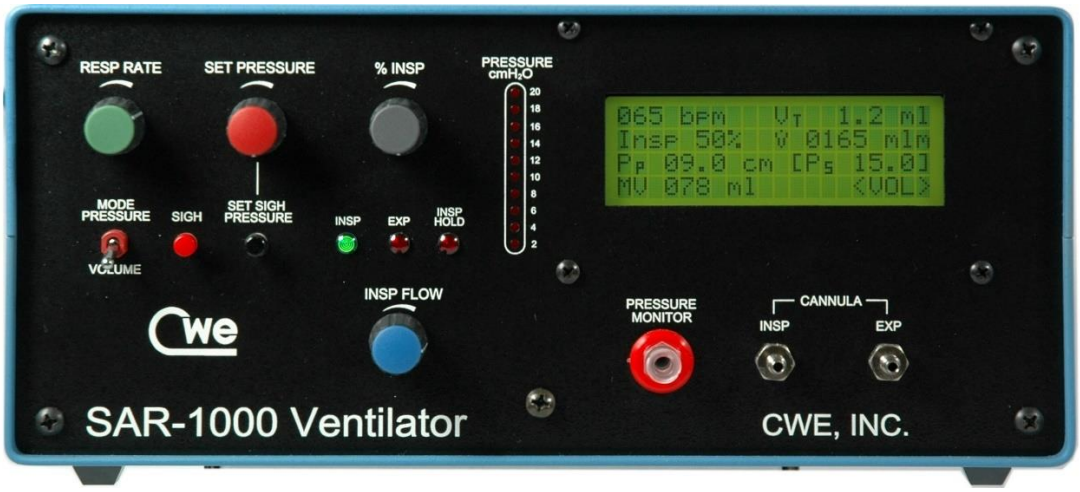
Instruction Manual

SAR-1000

Advanced Small Animal Ventilator



Read instructions carefully before operating this device.

❶ *This device is not to be used for Human Life Support applications.*
❷ *To avoid possible electrical shock, do not operate this device if is wet or has had liquids spilled onto it.*
❸ *Service or calibration procedures should only be performed by qualified personnel familiar with the electrical hazards of line-powered devices.*

CWE INCORPORATED

Ardmore PA 19003 U.S.A.
(610)642-7719
info@cwe-inc.com

www.cwe-inc.com

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Technical Support
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1.0 INTRODUCTION

The SAR-1000 Small Animal Ventilator is designed to provide safe and reliable mechanical ventilation for mice, rats, and other small laboratory animals.

This ventilator operates on the *flow-time* principle, where a measured airflow is gated into the animal for a set time, thus producing a known tidal volume. In addition, the SAR-1000 can operate in *pressure-cycled* mode, where the airway pressure is automatically limited to a user-set value. This approach to ventilator design permits great flexibility, since airflow, timing, and pressures are all independently adjustable over a wide range.

Special *sigh* breaths can be manually initiated or programmed to occur automatically at user determined intervals.

The SAR-1000 is completely self-contained, with a built-in air pump to provide airflow. All settings are made from the front panel and are displayed on an LCD display along with computed measurements.

Besides being a stand-alone ventilator, the SAR-1000 has a built-in USB interface for remote control applications. In addition, there is a **DATA PORT** for external logic signals, which maintains compatibility with the SAR-830 series ventilators.

The SAR-1000 is compatible with anesthetic gasses, and complete anesthesia setups are available. To ventilate multiple, or larger, animals, it can be used with any of the CTP-VA series external valve assemblies. These accessories are available for a range of animals (see: ***Ordering Information***).

The following sections of this Manual explain how the ventilator works, and how to set it up to suit your particular experimental needs. We encourage you to read through this Manual and welcome you to the next generation of CWE ventilators.

Figure 1: Model SAR-1000 Front Panel

2.0 BASIC VENTILATOR CONNECTIONS

Setting up the SAR-1000 is straightforward. For basic operation, only a mains power cord and a cannula tubing set need be connected.

Power connections

Plug an appropriate mains cord into the **MAINS INLET** receptacle on the right of the rear panel. This instrument uses a universal voltage input, so no mains voltage switch is required.

> ***CAUTION! To maintain electrical safety, use only a 3-wire grounded power cord. Operating this device from an un-grounded receptacle could result in a dangerous electrical shock hazard.***

Cannula Tubing Set connections

The *cannula tubing set* connects the front panel tubing ports to the animal's endotracheal tube. For rats and similar size animals, the **INSP** and **EXP** ports connect to the distal "W" connector using 0.125" ID x 0.250" OD (3 x 6mm) Tygon or similar flexible tubing. For mice, use 0.063" x 0.125" (1.5 x 3mm) tubing and appropriate barbed tube fittings. The **PRESSURE MONITOR** port is a female Luer connection and connects to the center tap of the distal "W" connector (rat), or to a miniature "Y" connector (mouse). Both rat and mouse tubing sets are provided with the instrument.

To reduce compression effects of large tubing volumes, these tubes should be as short as is convenient, but their length does not affect dead-space, since flow is unidirectional from the **CANNULA I** → tracheal tube → **CANNULA E** port. The only dead-space is the volume from the distal end of the "W" connector to the tracheal tube.

It is highly recommended that the new user become familiarized with how the ventilator operates before connecting an experimental animal. A test balloon is provided for this purpose.

3.0 VENTILATOR OPERATION

Volume mode

Once the ventilator is set up and operational, a few important settings need to be determined. The appropriate *respiratory rate* (RR) and *tidal volume* (V_T) are mainly dependent on body weight. ***Appendix 1*** contains tidal volume and rate vs. body weight charts. For example, if we have a 250g rat, the chart shows a suitable V_T of about 2.0ml at a RR of 55 breaths/min.

To set up the SAR-1000 for this example, first adjust the **RESP RATE** knob until 55 bpm is displayed. Adjust the **%INSP** knob until 50% Insp is displayed. Now adjust the **INSP FLOW** knob until V_T 2.0 ml is displayed.

Note that you are setting the tidal volume by adjusting the inspiratory airflow, rather than just dialing in V_T directly. This may at first seem unintuitive, but it follows from the basic *flow-time ventilator* principle: V_T = flow x time. The time (T_I) was set as a fraction (%Insp) of the total respiratory cycle time (1/RR). V_T is then dependent on the flow rate setting. All the calculations are performed by a microprocessor so you don't have to!

Figure 2: SAR-1000 LCD Display Panel

Pressure mode

Pressure mode operation is similar to the above description, except that inspiration is terminated when a certain airway pressure (P_P) is reached, rather than when the inspiration time (T_I) has elapsed.

This pressure is set using the **PRESSURE** knob, and is displayed, for example, as P_P 10.0 cm. Now, inspiratory flow will cease on each breath when the set P_P pressure is reached.

Inspiratory hold

Note that the SAR-1000 has another important feature that applies to *pressure mode*: If P_P is reached *before* the set T_I has elapsed, the lung volume will be clamped for the duration of T_I. This *inspiratory hold* feature is known to improve the efficiency of ventilation and gas exchange by maintaining the end-inspiratory pressure, instead of simply releasing the lung volume immediately when P_P is reached. You can observe this via the **INSP**, **EXP**, and **INSP HOLD** LED's, which indicate exactly what is happening during the respiratory cycle. *Figure 3* illustrates this by observing the *pressure* signal.

NOTE: By default, the **INSP HOLD** function is enabled. You can disable it by pressing the **SIGH** pushbutton while turning **POWER ON**. You will hear two beeps to indicate the function is disabled. Repeat this to re-enable **INSP HOLD** and you will hear four beeps to indicate that the function is active. This setting is stored and will apply from now on until the user changes it.

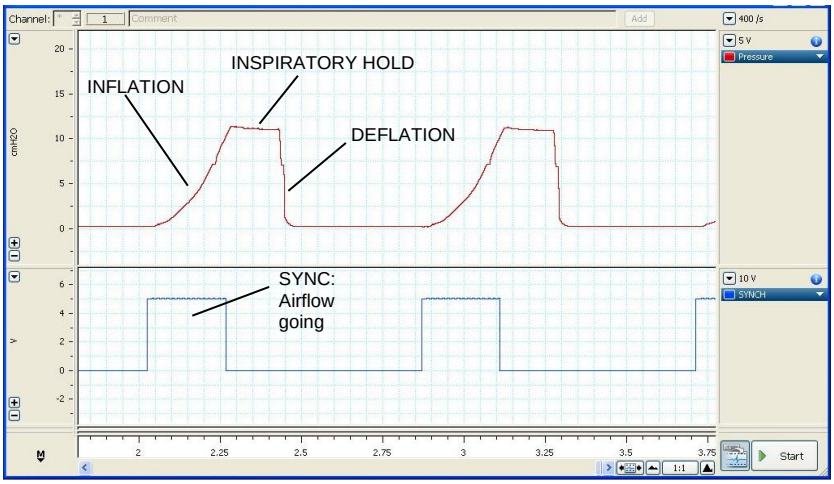


Figure 3: Top trace: Airway pressure, bottom trace: Sync Out

Manual Sigh function

Sighs, or periodic delivery of larger tidal volumes, are often used to maintain good lung ventilation and gas exchange. The SAR-1000 has a manual sigh function actuated by pressing the **SIGH** pushbutton. When this pushbutton is pressed, the ventilator is armed to deliver a sigh breath on the next inspiration. A short beep will indicate that a sigh breath is about to be delivered.

During a *sigh breath*, the inspiration will continue until the sigh pressure (P_S) is reached. This function is available regardless of whether the ventilator is in **VOLUME** or **PRESSURE** mode. On the sigh breath, the lung volume will be clamped once the P_S is reached, and held for the programmed sigh time (see *Programming the Auto Sigh function*).

To set the sigh pressure, press and hold the **SET SIGH PRES** pushbutton while adjusting the **PRESSURE** knob. The LCD display indicates the P_S setting in cmH_2O.

> ***NOTE: The sigh pressure (P_S) setting is normally several cmH_2O greater than the pressure limit (P_P) setting. However, it is possible to set the sigh pressure to a lower setting if desired. In this case, the sigh breath will deliver a lower than normal end-inspiratory pressure.***

Programming the Auto Sigh function

As described above, a single sigh breath can be initiated simply by pressing the **SIGH** pushbutton. You can also automate the delivery of periodic sigh breaths by using the auto sigh setup routine. You enter this routine by simultaneously pressing the **SIGH** and

SET SIGH PRES pushbuttons and holding for about ½ second. The setup screen shown in *Figure 4* will then be displayed:

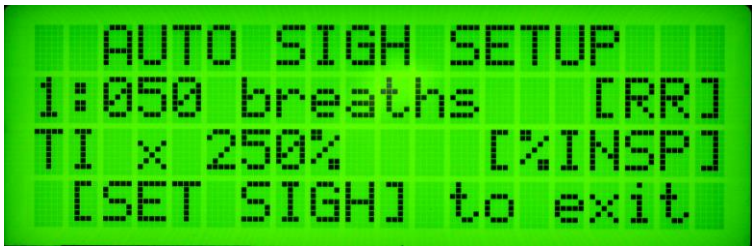


Figure 4: Auto-Sigh setup screen

The two settings you can change here are the *sigh frequency* and *sigh ratio* values. In the example shown, sigh frequency is set to 1:050, or a sigh every 50 normal breaths. The sigh ratio is set to 250%, so the inspiratory time (T_I) of the sigh breath will be 2.5X (or 250%) of the normal T_I. The other sigh variable, *sigh pressure* (P_S) is set from the main display screen as described earlier.

To change the *sigh frequency* setting, use the **RESP RATE** knob. To change the *sigh ratio*, use the **%INSP** knob. (These controls are shown in brackets on the right side of the display as a mnemonic aid.)

Any changes to the auto sigh settings take effect immediately. To exit the setup screen, press the **SET SIGH PRES** pushbutton. After 15 seconds of inactivity, the screen will automatically timeout and return to the main operating screen.

When *Auto Sigh* is in effect, the symbol **A S** will be displayed on the bottom line of the main operating screen.

Minute Ventilation

Minute ventilation (MV) is the sum of the inspired volumes delivered to the animal per minute. This measurement is a useful indicator of adequate ventilation and is normally proportional to body weight. MV is computed automatically and reported on the bottom line of the LCD display.

4.0 TUBING CONNECTIONS

Figure 5: SAR-1000 Rear Panel

Pump In / Pump Out ports

The SAR-1000 is equipped with an internal air pump to provide compressed gas for use as the *inspiratory flow*. The inlet and outlet connections of this pump are brought out to the rear panel as the **PUMP IN** and **PUMP OUT** ports, respectively.

The air pump has a capacity of approximately 2.5 lpm. For most setups, a tubing jumper should be placed between the **PUMP OUT** and the **GAS INLET** ports.

> ***NOTE: Never apply a pressure to the PUMP IN port. A collapsible bag with a gas mixture can, however, be connected to this port.***

Gas Inlet port

This port receives the compressed gas used for generating the controlled *inspiratory flow*. Although normally this will connect to the **PUMP OUT** port, in some circumstances it is desirable to connect a gas source directly to the **GAS INLET** port, thus bypassing the internal air pump.

Expired Air port

The **EXP AIR** port is connected directly to the lungs during expiration. In most cases, this port should be left unconnected. However, there are some circumstances where a connection is made:

PEEP (Positive End-Expiratory Pressure) --- PEEP is a commonly used technique to maintain a small pressure in the lungs during expiration. For example, in open-chest preparations, PEEP is essential to keep the lungs from collapsing. To apply a PEEP, connect a flexible tubing to the **EXP AIR** port, and submerge it under a few cm of water (the depth under water = the PEEP pressure). This is illustrated in *Figure 7*.

Anesthesia --- If inhalational anesthesia is used, it is necessary to collect and evacuate the gas from the exp air port. A tube connected to this port can be directed to an anesthetic absorber or exhaust system.

NOTE: Never connect a vacuum source directly to this port, as it will cause serious injury to the animal!

In Vent port

During the inspiration phase of ventilation, the inspiratory flow is directed to the animal. During expiration, this same flow is gated out the **IN VENT** port. Thus, this is clean inspiratory gas. In anesthesia setups, this gas can be sent to an anesthetic evacuation system (see *Figure7*).

5.0 REAR PANEL INPUTS AND OUTPUTS

PRESSURE OUT

This BNC jack provides a continuous analog voltage signal corresponding to airway pressure. The scaling of this signal is 50mV/cmH_2O.

SYNC OUT

This BNC jack provides a TTL-compatible signal corresponding to the phase of respiration. During inspiration, the output is HIGH (+5V); during expiration the output is logic LOW (0V).

GROUND

This binding post is connected to chassis ground, or earth. If required, this post can be connected to a system-wide ground connection.

DATA PORT

The **DATA PORT** connector serves as a unified connection for several input and output functions. These are listed below, with a description of their functions. The connector required is a DB9M (9-pin DSUB male plug):

PIN 1	Ground
PIN 2	HOLD input
PIN 3	MAN input
PIN 4	SYNC out
PIN 5	INSP out
PIN 6	EXP out
PIN 7	PRESSURE out
PIN 8	RATE out
PIN 9	+5V

HOLD input – When a logic LOW (0V) is applied to this pin, the ventilator will stop cycling and enter a HOLD mode, with the valves set for expiration.

MAN input – When a logic LOW (0V) is applied to this pin, the ventilator valves will be set to inspiration, and remain so as long as the pin is held LOW.

SYNC out – This is a TTL-compatible logic signal corresponding to the phase of respiration. Logic HIGH = inspiration, and logic LOW = expiration.

INSP out – This is a TTL-compatible logic signal that is logic HIGH during inspiration.

EXP out – This is a TTL-compatible logic signal that is logic HIGH during expiration.

PRESSURE out – This is an analog voltage corresponding to the current airway pressure reading (same as the **PRESSURE OUT** BNC jack).

RATE out – This is an analog voltage corresponding to the current respiratory rate (RR) setting. The scale factor is 10mV/bpm.

The data port connections HOLD and MAN can be used to provide a powerful remote-control function. By connecting these two TTL inputs to a data acquisition system with I/O capabilities, it is possible to create a ventilator system with many possibilities, such as constant-CO_2 operation, neural-controlled ventilation, ventilation synchronized to MRI or CT scanners, etc. If this is of interest, please contact CWE, Inc. for details.

EXTERNAL VALVES CONNECTION

This 4-pin jack is used to connect one or more External Valve Assemblies to the SAR-1000. By connecting an external valve set (e.g., CTP-VA-1), you allow an additional animal to be ventilated. The additional ventilator station will operate synchronously with the primary ventilator, but the tidal volume (V_T) can be independently set using an external flowmeter (see: *Figure 6*).

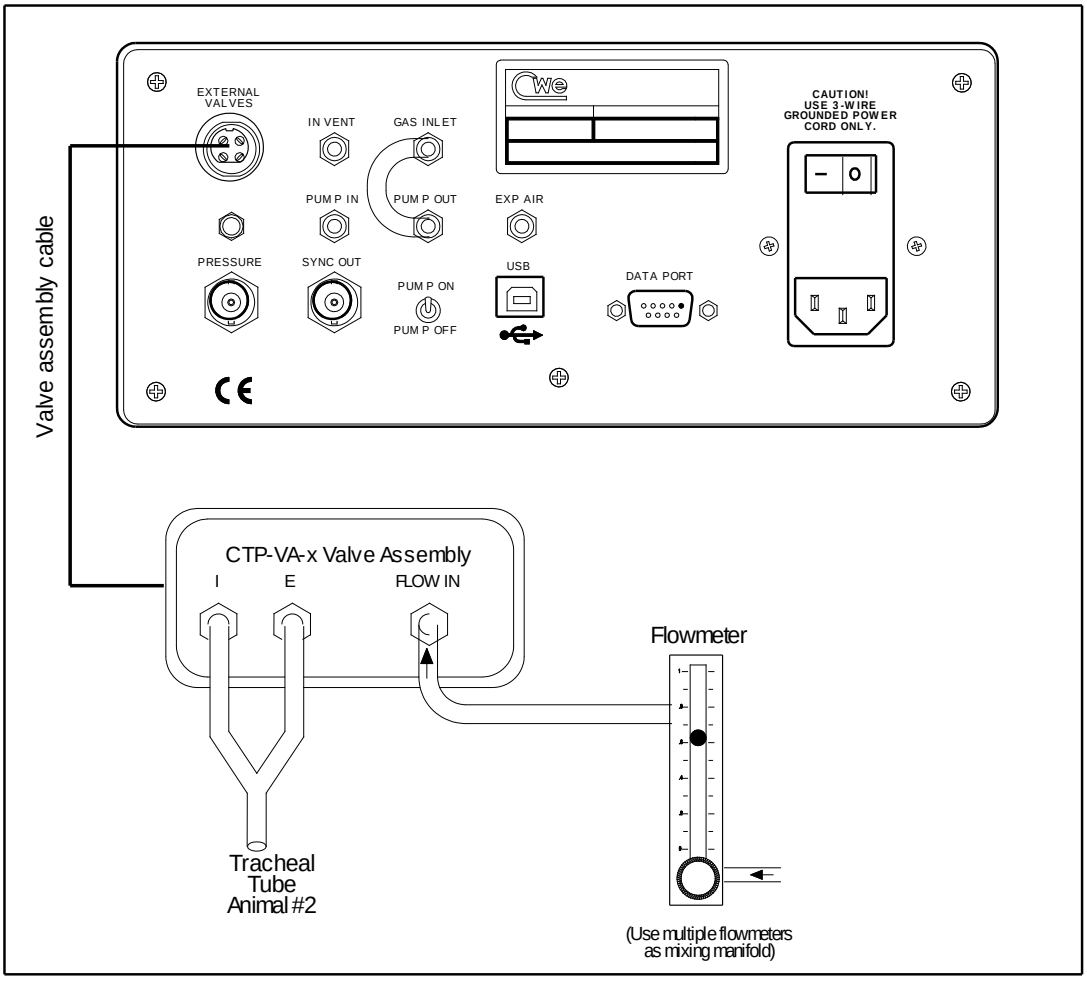


Figure 6: Connecting an external valve set

It is also possible to ventilate up to four rodents simultaneously with just one SAR-1000 as the control unit. The valve assemblies will all operate synchronously, but individual tidal volumes can be adjusted independently by varying the flow rate to each animal. When adding more than one external valve assembly, an electrical cable adapter is required (Part No. MVA-4). This part provides four expansion jacks for adding the valve assemblies. With multiple animal setups, a flowmeter manifold (Part No. EFM-4-x) is useful. With this manifold, one air source can be used for all the animals being ventilated. The required accessories are listed below:

Valve Assembly	Flowmeter	Animal
CTP-VA-1	EFM-1-1 (rat), EFM-1-100 (mouse)	Mouse, Rat, Guinea pig
CTP-VA-3	EFM-1-2.5	Cat, Rabbit, Monkey

6.0 REMOTE CONTROL USING THE USB PORT

The SAR-1000 Ventilator has a powerful new capability: remote control via a USB connection. This allows an external computer to remotely change the ventilator settings, exactly as they are done using the front-panel controls. In addition, a set of primitive, low-level commands allow direct control of ventilator internal functions. These functions are described below.

Setup for USB connection

Before connecting the USB cable to the SAR-1000, you must install the software drivers from the supplied CD-ROM. Locate and execute the following program: `CDM20600.EXE`. This program will install *Virtual Com Port* (VCP) drivers, creating a new serial port connection on your computer (for example, COM5).

Connect the USB cable and power on the SAR-1000. Locate the new COM port by: `Start / Control Panel / System / Hardware / Device Manager / Ports`. This port will then be used by the optional SAR-COMM software or the supplied terminal (`terminal.exe`) program to communicate with the ventilator.

The serial port settings used are 9600,N,8,1. All commands should be sent as simple ASCII text character strings. Besides the optional SAR-COMM program, any control program (such as Labview) that can generate these commands can be used. Note that the syntax must be exactly as shown below, and all characters should be sent as a string, including leading zeros as necessary. Alphabetic characters may be upper or lower case.

Ventilator setup commands

RRnnn – Set Respiratory Rate, nnn = 010 – 200	(bpm)
FLnnnn – Set Insp. Flow rate, nnnn = 0010 – 1100	(ml/min)
IEnn -- %Inspiration, 10 – 90	(percent)
PPnnn – Pressure limit, 10 – 500	(mmH_2O)
PSnnn – Sigh pressure, 10 – 500	(mmH_2O)
SFnnn – Sigh frequency, 0 – 255	(1 sigh per nnn breaths)
SRnnn – Sigh ratio, 100 – 999	(percent of normal T_I)

Multiple settings commands

GS – Sends a full set of machine settings back to host computer in the format:

`aaa,bbbb,ccc,ddd,ee,fff,ggg` where:

`aaa` = Respiratory Rate

`bbbb` = Inspiratory Flow

`ccc` = Pressure Limit

`ddd` = Sigh Pressure

`ee` = %Inspiration

`fff` = Sigh Frequency

`ggg` = Sigh Ratio

ISaaa,bbbb,ccc,ddd,ee,fff,ggg – Downloads a full instruction set of machine settings into the ventilator. The description and formatting of the individual elements of this command string is the same as for the GS command described above.

> ***Note:*** *This above command strings are sent (or received) as simple ASCII characters with comma delimiting between values. Numbers are all integers, and leading zeros are required.*

Primitive commands

RC – Put ventilator in remote-control mode (valves set to expiration)

LC – Return to local control

I1 – Inspiration valve ON

I0 – Inspiration valve OFF

E1 – Expiration valve ON

E0 – Expiration valve OFF

A1 – Auxiliary valve ON

A0 – Auxiliary valve OFF

IN – Set valves for inspiration

EX – Set valves for expiration

BH – Set valves for breath-hold (inspiratory hold)

> ***Note:*** *The latency time after a command is sent before another one can be received is approximately 5mS. If commands are received too quickly, they will be ignored or possibly corrupted.*

7.0 USING ANESTHESIA WITH THE SAR-1000

The SAR-1000 Ventilator can be used with Isoflurane or other inhalational anesthetic systems. *Figure 7* shows how to do this.

Principle of operation

The preferred method of interfacing an anesthesia machine (gas source + vaporizer) to the ventilator is by using a *blow-by system*, as shown. If you examine the flow path from the vaporizer, you will see that the anesthetic flow passes across the **PUMP IN** port of the ventilator, and then passes to the absorber canister or evacuation system. The ventilator draws in the gas it needs from this stream. This setup prevents harmful back-pressure on the vaporizer, and also avoids applying pressure to the internal air pump on the ventilator. In operation, the gas flow from the vaporizer is adjusted to be a little greater than the **INSPIRATORY FLOW** shown on the ventilator LCD display.

Mandatory anesthetic absorber or evacuation connections

As shown on the diagram, the following port connections *must* be sent to an absorber canister or evacuation system when using anesthesia:

IN VENT --- The gas from this port is clean inspiratory gas, which comes out of this port when it is not being directed to the animal.

EXPIRED AIR --- This port is in direct communication with the animal's airways during the expiration phase of ventilation. Therefore, it is important not to apply suction or any restrictions on this connection.

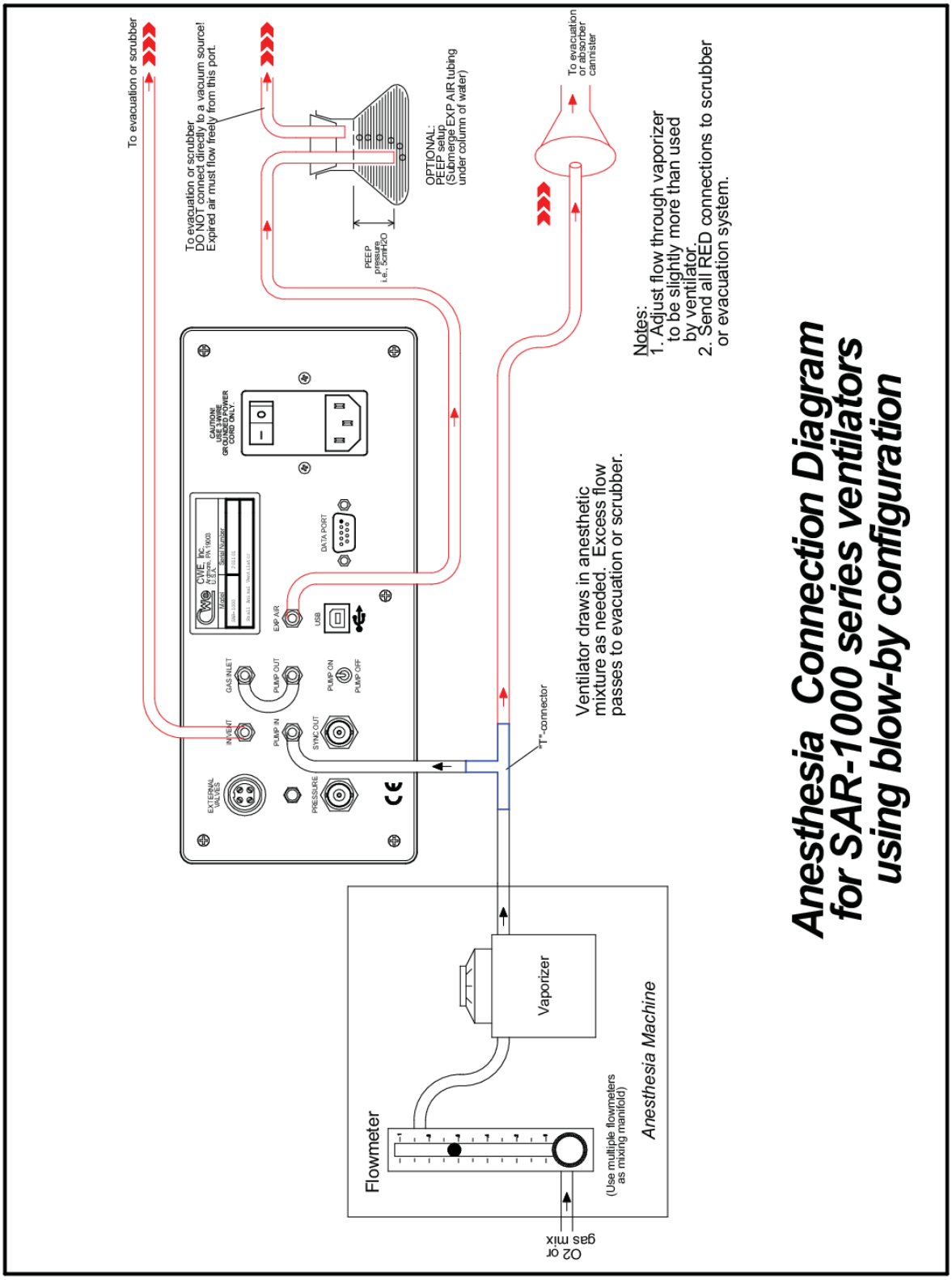


Figure 7: SAR-1000 anesthesia connections with optional PEEP.

8.0 SPECIFICATIONS

Respiratory rate range..... 5 - 200 breaths/min

Inspiratory flow range ..... 10 - 1100ml/min

Inspiration/Expiration (I/E ratio) range ..... 10 - 90%

Tidal volume range (see Note 1) ..... 0.1 - 30ml

LCD panel ..... 4 lines x 20 chars, backlit

Indicator lights ..... INSP, EXP, INSP HOLD

Internal airpump capacity ..... 2 lpm

Port connections ..... 0.125" (3mm) ID Tygon tubing

PRESSURE MONITOR port connection..... Luer female

SYNC OUT connector ..... BNC

PRESSURE OUT connector ..... BNC

PRESSURE OUT scaling ..... 50mV/cmH_2O

RATE OUT scaling (via DATA PORT jack)..... 10mV/bpm

DATA PORT connector DB-9S

Dimensions ..... 9W x 4H x 9D in. (23 x 10 x 23cm)

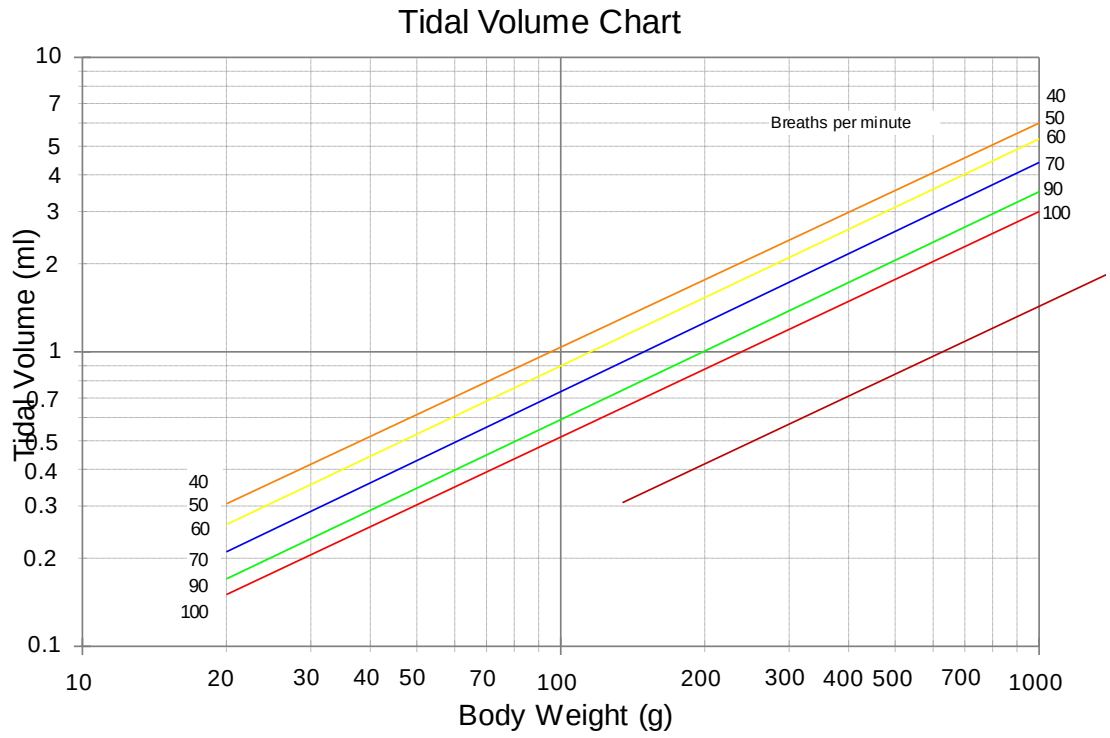
Power requirements ..... universal input,120/240V 50/60Hz, 100VA

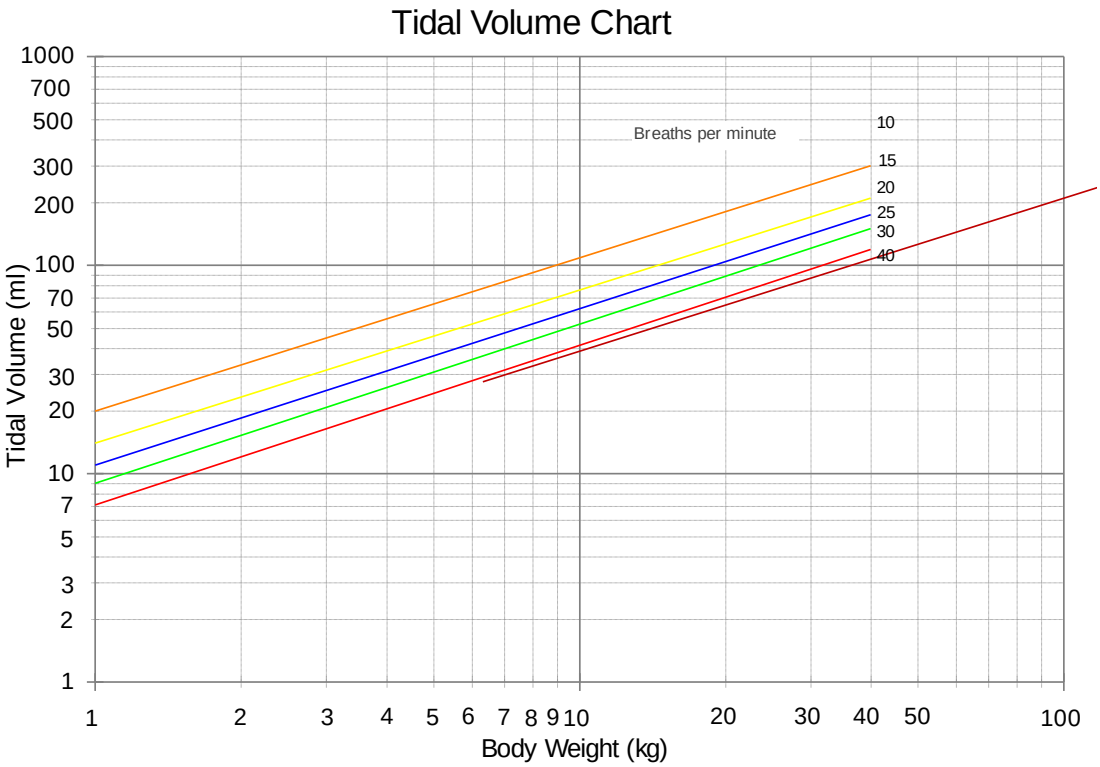
Note 1: Volume is dependent on respiratory rate and airflow rate settings. Large volumes can be delivered at slow respiratory rates only.

9.0 ORDERING INFORMATION

PART Nº	MODEL	DESCRIPTION
12-07000	SAR-1000	Ventilator with mouse & rat tubing sets, SAR-COMM software, USB cable, 115/230V
12-04000	CTP-VA-1	Solenoid Valve Assembly, mouse to Guinea pig size
12-05000	CTP-VA-3	Solenoid Valve Assembly, cat to small monkey size
12-10010	MVA-4	Electrical adapter for adding up to 4 external valve assemblies
12-10020	EFM-1	Flowmeter/regulator, with stand, specify range: 0.1, 1, 2.5, 5 l/min
12-10021	EFM-4	Flowmeter/regulator manifold w/ 4 flowmeters, with stand, specify range
12-10032	TRACH-1	Endotracheal tube for mice, flexible Teflon with Luer connector, 20 gauge, pack of 5
12-21032	TRACH-2	Endotracheal tube for rats, flexible Teflon with Luer connector, 14 gauge, pack of 5
11-10000	CAPSTAR-100	End-tidal CO_2 Analyzer, complete with accessory pack, 115/230V (rat and larger)
15-10000	MicroCapStar	End-tidal CO_2 Analyzer, complete with accessory pack, 115/230V (mouse and larger)

APPENDIX 1: TIDAL VOLUME VS. BODY WEIGHT CHARTS





APPENDIX 2: TYPICAL VENTILATOR SETTINGS FOR RODENTS

Body Weight (g)	Tidal Volume (ml)	Resp Rate (br/min)	Insp Flow (ml/min)	I/E Ratio (%)
25	0.25	90	56	40
100	0.90	60	135	40
200	1.80	55	250	40
300	2.40	50	300	40
500	4.00	40	400	40

Note: Settings above are suggested guidelines. You will probably need to adjust the settings for your particular animal, depending on its condition, anesthesia, or other factors.