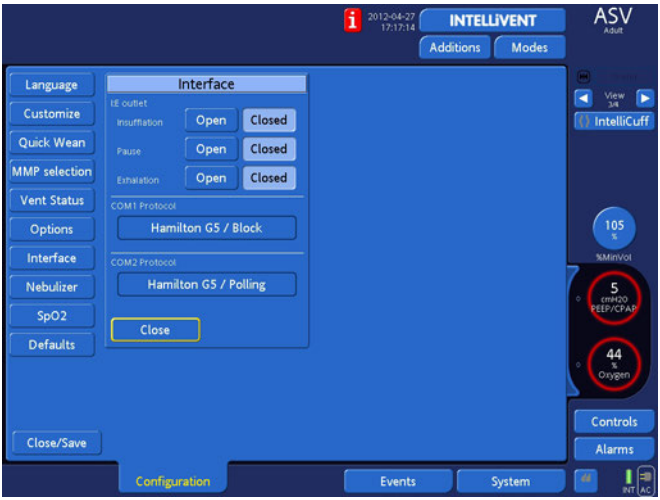


Figure J-12. Interface window

To configure the interface:

1. Determine the desired relay positions (**Open** or **Closed**) for each of the three breath cycle phases (**Insufflation, Pause,** and **Exhalation**).
2. Select a relay position.
3. Touch **Close**.
4. If you are done configuring the ventilator, touch **Close/ Save** to save your selections.

See Appendix I, Communication interface, for information on the communications interface option.

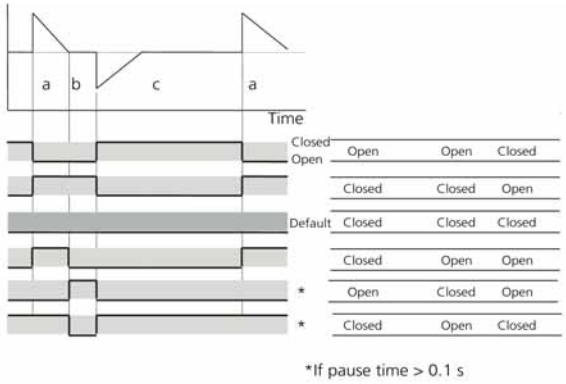


Figure J-13. I:E outlet timing

J.10 Nebulizer: Configuring the nebulizer type

NOTE:

If you are using an external pneumatic nebulizer ensure to configure the nebulizer. This configuration helps prevent nuisance alarms due to inappropriate nebulizer volume compensation.

With the **Nebulizer** window opened you can select a nebulizer type, or if you use the device's internal nebulizer select **Internal**.

The internal nebulizer function adds volume to the gas delivered to the patient, but selecting **Internal** compensates the total volume so that the set tidal volume is delivered.

If an external nebulizer is being used, either a pneumatic (small-volume) nebulizer powered by an external gas source or a standalone ultrasonic or electronic (piezo) micropump nebulizer, select **External**. This deactivates volume compensation. Then configure the nebulizer:

Figure J-14. Nebulizer window

To select the nebulizer type:

1. Select either the **`Internal`** or **`External`** button.
2. Touch **`Close`**.
3. If you are done configuring the ventilator, touch **`Close/ Save`** to save your selections.

J.11 SpO_2: Configuring pulse oximeter settings

Setting up the pulse oximeter comprises the following steps.

For detailed information about setting the parameters for the Masimo pulse oximeter, see Appendix F, Pulse oximeters.

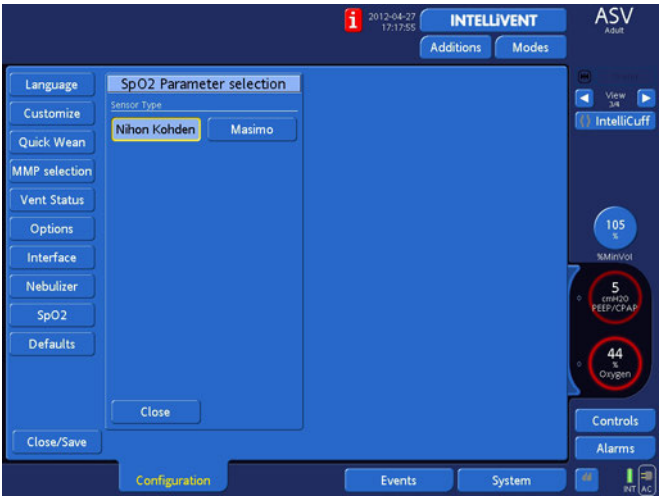


Figure J-15. SpO_2 Parameter selection window

To select the pulse oximeter type:

1. Select either the **`Nihon Kohden`** or **`Masimo`** button.

   When you select **`Masimo`**, the Data Acquisition settings are displayed.

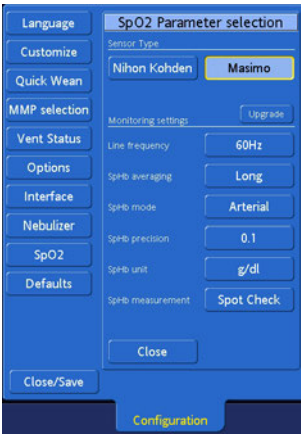


Figure J-16. Masimo Data Acquisition settings

2. Select the appropriate options. For details, see Section F.8.1.1.
3. Confirm the selection and touch **Close**.
4. If you are done configuring the ventilator, touch **Close/ Save** to save your selections.

Configuring the Masimo pulse oximeter settings continues in the **System -> Sensors On/Off** window and in the **System -> SpO2** window. For details, see Section F.8.1.3.

J.12 Defaults: configuring default settings

The **Defaults** window open you can configure default settings for mode and controls. All operator set defaults can be configured individually for each patient group.

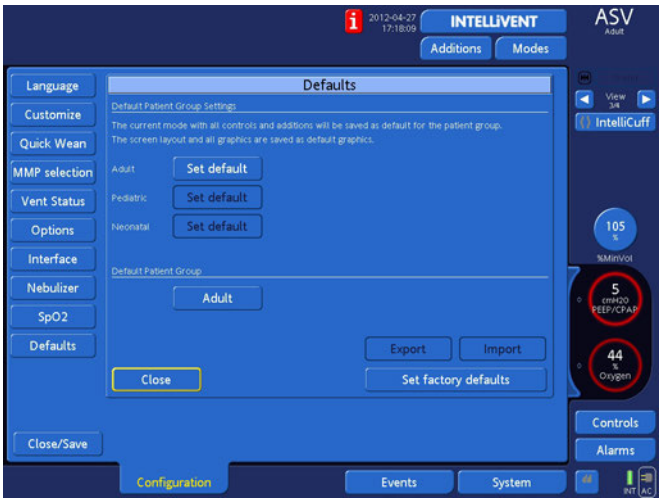


Figure J-17. Defaults window

To configure default settings:

1. Starting from the **Standby** screen, select the patient group for which you want to configure default settings.
2. Start normal ventilation using a lung model.

3. Define your defaults for the selected patient group.

   A. In the **Modes** window, select the mode you want to set as default for the active patient group.

   B. Adjust all controls in the **Controls** window according to your institution's standards as default controls.

   C. In the **Additions** window, set **TRC** and **Sigh** according to your institution's standards.

   D. Use the graphics layout in the **Graphics** window to configure the graphics layout. Activate the secondary monitoring parameters (**SMP**) according to your institution's standard for waveforms, loops, trends and the Intelligent Panels for the default graphics layout.

4. After setting mode, controls, addition and graphics return to the **Standby** window and activate the **Configuration > Defaults** window.

   For the last active patient group (where you set your defaults) the **Set default** button is available.

5. Save your default configuration for the active patient group. After pressing the **Set default** button a confirmation window opens.

6. Repeat these steps for the remaining patient groups.

   The default patient group can also be selected in the **Defaults** window. This patient group will be the default for **New Patient**.

7. Select the current patient group. A drop-down list opens.

8. Touch **Close**.

9. If you are done configuring the ventilator, touch **Close/ Save** to save your selections.

Note that selecting **Set factory defaults** deletes all user-configured defaults (mode, controls and graphics).

Glossary

A	Ampere, a unit of current.
AC	Alternating current.
Aeroneb	Integrated nebulization tool
active alarm buffer	Contains information on up to six currently active alarms.
alarm delay	Used with Masimo pulse oximeter. The SpO_2 value must be above or below the specified alarm limits for the selected amount of time before the audible alarm sounds.
alarm lamp	Lamp atop the HAMILTON-G5 that lights in a color corresponding to the active alarm.
alarm silence key	Silences alarm sound for 2 min.
ALI	Acute lung injury.
ambient state	An emergency state, in which the ventilator opens the ambient and exhalation valves and closes the inspiratory valves. This lets 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 mode.
APVcmv	Adaptive pressure ventilation CMV mode.
APVsimv	Adaptive pressure ventilation SIMV mode.
ARDS	Adult respiratory distress syndrome.
ASV	Adaptive support ventilation, a positive pressure ventilation mode intended to adapt with the patient as he/she progresses from full mechanical ventilation to spontaneous breathing.

ASV target graphics window	ASV graphical data representation, an Intelligent Panel.
ASV monitored data window	ASV numeric patient data, an Intelligent Panel.
ATPD	Ambient temperature and pressure, dry.
AutoPEEP	Unintended positive end-expiratory pressure, a monitored parameter.
b/min	Breaths per minute.
backup	Apnea backup ventilation.
breathing circuit	Includes the inspiratory-expiratory tubing, humidifier, filters, and water traps.
breathing pattern	A specific sequence of breaths (CMV, IMV, or CSV) with a designated control variable (volume, pressure, or dual control) for the mandatory breaths (or the spontaneous breaths for CSV).
bronchial tree	A part of the Dynamic Lung that shows resistance.
BTPS	Body temperature, barometric pressure, saturated with water vapor.
C	Compliance.
cursors	Linear compliance between cursors 1 and 2, a calculated parameter displayed by the P/V Tool.
CE	A certification mark that indicates compliance with the Medical Device Directive, 93/42/EEC.
cm	Centimeter, a unit of length.
cmH_2O	Centimeters of water, a unit of pressure. 1 cmH_2O is approximately equal to 1 mbar, which equals 1 hPa.
CMV	Controlled mandatory ventilation.
CO_2 sensor	An optional mainstream CO_2 sensor.
Cockpit	Ventilation Cockpit.

communications interface	An option that lets you monitor the patient from a remote workstation, that transmits alarms through a nurse call relay system, and that transmits I:E timing signals.
CompactFlash	A type of data storage device that can be used to capture screens or install software on the HAMILTON-G5.
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.
DIN	Deutsches Institut für Normung (German institute for standardization).
DISS	Diameter index safety standard, a standard for high-pressure gas inlet fittings.
DuoPAP	Duo positive airway pressure ventilation mode.
Dynamic Lung	An Intelligent Panel that visualizes tidal volume, lung compliance, patient triggering, and resistance in real-time.
E	Exhalation.
EMC	Electromagnetic compatibility.
EMI	Electromagnetic interference.
emergency buzzer	The buzzer designed to sound for at least 2 min as a backup to the alarm speaker.
EN	European Norm, a European standard.
End PEEP	PEEP to be applied after the maneuver, a control setting for the P/V Tool maneuver.
ET	Endotracheal.
ETO	Ethylene oxide.
ETS	Expiratory trigger sensitivity, a control setting.

event log	A record of clinically relevant ventilator occurrences, including alarms, setting changes, calibrations, maneuvers, and special functions since the ventilator was powered on. The HAMILTON-G5 has three event logs: a Settings log, an Alarms log, and an All events log.
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.
extended battery pack	An optional, hot-swappable "smart" battery on the HAMILTON-G5, which extends the backup capability of the standard internal battery.
f	Respiratory rate.
FCO_2	Fractional concentration of CO_2.
fcombi	A parameter trend setting including both fControl and fSpont.
fControl	Mandatory breathing frequency, a monitored parameter in ASV mode.
$FetCO_2$	Fractional end-tidal CO_2 concentration, a monitored parameter.
FiO_2	Fraction of inspired oxygen.
FlowPattern	Flow pattern, a control setting.
Flowtrigger	Flow trigger sensitivity, a control setting.
FRC	Functional residual capacity, the volume in the lungs at the end-expiratory position.
%fSpont	Spontaneous breath percentage, a monitored parameter in the Vent Status panel only.
fSpont	Spontaneous breathing frequency, a monitored parameter.
fTotal	Total breathing frequency, a monitored parameter. The moving average of the patient's total breathing frequency over the past 8 breaths.

ft	Foot, a unit of length.
Gender	Sex of patient, a control setting.
HME	Heat and moisture exchanger (artificial nose).
hPa	Hectopascal, a unit of pressure. 1 hPa is equal to 1 mbar, which is approximately equal to 1 cmH_2O.
Hz	Hertz, or cycles per second, a unit of frequency.
I	Inspiration.
IBW	Ideal body weight.
ICU	Intensive care unit.
ID	Inner diameter.
IEC	International Electrotechnical Commission.
I:E	Inspiratory:expiratory ratio, a setting, timing parameter, and monitored parameter. Ratio of inspiratory time to expiratory time.
IMV	Intermittent mandatory ventilation.
in.	Inch, a unit of length.
Insp Flow	Peak inspiratory flow, a monitored parameter.
Insp time	Inspiratory time, in ASV.
inspiratory hold	A respiratory maneuver in which gas is retained in the patient's airways, often for X-raying purposes.
Intelligent Panel	A type of graphic display on the HAMILTON-G5. The Intelligent Panels include the Dynamic Lung, Vent Status, ASV target graphics window, and ASV monitored data window panels.
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 %Min-Vol, PEEP and oxygen adjustment, based on physiological patient conditions.

internal battery	The integral backup battery on the HAMILTON-G5.
IPP	Interaction panel processor.
IRV	Inverse ratio ventilation.
ISO	International Organization for Standardization, a world-wide federation of national standards bodies.
J	Joule, a unit of work.
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.
Leak	Percent leakage volume, an alarm setting.
Loudness	Alarm loudness, a control setting.
LSF	Least squares fitting, a mathematical procedure for finding the best fitting curve to 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	A breath for which either the timing or size is controlled by the ventilator. That is, the machine triggers and/or cycles the breath.
manual breath	A user-triggered mandatory breath started by pressing the **`Manual breath`** key.
mbar	Millibar, a unit of pressure. 1 mbar equals 1 hPa, which is approximately equal to 1 cmH_2O.
%MinVol	Percentage of minute ventilation, a control setting in ASV mode.
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 it in the ASV target window.

ml	Milliliter, a unit of volume.
MMP	Main monitoring parameters.
ms	Millisecond, a unit of time.
nCPAP-PS	Ventilation mode which applies nCPAP by nasal interfaces with reduced dead space on neonates.
NIST	Non-interchangeable screw thread, a standard for high-pressure gas inlet fittings.
NIV	Noninvasive ventilation.
NIV-ST	Spontaneous/timed noninvasive ventilation, a ventilation mode.
O_2	Oxygen.
Oxygen	Oxygen concentration of the delivered gas, a setting and monitored parameter.
P0.1	Airway occlusion pressure, a monitored parameter.
Patient	Patient type, a control setting.
Patient height	A control setting used to compute the patient's ideal body weight (IBW).
Pause	Inspiratory pause, a control setting and timing parameter.
Paux	Auxiliary pressure.
Paw	Airway pressure.
PCO_2	Partial pressure of CO_2.
Pcombi	A parameter trend setting including Ppeak, Pmean, and PEEP/CPAP.
Pcontrol	Pressure control, a control setting in P-CMV and P-SIMV modes. Pressure (additional to PEEP/CPAP) to be applied during the inspiratory phase.
Pcursor	Monitored pressure at selected point, a displayed value when the P/V Tool's cursor measurement function is active.
Peak Flow	Maximum flow during the breath cycle, a control setting.

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.
$PetCO_2$	End-tidal CO_2 pressure, a monitored parameter.
P high	High positive airway pressure level, a control setting.
PI	Perfusion index, an indicator of pulse strength. A monitored parameter.
Pinsp	Inspiratory pressure, the target pressure (additional to PEEP/CPAP) to be applied during the inspiratory phase, in ASV mode.
PIP	Positive inspiratory pressure.
P low	Low positive airway pressure level, a control setting.
Pmean	Mean airway pressure, a monitored parameter.
Pminimum	Minimum airway pressure, a monitored parameter
PN	Part number.
Ppeak	Peak airway pressure, a monitored parameter. The Pressure alarm uses Ppeak as its reference pressure.
Pplateau	Plateau airway pressure, a monitored parameter.
P-ramp	Pressure ramp, a control setting. It is the rise time for pressure in pressure-controlled and pressure-supported breaths.
Pressure	An alarm setting.
pressure control	Maintenance of a consistent transrespiratory pressure waveform despite changing respiratory system mechanics.
Print screen	A key used to saves a JPG file of the current ventilator screen to a CompactFlash storage device.
psi	Pounds per square inch, a unit of pressure.

P-SIMV	Pressure-controlled synchronized intermittent mandatory ventilation mode.
Pstart	Starting PEEP, a control setting for the P/V Tool maneuver.
Psupport	Inspiratory pressure support, a control setting valid during SPONT breaths. Psupport is pressure (additional to PEEP/CPAP) to be applied during the inspiratory phase.
Ptop	Pressure target, a control setting for the P/V Tool maneuver.
PTP	Pressure time product, a monitored parameter.
P-trigger	Pressure trigger sensitivity, a control setting.
P/V Tool	Respiratory maneuver used to record a "quasi-static" pressure-volume curve. The P/V Tool offers both inflation and deflation limb data.
Ramp speed	Rate of pressure change, a control setting for the P/V Tool maneuver.
Rate	Number of breaths per minute, a control setting, alarm setting, and timing parameter.
RCexp	Expiratory time constant, a monitored parameter.
RCinsp	Inspiratory time constant, a monitored parameter.
RDS	Respiratory distress syndrome.
Rexp	Expiratory flow resistance, a monitored parameter.
Rinsp	Inspiratory flow resistance, a monitored parameter.
RSB	Rapid shallow breathing index, a monitored parameter.
SBT	Spontaneous breathing trial.
sec	Second, a unit of time.
(S)CMV	Synchronized controlled mandatory ventilation mode.
sigh	Breaths delivered to deliberately increase tidal volume at a regular interval.
SIMV	Synchronized intermittent mandatory ventilation mode.

slopeCO_2	Volume/flow status of the lungs, a monitored parameter.
SMP	Secondary monitoring parameters.
SpCO	Carbon monoxide concentration in arterial blood, a monitored parameter.
SpHb	Total haemoglobin in arterial blood, a monitored parameter.
SpMet	Methaemoglobin concentration in arterial blood, a monitored parameter.
SpOC	Calculated measurement of amount of oxygen in arterial blood, a monitored parameter.
SPONT	Spontaneous pressure support mode of ventilation.
spontaneous breath	A breath for which both the timing and size are controlled by the patient. That is, the patient both triggers and cycles the breath.
SpO_2/FiO_2	Ratio which is an approximation of the PaO_2/FiO_2 ratio
standby	The ventilator is in a waiting state, during which time there is no breath delivery.
STPD	Standard temperature and pressure, dry. Defined as gas at 0 °C (273 °K), barometric pressure at sea level, and dry.
Suctioning tool	The ventilator is in a waiting state that lets you maintain ventilator settings for a very short time while the HAMILTON-G5 is not performing any ventilatory functions. This mode is useful when preparing the ventilator before attaching it to a patient, during tracheal suctioning, or when changing a patient breathing circuit.
TE	Expiratory time, a monitored parameter.
technical fault	A type of alarm, resulting because HAMILTON-G5's ability to ventilate safely is questionable.
Texp	Duration of expiratory phase, a timing parameter.
TF	Technical fault.
T high	Duration of high airway pressure level, a control setting.

%TI	Inspiratory time, as a percentage of total cycle time, a control setting.
TI	Inspiratory time, in s, a control setting and monitored parameter.
Ti max	Maximum inspiratory time in s, a control setting.
Tinfl	Inflation time, a calculated parameter displayed by the P/V Tool maneuver.
Tinsp	Duration of inspiratory phase, including any pause, a timing parameter.
Tip	Inspiratory pause time in s, a setting.
T low	Duration of low airway pressure level, a control setting.
Tmand	Time period for the mandatory breaths in the SIMV/P-SIMV breath interval.
Tpause	Pause to be applied at top pressure, a control setting for the P/V Tool maneuver.
Trach tube	Tracheostomy tube.
TRC	Tube resistance compensation.
trend	The patient's data stored in the HAMILTON-G5 for the last 1, 12, or 24 hours.
trigger	The patient's inspiratory effort, either flow or pressure, that causes the ventilator to deliver a breath.
Tspont	Time period for spontaneous breaths in the SIMV/P-SIMV breath interval.
Ttotal	Total breath cycle time, a timing parameter; or total maneuver time, a calculated parameter displayed by the P/V Tool maneuver.
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.
VariIndex	Variability index (variability of volume and timing), a monitored parameter available in the Vent Status panel only.

VC	Vital capacity.
V'CO_2	CO_2 elimination, a monitored parameter.
Vcursor	Delivered volume at selected point, a displayed value when the P/V Tool's cursor measurement function is active.
VDaw	Airway dead space, a monitored parameter.
VDaw/VTE	Airway dead space fraction at the airway opening, a monitored parameter.
VeCO_2	Exhaled CO_2 volume, a monitored parameter.
Vent Status panel	An Intelligent Panel that visualizes six parameters related to the patient's ventilator dependency, including oxygenation, CO_2 elimination, 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 EN 794-1.
Ventilation Cockpit	The graphical user interface or interaction panel of the HAMILTON-G5.
ventilation unit	The HAMILTON-G5 that contains the pneumatics (without the Ventilation Cockpit).
ViCO_2	Inspired CO_2 volume, a monitored parameter.
VIP	Ventilator interface processor.
VLeak	Leakage volume, a monitored parameter.
volume control	Maintenance of a consistent inspiratory volume waveform despite changing respiratory system mechanics, using feedback control with the volume signal.
Vpeep	PEEP volume, a calculated value, displayed when performing a zero-PEEP maneuver in P/V Tool. Volume related to the pressure difference between PEEP and ZEEP.
VRC	Ventilator real-time controller.
Vt	Tidal volume, a control setting and an alarm setting.

Vtalv	Alveolar tidal ventilation, a monitored parameter.
Vtarget	Target volume, a control setting in the APV modes.
VTE	Expiratory tidal volume, a monitored parameter. It is the integral of all negative flow measurements during exhalation.
VTI	Inspiratory tidal volume.
VUP	Ventilator unit processor.
WOBimp	Work of breathing, a monitored parameter. The work performed by the patient to breathe through the ventilator's demand flow system, the breathing circuit, and the endotracheal tube.

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